ANALYSIS OF FREE VIBRATION OF STIFFENED PLATES DUE TO VARIATION IN COMPONENT DIMENSIONS AND WELD PROFILES

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by

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ABSTRACT

The investigation, reported in this thesis, focused on the free vibration responses of two identically fabricated stiffened plates due to the inherent variation in dimensions of components of stiffened plates and also due to the presence of weld profiles along the connections between the components. The percent certainty of 99.73 of each data set to be measured was used, lying in between $\mu - 3\sigma$ and $\mu + 3\sigma$ of each data set; moreover, three sets, $\mu - 3\sigma$, μ and $\mu + 3\sigma$, of each dimension of the components and weld profiles were used to generate finite element analysis models. The possible effects of variation in spacings, between the two transverse girders, were analyzed by setting the spacings to be normal, close girder and away girder cases, respectively. Weld cross sections were transformed to equivalent rectangular cross sections in order to use two-dimensional quadrilateral shell elements to model in finite element analyses. The validation of the transformation was also examined.

The finite element analysis models were categorized into two groups, the models without and with weld profiles. Each model was generated using three different spacings of the girders, and each of them was generated using three prescribed sets of dimensions. All models were broken up into 4 stages in order to consider the influence of addition of components to structural behaviour and also to observe the variations in natural frequencies.

Two finite element analysis software packages, viz., ABAQUS and ANSYS, were used to confirm the reliability of certain results. In addition, a number of element types

and element sizes were used to determine the suitability of element types and convergence of results.

Two approximate methods were employed to obtain the natural frequencies of stiffened plates. The first one was the method of elastic equivalence, and the other one was the approximate method using concepts of static analysis. The results obtained from these two methods and finite element method were compared.

Once the weld profile geometries of the two models were obtained, it was observed that the weld qualities of Model I were better than those of Model II because the standard deviations of widths of weld on panel and on webs of girders of Model II were 1.39 and 2.59 times greater than those of Model I; the standard deviations of all the other dimensions of both models were comparable.

From all the analyses, it was observed that the variation in dimensions of components of stiffened plates and in weld profiles produced a variation in natural frequencies between -4.59 % to +4.74 % for Model I and -4.27 % to +5.04 % for Model II. The inclusion of weld profiles alone in the models produced a variation in natural frequencies between of -5.02 to +4.12 % for Model I and -4.50 to +3.14 % for Model II. Moreover, the inaccurate placement of the transverse girders produced -2.01 % to 2.04 % variation in natural frequencies for Model I, and -2.03 % to 1.99 % variation in natural frequencies for Model II. The method of elastic equivalence gave differences of -68.54 % and -59.96 % for the comparable natural frequencies of this method and finite element method. In addition, an approximate method using concepts of static analysis was also used to determine the first five natural frequencies of stiffened plate. The differences in results obtained from this method and finite element method were found to be between -4.39 % to +5.99 %.

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NOTATIONS

A	constant
A_{flange}	Area of flange of stiffener
A_{plate}	Area of plate
A_{web}	Area of web of stiffener
A_1, A_2, A_3, A_4	Area of the plate panel, weld profile, web of stiffener and flange of stiffener
A	Coefficient column vectors
a	Span in x direction
B	Coefficient column vectors
b	Width of rectangular cross section
C	Damping matrix
c	Damping coefficient
$D_{A\text{-}A}$	Flexural rigidity of the cross section of view A-A
D_x	Flexural rigidity x-direction
D_y	Flexural rigidity y-direction
D_{xy}	Torsional rigidity
E	Elastic modulus
$E_{orthotropic}$	Modified elastic modulus of the orthotropic plate
E_x, E_y	The modified moduli of elasticity in x- and y-direction
E'	Modified elastic modulus for plate

$[E]$	Constitutive matrix
$e_{flange_{N.A.}}$	Distance from centroid of flange of stiffener to N.A. of the whole section
$e_{plate_{N.A.}}$	Distance from centroid of plate to N.A. of the whole section
$e_{web_{N.A.}}$	Distance from centroid of web of stiffener to N.A. of the whole section
$F(x)$	Distribution function
$F_e(t)$	External force dependent on time
$\mathbf{F}_e$	External force matrix dependent on time
$f(x)$	Probability density function
$f(x;\mu,\sigma)$	Normal distribution function
G_{xy}	Shear modulus
H	Leg height of the weld
H	Torsional rigidity
h	Height of rectangular cross section
$h_{N.A.}$	Distance from base to neutral axis of the whole section
h_{flange}	Distance from base to centroid of area of flange of stiffener
h_{plate}	Distance from base to centroid of area of plate
h_{web}	Distance from base to centroid of area of web of stiffener

h_1, h_2, h_3, h_4	The distance from the neutral axis to the centroid of the plate panel, weld profile, web of stiffener and flange of stiffener
I	Moment of inertia
$I_{N.A.}$	Area moment of inertia of the entire stiffened plate with respect to its neutral axis
I_{flange}	Moment of inertia of flange of stiffener with respect to its N.A.
I_{local}	Local area moment of inertia
$I_{orthotropic}$	Moment of inertia of orthotropic plate with respect to its N.A.
I_{plate}	Moment of inertia of plate with respect to its N.A.
I_{web}	Moment of inertia of web of stiffener with respect to its N.A.
I_1, I_2, I_3, I_4	The local area moment of inertia the plate panel, weld profile, web of stiffener and flange of stiffener with respect to the neutral axis
$\mathbf{K}$	Stiffness matrix
k	Stiffness
$[k]$	Total elemental stiffness
$[k_b]$	Bending stiffness
$[k_s]$	Shear transverse stiffness
L	Leg length of the weld
L	Length of beam
M	Mass that participates in structure bending
$\mathbf{M}$	Mass matrix
m	Mass

N	Total number of x
P	Applied force
$p(x,y)$	Given load as a function of x and y
s	Throat thickness of the weld profile
w_h	Homogeneous solution for deflection
w_p	Particular solution for deflection
$w(x,y)$	Deflection as a function of x and y
X	Variable of interest
$\mathbf{X}(t)$	Displacement matrix dependent on time
$\dot{\mathbf{X}}(t)$	Velocity matrix dependent on time
$\ddot{\mathbf{X}}(t)$	Acceleration matrix dependent on time
x	Specific value of the variable X
$x(t)$	Displacement dependent on time
$\dot{x}(t)$	Velocity dependent on time
$\ddot{x}(t)$	Acceleration dependent on time
$\sum A$	Total area of cross section
$\sum Ah$	Summation of first moment of area with respect to base
Φ_i	Eigenvector
$\Phi(x;\mu,\sigma)$	Cumulative normal distribution
α	Constant
$(\beta_n L)$	Coefficients of beam vibration

δ	Deflection
$\{\varepsilon\}$	Strain matrix
θ	Angle of triangular geometry of the weld
μ	Mean value
ν	Poisson ratio
ν_{xy}	Poisson ratio of orthotropic plate
ρ	Notch root radius of the weld
ρ'	Mass per unit length of beam
σ	Standard deviation
$\{\sigma\}$	Stress matrix
ω_n	n^{th} natural frequency

CHAPTER 1

INTRODUCTION

Vibration, strength, stability and deformation characteristics of stiffened plates have been extensively studied since the applications of stiffened plates have been widely used in engineering structures, such as bridges, aircrafts and ships. This investigation has focused on how largely the variation of certain factors due to the fabrication process can changes the free vibration responses of the stiffened plate. The certain factors of interest in this investigation are the component dimensions of the stiffened plate and the weld used to connect the components together. The free vibration responses of the stiffened plate have been obtained mainly using finite element method; moreover, there are two more approximate methods applied to determine the free vibration responses. Additionally, this investigation can also be considered as an examination of the quality of fabrication since a large variation in free vibration responses would indicate a poor quality.

Two identical stiffened plates consisting of a panel and six T-section stiffeners with four different sizes, in two mutually perpendicular directions, were fabricated and used in the investigation. All dimensions of components of stiffened plate including weld profiles, along all connections, were manually measured using available instruments. All measured data were tested for the normality of distribution, and three sets of data, viz., $\mu - 3\sigma$, μ and $\mu + 3\sigma$, were used to generate finite element analysis models. ABAQUS, the finite element analysis software, was thoroughly used in this investigation. The range of data between $\mu - 3\sigma$ and $\mu + 3\sigma$ provides 99.73 % confidence of data to be found.

Once all finite element analysis models were generated and analyzed, the free vibration responses were obtained and interpreted. These results indicated the differences in free vibration responses caused by the variation in component dimensions and weld profiles, and reflected the quality of fabrication as well.

The thesis contains six chapters which can be briefly described as follows. The first chapter introduces the objectives of the study on free vibration of stiffened plates, scope and structure of the thesis. The second chapter illustrates the applications of stiffened plates that can be found in engineering structures, and also introduces some previous studies on weld profile and on the vibration and dynamic analysis of various stiffened plates using a variety of methods. From chapter three to five, the principles, theories and criteria, used in each chapter, are described along with the results.

The third chapter explains the approaches used to obtain the dimensions of components of stiffened plates and the weld profiles. Moreover, the transformation of weld cross sections to equivalent rectangular cross sections, in order to use quadrilateral shell elements to model in finite element analyses, is described. The normality tests of all data sets are carried out, and all sets are categorized into three groups to be used in finite element analyses.

The fourth chapter introduces first the steps of modeling, categories of models and numbers of finite element analyses, required to be carried out. The comparison between two finite element analysis software packages, viz., ABAQUS and ANSYS, was made to confirm the reliability of results obtained using ABAQUS; moreover, the selection of appropriate element types and element sizes was also investigated. Furthermore, verification of the effects of transformation of weld cross sections to equivalent rectangular cross sections was carried out as well. Once all analyzed results were obtained, they were compared and discussed.

The fifth chapter illustrates two approximate methods used to obtain the natural frequencies of stiffened plates. The first one was the method of elastic equivalence; the stiffened plate was transformed to a representative orthotropic plate, which had the same mechanical properties obtained by the method of elastic equivalence. Consequently, the free vibration responses of the representative orthotropic plate were obtained using ABAQUS. The other approach used to calculate the natural frequencies was to apply an approximate method using concepts of static analysis. By applying concentrated forces at particular points, the stiffened plate was deformed in patterns similar to mode shapes of interest; subsequently, the bending stiffness and mass were obtained and used to calculate the natural frequencies. The results obtained from both the approximate methods and finite element method were compared and discussed.

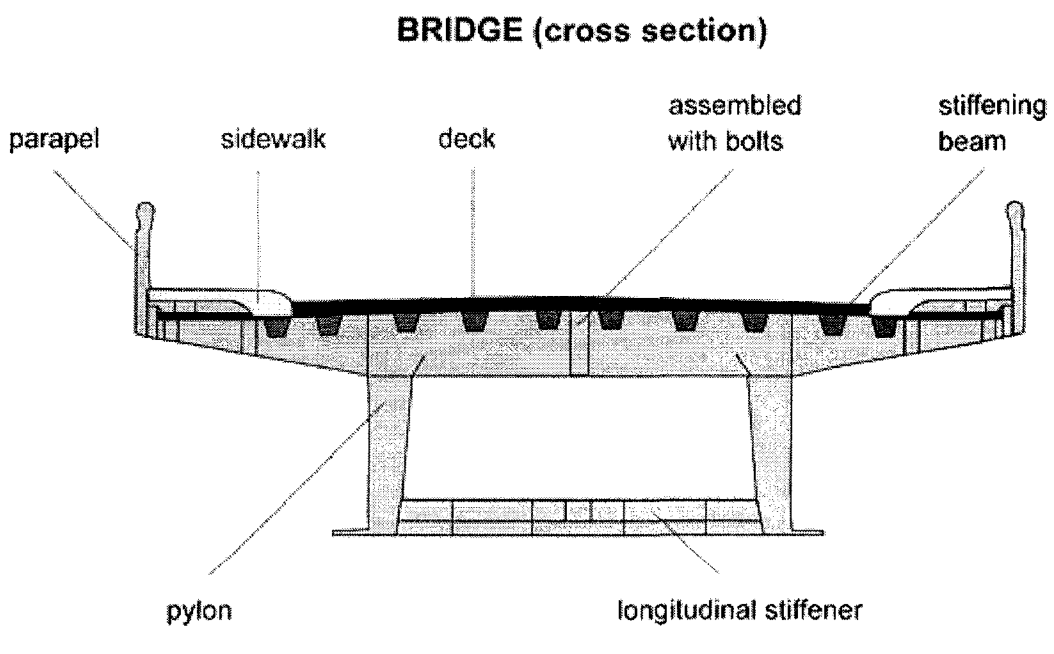
The sixth chapter gives the salient conclusions drawn from the results of the investigation, and recommendations for future investigations are also provided.

CHAPTER 2

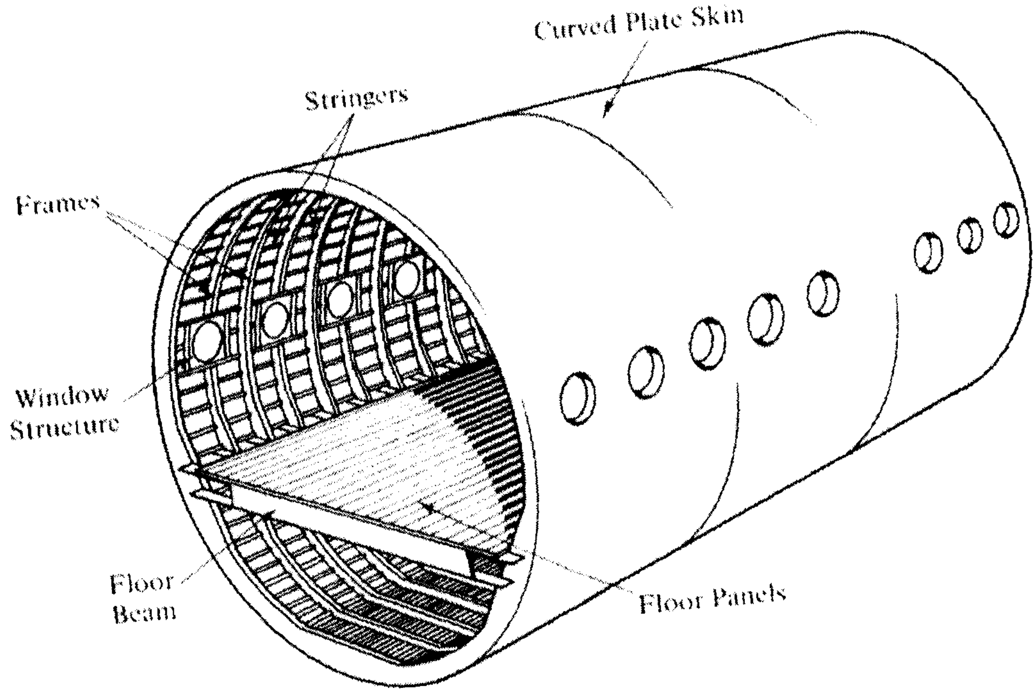
LITERATURE REVIEW

2.1 INTRODUCTION

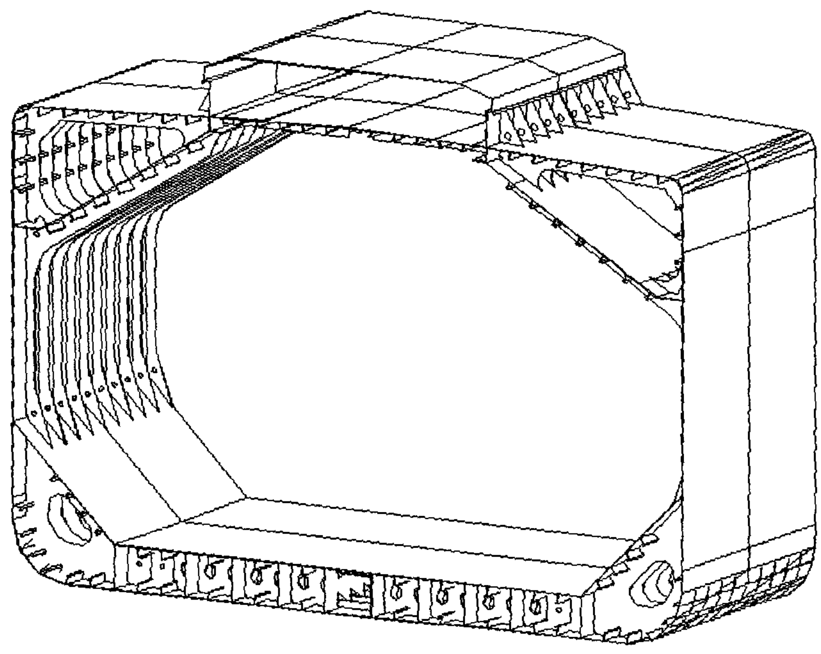
Stiffened plate is a combination of a plate and stiffeners, and is widely used in engineering structures; for instance, in bridge, aircraft and ship structures. The geometry of stiffened plates can be found to be varying depending mainly on the purpose of the application. Moreover, in the fabrication of metal stiffened plates, welding is generally used to connect the stiffeners with the plate. Figure 2.1 shows some examples of structures constructed of stiffened plates.



(a) Bridge structure, www.infovisual.info [1]



(b) Aircraft structure, Szilard [2]



(c) Ship structure, [3]

Figure 2.1 Bridge, Aircraft and Ship structures

Consider, for instance, ship structures that are mostly constructed with plates stiffened with various shapes and sizes of stiffeners. Both the plates and stiffeners are primarily made of steel. Typically, the ship panels are orthogonally stiffened by longitudinal and transverse stiffeners. Figure 2.2 shows a stiffened plate that could be modeled as an orthotropic plate.

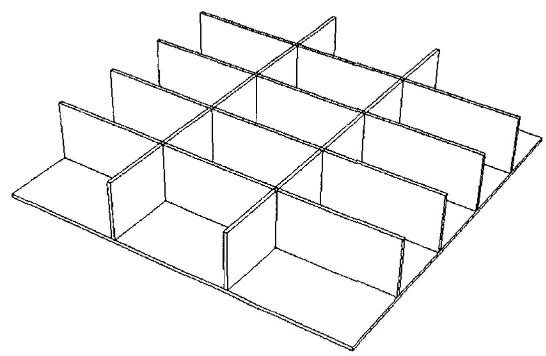


Figure 2.2 Example of a stiffened plate with longitudinal and transverse stiffeners

This investigation focuses mainly on the dynamic behaviour of stiffened plate structures; therefore, the review is carried out only on the vibration response of stiffened plates which have certain types of geometry. A number of methods have been used to study the vibration of stiffened plates, viz., method of elastic equivalence, finite element method and other numerical methods.

The method of elastic equivalence was applied using the concept that a stiffened plate could be transformed to an equivalent orthotropic plate possessing a constant thickness and the equivalent physical and mechanical properties. Finite element method has been employed from the earliest times (of its development), but was found to be inconvenient because the calculation procedure was tedious and time-consuming;

however, since better and better computers with faster computing power have been developed, this method has become more popular. In addition, certain numerical methods, such as finite difference method, Rayleigh's method, Galerkin's method, composite beam-plate (CBP) method, grillage method, spline compound strip method and others have also been used when found advantageous.

Moreover, since welding has been normally used to connect together the various components of stiffened plates, the review would also consider the issues related to welding and effect of weld profiles on structural behaviour.

2.2 CLASSIFICATION OF STIFFENED PLATES BY GEOMETRIES

In order to strengthen any plate structure, stiffeners are commonly used. The stiffeners can be attached onto the plates in one direction or more, and they also can be located on one or both sides of the plates. Figure 2.3 shows an example of stiffened plate in which stiffeners are attached on both sides of the plate.

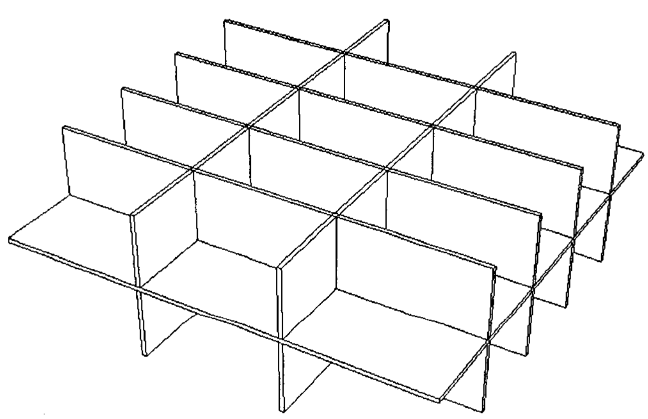
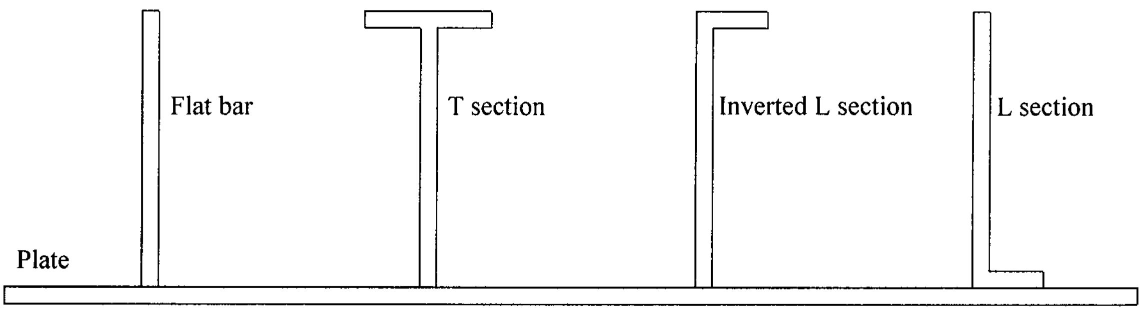


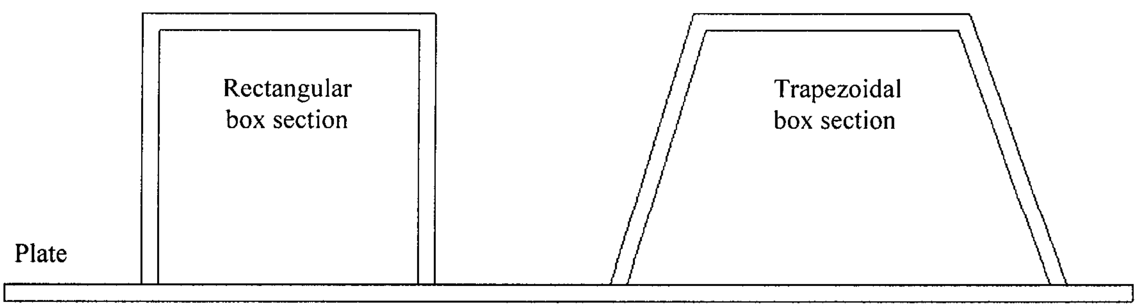
Figure 2.3 Example of a stiffened plate with stiffeners on both sides

The geometry of the stiffened plate can be rectangular, circular, curved or skewed plate. Normally, rectangular stiffened plates can be found in ship structures; circular stiffened plates can be found in architectural structures, and curved or skewed stiffened plates can be found in certain modern structures, such as bridges, airplane wings or missiles.

Moreover, the cross sections of stiffeners can be of a wide variety of shapes and can be generally classified into two categories, viz., that which have an open or a closed sectional profiles. The open sections are often found to use flat bars, T-, L- and inverted L- sections. The closed sections, which can be frequently found in engineering structures, such as bridges, are rectangular or trapezoidal box sections. Figure 2.4 shows some examples of stiffeners.



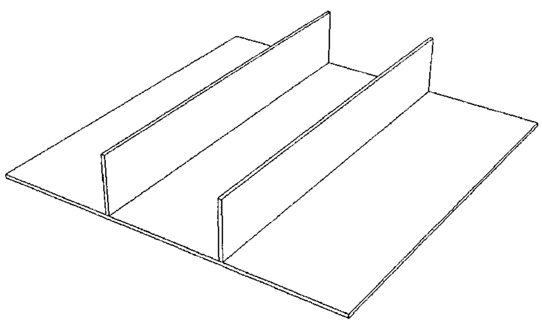
(a) Open sections



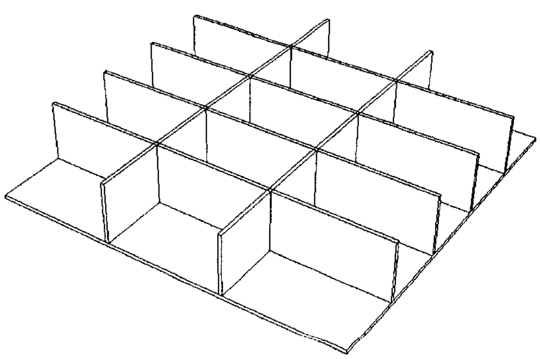
(b) Closed sections

Figure 2.4 Examples of various cross sections of stiffeners

In addition, a stiffened plate, which has stiffeners running only in one direction, is called a singly-stiffened plate. The reasons to construct a singly-stiffened plate may be because the structure needs high flexural rigidity only in one direction; therefore, the structure does not need to be strengthened in the other direction. If stiffeners are connected onto a plate in two directions, especially in two perpendicular directions, this structure is called a cross-stiffened plate. Basically, this kind of structure is constructed to carry both bending and twisting moments along the stiffened directions, and they can be normally found in aircraft and ship structures. Figure 2.5 shows examples of singly- and cross-stiffened plates.



(a) Singly stiffened plate



(b) Cross stiffened plate

Figure 2.5 Examples of singly- and cross- stiffened plates

2.3 CLASSIFICATION OF WELD PROFILES

Stiffened plates are produced by welding together the plate panels and the various stiffening members. Hence, the quality and type of welding would be contributing to the dynamic behaviour of stiffened plates. Although the geometry of weld profile is not uniform along the welded connections, the typical geometry of the weld profile used to connect engineering structures can be described and defined by some parameters. Figure 2.6 shows some of these parameters that define the actual geometry of weld profile.

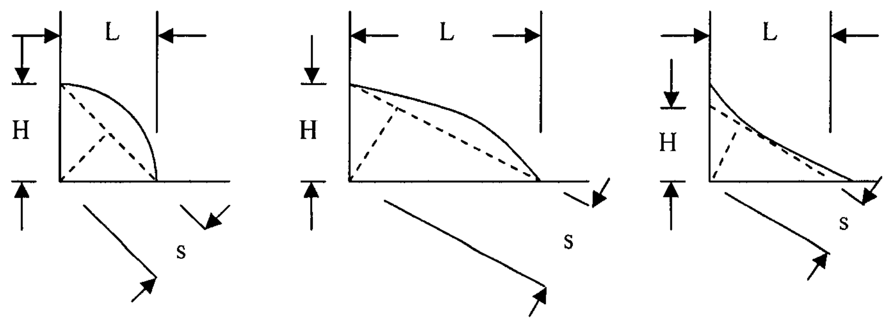


Figure 2.6 Parameters that define the actual geometries of weld profile (based on Faltus [4])

According to Figure 2.6, H is leg height of the weld, L is leg length of the weld and s is throat thickness of weld. The dashed lines represent the geometry of weld profile in engineering; furthermore, only two of these defined parameters are adequate to specify the unique weld geometry. In addition, angle, θ, of triangular geometry of the weld is an alternative parameter that is also normally used to define the weld geometry; moreover, in many specific situations, the notch root radius, ρ, of the weld is also defined. Figure 2.7 shows the geometry of fillet and butt weld profiles defined using the mentioned alternate parameters.

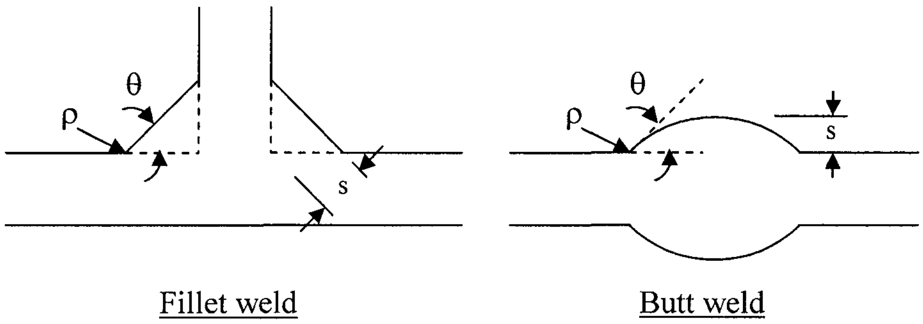


Figure 2.7 Alternate parameters that define the geometry of weld profile (based on Almar-Næss [5])

Welding is widely used in engineering structures; therefore, industrial standards and certification procedures for welding have been developed to ensure that the weld has sufficient strength to stand circumstances that may occur under operating conditions. For instance, DNV [6] has its specific requirements for the welding procedures, weld tests and qualification of welders. In order to connect two plates together, the plate should have their sizes such that they can distribute almost uniformly the heat generated during the welding process. Furthermore, tensile tests, face bend and root bend tests, Charpy V-notch tests and macrosection tests are also normally required. Also, the welders are required to be certified and should pass successfully the requirements of the specified standards; one of the most applicable standards is ISO 9606. Similarly, ABS [7] has rules and requirements for weld quality, welding operations and tests for weld and welders. For instance, the strength and toughness of sound welds should be equivalent to those of the base material; moreover, cracks or defects are to be repaired by certain procedures, such as clipping, machining or burning out the unacceptable weld and rewelding again. Also, tensile tests, face bend and root bend tests, Charpy V-notch impact test, macro-etch or other relevant tests are required. Specially, the welders are required to take the welder qualification tests based on the position in which welding is to be done for the given job.

The requirements and rules for welding procedures and welders have been strictly used and followed because improper welding can lead to structural failures that can lead to loss of lives and properties. In other words, the weld normally fails because it is unable to withstand the high stresses developed; high stresses commonly occur at the welded zones and especially at the connection between the weld metal and the base material called the weld root. In engineering terms, these stresses are called hot spot stresses and notch stresses. Figure 2.8 shows an example of location and nature of distribution of hot spot stress and notch stress.

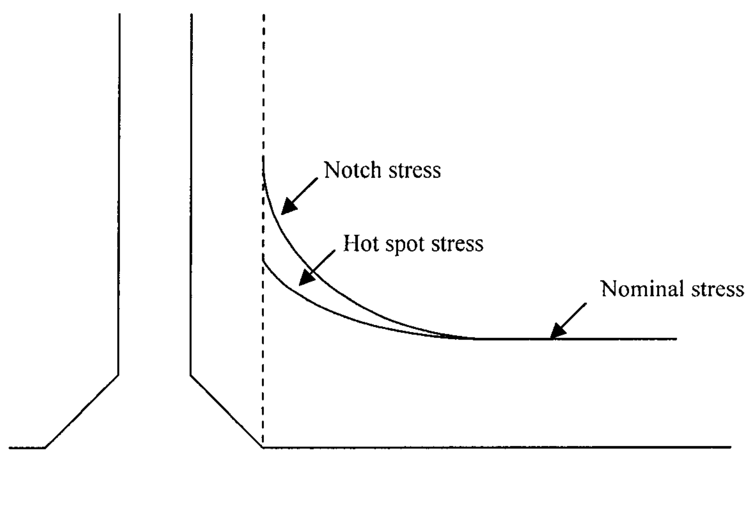
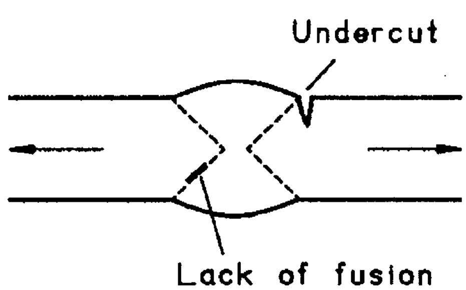
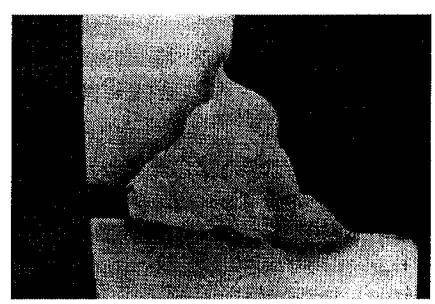


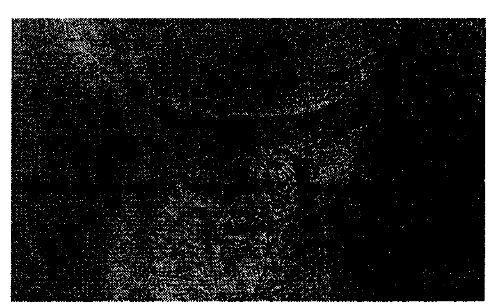
Figure 2.8 Example of location and distribution of hot spot and notch stress

Moreover, the magnitudes of stresses are also high at any sharp corner or where micro cracks occur, and the failure of weld begins when the micro cracks at the weld grow to a larger size. Additionally, the weld crack grows generally from defects that occur during the welding process. Certainly, defects always occur in the weld even though special care is taken in the welding process. Therefore, the Rules and Requirements prescribed in Codes of Standards are constituted to reduce the probability of the occurrences of unwanted shapes and edges in weld geometry that could introduce very high stresses. Many studies have been carried out to study the quality of the weld, which is an important factor that affects the fatigue life of weld. The fatigue cracks are categorized into three stages, which are crack initiation stage, crack growth stage and fracture stage. It was found that the defects in the weld affect largely the fatigue life of weld in the crack growth stage. Figure 2.9 shows some examples of various types of defects occurring in the welded region.





Undercut



Lack of fusion defect

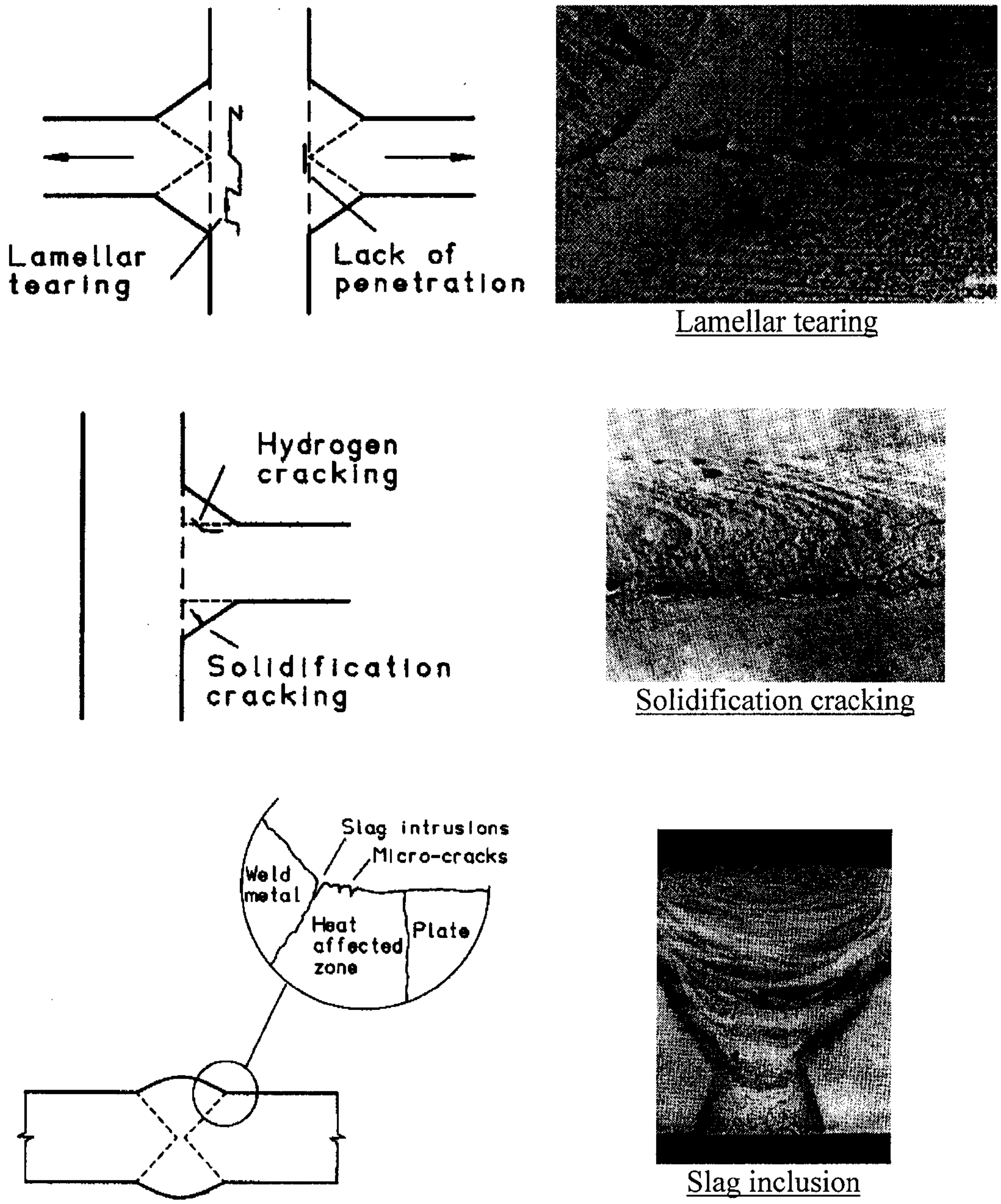


Figure 2.9 Examples of various types of defects, Almar-Næss [5]

Moreover, certain studies have focused on the improvement of weld geometry in order to decrease stress concentration at the weld. The methods that are widely used are grinding and machining, remelting (TIG and plasma dressing), superficial prestressing (hammer and shot peening) and stress relieving heat treatment [8]. These techniques are used to reduce sharp corners, undercuts, locked-in stresses or any other defects that may induce very high stresses. In addition, some studies indicate that even though the macro- and micro-stresses could be ignored regardless of weld defects, the physical properties of the weld metal, the fusion zone and the base material are not identical [4].

2.4 METHOD OF ELASTIC EQUIVALENCE IN VIBRATION OF STIFFENED PLATES

The concept of the method of elastic equivalence used in stiffened plates is to transform the stiffened plate to a simple plate having a constant thickness. Moreover, the physical and mechanical properties of the stiffened plate and the transformed plate should be the same. In addition, most stiffened plates have orthotropic properties due to the manner in which the component members are joined at 90 degree; therefore, these stiffened plates are commonly transformed to orthotropic plates with constant thicknesses. However, certain requirements should be fulfilled in order to use this method, and will be described clearly in Chapter 5. The dynamics and vibration analysis of stiffened plates using method of elastic equivalence has been investigated by a number of researchers, and are reviewed below.

Ng and Kulkarni [9] studied a deck slab stiffened by ribs with two simply-supported and two free edges by treating this structure as an equivalent orthotropic plate and using an approach based on the orthotropic plate theory for computing the natural frequencies. Trigonometric series, suggested by Levy, was employed in the solution of the non-homogeneous partial differential equation of vibration.

$$w(x,y,t) = \sum_m \sum_n W_{mn}(x,y) q_{mn}(t)$$

where,

$$q_{mn}(t) = \sin p_{mn} t$$

$$W_{mn} = \sum_{m=1}^{\infty} Y \sin \frac{m\pi x}{a}$$

Once the results were determined, they were compared with those obtained from the previous studies. A good agreement was then found.

The orthotropic plate approximation was also employed by Wah [10] to obtain the natural frequencies of rectangular plates possessing two simply-supported elastic beams, and arbitrary boundary conditions for the other two edges. Moreover, various ratios of width/length of the plate and number of stiffeners were investigated. Because the beams and their spacings were identical, the finite difference calculus became advantageous in the solution procedure. The analyses were carried out by both the methods, and the results were found to be in good agreement only for the lowest frequencies.

2.5 FINITE ELEMENT METHOD IN VIBRATION OF STIFFENED PLATES

Finite element analysis is one of the mostly used numerical methods, and is widely used for numerical solution of a variety of field problems including dynamics and vibration. A brief idea of dynamic analysis using finite element method is to discretize the structure into a number of elements and nodes. After that, the mass and stiffness matrices of the structure will be computed. Thereafter, the dynamic responses can be determined by solving the Eigenvalue problems corresponding to the assembled mass and stiffness matrices. Since stiffened plates are widely used, studies in dynamics and vibration of stiffened plate have been of considerable interest. Many of these studies have used finite element method, and some of them are reviewed below.

Mukherjee and Mukhopadhyay [11] applied finite element method to analyze free vibration of rectangular and skew stiffened plates possessing various boundary conditions and varying number of stiffeners and spacings. Isoparametric quadratic plate element was used in the analysis to accommodate irregular boundaries of stiffened plate geometries. Moreover, inplane deformation and inplane inertia of the plate were ignored. The obtained results of stiffened plates were well comparable to the results obtained from earlier studies of Wah [10] and Bhandari, Pujara and Juneja [12]. Subsequently, Mukherjee and Mukhopadhyay [13] used finite element method to analyze the free vibration of eccentrically stiffened plates. Once again, isoparametric quadratic plate elements were used in the modelling. Additionally, shear deformation was considered, so that both thick and thin plates could be investigated. In this study, it was stated that the stiffeners could be placed anywhere within the plate element and that they need not be always parallel to the nodal lines. Furthermore, the effect of consistent and lumped mass modelling, and the effects of eccentricity, shape and torsional stiffness of stiffeners were also investigated. It was observed that when the lumped mass approach was used, the results were better only for a coarser mesh division. With consistent mass formulation, when finer mesh divisions were utilized, the results improved greatly in accuracy. The effects of eccentricity in the stiffened plate became significant only when the boundary conditions for inplane motion of the supported edges were considered to be free. When the effect of torsional stiffness was considered, the natural frequencies of a closed U-section stiffener were much higher than the open T-section, for a comparable situation.

Harik and Guo [14] applied finite element method to examine the free vibration of eccentrically stiffened plates. This investigation presented mainly the effects of the eccentricity of stiffeners. The compound finite element model derived from the composite beam-plate section was used in this study. For rectangular stiffened plates, having stiffeners in one direction parallel to edge, the comparison of the obtained results with previous results showed very good agreement. On the other hand, for rectangular stiffened plates having stiffeners in two perpendicular directions parallel to the edges, the comparison between results obtained by the proposed formulation and results obtained by earlier finite element models showed good agreement for low natural frequencies only (modes 1 to 3); for higher modes, the difference was found to be larger. This was observed to be due to the inclusion of membrane forces in the plate and the axial forces in the beams in the compound finite element model, and the neglecting of membrane forces in the plate in the earlier finite element models. Also, two types of equivalent orthotropic plates were studied. The first one accounted for the influence of the eccentricities on the rigidities while the other one did not. Even though the results of these two systems showed good agreement, the first one's results were closer to the results obtained by using the compound finite element model than the results obtained by the second one.

Chandrashekhara and Kolli [15] applied finite element method to analyze free vibration of eccentrically stiffened laminated plates. The stiffened plates were treated as a combination of stiffeners as beams and plates. The formulation included inertia effects due to inplane, flexural and rotary motions of the plate and stiffeners; consequently, it was applicable for both thick and thin plates. 9- and 3-node isoparametric plate and beam elements were used in the finite element analysis. The natural frequencies of the stiffened laminated plates having various boundary conditions, and having varying number of stiffeners were obtained by the proposed method and compared with the natural frequencies obtained by previous studies. Also, the effects of depth, location and ply orientation of the stiffeners were studied. It was reported that the comparison between the results obtained by the proposed method and by the previous studies showed good agreement. Furthermore, it was observed that a change in the location of stiffeners could significantly alter the natural frequencies and the corresponding mode shapes.

Ahmadian and Zangeneh [16] applied the super-element, which was a macro element possessing analytical as well as the finite element shape function, to analyze free vibration of laminated stiffened plates. The stiffened plate was considered as a combination of a plate and beams; consequently, the plate and beam super-elements possessing 55 and 18 degrees of freedoms, respectively, were used. Moreover, singly-stiffened isotropic plate, singly-stiffened laminated plate stiffened in x direction, singly-stiffened laminated plate stiffened in y direction and cross stiffened-laminated plate were also studied. In the case of stiffened isotropic plates, the eccentricity of beam was considered; moreover, in cases of stiffened laminated plates, the fiber directions of 0° and

90° were considered. Regular finite element method was also used for all analyses for the purpose of comparison. Consequently, good agreement was found even though the super-finite-element method employed coarser mesh division; also, the analysis consumed much less time than the regular finite element method for the analyses. It should be noticed that this method had neglected to essential stiffening contributions from the inplane membrane/axial forces.

2.6 OTHER NUMERICAL METHODS IN VIBRATION OF STIFFENED PLATES

The stiffness method (fore-runner to finite element method) was employed by Long [17] to calculate the natural frequencies and mode shapes of rectangular plates possessing stiffeners in one direction with one pair of sides simply-supported. The effects of in-plane displacements were found to be small and neglected in the direction normal to the direction of stiffening. Also, it was observed that if the membrane stresses were small compared to the bending stresses, the results would be very accurate. The comparison between this method and the composite beam-plate (CBP) method showed very good agreement, and the computational time taken by this method was much less than the CBP method.

Aksu and Ali [18] applied finite difference method to examine the free vibration of rectangular stiffened plates having a single stiffener. Moreover, the effects of in-plane inertias were considered to be small and ignored. The variational technique was applied in order to obtain the minimum total energy of the stiffened plate in the finite difference formulations. The obtained results were compared with the results obtained from the stiffness method, and the results were shown to be in good agreement. Thereafter, Aksu [19] extended the previous work by including the effects of in-plane deformations and in-plane inertia. The main purpose of this work was to examine the effects of in-plane deformations and in-plane inertia on the natural frequencies of uniaxial and cross-stiffened rectangular plates with simply-supported edges. As a result, the in-plane displacement in the direction of stiffening was reduced when the in-plane displacement normal to the direction of stiffening was included. Furthermore, the stiffness of the entire structure was increased when the in-plane stiffness of the plate in the direction normal to the direction of stiffening and the bending stiffness of the stiffeners were included.

The grillage method was applied by Balendra and Shanmugam [20] to analyse free vibration of plates, stiffened plates and cellular plates. In the analysis of plates, it was found that a minimum of eight divisions in both longitudinal and transverse directions were required to obtain acceptable results. Moreover, aspect ratios of 1.5 and 2.0 of the plates were studied. In analysis of stiffened plates, three aspect ratios of 1.0, 1.5 and 2.0 of the plate with 1, 3 and 7 stiffeners in transverse direction were studied. And, for the stiffened plate with the aspect ratio of 1.5, the stiffened plate that was stiffened in both longitudinal and transverse directions was studied. Furthermore, in the analysis of cellular structures, the shear lag and torsional rigidity effects were considered, and the structures possessed eight, twelve and sixteen cells. Once the results from all analyses were obtained, they were compared with those obtained from finite element method and experiments. The results were in good agreement, but the computational time for the grillage method was found to be much less than that for the finite element method.

Michimoto and Zubaydi [21] applied the Rayleigh-Ritz energy method to obtain the approximate natural frequencies of rectangular, trapezoidal and triangular stiffened plates. Moreover, it was stated that the coordinate system could be transformed, so that the trapezoid could be expressed as a rectangle, and a method to determine the dimensions of the rectangular stiffened plate, whose fundamental natural frequency was equal to that of the trapezoidal stiffened plate, was proposed. The obtained results were compared with the experimental results. Good agreement was found in the vibration of trapezoidal stiffened plates. Furthermore, for trapezoidal stiffened plates, if the ratio between the upper and lower side was greater than 0.75 and the direction of stiffeners was normal to the upper and lower sides, the fundamental natural frequency was almost equal to that of the rectangular stiffened plate. For the triangular stiffened plate, according to the proposed equation:

$$w = \sum_{m=1}^{M} \sum_{m=1}^{M} w_{mn} \sin \frac{m\pi}{2} \left(\frac{x - C_2 y}{C_1 y + a/2} + 1 \right) \sin \frac{n\pi}{b} y$$

the direction of stiffeners needed to be in x-axis in order to obtain accurate results.

Chen, Liu and Chern [22] proposed the spline compound strip method to study vibration analysis of one-directional stiffened plates and cross stiffened plates. The proposed method used concepts similar to the finite element method by dividing the plates in one direction to finite strips. The Ritz-Galerkin method, with β-splines as trial functions, was applied in the other direction. The compound strip used the technique that the stiffener was attached to the strip, and the displacement fields of stiffener were constrained to those of the strip. Once the results were obtained, they were compared with the results obtained by finite difference, finite element method and experiments. Good agreement was found; however, the spline compound strip method took less computational time than the other two analytical methods.

Bedair and Troitsky [23] studied the fundamental frequency characteristics of eccentrically and concentrically stiffened simply supported plates. The stiffened plates were treated as an assemblage of plates and beams. The formulation to obtain the fundamental natural frequency was derived from the energy approach in terms of out-of and in-plane displacement functions, and then the fundamental natural frequency of the assembled structure was obtained by using the sequential quadratic programming (SQP). Once a number of stiffened plates with several stiffening configurations were analyzed, the results were presented in graphs that could be used to find the depth (of the stiffener) / thickness (of the plate) ratios that maximized the lowest natural frequencies of structures.

Zeng and Bert [24] applied the pb-2 Rayleigh-Ritz method, which used the trial functions obtained as the product of two-dimensional orthotropic polynomials, to examine free vibration analysis of discretely stiffened skew plates. Moreover, in this investigation, three different boundary conditions were used, and skew plates without stiffener, skew plate with stiffener running orthogonal to two opposite edges and skew plate with cross stiffeners were examined. Also, the effects of skew angle, edge ratio and stiffener height-plate thickness ratios were studied as well. Because no prior investigation was carried out on such plates, the finite element method was also employed in the study to compare the results. The results of the two methods were found to be in close agreement. Furthermore, it was found that the stiffeners with light weight provided the stiffness effect more than the mass effect, and, usually, the provision of stiffeners affected the higher modes considerably. In addition, higher skew angle or smaller edge ratio provided higher natural frequencies, and deeper stiffeners provided higher stiffness to the structures.

Mukhopadhyay [25] applied semi-analytic finite difference method in the vibration and stability analyses of stiffened plates. Moreover, only the bending displacements of plate and stiffeners were considered. The technique for this investigation was to substitute the displacement function satisfying boundary conditions in one direction (y or x) into partial differential equations (with constant coefficients) of the stiffened plates; the resultant ordinary differential equations were then solved by the finite difference technique. The eigenvalue problem was then solved, and the natural frequencies were obtained. In this analysis, rectangular stiffened plates having various boundary conditions, mass and stiffness properties and different number of stiffeners were studied. The obtained results were compared with available results from other sources and excellent agreement was obtained. In addition, the computational time consumed by this method was less than that used by the ordinary finite difference method.

2.7 SUMMARY

From the above literature review, it can be seen that no researchers had carried out any vibration studies concerning the effects of variations of plate and stiffener dimensions generated due to varying rolling and fabrication procedures. In addition, it can also be seen that no earlier investigator had examined the influence of welding on the free vibration response of stiffened plates. The present study was undertaken with the above two aspects in focus; moreover, two approximate methods were also applied to determine the natural frequencies of stiffened plates.

CHAPTER 3

EXPERIMENTAL MEASUREMENTS

3.1 INTRODUCTION

This investigation mainly focused on the effects of variability in thicknesses of components of stiffened plates and also on the variability of weld profiles that connected these components together. Figures 3.1 and 3.2 show the actual geometry of stiffened plate and a sample of the weld profiles.

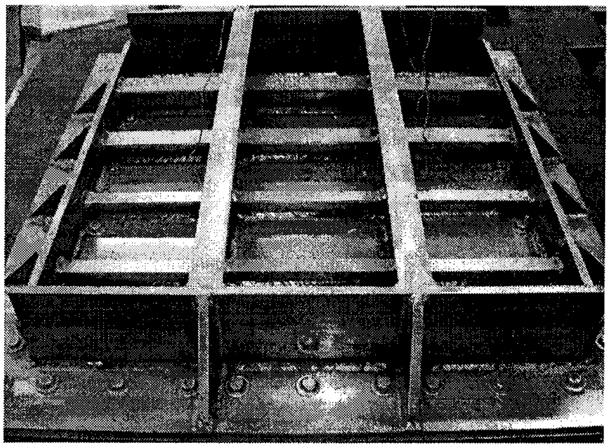


Figure 3.1 The actual stiffened plates used in this investigation

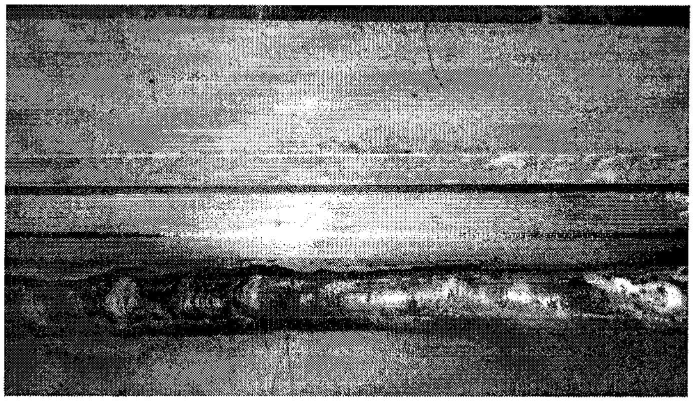


Figure 3.2 A sample of the weld profile

Due to the variability in dimensions of stiffened plate components and weld profiles, measurement had to be made carefully to obtain the most probable dimensions that were to be used for the finite element analysis.

Since large variation in dimensions of each component was obtained, these data were tested for normality in distribution. If the data was normally distributed, then the probability that the data ranged between $\mu - 3\sigma$ to $\mu + 3\sigma$ was 99.73%. This concept was used to verify whether it was practically possible to have the measured data within or outside this range.

3.2 STRUCTURE GEOMETRY IN FINITE ELEMENT ANALYSIS

Two identical stiffened plates, fabricated using aluminum plate panels and T-section rolled members, were used in this investigation. The plate panels were cut larger than the area representing the stiffened plates for the purpose of installation and provision of the fixed boundary as shown in Figure 3.1. Moreover, four rectangular flat plate members were attached along four sides (at the edges of stiffened plates) to provide fixed boundary conditions. However, when the finite element analysis models were generated, only the geometry representing the stiffened plates was modeled, and this is shown in Figure 3.3.

The expected dimensions of stiffened plate components were specified before the fabrication and are tabulated in Table 3.1. Moreover, Figure 3.4 illustrates these dimensions in various views.

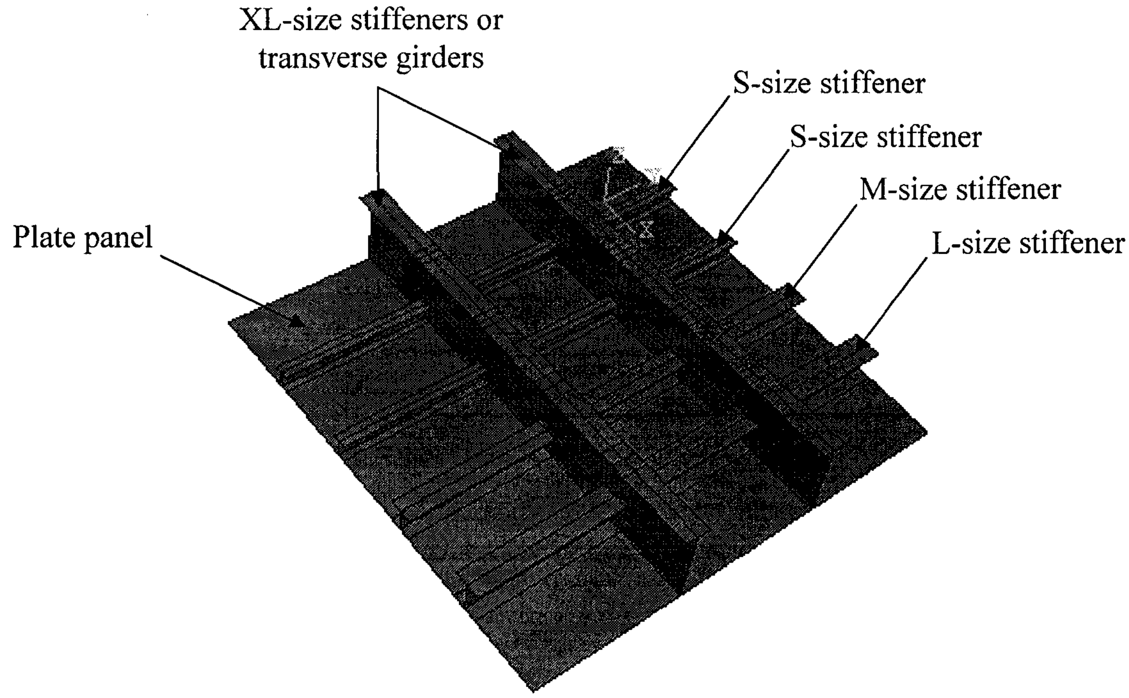


Figure 3.3 Perspective view of the stiffened plate

FLANGE		
Type	Size	Dimension
Thickness	S-size	4.76
	M-size	4.76
	L-size	6.35
	XL-size	6.35

WEB		
Type	Size	Dimension
Thickness	S-size	4.76
	M-size	4.76
	L-size	6.35
	XL-size	6.35

Type	Size	Dimension
Width	S-size	20.00
	M-size	31.75
	L-size	38.10
	XL-size	31.75

Type	Size	Dimension
Height	S-size	31.75
	M-size	38.10
	L-size	50.80
	XL-size	116.94

PANEL	
Type	Dimension
Width	600.00
Length	600.00
Thickness	6.35

SPACING (mm)	
Type	Dimension
Transverse stiffeners	200.00
Longitudinal stiffeners	120.00

Table 3.1 Expected dimensions of components of stiffened plate before fabrication

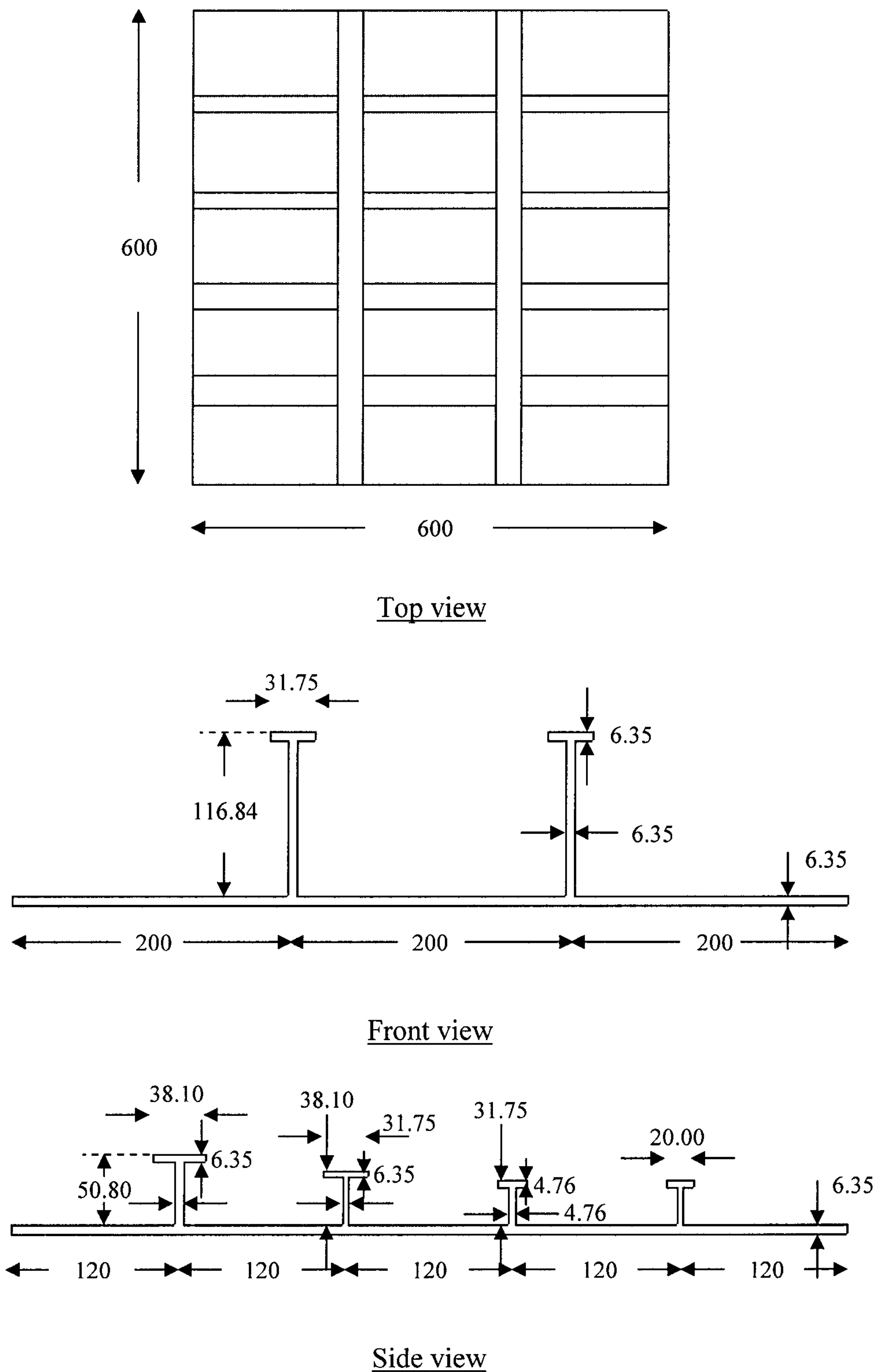


Figure 3.4 Various views of the illustrated geometry of stiffened plate

3.3 DIMENSIONS OF COMPONENTS OF STIFFENED PLATE

3.3.1 Panel

The width and length of panel were specified to be equal to 600 by 600 mm, and these dimensions were kept unchanged in the finite element analysis models. However, the thicknesses of panels varied due to the fabrication (rolling) procedures; these thicknesses were measured using a digital micrometer, as shown in Figure 3.5. The accuracy in measurement was up to three decimal places.

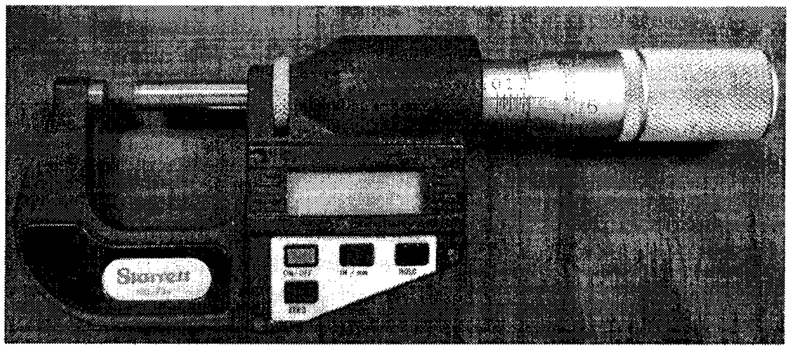


Figure 3.5 Digital micrometer

Nonetheless, these measurements could not be made on the stiffened plate models used for this investigation since the stiffened plate models were fabricated before this investigation was begun. Even though the thicknesses of panels around the four edges of the stiffened plates could be measured, the thicknesses at these locations did not seem to be reliable because there were sanded and ground around these areas. Therefore, the thicknesses of panels were measured from the original plates from which the panels were cut, and 200 measurements were made.

3.3.2 Stiffeners

Four different sizes of stiffeners were used in the fabrication of stiffened plates; all of them had the same T-section profile. The sizes were named as S- , M- , L- and XL-size beginning from the smallest to the biggest size, respectively; furthermore, the XL-size stiffeners were also called as transverse girders of the stiffened plate. In longitudinal direction, there were three different sizes of stiffeners consisting of two S-sizes stiffeners, one M- and one L-size stiffener. Moreover, there were two XL-size stiffeners in transverse direction. The spacings of the longitudinal stiffeners were specified to be equal to 120 mm. The spacing was 200 mm for the transverse stiffeners. These spacings were kept unaltered in the finite element analysis models, and the side view and front view of this model were given earlier in Figure 3.4.

Consequently, only the dimensions of T-section stiffeners were measured. The thicknesses of flange and web of stiffeners were measured using the digital micrometer. The thicknesses of flanges were directly measured from the stiffened plates while the thicknesses of webs had to be measured from the original T-section members from which the T-section stiffeners were cut. Because the digital micrometer had a limit in measurement, it could not measure the thicknesses of webs with wide flanges attached on the top. In addition, due to the limitations in length measurement of the micrometer, the width of flanges and the height of T-section stiffener were measured using a digital vernier caliper, shown in Figure 3.6, with two decimal accuracy; they were measured directly from the fabricated stiffened plates. Measurements were made approximately along every ten millimeters, in both the transverse and longitudinal directions.

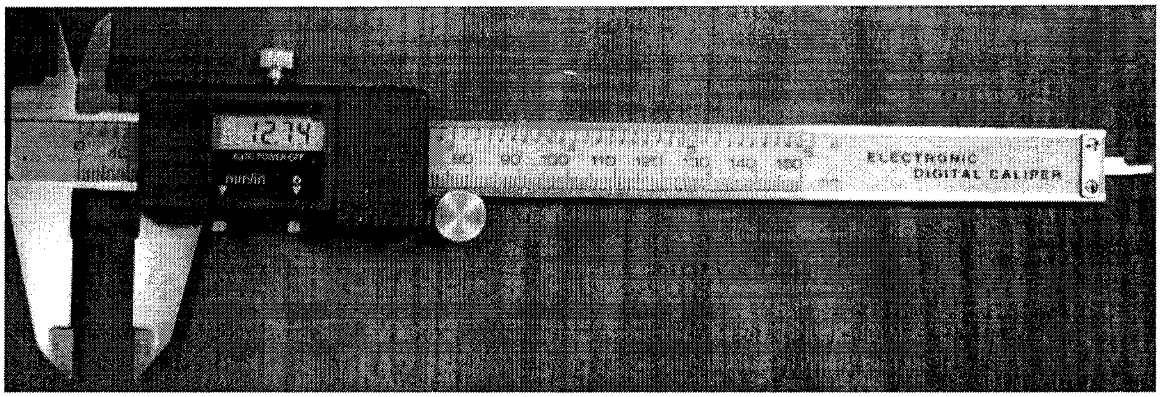


Figure 3.6 Vernier caliper

3.4 WELD PROFILES

3.4.1 Acquisition of weld profile geometry

Since welding was used to connect together the various components of stiffened plates, the weld profiles became parts of the stiffened plate. Normally, when a finite element analysis model is generated for dynamic analysis, the weld is not modeled because the effects of the weld on dynamic responses were anticipated to be very small. However, the effects of weld and the variability of weld profile on the dynamic responses were of interest in this investigation regardless how small the effects would be. Therefore, weld profiles had to be measured very carefully, so as to be used in the subsequent analyses.

Since the surface of weld profile was very rough and highly irregular, the measurements had to be made using a relevant technology. Consequently, a microscribe digitizer, which is a measuring instrument connected to a 3-D CAD software, was utilized in this investigation. With respect to its reference point, the digitizer, as shown in

Figure 3.7, could effectively be used to identify any and every location reached by its pen.

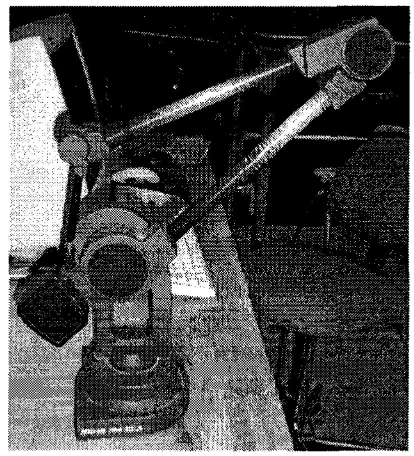


Figure 3.7 Microscribe digitizer

When the weld profiles were to be measured, the digitizer was used to locate a number of points on the weld surface of each section. Then, Rhinoceros 3.0, the 3-D CAD software, interpreted the measurements and plotted those positions as shown in Figure 3.8.

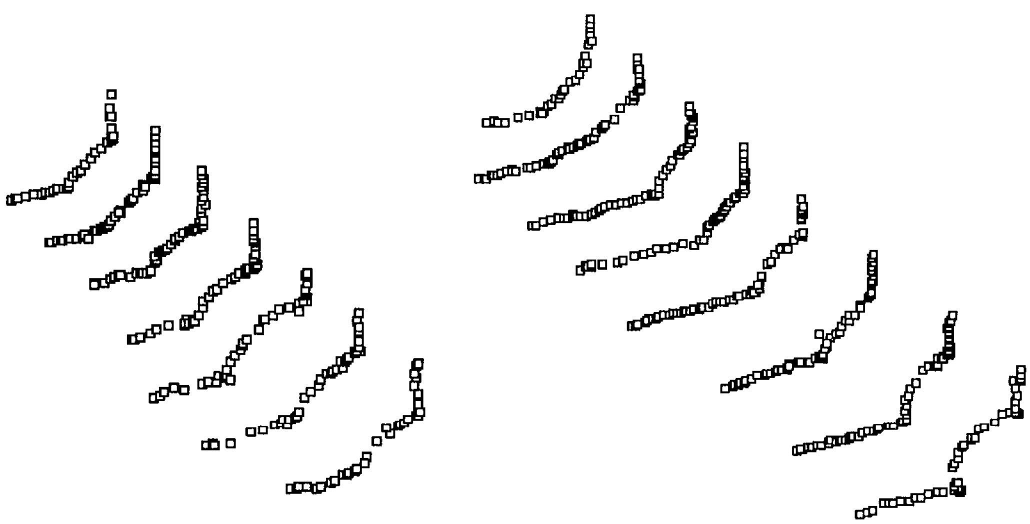


Figure 3.8 Examples of a number of locations on the weld profile, representing several cross sections of weld surface

Functions available in Rhinoceros 3.0 were utilized to generate regular cross sections of weld profile from those measured points. Figure 3.9 illustrates a weld profile obtained by Rhinoceros 3.0. Moreover, areas, centroid of areas and local moments of inertia of areas of each section were also computed by particular functions available in Rhinoceros 3.0.

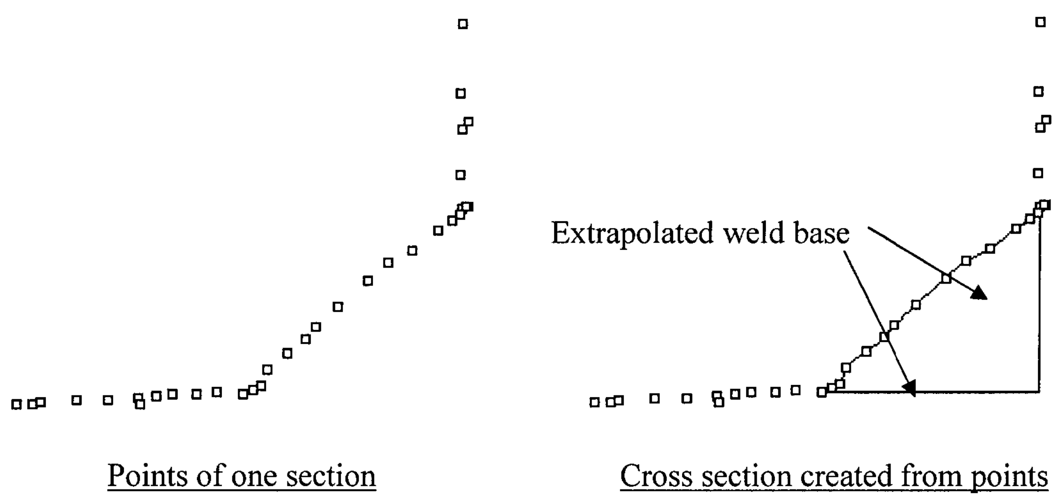
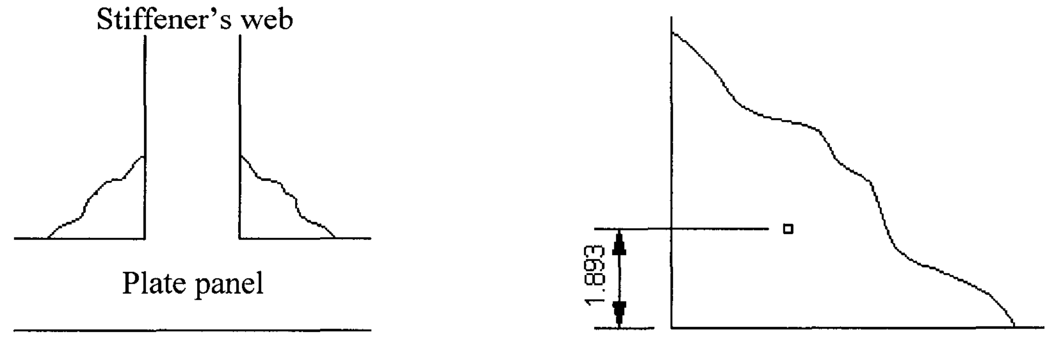


Figure 3.9 Plotting of cross section of weld profile from the measured points

The cross sections of weld profiles were acquired at almost every ten millimeters along the welding lines, and the possibility of acquisition depended mainly on the accessibility around these areas. Consequently, more than 1,400 cross sections of weld profiles were obtained for the two stiffened plates. A few of them are shown here and some of the rest are shown in Appendix A. Figure 3.10 illustrates another example of weld cross section obtained using Rhinoceros 3.0. This example shows the cross section with parts of panel and stiffener, and the location of centroid of weld area in vertical direction.



Weld profile
along with panel and stiffener

Expanded view of weld profile
with the identified centroid

Figure 3.10 Cross section of weld profile with parts of panel and stiffener

3.4.2 Computation of equivalent weld profile geometry

Since quadrilateral shell elements were used in finite element analysis, the cross section of weld profile had to be appropriately transformed to an equivalent rectangular cross section. However, certain assumptions had to be made in order to obtain the equivalent cross sections of the weld.

Since the natural frequencies of structures depended mainly on their stiffness and mass contributions, these two parameters were taken as the significant parameters to be considered in the transformation. These two significant parameters were kept the same for the finite element analysis models, both before and after the weld transformation. An example of a simple stiffened plate, shown in Figure 3.11, illustrates the weld profile transformation and some assumptions that were made in the process.

Assume that a simple stiffened plate consisted of a panel and two T-section stiffeners and had a certain length as shown in Figure 3.11. The stiffeners were connected to the panel by welding.

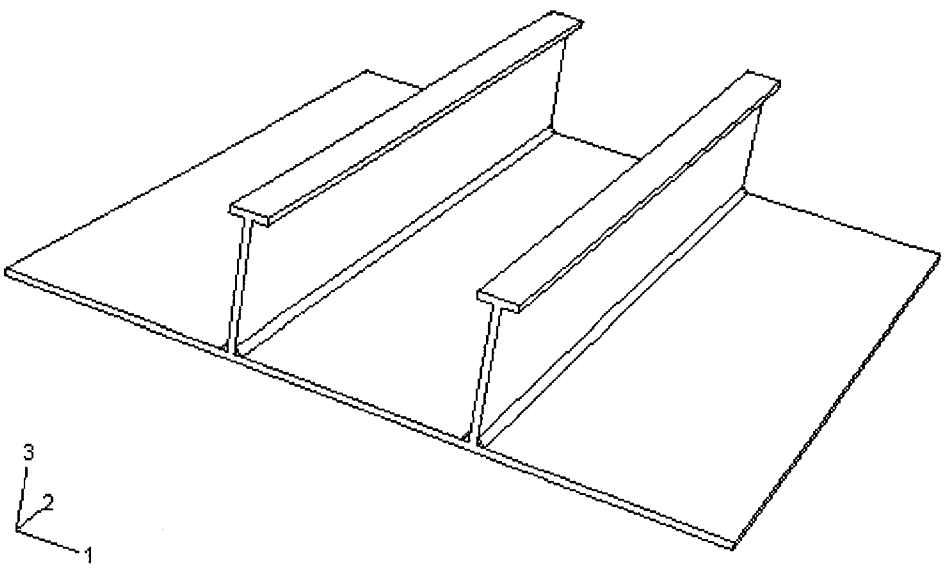


Figure 3.11 A simple stiffened plate

Since only the average of all cross sections, obtained for each welding line, was used, the mass of the entire structure depended primarily on the cross sectional area and length of the structure. Figure 3.12 shows the cross section of the stiffened plate.

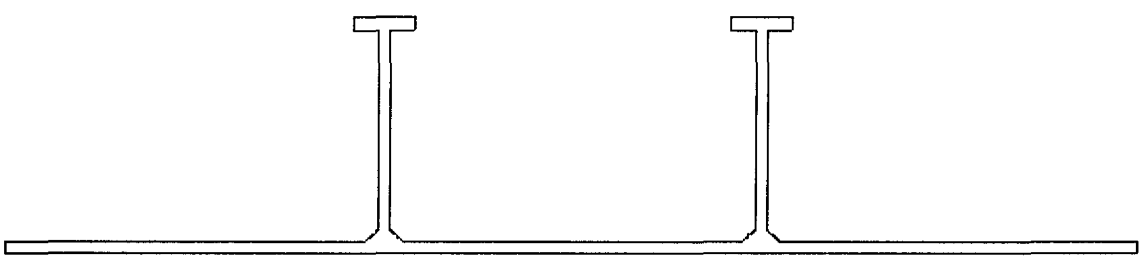


Figure 3.12 Cross section of the simple stiffened plate

Moreover, the stiffness of the structure depended mainly on the elastic modulus and the moment of inertia of the structure. If the elastic modulus was the same for the entire structure, the stiffness would only depend on the moment of inertia which depended on the cross sectional areas and the location of neutral axis. Precisely, when the entire cross section (global section) of the structure was separated to smaller cross sections (local sections), the stiffness of structure depended essentially on distances from the neutral axis of global section to centroid of area of local sections and area of those local sections. Figure 3.13 illustrates the separated cross sections of the stiffened plate and also the locations of centroid of each local section and distances between the local centroids to the neutral axis of the entire cross section.

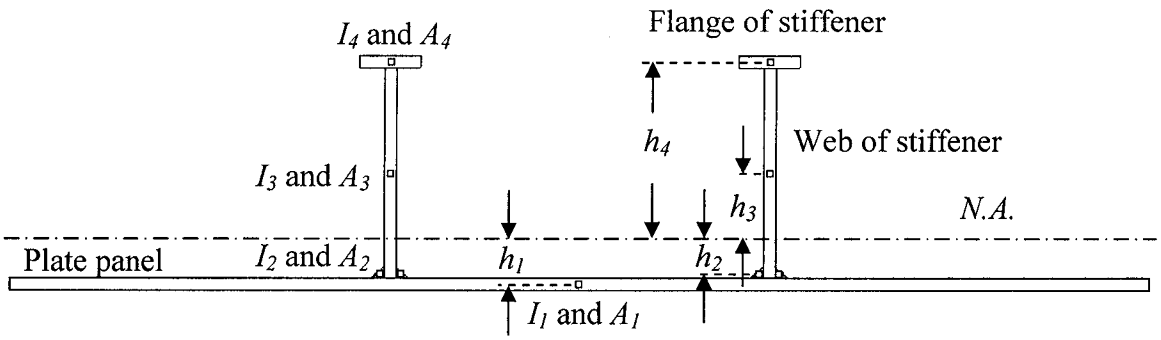


Figure 3.13 Demonstration of distances between centroids of local sections to centroid of global section

where

The dashed line represents the neutral axis of the global section;

I_1, A_1 and h_1 are the local area moment of inertia, area and the distance from the neutral axis to the centroid of the plate panel;

I_2, A_2 and h_2 are the local area moment of inertia, area and the distance from the neutral axis to the centroid of the weld profile;

I_3, A_3 and h_3 are the local area moment of inertia, area and the distance from the neutral axis to the centroid of the web of stiffener, and

I_4, A_4 and h_4 are the local area moment of inertia, area and the distance from the neutral axis to the centroid of the flange of stiffener.

This implies that the areas and positions of centroid of areas of all local cross sections would mainly affect the entire stiffness of stiffened plate. Therefore, when the equivalent transformation of weld cross section was made, these parameters were kept the same. In addition, the area moment of inertia of the entire stiffened plate, $I_{N.A.}$, with respect to its neutral axis could be obtained using formula given below:

<u>Calculation of moment of inertia of the simple stiffened plate structure</u>

$$I_{N.A.} = \left\lfloor I_1 + A_1(h_1)^2 \right\rfloor + 4 \cdot \left\lfloor I_2 + A_2(h_2)^2 \right\rfloor + 2 \cdot \left\lfloor I_3 + A_3(h_3)^2 \right\rfloor + 2 \cdot \left\lfloor I_4 + A_4(h_4)^2 \right\rfloor$$

Based on the above formula, it is obvious that the centroids and areas of all local cross sections should be kept the same before and after the transformation was made. Additionally, keeping the centroids and areas the same led to the same first and second moments of area.

Since any rectangular cross section had only two parameters, viz., height and width, only they were computed. Figure 3.14 shows the geometry of a particular cross section of weld and the equivalent rectangle, having the same area and location of centroid. The procedure of transformation is demonstrated below.

<u>Data obtained from Rhinoceros 3.0</u>

Area of a weld cross section	=	18.703	mm^2
Centroid of area	=	1.893	mm
Local moment of inertia	=	33.893442	mm^4

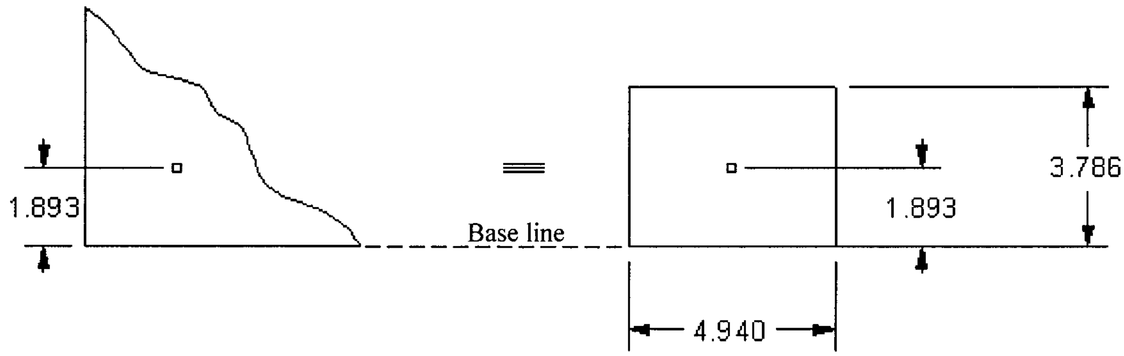


Figure 3.14 Transformation of cross section of weld to rectangular cross section

Transformation to a rectangular cross section

$$Centroid\ of\ area = \frac{h}{2}$$

$$\frac{h}{2} = 1.893$$

$$h = 1.893 \times 2 = 3.786 \qquad \text{mm}$$

$$Area\ of\ a\ section = h \times b$$

$$h \times b = 18.703$$

$$b = \frac{18.703}{h} = \frac{18.703}{3.786} = 4.940 \qquad \text{mm}$$

$$Local\ moment\ of\ inertia = \frac{b \cdot h^3}{12}$$

$$I_{local} = \frac{4.940 \times 3.786^3}{12} = 22.340 \qquad \text{mm}^4$$

Once the height and width of rectangular cross section were obtained, the rectangular cross section could be generated. Since the centroid and area of the cross section were kept the same, the first and second moments of area with respect to the base line were automatically equal for both the original and transformed sections. However, the local moment of inertia of the weld cross section was not equal to the local moment of inertia of the transformed rectangular cross section. This could not be avoided because the assumptions made earlier were to keep the centroid and area (or first and second moment of area) of the cross section the same.

Based on these procedures, all cross sections of weld were transformed to equivalent rectangular cross sections. Table 3.2 and 3.3 show some examples of data of the transformation, and the values shown in bold numbers were kept the same, before and after the transformation; the italic numbers give the height and width of the transformed rectangular cross sections. In addition, all the transformed data are given in Appendix B.

No.	**Original cross section**					
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis				
	mm.	mm.	$mm.^2$	$mm.^3$	$mm.^4$	$mm.^4$
1	1.862	**1.566**	**13.100**	**20.515**	15.2468902 (+/- 3.3e-007)	32.126
2	2.222	**1.711**	**16.938**	**28.981**	26.1880409 (+/- 3.8e-007)	49.586
3	2.207	**1.440**	**14.122**	**20.336**	12.5805211 (+/- 4e-007)	29.283
4	2.342	**1.894**	**19.719**	**37.348**	30.4286693 (+/- 7e-007)	70.737
5	3.115	**2.418**	**33.257**	**80.415**	80.0034677 (+/- 8e-007)	194.445
6	2.460	**2.008**	**22.042**	**44.260**	38.913157 (+/- 6.1e-007)	88.875
7	2.166	**1.842**	**17.676**	**32.559**	25.2651385 (+/- 4.1e-007)	59.974
8	1.962	**2.167**	**18.909**	**40.976**	52.3505403 (+/- 4.9e-007)	88.795
9	3.479	**1.943**	**30.177**	**58.634**	63.9557814 (+/- 6.4e-007)	113.926
10	1.600	**1.924**	**13.693**	**26.345**	21.7808367 (+/- 3.5e-007)	50.688

Table 3.2 Examples of data of the original cross section of weld profiles

No.	Modified cross section (Rectangular cross section)							
	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis	height	width				
	mm.	mm.	mm.	mm.	$mm.^2$	$mm.^3$	$mm.^4$	$mm.^4$
1	2.091	**1.566**	*3.132*	*4.183*	**13.100**	**20.515**	10.709	32.126
2	2.475	**1.711**	*3.422*	*4.950*	**16.938**	**28.981**	16.529	49.586
3	2.452	**1.440**	*2.880*	*4.903*	**14.122**	**20.336**	9.761	29.283
4	2.603	**1.894**	*3.788*	*5.206*	**19.719**	**37.348**	23.579	70.737
5	3.438	**2.418**	*4.836*	*6.877*	**33.257**	**80.415**	64.815	194.445
6	2.744	**2.008**	*4.016*	*5.489*	**22.042**	**44.260**	29.625	88.875
7	2.399	**1.842**	*3.684*	*4.798*	**17.676**	**32.559**	19.991	59.974
8	2.181	**2.167**	*4.334*	*4.363*	**18.909**	**40.976**	29.598	88.795
9	3.883	**1.943**	*3.886*	*7.766*	**30.177**	**58.634**	37.975	113.926
10	1.779	**1.924**	*3.848*	*3.558*	**13.693**	**26.345**	16.896	50.688

Table 3.3 Examples of data of the transformed cross section of weld profiles

All data in Table 3.2 were obtained from the weld profile measurements, and Rhinoceros 3.0 was utilized to interpret and calculate. Only the vertical distance between the base line (horizontal axis) to the centroid and the area of weld profile were kept constant. Once all data of interest of the weld profile cross section were obtained and interpreted, the width and height of the modified rectangular cross sections were calculated. All data of the width and height were later tested for the normality of distribution, and their mean values and standard deviations were used in generating the finite element analysis models.

3.5 STATISTICAL ANALYSIS

Once all dimensions of components of stiffened plates and equivalent weld profiles were obtained, these data were analyzed and tested based on the statistical criteria. Brief general concepts of the statistical criteria used in this investigation are given below.

3.5.1 Probability density function

In statistics, the first derivative of distribution function, $F(x)$, with respect to the interested variable x is called probability density function, $f(x)$. The expression of probability density function can be written in mathematical term as shown in equation (3.1) [26] and plotted as shown in Figure 3.15 [27].

$$f(x)=\frac{d(F(x))}{dx} \tag{3.1}$$

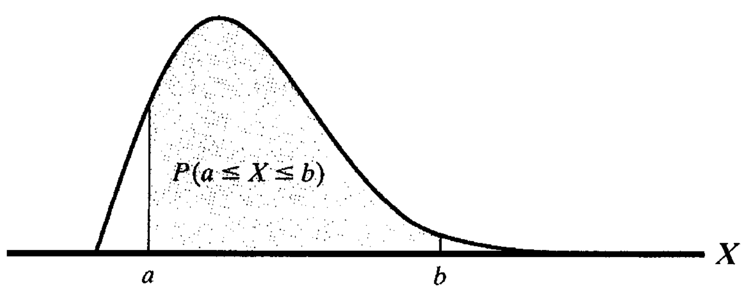


Figure 3.15 Probability density function

Normally, the area under probability density function between two interested points, for instance, a and b is equal to probability that a random variable of X will fall in between those two points. Equation (3.2) illustrates, in mathematical form, the probability that a random variable of X will be in the interval a and b.

$$P(a \leq X \leq b) = \int_a^b f(x)dx \tag{3.2}$$

It is noted that the total area under any probability density function is equal to one, and give a 100 % probability for the event.

3.5.2 Normal distribution

Normal distribution is a mathematical distribution that possesses a typical shape of bell curve, and the curve is symmetric. Moreover, normal distribution is also referred to as Gaussian distribution. Assume that X is the variable of interest and X is normally distributed; then normal distribution of X can be obtained by plotting the variable X versus its probability density. In engineering applications, normal distribution is very useful once it is known that the error will tend to be canceled out if there is a lot of data collected. In addition, normal distribution can be represented by two significant parameters which are the mean value and standard deviation. Mean value represents the average of values obtained from all data and can be calculated by the sum of all data divided by number of that data. The mean value can be expressed in mathematical form as:

$$\mu = \frac{\sum_{all\ x} x}{N} \tag{3.3}$$

where

μ is the mean value

x is a specific value of the variable X

N is the total number of x

Standard deviation is a square root of variance which is a parameter used to indicate the variability of data. The shape of normal distribution (broad or narrow) depends on this parameter, and it can be mathematically presented as:

$$\sigma = \sqrt{\frac{\sum_{all\ x} (x-\mu)^2}{N-1}} \tag{3.4}$$

where σ is standard deviation

Furthermore, normal distribution function also can be expressed in mathematical form as shown in equation (3.5) and plotted as shown in Figure 3.16 [25]:

$$f(x;\mu,\sigma) = \frac{1}{\sigma\sqrt{2\pi}} e^{\left[\frac{-(x-\mu)^2}{2\sigma^2}\right]} \tag{3.5}$$

where $f(x;\mu,\sigma)$ is normal distribution function

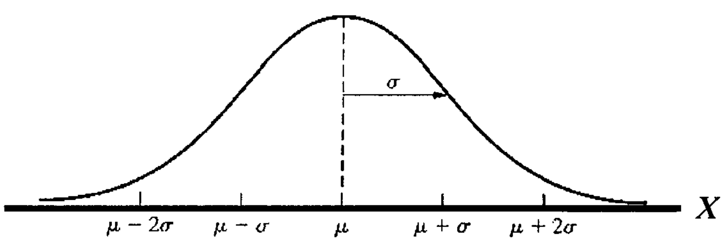


Figure 3.16 Normal distribution

3.5.3 Cumulative normal distribution

Cumulative normal distribution is a probabilistic distribution which is used to show the probability that the variable X is below a given value x for a normal distribution that has the mean value and standard deviation of μ and σ, respectively. Cumulative normal distribution can be expressed as:

$$\Phi(x,\mu,\sigma) = \frac{1}{\sigma\sqrt{2\pi}} \int e^{\left[\frac{-(x-\mu)^2}{2\sigma^2}\right]} dx \tag{3.6}$$

In other words, the area between a pair of limits a and b under the normal distribution is the probability that the variable X is greater than a but less than b. However, there is no closed form solution for the integration between the limits a and b; therefore, tables of normal probability are usually employed. The most commonly used table is the table of standard normal probabilities. This table represents the probability of the normal distribution having a mean = 0 and a standard deviation = 1. This table is included in Appendix C.

3.5.4 Data transformation

Normally, it is very convenient to work with normal distribution, but not all types of data are normally distributed. If normal distribution concept is preferred, the data, which is not normally distributed, needs to be transformed. Transformation is used to change the scale and shape of data distribution. There are many ways to transform the data; for example, the data can be transformed by logarithmic, square root or Box-Cox procedures. However, it is possible that after the transformation is achieved, the transformed data is still not normally distributed.

3.6 PRESENTATION OF MEASURED DATA

Since the statistical criteria and normal distribution are of interest, all the obtained data were tested for normality of distribution by applying certain functions in MINITAB 14 [28], which is a well-known statistical software. All data were plotted as histograms, normal distributions and cumulative distributions. Subsequently, significant parameters, particularly mean value, μ, and standard deviation, σ, were obtained.

3.6.1 Plots of data

Since a lot of data were collected, it is reasonably practical to show here some plots of data. Figure 3.17 and 3.18 show, respectively, plots of normal and cumulative distributions of thicknesses of flanges of S- , M- , L- and XL-size stiffeners.

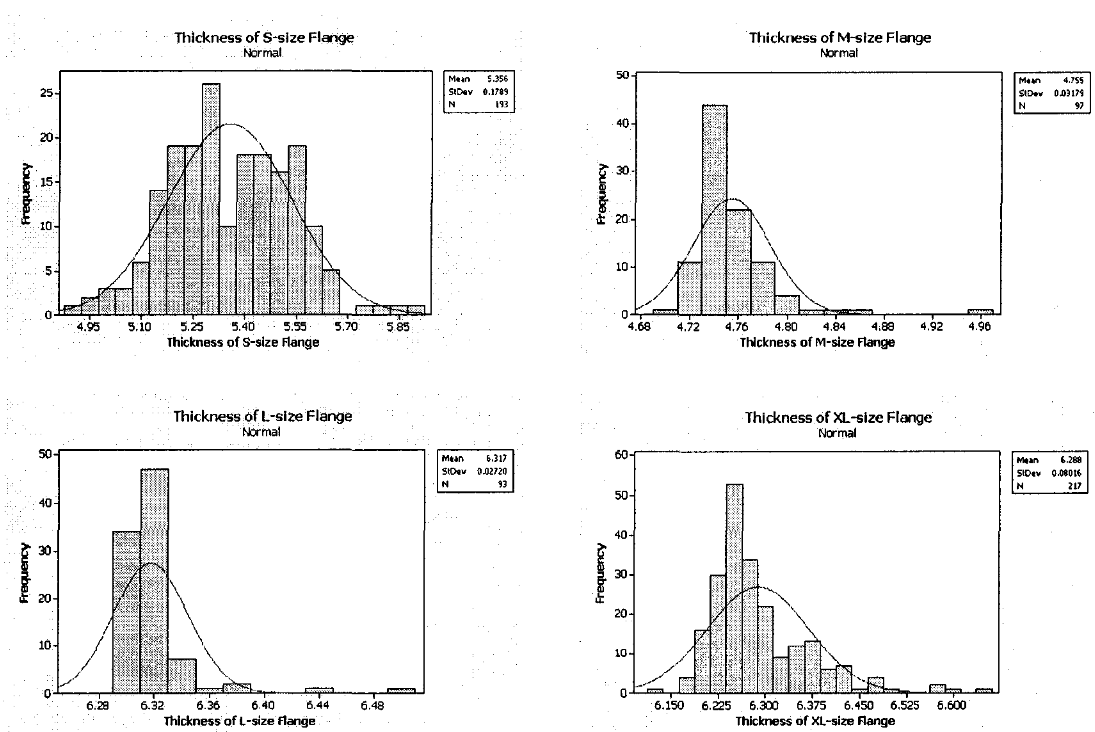


Figure 3.17 Examples of histograms and most possible normal distributions of thickness of flanges of stiffeners

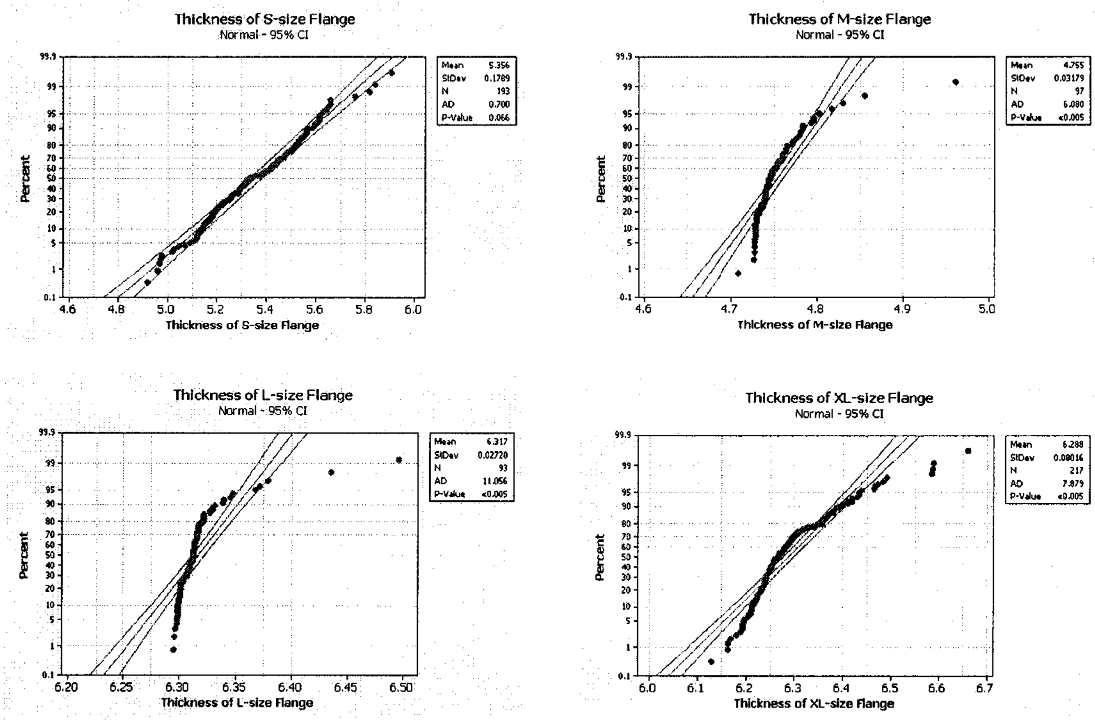


Figure 3.18 Example of cumulative distribution of thickness of flanges of stiffeners

According to the normal and cumulative distributions, it seems that the data of thickness of S-size flange could be regarded as normally distributed while the others could not be accepted as normally distributed. However, the data that did not fit in normal distribution could be transformed and plotted once again to test its normality. But, as stated earlier, the statistical transformations was not the primary objectives of this investigation and could take a lot of time with no guarantee that the transformed data would be normally distributed. Figure 3.19 shows an example of plots of cumulative distribution of the width of weld on panel in both original and transformed data and also the height of weld on panel. This transformation showed that the transformed data fitted better for normal distribution.

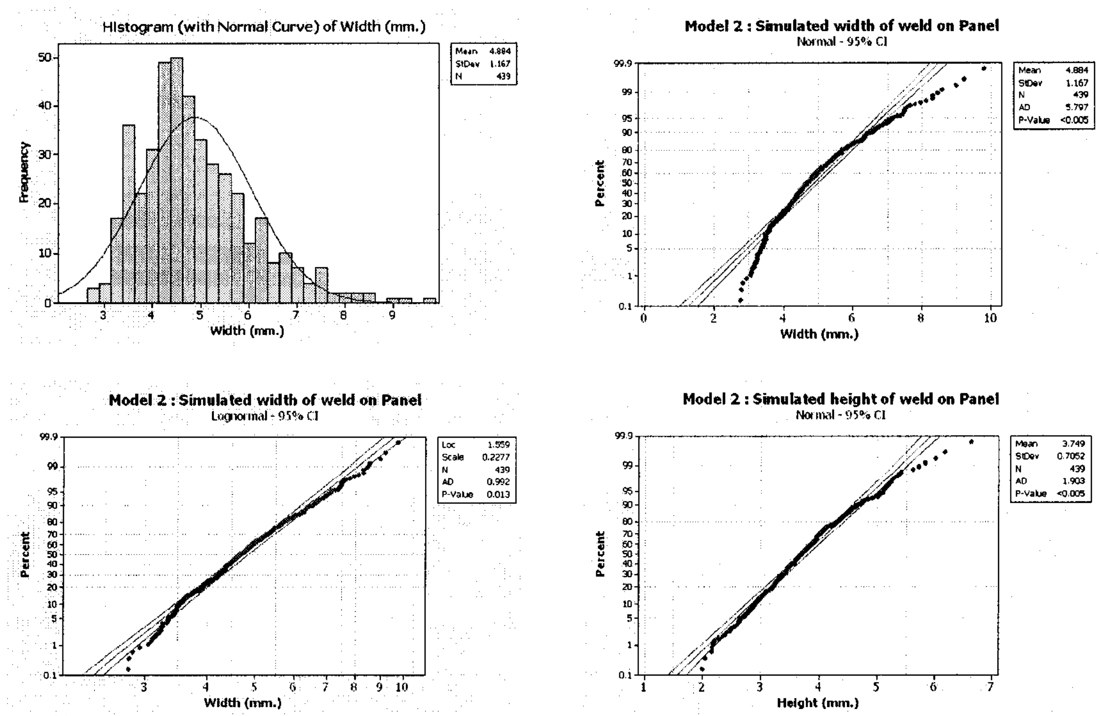


Figure 3.19 Examples of distributions of simulated width and height of weld on panel and one example of transformed data by logarithm

Hence, it is practically applicable to assume that all the collected data were normally distributed, and as well as to assume that 99.73% of data fall in the ranges between $\mu - 3\sigma$ to $\mu + 3\sigma$. In addition, all plots of data are given in Appendix D.

3.6.2 Tables of data

Since MINITAB 14 was used to analyze all data, the means and standard deviations of all data were also obtained. The means and standard deviations of components of Model I and II are tabulated in Tables 3.4 and 3.5, respectively. Furthermore, Tables 3.6 and 3.7 gives the means and standard deviations of width and height of equivalent rectangular cross sections, obtained from weld profile cross sections of Model I and II, respectively.

FLANGE				
	Size	Dimension		σ
Thickness	S	μ	5.356	0.1789
		$\mu+3\sigma$	5.893	
		$\mu-3\sigma$	4.819	
	M	μ	4.755	0.0318
		$\mu+3\sigma$	4.850	
		$\mu-3\sigma$	4.660	
	L	μ	6.317	0.0272
		$\mu+3\sigma$	6.399	
		$\mu-3\sigma$	6.235	
	XL	μ	6.288	0.0802
		$\mu+3\sigma$	6.529	
		$\mu-3\sigma$	6.047	

WEB				
	Size	Dimension		σ
Thickness	S	μ	4.755	0.0318
		$\mu+3\sigma$	4.850	
		$\mu-3\sigma$	4.660	
	M	μ	4.755	0.0318
		$\mu+3\sigma$	4.850	
		$\mu-3\sigma$	4.660	
	L	μ	6.380	0.0126
		$\mu+3\sigma$	6.418	
		$\mu-3\sigma$	6.342	
	XL	μ	6.380	0.0126
		$\mu+3\sigma$	6.418	
		$\mu-3\sigma$	6.342	

	Size	Dimension		σ
Width	S	μ	19.917	0.1653
		$\mu+3\sigma$	20.413	
		$\mu-3\sigma$	19.421	
	M	μ	31.965	0.1851
		$\mu+3\sigma$	32.520	
		$\mu-3\sigma$	31.410	
	L	μ	37.789	0.1107
		$\mu+3\sigma$	38.121	
		$\mu-3\sigma$	37.457	
	XL	μ	32.123	0.1261
		$\mu+3\sigma$	32.501	
		$\mu-3\sigma$	31.745	

	Size	Dimension		σ
Height	S	μ	31.759	0.404
		$\mu+3\sigma$	32.971	
		$\mu-3\sigma$	30.547	
	M	μ	38.609	0.2753
		$\mu+3\sigma$	39.435	
		$\mu-3\sigma$	37.783	
	L	μ	50.557	0.3381
		$\mu+3\sigma$	51.571	
		$\mu-3\sigma$	49.543	
	XL	μ	116.584	0.2741
		$\mu+3\sigma$	117.406	
		$\mu-3\sigma$	115.762	

PANEL			
	Dimension		σ
Thickness	μ	6.190	0.0157
	$\mu+3\sigma$	6.237	
	$\mu-3\sigma$	6.143	

Table 3.4 Analyzed data of components of Model I

FLANGE				
	Size	Dimension		σ
Thickness	S	μ	4.919	0.1104
		$\mu+3\sigma$	5.250	
		$\mu-3\sigma$	4.588	
	M	μ	4.752	0.0320
		$\mu+3\sigma$	4.848	
		$\mu-3\sigma$	4.656	
	L	μ	6.316	0.0203
		$\mu+3\sigma$	6.377	
		$\mu-3\sigma$	6.255	
	XL	μ	6.048	0.0229
		$\mu+3\sigma$	6.117	
		$\mu-3\sigma$	5.979	

WEB				
	Size	Dimension		σ
Thickness	S	μ	4.752	0.0320
		$\mu+3\sigma$	4.848	
		$\mu-3\sigma$	4.656	
	M	μ	4.752	0.0320
		$\mu+3\sigma$	4.848	
		$\mu-3\sigma$	4.656	
	L	μ	6.380	0.0126
		$\mu+3\sigma$	6.418	
		$\mu-3\sigma$	6.342	
	XL	μ	6.380	0.0126
		$\mu+3\sigma$	6.418	
		$\mu-3\sigma$	6.342	

	Size	Dimension		σ
Width	S	μ	20.152	0.1270
		$\mu+3\sigma$	20.533	
		$\mu-3\sigma$	19.771	
	M	μ	32.154	0.1745
		$\mu+3\sigma$	32.678	
		$\mu-3\sigma$	31.631	
	L	μ	37.928	0.1953
		$\mu+3\sigma$	38.514	
		$\mu-3\sigma$	37.342	
	XL	μ	32.195	0.0779
		$\mu+3\sigma$	32.429	
		$\mu-3\sigma$	31.961	

	Size	Dimension		σ
Height	S	μ	31.227	0.2773
		$\mu+3\sigma$	32.059	
		$\mu-3\sigma$	30.395	
	M	μ	37.906	0.3434
		$\mu+3\sigma$	38.936	
		$\mu-3\sigma$	36.876	
	L	μ	50.819	0.3926
		$\mu+3\sigma$	51.997	
		$\mu-3\sigma$	49.641	
	XL	μ	116.788	0.3586
		$\mu+3\sigma$	117.864	
		$\mu-3\sigma$	115.712	

PANEL			
	Dimension		σ
Thickness	μ	6.190	0.0157
	$\mu+3\sigma$	6.237	
	$\mu-3\sigma$	6.143	

Table 3.5 Analyzed data of components of Model II

ON PANEL			
	Dimension		σ
Height	μ	3.786	0.7125
	$\mu+3\sigma$	5.924	
	$\mu-3\sigma$	1.649	

ON PANEL			
	Dimension		σ
Width	μ	4.94	0.8406
	$\mu+3\sigma$	7.462	
	$\mu-3\sigma$	2.418	

ON WEB OF GIRDERS			
	Dimension		σ
Height	μ	3.237	0.6284
	$\mu+3\sigma$	5.122	
	$\mu-3\sigma$	1.352	

ON WEB OF GIRDERS			
	Dimension		σ
Width	μ	4.039	0.585
	$\mu+3\sigma$	5.794	
	$\mu-3\sigma$	2.284	

UNDER FLANGE OF GIRDERS			
	Dimension		σ
Height	μ	3.093	0.5338
	$\mu+3\sigma$	4.694	
	$\mu-3\sigma$	1.492	

UNDER FLANGE OF GIRDERS			
	Dimension		σ
Width	μ	3.854	0.6763
	$\mu+3\sigma$	5.883	
	$\mu-3\sigma$	1.825	

Table 3.6 Analyzed data of weld profiles of Model I

ON PANEL			
	Dimension		σ
Height	μ	3.749	0.7052
	$\mu+3\sigma$	5.865	
	$\mu-3\sigma$	1.633	

ON PANEL			
	Dimension		σ
Width	μ	4.884	1.167
	$\mu+3\sigma$	8.385	
	$\mu-3\sigma$	1.383	

ON WEB OF GIRDERS			
	Dimension		σ
Height	μ	3.598	0.6244
	$\mu+3\sigma$	5.471	
	$\mu-3\sigma$	1.725	

ON WEB OF GIRDERS			
	Dimension		σ
Width	μ	4.651	1.514
	$\mu+3\sigma$	9.193	
	$\mu-3\sigma$	0.109	

UNDER FLANGE OF GIRDERS			
	Dimension		σ
Height	μ	2.737	0.4817
	$\mu+3\sigma$	4.182	
	$\mu-3\sigma$	1.292	

UNDER FLANGE OF GIRDERS			
	Dimension		σ
Width	μ	3.268	0.6466
	$\mu+3\sigma$	5.208	
	$\mu-3\sigma$	1.328	

Table 3.7 Analyzed data of weld profiles of Model II

3.7 DISCUSION OF RESULTS

3.7.1 Comparison between the expected and measured dimensions of stiffened plate components

According to Tables 3.1, 3.4 and 3.5 which are the tables of the expected and measured dimensions of Model I and II, respectively, it can be seen that most of the expected dimensions are in the range between $\mu - 3\sigma$ and $\mu + 3\sigma$. Table 3.8 shows this comparison.

FLANGE

	Size	Dimensions	Expected dimensions	Measured dimensions Model I	Measured dimensions Model II
Thickness	S	μ	4.760	5.356	4.919
		$\mu + 3\sigma$		5.893	5.250
		$\mu - 3\sigma$		4.819	4.588
	M	μ	4.760	4.755	4.752
		$\mu + 3\sigma$		4.850	4.848
		$\mu - 3\sigma$		4.660	4.656
	L	μ	6.350	6.317	6.316
		$\mu + 3\sigma$		6.399	6.377
		$\mu - 3\sigma$		6.235	6.255
	XL	μ	6.350	6.288	6.048
		$\mu + 3\sigma$		6.529	6.117
		$\mu - 3\sigma$		6.047	5.979

WEB

	Size	Dimensions	Expected dimensions	Measured dimensions Model I	Measured dimensions Model II
Thickness	S	μ	4.760	4.755	4.752
		$\mu + 3\sigma$		4.850	4.848
		$\mu - 3\sigma$		4.660	4.656
	M	μ	4.760	4.755	4.752
		$\mu + 3\sigma$		4.850	4.848
		$\mu - 3\sigma$		4.660	4.656
	L	μ	6.350	6.380	6.380
		$\mu + 3\sigma$		6.418	6.418
		$\mu - 3\sigma$		6.342	6.342
	XL	μ	6.350	6.380	6.380
		$\mu + 3\sigma$		6.418	6.418
		$\mu - 3\sigma$		6.342	6.342

Table 3.8 Part I: Expected and measured dimensions of Model I and II

FLANGE					
	Size	Dimensions			
			Expected dimensions	Measured dimensions	
				Model I	Model II
Width	S	μ	20.00	19.917	20.152
		$\mu + 3\sigma$		20.413	20.533
		$\mu - 3\sigma$		19.421	19.771
	M	μ	31.75	31.965	32.154
		$\mu + 3\sigma$		32.520	32.678
		$\mu - 3\sigma$		31.410	31.631
	L	μ	38.10	37.789	37.928
		$\mu + 3\sigma$		38.121	38.514
		$\mu - 3\sigma$		37.457	37.342
	XL	μ	31.75	32.123	32.195
		$\mu + 3\sigma$		32.501	32.429
		$\mu - 3\sigma$		31.745	31.961

WEB					
	Size	Dimensions			
			Expected dimensions	Measured dimensions	
				Model I	Model II
Height	S	μ	31.75	31.759	31.227
		$\mu + 3\sigma$		32.971	32.059
		$\mu - 3\sigma$		30.547	30.395
	M	μ	38.10	38.609	37.906
		$\mu + 3\sigma$		39.435	38.936
		$\mu - 3\sigma$		37.783	36.876
	L	μ	50.80	50.557	50.819
		$\mu + 3\sigma$		51.571	51.997
		$\mu - 3\sigma$		49.543	49.641
	XL	μ	116.94	116.584	116.788
		$\mu + 3\sigma$		117.406	117.864
		$\mu - 3\sigma$		115.762	115.712

PANEL			
	Dimensions		
		Expected dimensions	Measured dimensions of Model I and II
Thickness	μ	6.350	6.190
	$\mu + 3\sigma$		6.237
	$\mu - 3\sigma$		6.143

Table 3.8 Part II: Expected and measured dimensions of Model I and II

Since the statistical criterion of 99.73 % probability that the data is in between $\mu - 3\sigma$ and $\mu + 3\sigma$ was used, the expected dimensions should also be in that range. However, according to Table 3.8, it can be seen that certain dimensions did not follow the criteria. The variations of measured dimensions that do not cover the expected dimensions are the variations of thickness of flange of S-size stiffener of Model I, the variations of thickness of XL-size stiffener of Model II, the variations of width of flange of XL-size stiffener of Model II and the variations of thickness of panel.

In addition, the minimum percentage difference that can be found between the expected dimensions and the mean value of the measured dimensions is 0.028 % occurring for the height of S-size stiffener of Model I. Furthermore, the maximum % difference that can be found between the expected dimensions and the mean value of the measured dimensions is 12.52 % occurring at the thickness of flange of S-size stiffener of Model I. The main reason for this high difference is because the S-size stiffeners were cut from the T-section members whose width of the flange were longer than the required width; therefore, the flange was cut to have the specified width. Additionally, the cut flange of the S-size stiffener seemed to be tapered from the cut edges to the web of the stiffener. Hence, when measurements were made, the locations between the edges and the web of the stiffeners were the location that the measurements were made. As a result, the measured thickness of the flanges of S-size stiffeners was larger than the expected thickness. For the M- and L-size stiffener, the effect of tapered flanges seemed to be very small to be neglected. However, the XL-size stiffeners were fabricated from two plates, web and flange, connected together by welding; therefore, there was no effect of a tapered flange at all. But the weld profiles at the connection between the web and flange were modeled in finite element analysis models. The consolidated results from weld profile measurements are shown in Tables 3.6 and 3.7, for the two models. The welding procedures used for Model I seem to be better than those for Model II since the standard deviation of the width of the weld on panel and on web of girders for Model II are much larger, approximately 2.59 times, than those for Model I whereas the other standard deviations appear to be similar. This indicates one aspect of the quality of welding carried out in the fabrication of the stiffened plates.

3.7.2 Qualities of fabrication and variation of dimensions and weld profiles

According to Tables 3.4 and 3.5, the largest variation of dimensions occurs for the dimensions of height of stiffeners, particularly for the S-size stiffener of Model I. Moreover, the smallest variation of dimensions occurs for the dimensions of thickness of web of stiffeners, particularly at the L- and XL-size stiffener of both Model I and II. Even though the % difference that can be found between the expected dimension and the mean value of the measured dimension of height of S-size stiffener is the smallest, it does not mean that the variation has to be smallest as well. These results can be explained from the fact that the stiffener components were cut from the bigger plate to have the specific heights; hence, larger variations occurred. The thickness of the plate was not modified, so the smaller variations were found. In other words, the uncertainty of industrial fabrication is much smaller than that for fabrication made by human intervention, viz., cutting and welding. Moreover, considering the variation of weld profiles, the larger standard deviation, especially 1.514 mm (over a mean value of 4.65 mm) for the width of the modified rectangular cross section on the web of girders of Model II, were found. The weld profiles had the largest variation of all measured values. This helps to support the contention that the uncertainty made by human intervention is much greater than that occurring in industrial fabrication.

CHAPTER 4

FREE VIBRATION ANALYSIS USING FINITE ELEMENT METHOD

4.1 INTRODUCTION AND SCOPE OF THIS ANALYSIS

Finite element analysis software, ABAQUS, was employed throughout this entire investigation to obtain the free vibration responses, the natural frequencies and mode shapes, of the two identically stiffened plates. For each stiffened plate, two types of models were generated, viz., (1) a model generated ignoring the weld profile, and (2) a model generated including the weld profile. For each of these two types, three different spacings between locations of two transverse girders (XL-stiffeners) were set, and effects of these spacings on the dynamic responses were also analyzed. For the normal model, the spacing between the girders was 200 mm. For the other two models, the girders were moved closer and away from each other, and the spacings between girders were considered to be 195 and 205 mm, respectively. For each of the models with different locations of girders, three more models with different dimensions, viz., μ, $\mu - 3\sigma$ and $\mu + 3\sigma$ were analyzed. The three different dimensions were obtained from measurements, as stated earlier in Chapter 3 and given in Tables 3.4 to 3.7. Furthermore, for each individual model, four stages (of construction) of the models (both without and with weld profile) were generated and analyzed in order to observe the changes of free vibration responses.

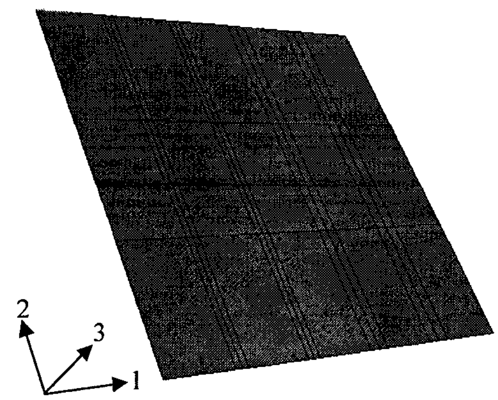
1. Model without weld profile	Girders were located normally with a c/c distance of 200 mm.	Using mean values of thicknesses	4 stages of modeling
		Using mean values + 3 S.D. of thicknesses	4 stages of modeling
		Using mean values - 3 S.D. of thicknesses	4 stages of modeling
	Girders were moved closer to each other with a c/c distance of 195 mm.	Using mean values of thicknesses	4 stages of modeling
		Using mean values + 3 S.D. of thicknesses	4 stages of modeling
		Using mean values - 3 S.D. of thicknesses	4 stages of modeling
	Girders were moved away from each other with a c/c distance of 205 mm.	Using mean values of thicknesses	4 stages of modeling
		Using mean values + 3 S.D. of thicknesses	4 stages of modeling
		Using mean values - 3 S.D. of thicknesses	4 stages of modeling

Table 4.1 Classification of the model without modeling of weld profile

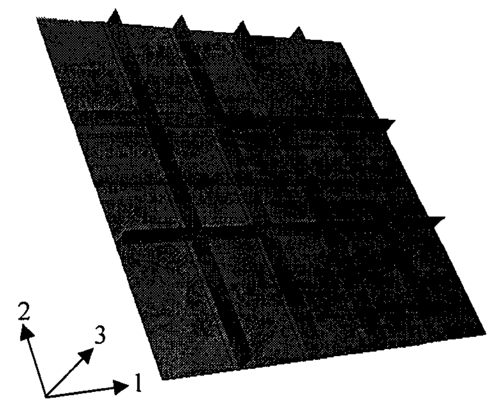
2. Model with weld profile	Girders were located normally with a c/c distance of 200 mm.	Using mean values of thicknesses	4 stages of modeling
		Using mean values + 3 S.D. of thicknesses	4 stages of modeling
		Using mean values - 3 S.D. of thicknesses	4 stages of modeling
	Girders were moved closer to each other with a c/c distance of 195 mm.	Using mean values of thicknesses	4 stages of modeling
		Using mean values + 3 S.D. of thicknesses	4 stages of modeling
		Using mean values - 3 S.D. of thicknesses	4 stages of modeling
	Girders were moved away from each other with a c/c distance of 205 mm.	Using mean values of thicknesses	4 stages of modeling
		Using mean values + 3 S.D. of thicknesses	4 stages of modeling
		Using mean values - 3 S.D. of thicknesses	4 stages of modeling

Table 4.2 Classification of the model with modeling of weld profile

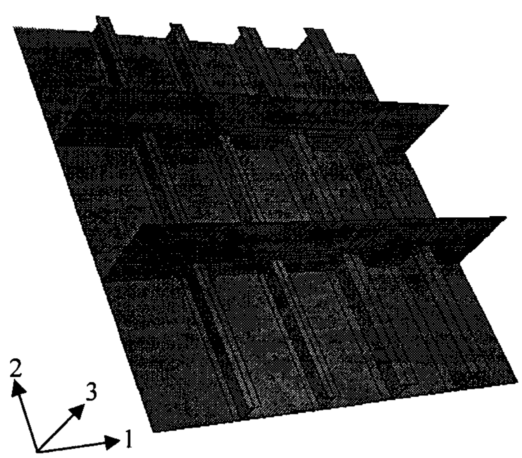
Tables 4.1 and 4.2 show the total number of finite element analysis models, of one of the two stiffened plates, which were analyzed. Figures 4.1 and 4.2 show the four stages of the models used in analysis.



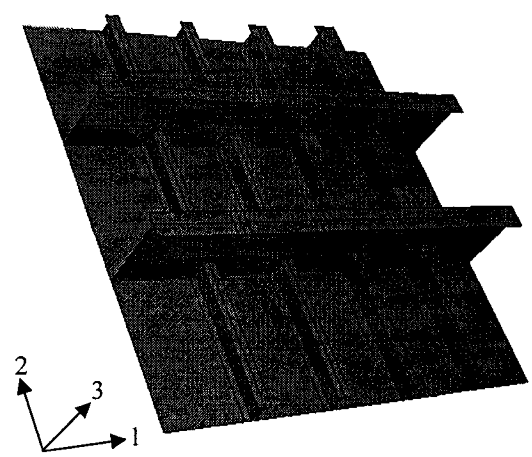
Stage 1
Represents the plate panel only.



Stage 2
Webs of all stiffeners were generated.

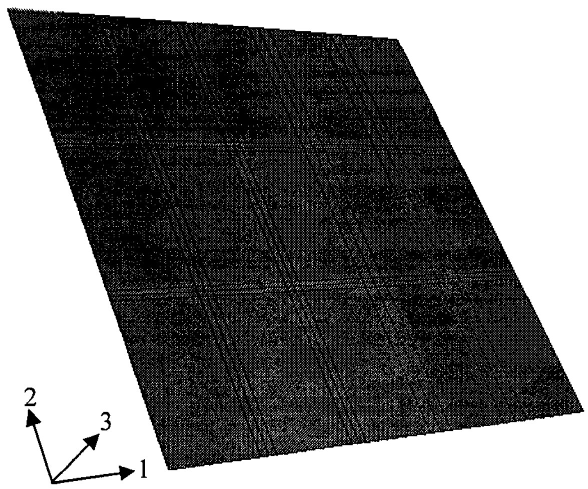


Stage 3
Flanges of S- , M- and L-stiffeners were generated and webs of girders (XL-size stiffeners) were built higher.

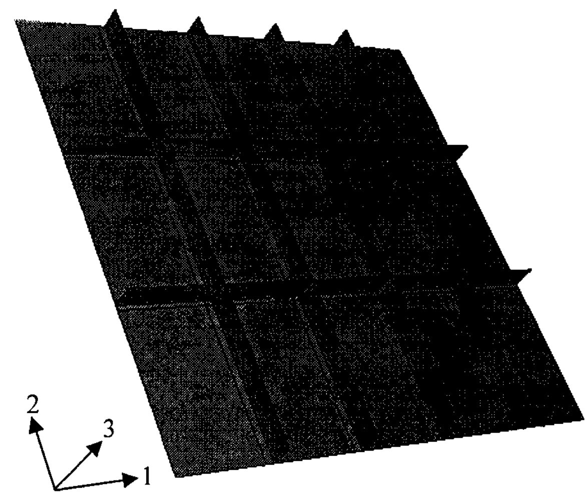


Stage 4
Flanges of girders (XL-size stiffener) were generated.

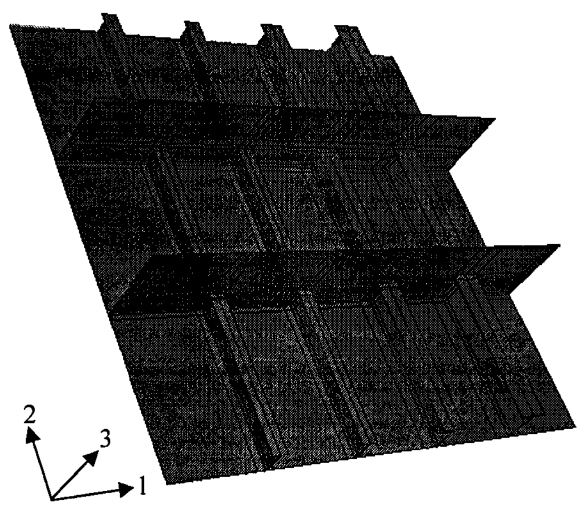
Figure 4.1 Four stages of modeling without the weld profile



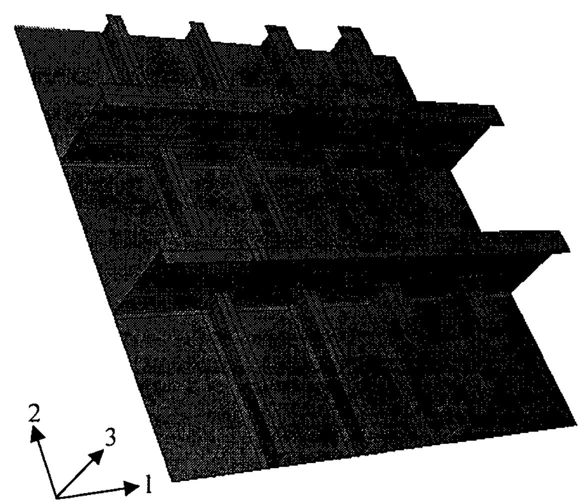
Stage 1
Same as stage 1. in Figure 4.1



Stage 2
The heights of stiffeners' web were the same as those of stage 2 in Figure 4.1. The only difference is the inclusion of weld in this model



Stage 3
Flanges of S- , M- and L-stiffeners were completely generated, and the height of girders' web was little shorter than those of stage 3 in Figure 4.1. The differences are the total height of girders and the inclusion of the weld in this model



Stage 4
Flanges of girders were generated and the height of stiffened plate is the same as those of stage 4 in Figure 4.1. The difference is just the inclusion of the weld in this model

Figure 4.2 Four stages of modeling with the weld profile

Moreover, another finite element analysis software, ANSYS, was also employed to obtain the free vibration responses of a simple stiffened plate, which was a second stage of model without modeling weld profile. This analysis was carried out for the purposes of the comparison of results between the two softwares and also between the two element types used in the study. This became necessary since some unexpected behaviour of stiffened plate (viz., the first natural frequency of a stiffened plate with weld profile was less than that of a stiffened plate without weld profile) was observed from the results obtained from ABAQUS. Two element types used in the above analysis were 4-node and 8-node shell elements.

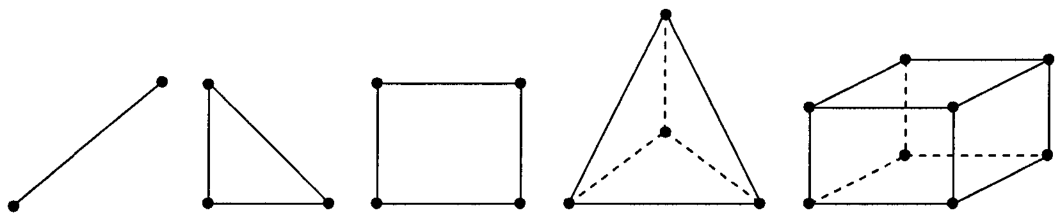
In addition, the selection of the type of element used in finite element analysis was also investigated. The selection of the element was based on the assessment of the difference of obtained results and time consumed for each analysis. Moreover, to select the proper element size, a study examining the convergence was also carried out.

Furthermore, to verify whether the modified rectangular cross section reasonably represented the weld profile, a simple 3-D model composed of a panel, a flat plate stiffener and the weld profile was also analyzed. Different representative weld cross sectional profiles, such as a triangle, quarter-circle, semiparabola, exparabola and rectangle, were used in the process. The 3-D elements, with 15 and 20 nodes, were employed in this part of the study. Moreover, the above situation was also examined by using shell elements with the weld modeled as a rectangular plate section. The free vibration responses obtained from these various models were compared and the salient findings discussed.

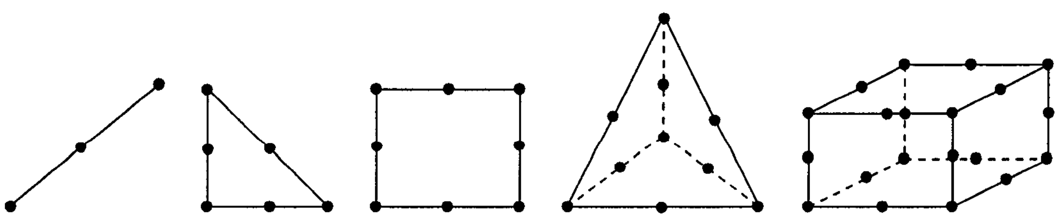
4.2 FINITE ELEMENT METHOD

4.2.1 Basic concepts in finite element method

Finite element method is a numerical method that is widely used for solutions of a variety of field problems, such as static stress/displacement analysis, dynamic stress/displacement analysis, heat transfer and thermal stress analyses, electrical analysis and fluid analysis. The idea of the finite element method is to divide a body into numbers of simpler parts called elements. Geometry of elements can vary depending on the problem at hand. Normally, a line can be used for an element in one dimension, triangle and rectangle for two dimensional elements and tetrahedral and cubic forms for three dimensional elements. The points that represent elements when connected to each other are called nodes; the positions of nodes normally are at the corners and on the sides of elements. Figure 4.3 shows examples of elements and nodes.



(a) Various element types with nodes only at corners



(b) Various element types with nodes at corners and on the sides of elements

Figure 4.3 Various types of elements with nodes

Moreover, the procedure of discretizing the body into a mesh of finite elements is called discretization, and the mesh actually is the element pattern. Figure 4.4 shows examples of discretized plates with triangular and rectangular elements.

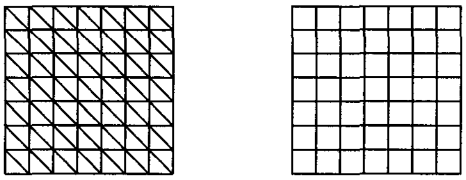


Figure 4.4 Discretized plates with triangular and rectangular elements

Mathematically, the finite element method uses a system of algebraic equations to relate the unknown and known variables at nodes. The accuracy of the results generally depends on the selection of this relation, commonly called shape function (or displacement function), between nodes in the elements. Normally, linear, quadratic and cubic polynomial functions are used as well as trigonometric functions. Moreover, the shape functions of two- and three-dimensional elements can be presented in Cartesian coordinates (x, y and x, y, z) or can also be presented in polar coordinates (r, θ and r, θ, z).

Furthermore, the strains/stresses within the body are related to these nodal displacements. This relation can be represented in the constitutive matrix (or elastic matrix) as shown below:

$$\{\sigma\} = [E]\{\varepsilon\}$$

where $\{\sigma\}$ represents the stress matrix, $[E]$ represents the constitutive matrix and $\{\varepsilon\}$ represents the strain matrix.

Equating the work done within the body to that due to the external forces applied on the body, the stiffness matrix can be obtained to relate the external forces and internal displacements. Once all the element stiffness matrices are obtained, they are assembled together. The assembled matrices are called the global matrices. Once the global matrices are obtained, the problems can be subsequently solved [29, 30, 31 and 32].

4.2.2 Finite element method for structural dynamics

The variable, ω_n, called the nth undamped natural frequency of vibration, is important in structural dynamics because it is used to represent the unique vibration characteristic of the structure. Number of undamped natural frequencies of vibration used in the analysis depends on number of degrees of freedom of the structure; only certain number of lowest frequencies usually are of interest to structural engineers. The deformation of the structure corresponding to the selected undamped natural frequency of vibration is called the mode shape of vibration. For a single degree of freedom, the procedure used to determine the natural frequency and mode shape of the structure is not difficult; however, when structures have multi-degrees-of-freedom, the determination of natural frequencies and mode shapes become quite complicated. The general method used to determine natural frequencies and mode shapes are described below [33].

4.2.2.1 Single degree of freedom (SDOF) model

Dynamic equilibrium equation or equation of motion of a single-degree-of-freedom can be written as:

$$m\ddot{x}(t) + c\dot{x}(t) + kx(t) = F_e(t) \tag{4.1}$$

The undamped natural frequency of vibration of a single degree of freedom can be obtained by considering undamped free vibration, which means the damping coefficient, c, and external force, F_e, are zero. Therefore, equation (4.1) becomes

$$m\ddot{x}(t) + kx(t) = 0 \tag{4.2}$$

The solution of equation (4.2) can be expressed as:

$$x(t) = A\cos\omega_1 t + B\sin\omega_1 t \neq 0 \tag{4.3}$$

Substitute equation (4.3) into (4.2); then,

$$m\left(-\omega_1^2 A\cos\omega_1 t - \omega_1^2 B\sin\omega_1 t\right) + k(A\cos\omega_1 t + B\sin\omega_1 t) = 0 \tag{4.4}$$

Rearrange equation (4.4):

$$\omega_1^2 = \frac{k}{m} \tag{4.5}$$

The undamped natural frequency, ω_1, of a single degree of freedom can be calculated from:

$$\omega_1 = \sqrt{\frac{k}{m}} \tag{4.6}$$

4.2.2.2 Multi-degree of freedom (MDOF) model

When structures have multi-degrees-of-freedom, it is more convenient to represent the dynamic equilibrium equation or equation of motion in the form of matrices as shown below:

$$\mathbf{M}\ddot{\mathbf{X}}(t) + \mathbf{C}\dot{\mathbf{X}}(t) + \mathbf{K}\mathbf{X}(t) = \mathbf{F}_e(t) \tag{4.7}$$

where **M** is the mass matrix, **C** is the damping matrix, **K** is the stiffness matrix and $\mathbf{F}_e$ is the external force matrix. Once again, when undamped free vibration is considered, the damping matrix and the external force matrix become zero matrices. Therefore, equation (4.7) becomes:

$$\mathbf{M}\ddot{\mathbf{X}}(t) + \mathbf{K}\mathbf{X}(t) = \mathbf{0} \tag{4.8}$$

Assuming n degrees-of-freedom, the solution of equation (4.8) can be written in terms of vector as:

$$\mathbf{X}(t) = \begin{Bmatrix} x_1(t) \\ x_2(t) \\ \vdots \\ x_n(t) \end{Bmatrix} = \begin{Bmatrix} \alpha_1(t) \\ \alpha_2(t) \\ \vdots \\ \alpha_n(t) \end{Bmatrix} \cos \omega t + \begin{Bmatrix} \beta_1(t) \\ \beta_2(t) \\ \vdots \\ \beta_n(t) \end{Bmatrix} \sin \omega t = \mathbf{A} \cos \omega t + \mathbf{B} \sin \omega t \tag{4.9}$$

where **A** and **B** are column vectors. Substituting equation (4.9) into (4.8) and rearranging the form, the equation can be written as:

$$\lfloor -\mathbf{M}\omega^2 + \mathbf{K} \rfloor \mathbf{X}(t) = \mathbf{0} \tag{4.10}$$

A trivial solution is obtained when $\mathbf{X}(t) = 0$; however, this solution is not of interest. Therefore, Cramer's rule [34] is applied to solve this equation by setting the determinant of the coefficient of $\mathbf{X}(t)$ equal to zero.

$$\left| -\mathbf{M}\omega^2 + \mathbf{K} \right| = 0 \tag{4.11}$$

This solution procedure leads to an eigenvalue problem, and the natural frequencies are called the eigenvalues. Each eigenvalue has a corresponding eigenvector which can be obtained from

$$\lfloor -\mathbf{M}\omega_i^2 + \mathbf{K} \rfloor \Phi_i = \mathbf{0} \tag{4.12}$$

where Φ_i is the eigenvector corresponding to the i^{th} eigenvalue, and the eigenvectors are the mode shapes of vibration.

Once the structure is discretized into a number of finite elements with numbering of nodes and degrees of freedom, the elemental and global mass and stiffness matrices are subsequently formed and solved. As a result, the natural frequencies and mode shapes of the structure can be determined.

4.2.3 Brief concepts of plate theory

Since the stiffened plates, used in this investigation, were fabricated using plate components, it is appropriate to understand the characterization used in the analysis of plates. A plate can be defined from its geometry as thin, when the ratio of its thickness to span is very small; moreover, when the thickness/span ratio is appreciable, the plate can be categorized as a thick plate. Normally, if the ratio between thickness and span of a plate is greater than 0.10 [35], the plate is considered as a thick plate. And if the ratio between thickness and width of a plate is smaller than 0.01 [30], the plate is considered as a thin plate. Therefore, to model the characteristic behaviour of a plate, the plate must be first specified either as a thick or thin plate. Two well-known theories [30] that are normally used to consider plate behaviours are Poisson-Kirchhoff and Reissner-Mindlin theory of plates. The two theories can be briefly explained as:

4.2.3.1 Poisson-Kirchhoff plate theory

Poisson-Kirchhoff plate theory or thin plate theory states that the effects of transverse shear deformation can be neglected. In other words, the transverse shear is assumed to be negligible and equal to zero when thin plate theory is applied. Moreover, use of this criterion to thin plates is regarded to be the same as Euler-Bernoulli beam theory [30].

4.2.3.2 Reissner-Mindlin plate theory

Reissner-Mindlin plate theory is only applied to thick plates because this theory states that once a plate is thick enough, the effects of transverse shear deformation would influence the behaviour of the plate and should be taken into account in its formulation.

4.2.3.3 Plate bending element

As mentioned earlier, any plate can be categorized into two groups (viz., thin and thick plate); consequently, this characterization should also be applied to plate bending element formulation in finite element analysis. The normal shapes of plate bending elements used in analysis are triangles, rectangles, trapezoids and parts of a circle. The determination of the proper stiffness matrix of the plate bending element is usually of great interest, and will be different depending on whether a thin or thick plate theory is applied. When thin plate theory is used, the effect of transverse shear is ignored. The stiffness matrix can be simply expressed as $[k]=[k_b]$. However, when thick plate theory is used, the stiffness matrix becomes $[k]=[k_b]+[k_s]$ where $[k]$ represents the total elemental stiffness, $[k_b]$ the bending stiffness and $[k_s]$ the shear transverse stiffness. Moreover, the plate bending element can be classified by the number of nodes used in the element. Figure 4.5 shows different types of plate bending elements.

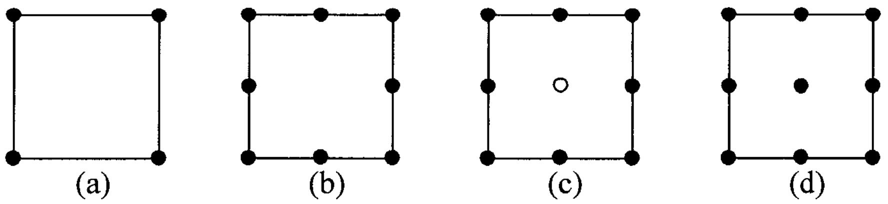


Figure 4.5 Various types of plate bending elements

where ● represents w, θ_x, θ_y degrees of freedom and ○ represents θ_x, θ_y degrees of freedom. Consequently, Figure 4.5 (a) represents a linear quadrilateral plate element having 4 nodes with 12 d.o.f. Figure 4.5 (b) called the Serendipity element represents a quadratic quadrilateral plate element having 8 nodes with 3 d.o.f. at each node. The plate bending element given in Figure 4.5 (c) has 9 nodes; each node has 3 d.o.f. except the middle node that only has 2 rotational d.o.f. This element is called the Heterosis element. The Lagrange element also has 9 nodes, but all nodes have 3 d.o.f. This element is shown in Figure 4.5 (d) [27, 28].

4.3 COMPARISON BETWEEN ABAQUS AND ANSYS

Two finite element analysis software packages, viz., ABAQUS and ANSYS were available at the faculty for carrying out this study. Both are well-tested and well-documented finite element analysis software packages. Since some unexpected behaviours were observed from the compiled results of ABAQUS for the stiffened plates, this comparative study was undertaken to validate the results reported in this thesis. Even though ABAQUS was finally chosen, the study demonstrates that results obtained using the two softwares are very close to one another.

The first model considered in this comparative study was the simple panel shown as stage 1 in Figure 4.1 and 4.2. The model was analyzed using ABAQUS and ANSYS with 4- and 8-node elements. The second model, which is the same as stage 2 in Figure 4.1 and 4.2, was also analyzed. Once again, both the 4- and 8-node elements were employed in the study. The natural frequencies of the panel and the simple stiffened plate are given in Table 4.3 and 4.4, respectively, and the corresponding mode shapes are shown in Appendix E.

Natural frequencies	**Simple panel in stage 1**				% difference between 4-node elements	% difference between 8-node elements
	ANSYS		**ABAQUS**			
	Element type		Element type			
	4-node	8-node	4-node	8-node		
	shell63	shell93	S4R	S8R		
1st	155.32	155.14	155.18	155.12	-0.09	-0.01
2nd	316.75	316.13	316.40	316.05	-0.11	-0.03
3rd	316.76	316.14	316.40	316.06	-0.11	-0.03
4th	466.96	465.72	466.00	465.54	-0.21	-0.04
5th	567.85	566.05	564.16	565.78	-0.65	-0.05
6th	570.57	568.78	569.90	568.51	-0.12	-0.05
7th	711.88	709.25	710.09	708.81	-0.25	-0.06
8th	711.90	709.26	710.12	708.82	-0.25	-0.06
9th	908.45	904.28	907.37	903.56	-0.12	-0.08
10th	908.48	904.29	907.47	903.57	-0.11	-0.08

Table 4.3 Natural frequencies of the simple panel (shown in Figure 4.1-stage 1) from ABAQUS and ANSYS, and comparison between the results

Natural frequencies	Simple stiffened plate in stage 2				% difference between 4-node elements	% difference between 8-node elements
	ANSYS		ABAQUS			
	Element type		Element type			
	4-node	8-node	4-node	8-node		
	shell63	shell93	S4R	S8R		
1^{st}	448.38	447.49	444.86	447.76	-0.79	0.06
2^{nd}	801.63	798.78	795.42	799.40	-0.78	0.08
3^{rd}	890.54	887.66	883.94	888.37	-0.75	0.08
4^{th}	1168.0	1162.6	1159.2	1163.5	-0.76	0.08
5^{th}	1232.8	1225.3	1223.3	1226.3	-0.78	0.08
6^{th}	1487.6	1475.7	1475.3	1476.8	-0.83	0.07
7^{th}	1502.3	1489.7	1489.9	1490.2	-0.83	0.03
8^{th}	1521.1	1506.4	1507.6	1507.0	-0.90	0.04
9^{th}	1571.3	1553.2	1556.3	1553.0	-0.96	-0.01
10^{th}	1667.7	1653.3	1654.1	1654.2	-0.82	0.05

Table 4.4 Natural frequencies of the stiffened plate (shown in Figure 4.1-stage 2) from ABAQUS and ANSYS, and comparison between the results

Table 4.3 shows that there is very little difference in natural frequencies between the elements and the two software packages (ABAQUS and ANSYS) till the third mode. Beyond the third mode, slight differences are observed between the various elements in the study. Shell 93 element of ANSYS and S8R element of ABAQUS seem to give the same values while shell 63 element of ANSYS and S4R element of ABAQUS seem to give similar values. When the stiffened plate (stage 2 in Figure 4.1) is considered, a similar overall trend is shown (Table 4.4). The differences in natural frequencies vary between 0.01% and 0.96 %. For higher natural frequencies, ABAQUS seems to give better correlation between 4-node and 8-node shell elements. Consequently, all the analyses reported hereafter used only the computer software ABAQUS.

4.4 SELECTION OF ELEMENT TYPES AND ELEMENT SIZES

4.4.1 Element types

In finite element analysis, selection of element type is an important procedure to obtain accurate results. Therefore, a simple assessment was carried out by analyzing the panel in stage 1 of Figure 4.1 and 4.2. Different types of element were employed, and the results from the analyses were compared and assessed to select the element type suitable for this investigation. Three different element types were studied in this part of the investigation. The three typical types were (1) 4- and 8-node quadrilateral elements, S4R, S4R5, S8R and S8R5; (2) 3- and 6-node triangular elements, STRI3 and STRI65, and (3) 20-node continuum elements, C3D20 and C3D20R. The models using continuum elements represented the actual geometry of the panel. Therefore, including these types of models in the comparison was considered to be reasonable. The results of this analysis are shown in Table 4.5.

Natural frequencies	**Plate panel in stage 1**							
	Element type							
	Quadrilateral				Triangular		Continuum	
	S4R	S4R5	S8R	S8R5	STRI3	STRI65	C3D20	C3D20R
1st	155.18	155.18	155.12	155.14	155.30	155.10	155.88	155.86
2nd	316.40	316.40	316.05	316.11	316.65	315.96	317.65	317.59
3rd	316.40	316.40	316.06	316.12	316.66	316.01	317.65	317.59
4th	466.00	466.00	465.54	465.68	466.76	465.40	467.96	467.87
5th	564.16	567.16	565.78	565.99	567.48	565.64	568.79	568.65
6th	569.90	569.90	568.51	568.72	570.18	568.38	571.53	571.39
7th	710.09	710.10	708.81	709.15	711.36	708.60	712.66	712.50
8th	710.12	710.13	708.82	709.16	711.46	708.67	712.66	712.50
9th	907.37	907.37	903.56	904.11	907.46	903.09	908.66	908.38
10th	907.47	907.48	903.57	904.13	907.77	903.49	908.66	908.38

Table 4.5 Comparison of natural frequencies of panel using different element types

The results of the above comparison show that quadrilateral and triangular shell elements and continuum elements give results that are in reasonably good agreement. The maximum difference obtained in this part of the study is around 0.82 % occurring at mode 5 between S4R and C3D20 elements; however, the maximum differences of the other modes are found between STRI65 and C3D20 elements. This confirms that the shell element type was appropriate to be used in this investigation. Moreover, according to the topology of the components of stiffened plate, quadrilateral elements seem to fit very well for all these components. Therefore, in this investigation, the quadrilateral elements were used rather than triangular elements. In addition, the model of stage 2 in Figure 4.1 was analyzed by using only various types of quadrilateral shell elements of type S4R, S4R5, S8R and S8R5. This analysis was carried out in order to compare the results obtained from 4- and 8-node elements possessing 5- and 6-degrees of freedom per node. The results of this analysis are shown in Table 4.6.

Natural frequencies	**Stiffened plate in stage 2**			
	Shell element			
	4-node		8-node	
	S4R	S4R5	S8R	S8R5
1st	444.86	444.47	447.76	447.36
2nd	795.42	794.45	799.40	798.49
3rd	883.94	882.86	888.37	887.31
4th	1159.20	1157.80	1163.50	1162.30
5th	1223.30	1221.80	1226.30	1224.90
6th	1475.30	1473.80	1476.80	1475.40
7th	1489.90	1489.10	1490.20	1489.50
8th	1507.60	1507.20	1507.00	1506.40
9th	1556.30	1557.10	1553.00	1553.40
10th	1654.10	1652.70	1654.20	1652.70

Table 4.6 Comparison of natural frequencies of a simple stiffened plate using different shell element types

This analysis has shown very good agreement between 4- and 8-node shell elements possessing 5- and 6-degrees of freedom per node; the maximum difference was 0.74 % occurring at mode 1 between S4R5 and S8R elements. Therefore, at this point, it was found appropriate to select the element type by considering only the analysis time consumed by each of these element types. For this part of the study, the actual model of stiffened plate given in stage 4 of Figure 4.1 was considered. Since the last comparison showed very good agreement between 4- and 8-node shell elements with 5- and 6-degrees of freedom per node, only elements having 6-degrees of freedom were considered proper to be used in the analysis. As a result, 4- and 8-node quadrilateral elements, S4R and S8R, were used in the study. The results of this analysis are given in Table 4.7.

Natural frequencies	**Stiffened plate in stage 4**		
	Element type		% difference
	S4R	S8R	
1^{st}	587.10	592.98	0.99
2^{nd}	589.17	595.06	0.99
3^{rd}	1097.90	1117.40	1.75
4^{th}	1100.20	1119.80	1.75
5^{th}	1135.20	1137.40	0.19
6^{th}	1508.30	1511.60	0.22
7^{th}	1646.80	1654.20	0.45
8^{th}	1738.50	1740.60	0.12
9^{th}	1771.70	1785.10	0.75
10^{th}	1789.50	1799.40	0.55

Table 4.7 Comparison of natural frequencies of the actual stiffened plate using different types of shell elements

From the results given in Table 4.7, it is seen that that 4-node quadrilateral element, S4R, seems to give a flexible response for all modes than the 8-node quadrilateral element, S8R. The maximum difference in natural frequencies between S4R and S8R quadrilateral shell elements seem to be less than 1.75 % for the third and fourth modes. The experimental natural frequencies, reported later on in this Chapter, seem to be closer to the results of S4R than those of S8R. Also, the time consumed for using S4R elements was much less than that for S8R elements. Consequently, only S4R elements were used in the subsequent studies.

4.4.2 Element sizes

It is also important to select the proper element size to obtain accurate results. The element size that had been used in the procedure of element type selection was considered from the approach that the plate element should have the width and length larger than its thickness. Therefore, an approximate 8 mm width and length of element was selected since the thickness of the element was approximately 6 mm. This ratio was initially considered reasonable; however, to validate that this ratio is appropriate, the study of convergence in results using 4 different sizes of element were carried out. The first study was an analysis of a simple plate panel given in stage 1 of Figure 4.1. Both width and length of elements in this study were approximately 8 mm, 12 mm, 16 mm and 24 mm. and the thickness of element was about 6 mm. The results obtained in this analysis are given in Table 4.8.

Natural frequencies	Plate panel in stage 1			
	Various sizes of S4R shell element			
	8 mm	12 mm	16 mm	24 mm
1st	155.18	155.26	155.35	155.63
2nd	316.40	316.80	317.32	318.73
3rd	316.40	316.85	317.47	319.43
4th	466.00	466.56	467.33	469.53
5th	567.20	568.81	571.09	577.29
6th	569.90	571.57	573.92	581.41
7th	710.10	711.58	713.62	718.97
8th	710.10	711.68	714.00	721.24
9th	907.40	911.82	917.74	932.82
10th	907.50	912.50	919.17	942.10

Table 4.8 Natural frequencies of plate panel using different sizes of elements

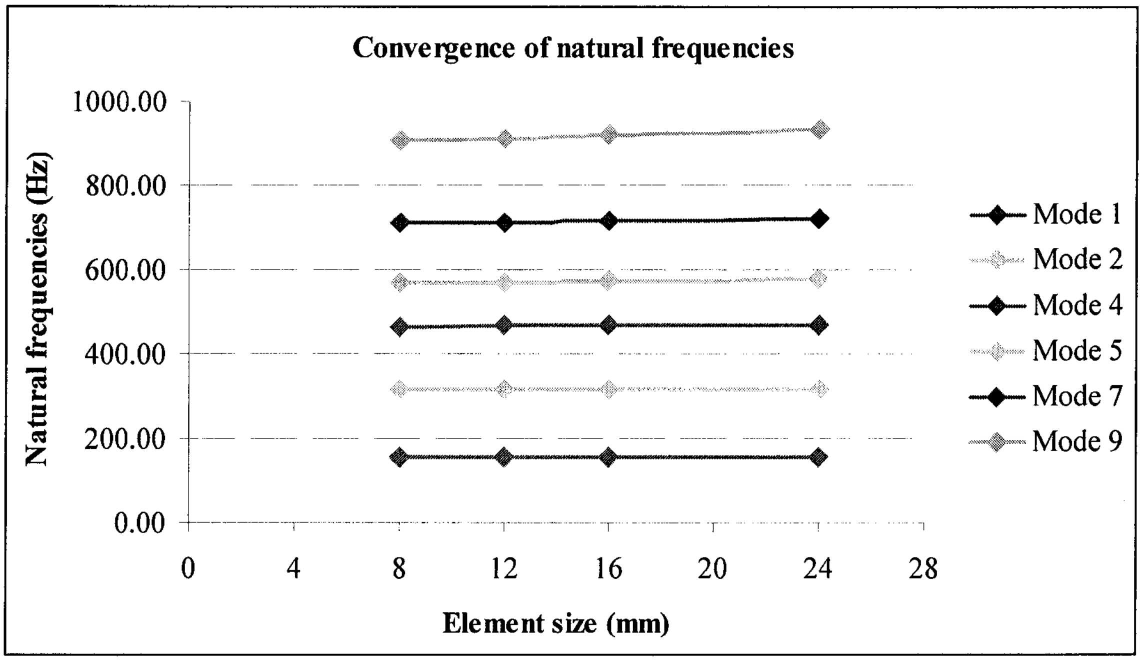


Figure 4.6 Plot of natural frequencies of plate panel using different sizes of elements

According to the results in Table 4.8, it can be seen that once the element sizes are smaller, the natural frequencies tends to be lower. This can be seen to be obvious when the results are plotted and shown as in Figure 4.6; since the natural frequencies of certain modes were very close to each other, only modes 1, 2, 4, 5, 7 and 9 are plotted. The results shown in Figure 4.6 confirm that as the element size get smaller, the natural frequencies tend to converge to the actual one.

The same approach was used to analyze the stiffened plate in stage 4 of Figure 4.1, but approximate 4, 5, 6, 7, 8, 9 and 10 mm sizes of element were used to observe the convergence more specifically. The results of this study are given in Table 4.9.

Natural frequencies	**Stiffened plate in stage 4**						
	Various sizes of S4R shell element						
	4 mm	5 mm	6 mm	7 mm	8 mm	9 mm	10 mm
1st	590.19	589.38	589.63	586.70	587.10	587.47	587.81
2nd	592.23	591.43	591.69	588.76	589.17	589.54	589.89
3rd	1110.5	1107.2	1107.8	1097.2	1097.9	1099.0	1099.6
4th	1112.9	1109.5	1110.1	1099.4	1100.2	1101.3	1101.9
5th	1134.2	1134.5	1134.7	1135.0	1135.2	1135.6	1135.6
6th	1506.3	1506.8	1507.2	1507.9	1508.3	1509.2	1509.3
7th	1647.9	1649.1	1650.2	1645.6	1646.8	1649.0	1650.4
8th	1736.3	1737.5	1738.8	1737.0	1738.5	1740.9	1742.6
9th	1779.0	1780.4	1781.8	1770.1	1771.7	1774.4	1776.8
10th	1793.4	1794.6	1795.9	1788.1	1789.5	1792.0	1793.8

Table 4.9 Natural frequencies of stiffened plate using different sizes of element

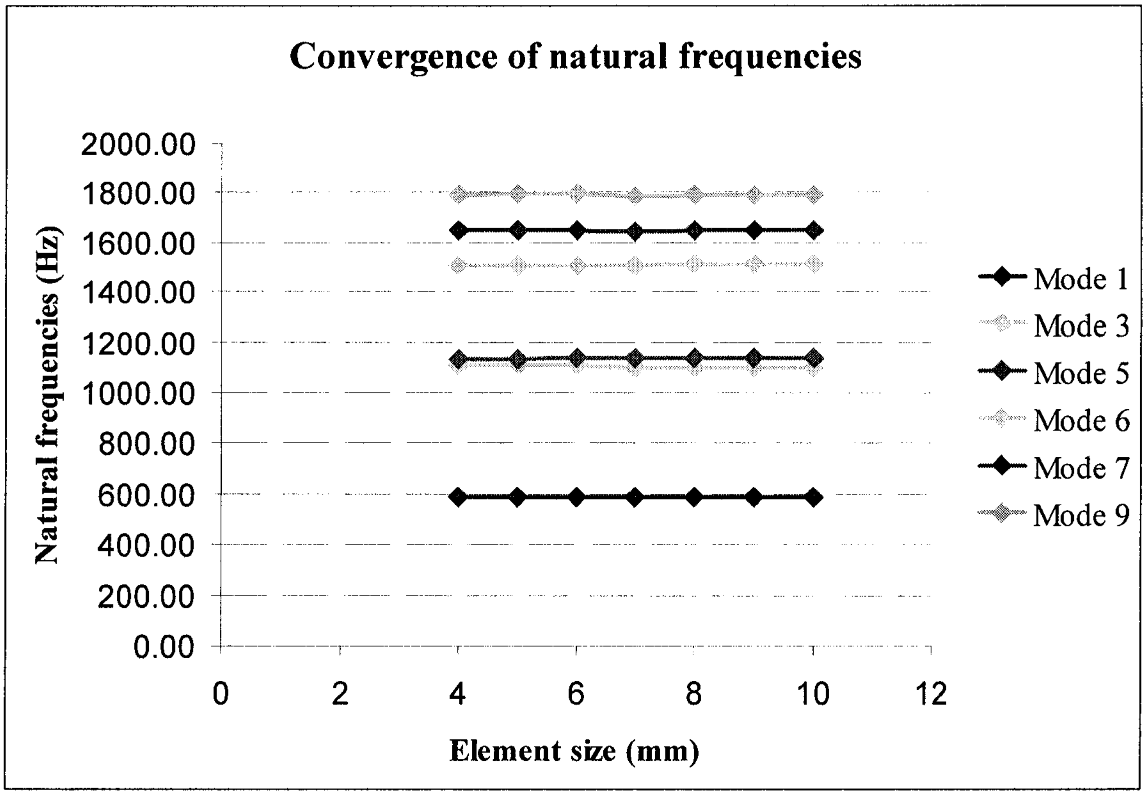


Figure 4.7 Plot of natural frequencies of stiffened plate using different sizes of element

Once again, since the natural frequencies of certain modes were very close to each other, only modes 1, 3, 5, 6, 7 and 9 are plotted and shown in Figures 4.7. According to the results from Table 4.9 and Figure 4.7, it can be seen that as elements sizes became smaller, the convergence of fundamental natural frequencies occurs. As a result, the approximate element size of $8 \times 8 \times 6$ mm seemed to be appropriate for using in this investigation. Moreover, it should be noted that the width and length of element in finite element models can be made smaller, but it is inappropriate based on the plate element geometry that the thickness should not be greater than the other dimensions.

4.5 VERIFICATION OF MODELLED WELD CROSS SECTION TO REPRESENT THE ACTUAL WELD PROFILE

As mentioned earlier that the models, of stiffened plates, were classified into two types, viz., a model without and a model with the weld profile. A simple stiffened plate consisting of one plate panel and one flat bar stiffener, as shown in Figure 4.8, was considered for this analysis.

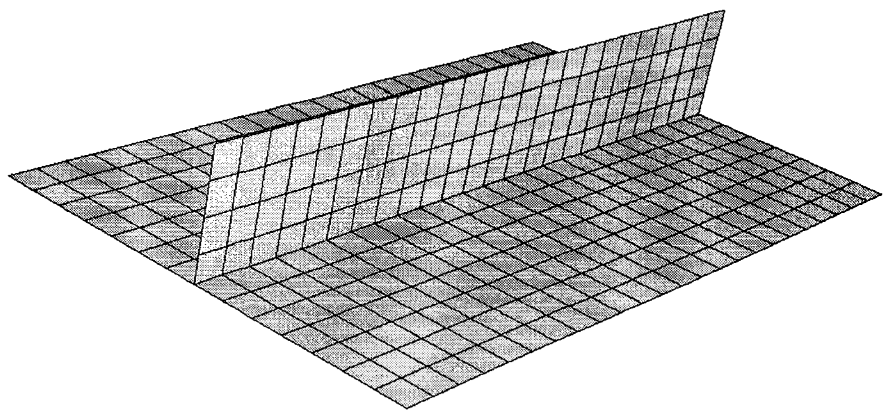
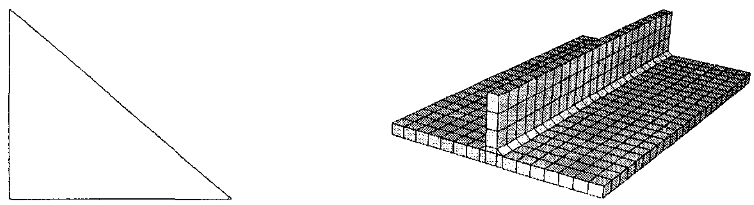
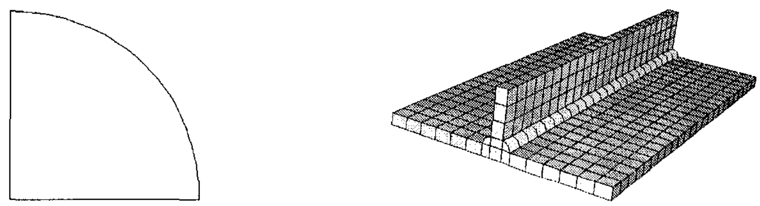


Figure 4.8 A simple stiffened plate

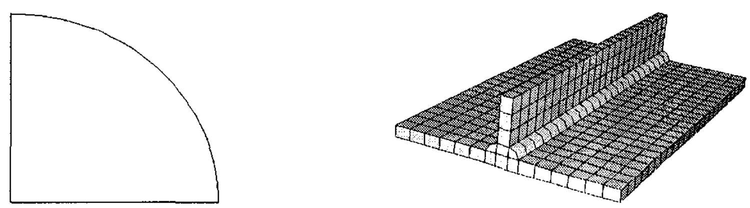
Model of exact weld profile was generated by assuming various types of representative cross sections to model the weld. As a result, the various cross sections that were used to model the weld were triangles, quarter-circles, semiparabolas, exparabolas or rectangles. The 3-D solid models with the specified cross section were generated, and continuum elements were employed. Figure 4.9 shows various types of representative weld cross sections and the models generated using these sections to model the weld.



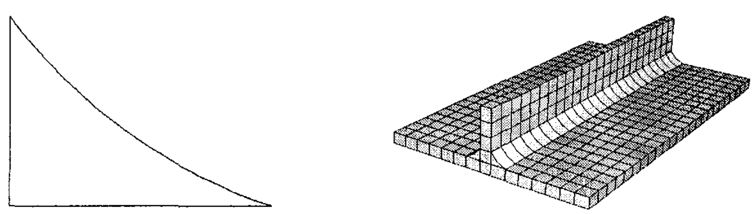
(a) Triangular cross section as a representative cross section of the weld



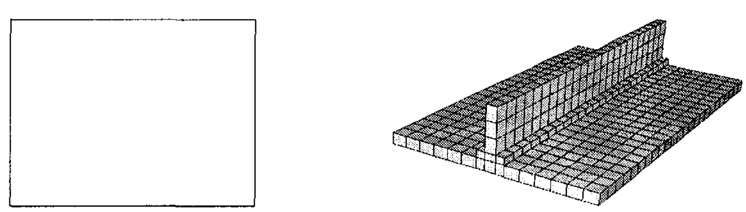
(b) Quarter-circular cross section as a representative cross section of the weld



(c) Semiparabolic cross section as a representative cross section of the weld



(d) Exparabolic cross section as a representative cross section of the weld



(e) Rectangular cross section as a representative cross section of the weld

Figure 4.9 Various types of representative weld cross sections and the models using these sections to model the weld

In this analysis, 15-node continuum elements were used for modeling all the representative weld cross sections other than rectangles, and 20-node continuum elements were used for rectangular solid geometries. The free vibration responses of all of these models were obtained and compared with one another. Table 4.10 shows the natural frequencies of the models generated with 3-D continuum elements. The rectangular element seems to give results closer to the almost actual weld shape of triangle than the other shapes of elements used. Table 4.11 shows the natural frequencies of the two types of models (with and without weld profile) generated using shell elements. One interesting finding is when the stiffened plate was strengthened with the representative weld cross section, the first fundamental natural frequency was lower. Probably, the representative weld cross section strengthening does not seem to increase the stiffness of the fundamental bending mode to the extent it does for the higher modes (according to Table 4.11). The mass added at the locations of weld seem to overpower the effect of stiffening (provided by the weld profile) for the fundamental bending mode, that the first natural frequency is reduced by 2.79 %.

Natural frequencies	The simple stiffened plate				
	Cross section				
	Triangular	Arc-circle	Semiparabolic	Exparabolic	Rectangular
1st	3918.8	3981.6	3971.5	3988.0	3951.3
2nd	4426.6	4852.3	4986.8	5097.5	4806.9
3rd	5824.3	6383.8	6855.7	6686.8	6326.7
4th	7264.5	7477.8	7481.1	7490.7	7416.4
5th	7995.2	8662.9	8920.3	9011.7	8594.2
6th	8935.4	9950.7	10250	10506	9752.5
7th	9862.5	10825	11010	11044	10651
8th	10497	10918	11120	11354	10870
9th	10846	11574	11856	11945	11497
10th	11476	12360	12644	12851	12218

Table 4.10 Natural frequencies of a simple stiffened plate with various cross sections representing weld cross section

Natural frequencies	The simple stiffened plate							
	Weld was modeled				**Weld was not modeled**			
	S4R	S4R5	S8R	S8R5	S4R	S4R5	S8R	S8R5
1st	3714.0	3706.3	3717.2	3700.0	3817.5	3810.6	3811.3	3794.8
2nd	4422.6	4526.2	4453.1	4444.0	3984.3	3997.6	3961.7	3975.7
3rd	5826.2	6116.4	5976.0	5906.2	5315.5	5357.6	5299.5	5317.2
4th	7070.0	7053.5	7009.3	6983.1	7094.5	7082.4	7015.5	6991.0
5th	8049.3	8482.6	8218.2	8148.0	7455.1	7530.6	7392.5	7426.3
6th	9217.9	9228.6	8854.1	8896.0	8296.0	8303.0	7982.9	8016.8
7th	9981.7	10020	9661.9	9717.1	9144.9	9170.8	8868.3	8914.1
8th	10189	10192	9972.4	9982.5	10129	10138	9903.6	9912.4
9th	11039	11231	10622	10668	10370	10483	10156	10223
10th	11226	11497	11074	11063	10705	10758	10443	10510

Table 4.11 Natural frequencies of a simple stiffened plate generated using various types of shell elements

Since the quadratic quadrilateral shell element S4R was chosen for modeling the stiffened plate throughout this investigation, it is appropriate to compare the results obtained using this type of element and those obtained using other types. Table 4.12 shows the comparison between the natural frequencies of the model with weld profile generated using S4R and those of the models with weld profile generated using 3-D continuum elements.

Natural frequencies	Various cross sections with % differences									
	Triangular	% differences	Arc-circle	% differences	Semiparabolic	% differences	Exparabolic	% differences	Rectangular	% differences
1st	3918.8	+5.51	3981.6	+7.21	3971.5	+6.93	3988.0	+7.38	3951.3	+6.39
2nd	4426.6	+0.09	4852.3	+9.72	4986.8	+12.76	5097.5	+15.26	4806.9	+8.69
3rd	5824.3	-0.03	6383.8	+9.57	6855.7	+17.67	6686.8	+14.77	6326.7	+8.59
4th	7264.5	+2.75	7477.8	+5.77	7481.1	+5.81	7490.7	+5.95	7416.4	+4.90
5th	7995.2	-0.67	8662.9	+7.62	8920.3	+10.82	9011.7	+11.96	8594.2	+6.77
6th	8935.4	-3.06	9950.7	+7.95	10250	+11.20	10506	+13.97	9752.5	+5.80
7th	9862.5	-1.19	10825	+8.45	11010	+10.30	11044	+10.64	10651	+6.71
8th	10497	+3.02	10918	+7.15	11120	+9.14	11354	+11.43	10870	+6.68
9th	10846	-1.75	11574	+4.85	11856	+7.40	11945	+8.21	11497	+4.15
10th	11476	+2.23	12360	+10.10	12644	+12.63	12851	+14.48	12218	+8.84

Table 4.12 Comparison between the natural frequencies of the model with weld profile generated using S4R elements and those generated using 3-D continuum elements

It can be seen from Table 4.12 that the models with 3-D continuum elements seem to produce stiffer responses than 2-D shell elements. The difference between these results may be much less if a finer discretization was used for 3-D continuum finite element analysis models. Moreover, it is obvious that when triangular cross section was used to represent the weld cross sections, the natural frequencies were closest to those obtained using the shell element, S4R. Also, it can be seen that when the rectangular cross section was used, the results were the next closest. Hence, the rectangular cross section was the best alternative available for modeling the weld cross section using shell elements; this makes it compatible with the S4R shell element used in the overall discretization of the stiffened plate.

Additionally, the models, generated using various types of shell elements (with and without the weld profiles), were also analyzed. The comparisons were made between the results obtained using S4R element and those obtained using S4R5, S8R and S8R5 elements. These comparisons are shown in Table 4.13 and 4.14.

Natural frequencies	**Simple stiffened plate with weld profile**						
	Element types and % differences						
	S4R	S4R5	%	S8R	%	S8R5	%
1st	**3714.0**	3706.3	0.21	3717.2	-0.09	3700.0	0.38
2nd	**4422.6**	4526.2	-2.34	4453.1	-0.69	4444.0	-0.48
3rd	**5826.2**	6116.4	-4.98	5976.0	-2.57	5906.2	-1.37
4th	**7070.0**	7053.5	0.23	7009.3	0.86	6983.1	1.23
5th	**8049.3**	8482.6	-5.38	8218.2	-2.10	8148.0	-1.23
6th	**9217.9**	9228.6	-0.12	8854.1	3.95	8896.0	3.49
7th	**9981.7**	10020	-0.38	9661.9	3.20	9717.1	2.65
8th	**10189**	10192	-0.03	9972.4	2.13	9982.5	2.03
9th	**11039**	11231	-1.74	10622	3.78	10668	3.36
10th	**11226**	11497	-2.41	11074	1.35	11063	1.45

Table 4.13 Natural frequencies of the simple stiffened plate with weld profile generated using various types of shell element

Natural frequencies	Simple stiffened plate with weld profile	Simple stiffened plate without weld profile							
		Element types and % differences							
	S4R	S4R	%	S4R5	%	S8R	%	S8R5	%
1st	**3714.0**	3817.5	+2.79	3810.6	+2.81	3811.3	+2.53	3794.8	+2.56
2nd	**4422.6**	3984.3	-9.91	3997.6	-11.68	3961.7	-11.04	3975.7	-10.54
3rd	**5826.2**	5315.5	-8.77	5357.6	-12.41	5299.5	-11.32	5317.2	-9.97
4th	**7070.0**	7094.5	+0.35	7082.4	+0.41	7015.5	+0.09	6991.0	+0.11
5th	**8049.3**	7455.1	-7.38	7530.6	-11.22	7392.5	-10.05	7426.3	-8.86
6th	**9217.9**	8296.0	-10.00	8303.0	-10.03	7982.9	-9.84	8016.8	-9.88
7th	**9981.7**	9144.9	-8.38	9170.8	-8.48	8868.3	-8.21	8914.1	-8.26
8th	**10189**	10129	-0.59	10138	-0.53	9903.6	-0.69	9912.4	-0.70
9th	**11039**	10370	-6.06	10483	-6.66	10156	-4.39	10223	-4.17
10th	**11226**	10705	-4.64	10758	-6.43	10443	-5.70	10510	-5.00

Table 4.14 Natural frequencies of the simple stiffened plate without weld profile generated using various types of shell element

It can be seen that the inclusion of the weld profiles seems to affect all the ten natural frequencies of the simple stiffened plate. The first natural frequency is lowered due to the presence of the weld mass while the natural frequencies of the higher modes seem to be greater. Generally, the natural frequencies increase due to the presence of the weld profiles.

From Tables 4.11, 4.13 and 4.14, it can be seen that the use of S4R and S8R elements seem to give almost similar results in both cases of modeling without and with weld profiles. Hence, S4R element was chosen for all the subsequent studies.

4.6 FREE VIBRATION RESPONSES OF ALL MODELS

Once the finite element analysis software was chosen, and the element type identified (S4R) to give the correct results, all the models outlined in Table 4.1 and 4.2 for the fabricated models of stiffened plates I and II were generated and analyzed. Only the natural frequencies of the final stage, viz., stage 4 shown in Figures 4.1 and 4.2 (without and with weld profile), are given here in Tables 4.15, 4.16, 4.17 and 4.18. These tables show the natural frequencies of two stiffened plate models I and II, respectively. In addition, because there were interchanges of mode shapes of the stiffened plates, only typical mode shapes are shown here in Figure 4.10, and mode shapes of all stages are given in Appendix F.

Table 4.15 Natural frequencies of the stiffened plate I without weld profile

Model without weld profile									Model I
Girders are **moved away**			Girders are **moved closer**			Girders are **not moved**			
Using Mean Values - 3 S.D.	Using Mean Values + 3 S.D.	Using Mean Values	Using Mean Values - 3 S.D.	Using Mean Values + 3 S.D.	Using Mean Values	Using Mean Values - 3 S.D.	Using Mean Values + 3 S.D.	Using Mean Values	Natural frequencies
581.49	592.16	586.83	581.75	592.40	587.06	581.62	591.55	587.10	1st
583.96	594.16	589.05	583.87	594.07	588.93	583.91	593.38	589.17	2nd
1080.5	1114.9	1097.7	1080.9	1115.3	1098.0	1080.7	1111.8	1097.9	3rd
1083.3	1117.2	1100.2	1083.2	1117.1	1100.1	1083.3	1113.8	1100.2	4th
1116.8	1134.3	1125.7	1135.7	1151.9	1143.7	1126.5	1140.7	1135.2	5th
1493.5	1532.5	1513.3	1481.1	1521.4	1501.5	1487.5	1525.1	1508.3	6th
1589.7	1638.0	1614.6	1648.2	1699.4	1674.8	1620.6	1669.6	1646.8	7th
1695.9	1738.7	1718.4	1726.4	1768.2	1748.0	1715.9	1754.8	1738.5	8th
1766.3	1814.5	1790.5	1728.4	1774.6	1751.4	1747.2	1794.0	1771.7	9th
1768.8	1821.7	1795.3	1756.4	1818.1	1787.5	1758.8	1815.2	1789.5	10th

Model I: Natural frequencies	Model with weld profile								
	Girders are **moved away**			Girders are **moved closer**			Girders are **not moved**		
	Using Mean Values - 3 S.D.	Using Mean Values + 3 S.D.	Using Mean Values	Using Mean Values - 3 S.D.	Using Mean Values + 3 S.D.	Using Mean Values	Using Mean Values - 3 S.D.	Using Mean Values + 3 S.D.	Using Mean Values
1st	576.44	567.80	571.06	576.68	567.99	571.92	576.56	567.89	571.81
2nd	578.94	569.69	573.23	578.84	569.60	573.79	578.89	569.64	573.84
3rd	1070.7	1092.8	1076.3	1071.1	1093.1	1076.7	1070.9	1093.0	1076.5
4th	1073.5	1094.8	1078.6	1073.4	1094.7	1078.5	1073.4	1094.7	1078.6
5th	1118.7	1114.6	1121.3	1137.1	1130.3	1138.2	1128.1	1122.6	1129.8
6th	1499.0	1513.9	1513.1	1487.4	1505.8	1502.8	1493.3	1510.0	1507.9
7th	1612.8	1700.4	1658.8	1673.5	1770.7	1725.1	1644.8	1735.8	1693.0
8th	1726.6	1826.0	1775.0	1750.0	1833.9	1791.2	1744.9	1839.1	1790.9
9th	1784.6	1862.2	1814.4	1750.6	1849.1	1796.6	1768.4	1862.2	1811.9
10th	1786.4	1865.5	1817.8	1776.1	1861.5	1813.4	1778.2	1863.3	1815.5

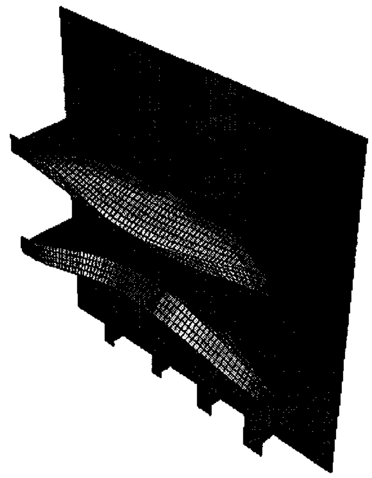
Table 4.16 Natural frequencies of the stiffened plate I with weld profile

Table 4.17 Natural frequencies of the stiffened plate II without weld profile

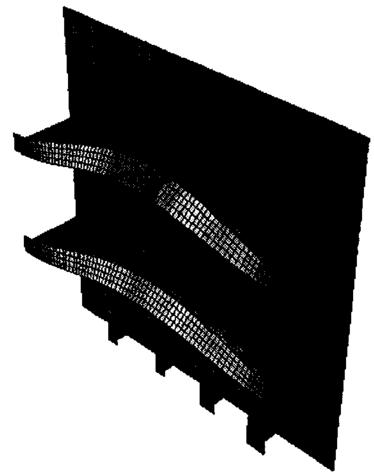
Model **without** weld profile									Model II
Girders are **moved away**			Girders are **moved closer**			Girders are **not moved**			
Using Mean Values - 3 S.D.	Using Mean Values + 3 S.D.	Using Mean Values	Using Mean Values - 3 S.D.	Using Mean Values + 3 S.D.	Using Mean Values	Using Mean Values - 3 S.D.	Using Mean Values + 3 S.D.	Using Mean Values	Natural frequencies
580.19	586.32	583.26	580.41	586.53	583.50	580.44	585.66	583.40	1st
582.70	588.44	585.57	582.56	588.31	585.46	582.78	587.67	585.53	2nd
1083.2	1100.4	1091.9	1083.7	1100.7	1092.3	1083.5	1099.9	1092.4	3rd
1086.2	1102.8	1094.5	1086.1	1102.6	1094.4	1086.2	1102.1	1094.8	4th
1115.1	1132.8	1124.0	1134.1	1151.1	1142.6	1124.6	1141.8	1133.7	5th
1488.8	1525.5	1505.9	1476.4	1513.6	1495.3	1482.2	1517.4	1501.7	6th
1588.5	1629.5	1609.1	1647.4	1690.7	1669.6	1619.0	1657.1	1641.7	7th
1696.1	1735.1	1715.0	1726.3	1763.6	1745.7	1715.7	1752.3	1736.9	8th
1767.6	1808.6	1782.8	1729.1	1769.2	1749.3	1748.2	1784.8	1769.5	9th
1768.7	1811.9	1788.3	1755.1	1804.3	1779.8	1757.9	1799.1	1782.1	10th

Table 4.18 Natural frequencies of the stiffened plate II with weld profile

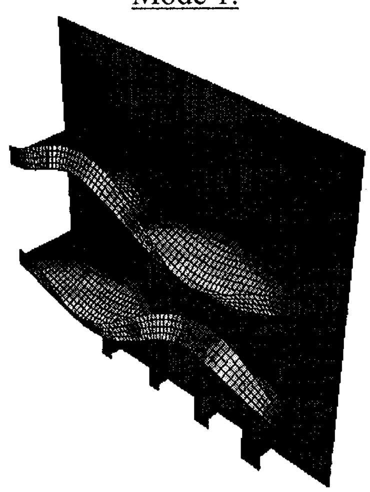
Model **with** weld profile									Model II
Girders are **moved away**			Girders are **moved closer**			Girders are **not moved**			
Using Mean Values - 3 S.D.	Using Mean Values + 3 S.D.	Using Mean Values	Using Mean Values - 3 S.D.	Using Mean Values + 3 S.D.	Using Mean Values	Using Mean Values - 3 S.D.	Using Mean Values + 3 S.D.	Using Mean Values	Natural frequencies
573.84	568.09	572.79	574.07	568.30	573.02	573.95	568.18	572.90	1st
576.32	570.25	575.20	576.21	570.16	575.10	576.26	570.19	575.15	2nd
1073.3	1080.6	1074.4	1073.7	1081.0	1074.8	1073.5	1018.7	1074.6	3rd
1076.1	1082.9	1077.0	1076.0	1082.8	1076.9	1076.1	1082.8	1076.9	4th
1115.3	1099.2	1114.8	1134.4	1114.9	1132.1	1125.2	1107.0	1123.2	5th
1490.3	1488.3	1500.0	1477.9	1480.1	1489.7	1484.2	1484.3	1494.1	6th
1597.8	1685.7	1649.7	1658.8	1754.4	1715.0	1629.8	1720.3	1682.6	7th
1714.2	1813.2	1770.3	1740.5	1822.5	1787.3	1733.3	1821.0	1784.5	8th
1778.0	1836.3	1810.5	1741.5	1832.1	1792.3	1760.4	1835.0	1805.2	9th
1779.6	1850.6	1810.7	1764.4	1840.6	1804.4	1767.0	1853.1	1809.9	10th



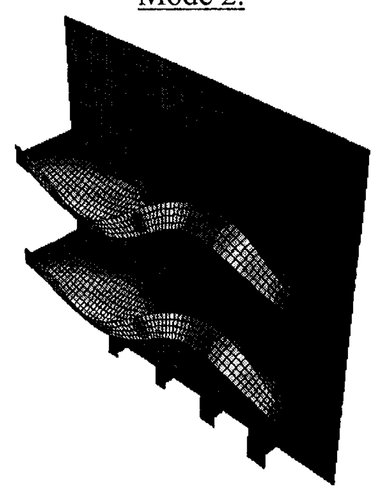
Mode 1.



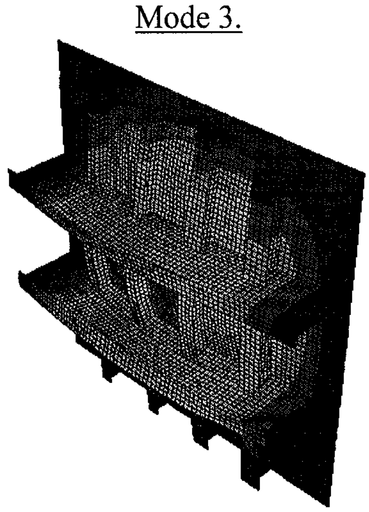
Mode 2.



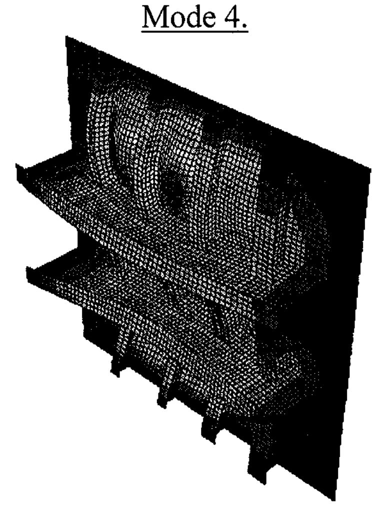
Mode 3.



Mode 4.

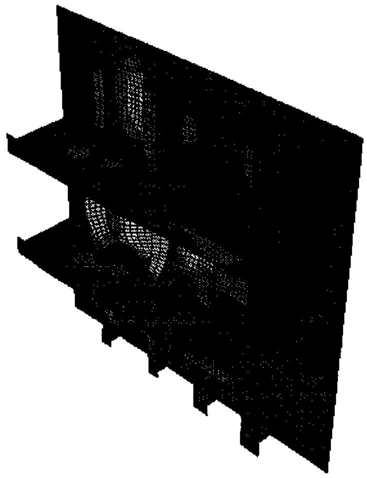


Mode 5.

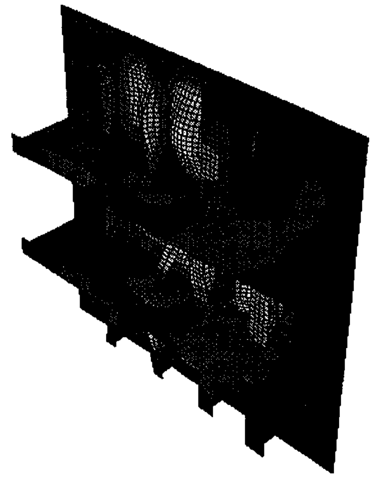


Mode 6.

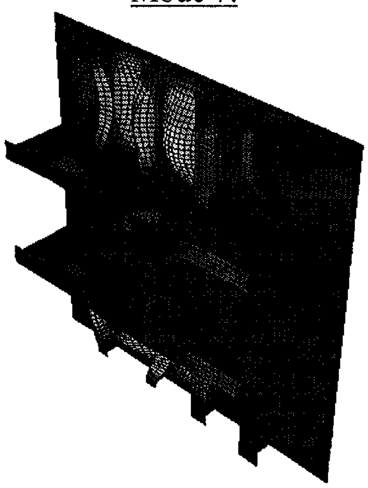
Figure 4.10 Part I : First six of ten mode shapes of the stiffened plate



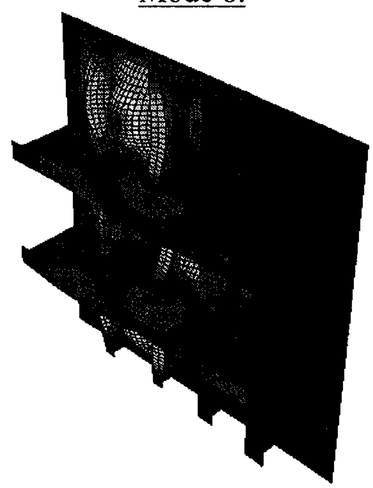
Mode 7.



Mode 8.



Mode 9.



Mode 10.

Figure 4.10 Part II : Last four of ten mode shapes of the stiffened plate

4.7 COMPARISON AND DISCUSSION OF RESULTS

The first comparison was made between the results obtained from the present analysis and those obtained from experiments in order only to verify that the results obtained from finite element analysis are reliable. Only the natural frequencies of modes 1, 2 and 5 could be obtained from the experiment by Mr. A. Budipriyanto, a student under the supervision of Dr. A. Swamidas. The 1st, 2nd and 5th natural frequencies were 586.16, 591.53, 1136.58 and 585.62, 591.54, 1136.60 Hz for stiffened plates I and II, respectively. When comparing these experimental results with models without weld profile in Table 4.15 and 4.17 (using mean values for all components dimensions), the maximum difference was +0.40 % occurring at mode 2 of stiffened plate I, and +1.03 % for stiffened plate II. The difference was +0.16 % for mode 1 and +0.12 % for mode 5 for stiffened plate I; it was respectively -0.38 % and -0.26 % for stiffened plate II. Moreover, according to Table 4.15 and 4.17, the maximum difference due to the dimensional uncertainties (using either mean values -3 S.D. or mean values +3 S.D.) was -1.28 % for stiffened plate I and it was -1.48 % for stiffened plate II (for mode 2).

When the experimental results were compared with the numerical results obtained from the inclusion of the weld profile in Table 4.16 and 4.18 (with mean values of component dimensions), the maximum difference occurring at mode 2 of the stiffened plate I was -2.99 % and -2.77 % for stiffened plate II. Moreover, according to Table 4.16 and 4.18, the maximum difference due to dimensional uncertainties was -3.70 % for stiffened plate I and -3.61 % for stiffened plate II (for mode 2).

Model I	Girders are **moved away**			Girders are **moved closer**			Girders are **not moved**		
% differences of natural frequencies	Using Mean Values - 3 S.D.	Using Mean Values + 3 S.D.	Using Mean Values	Using Mean Values - 3 S.D.	Using Mean Values + 3 S.D.	Using Mean Values	Using Mean Values - 3 S.D.	Using Mean Values + 3 S.D.	Using Mean Values
1st	0.87	4.11	2.69	0.87	4.12	2.58	0.87	4.00	2.60
2nd	0.86	4.12	2.69	0.86	4.12	2.57	0.86	4.00	2.60
3rd	0.91	1.98	1.95	0.91	1.99	1.94	0.91	1.69	1.95
4th	0.90	2.01	1.96	0.90	2.01	1.96	0.91	1.71	1.96
5th	-0.17	1.74	0.39	-0.12	1.88	0.48	-0.14	1.59	0.48
6th	-0.37	1.21	0.01	-0.43	1.03	-0.09	-0.39	0.99	0.03
7th	-1.45	-3.81	-2.74	-1.54	-4.20	-3.00	-1.49	-3.97	-2.81
8th	-1.81	-5.02	-3.29	-1.37	-3.72	-2.47	-1.69	-4.80	-3.01
9th	-1.04	-2.63	-1.33	-1.28	-4.20	-2.58	-1.21	-3.80	-2.27
10th	-1.00	-2.40	-1.25	-1.12	-2.39	-1.45	-1.10	-2.65	-1.45

Table 4.19 Comparison of results of Model I: Differences in natural frequencies between any two models generated using the same dimensions; weld was included in one model and was not included in the other model

Model II		% differences of natural frequencies									
		1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
Girders are **moved away**	Using Mean Values - 3 S.D.	1.09	1.09	0.91	0.93	-0.02	-0.10	-0.59	-1.07	-0.59	-0.62
	Using Mean Values + 3 S.D.	3.11	3.09	1.80	1.80	2.97	2.44	-3.45	-4.50	-1.53	-2.14
	Using Mean Values	1.80	1.77	1.60	1.60	0.82	0.39	-2.52	-3.22	-1.55	-1.25
Girders are **moved closer**	Using Mean Values - 3 S.D.	1.09	1.09	0.92	0.93	-0.03	-0.10	-0.69	-0.82	-0.72	-0.53
	Using Mean Values + 3 S.D.	3.11	3.09	1.79	1.80	3.14	2.21	-3.77	-3.34	-3.56	-2.01
	Using Mean Values	1.80	1.77	1.60	1.60	0.92	0.37	-2.72	-2.38	-2.46	-1.38
Girders are **not moved**	Using Mean Values - 3 S.D.	1.12	1.12	0.92	0.93	-0.05	-0.13	-0.67	-1.03	-0.70	-0.52
	Using Mean Values + 3 S.D.	2.98	2.97	1.65	1.75	3.05	2.18	-3.81	-3.92	-2.81	-3.00
	Using Mean Values	1.80	1.77	1.63	1.64	0.93	0.51	-2.49	-2.74	-2.02	-1.56

Table 4.20 Comparison of results of Model II: Differences in natural frequencies between any two models generated using the same dimensions; weld was included in one model and was not included in the other model

Considering the results (in Table 4.19 and 4.20) between any two complete models that had only one difference, in which one had weld and the other did not, the first four natural frequencies of the models without weld were always higher than those of the models with weld. Moreover, the last four natural frequencies of the models without weld were always less than those of the models with weld. The differences between the fifth and sixth natural frequencies were not consistent; in other words, the fifth and sixth natural frequencies, the fundamental global-bending modes, of the models without modeling weld could be higher or lower than those of the models with modeling weld. This indicates that the mass effect of the weld profile was dominant for the first four modes, and, for the higher modes, the stiffening effect of the weld profile became dominant. Moreover, considering the results in Table 4.19 and 4.20, the difference in natural frequencies for the ten modes were in between -5.02 to 4.12 % and -4.50 to 3.14 % for Model I and II, respectively. If the differences were much higher, it can be immediately attributed to some other unidentified problem in the fabricated structures.

The maximum and minimum of natural frequencies of the categorized models in which weld was included and the other in which weld was not included are respectively given in Table 4.21 and 4.22 for Models I and II. It can be seen that the natural frequencies of the normal models, which used the mean values of all dimensions were in between the maximum and minimum natural frequencies. The difference between the natural frequencies of the normal models to those with minimum and maximum natural frequencies of Models I and II are given in Tables 4.23 and 4.24, respectively.

Model I		Natural frequencies									
		1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
No Weld was included	Min	581.49	583.87	1080.5	1083.2	1116.8	1481.1	1589.7	1695.9	1728.4	1756.4
	Max	592.40	594.16	1115.3	1117.2	1151.9	1532.5	1699.4	1768.2	1814.5	1821.7
Weld was included	Min	567.80	569.60	1070.7	1073.4	1114.6	1487.4	1612.8	1726.6	1750.6	1776.1
	Max	576.68	578.94	1093.1	1094.8	1138.2	1513.9	1770.7	1839.1	1862.2	1865.5

Table 4.21 Minimum and maximum of natural frequencies of Model I

Model II		Natural frequencies									
		1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
No Weld was included	Min	580.19	582.56	1083.2	1086.1	1115.1	1476.4	1588.5	1696.1	1729.1	1755.1
	Max	586.53	588.44	1100.7	1102.8	1151.1	1525.5	1690.7	1763.6	1808.6	1811.9
Weld was included	Min	568.09	570.16	1073.3	1076.0	1099.2	1477.9	1597.8	1714.2	1741.5	1764.4
	Max	574.07	576.32	1081.0	1082.9	1134.4	1500.0	1754.4	1822.5	1836.3	1853.1

Table 4.22 Minimum and maximum of natural frequencies of Model II

Model I	Weld was included			No Weld was included		
Natural frequencies	% difference from the maximum	**Normal**	% difference from the minimum	% difference from the maximum	**Normal**	% difference from the minimum
1st	-0.85	571.81	0.70	-0.90	587.10	0.96
2nd	-0.89	573.84	0.74	-0.85	589.17	0.90
3rd	-1.54	1076.5	0.54	-1.58	1097.9	1.58
4th	-1.50	1078.6	0.48	-1.55	1100.2	1.55
5th	-0.74	1129.8	1.35	-1.47	1135.2	1.62
6th	-0.40	1507.9	1.36	-1.60	1508.3	1.80
7th	-4.59	1693.0	4.74	-3.19	1646.8	3.47
8th	-2.69	1790.9	3.59	-1.71	1738.5	2.45
9th	-2.78	1811.9	3.38	-2.42	1771.7	2.44
10th	-2.75	1815.5	2.17	-1.80	1789.5	1.85

Table 4.23 Natural frequencies of normal models and the % differences between the minimum and maximum natural frequencies of Model I

Model II		Natural frequencies									
		1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
No Weld was included	% difference from the minimum	0.55	0.51	0.84	0.79	1.64	1.68	3.24	2.35	2.28	1.52
	Normal	583.40	585.53	1092.4	1094.8	1133.7	1501.7	1641.7	1736.9	1769.5	1782.1
	% difference from the maximum	-0.54	-0.50	-0.76	-0.73	-1.53	-1.58	-2.98	-1.54	-2.21	-1.67
Weld was included	% difference from the minimum	0.84	0.87	0.12	0.08	2.14	1.08	5.04	3.94	3.53	2.51
	Normal	572.90	575.15	1074.6	1076.9	1123.2	1494.1	1682.6	1784.5	1805.2	1809.9
	% difference from the maximum	-0.20	-0.20	-0.60	-0.56	-1.00	-0.39	-4.27	-2.13	-1.72	-2.39

Table 4.24 Natural frequencies of normal models and the % differences between the minimum and maximum natural frequencies of Model II

It is observed that when the weld effect was included for Model I, the uncertainties in the natural frequencies could vary between -4.59 % to +4.74 %; for Model II, it could vary between -4.27 % to +5.04 %. When the weld effect was not included the variations were between -3.19 % to +3.47 % for Model I and between -2.98 % to +3.24 % for Model II.

Tables 4.25 and 4.26 show the differences between the natural frequencies of the normal models in which weld was not included for Models I and II, respectively. Moreover, the changes of natural frequencies when the girders were moved closer to and away from each other were also examined. Tables 4.25, 4.26, 4.27 and 4.28 show the % differences between the natural frequencies of any two models, in which one model was the normal model that the transverse girders were not moved and the other model was the "moved closer" model or " moved away" model. For example in Model I, in which weld was not included, the first natural frequencies of the models for the three cases were 587.10, 587.06 and 586.83, respectively. The % difference between the normal models and the other in which the girders were moved closer was computed to be 0.01 %; moreover, the % difference for the "moved away" case was 0.05%. These numbers are shown in Table 4.25. Similar interpretations could be made for the results shown in Table 4.26 to 4.28.

It can be seen that the natural frequencies of modes 1 to 6 and 10 changed by less than 1 % no matter whether the girders were moved closer or away from one another. Also, the maximum differences of natural frequencies were 2.04 and 2.03 % in Model I and II for mode 7. Also, in mode 7, the natural frequencies could vary between -2.01 to +2.04 % and -2.03 to +2.01 % for Models I and II, due to the uncertainties in girders placement.

Natural frequencies (Model I, weld was not included)	Girders were **moved away**: Using Mean Values - 3 S.D.	Girders were **moved away**: Using Mean Values + 3 S.D.	Girders were **moved away**: Using Mean Values	Girders were **moved closer**: Using Mean Values - 3 S.D.	Girders were **moved closer**: Using Mean Values + 3 S.D.	Girders were **moved closer**: Using Mean Values	Girders were **not moved**: Using Mean Values - 3 S.D.	Girders were **not moved**: Using Mean Values + 3 S.D.	Girders were **not moved**: Using Mean Values
	% differences of natural frequencies between this category and the category that the girders were not moved; others dimensions were the same			% differences of natural frequencies between this category and the category that the girders were not moved; others dimensions were the same			**Natural frequencies**		
1st	0.02	-0.10	0.05	-0.02	-0.14	0.01	581.62	591.55	587.10
2nd	-0.01	-0.13	0.02	0.01	-0.12	0.04	583.91	593.38	589.17
3rd	0.02	-0.28	0.02	-0.02	-0.31	-0.01	1080.7	1111.8	1097.9
4th	0.00	-0.31	0.00	0.01	-0.30	0.01	1083.3	1113.8	1100.2
5th	0.86	0.56	0.84	-0.82	-0.98	-0.75	1126.5	1140.7	1135.2
6th	-0.40	-0.49	-0.33	0.43	0.24	0.45	1487.5	1525.1	1508.3
7th	1.91	1.89	1.96	-1.70	-1.78	-1.70	1620.6	1669.6	1646.8
8th	1.17	0.92	1.16	-0.61	-0.76	-0.55	1715.9	1754.8	1738.5
9th	-1.09	-1.14	-1.06	1.08	1.08	1.15	1747.2	1794	1771.7
10th	-0.57	-0.36	-0.32	0.14	-0.16	0.11	1758.8	1815.2	1789.5

Table 4.25 Comparison of natural frequencies based on different spacings of girders of models in which weld was not included for Model I

Model I weld was included	Girders were **moved away**			Girders were **moved closer**			Girders were **not moved**		
	Using Mean Values - 3 S.D.	Using Mean Values + 3 S.D.	Using Mean Values	Using Mean Values - 3 S.D.	Using Mean Values + 3 S.D.	Using Mean Values	Using Mean Values - 3 S.D.	Using Mean Values + 3 S.D.	Using Mean Values
Natural frequencies	% differences of natural frequencies between this category and the category that the girders were not moved; others dimensions were the same			% differences of natural frequencies between this category and the category that the girders were not moved; others dimensions were the same			**Natural frequencies**		
1st	0.02	0.02	0.13	-0.02	-0.02	-0.02	576.56	567.89	571.81
2nd	-0.01	-0.01	0.11	0.01	0.01	0.01	578.89	569.64	573.84
3rd	0.02	0.02	0.02	-0.02	-0.01	-0.02	1070.9	1093.0	1076.5
4th	-0.01	-0.01	0.00	0.00	0.00	0.01	1073.4	1094.7	1078.6
5th	0.83	0.71	0.75	-0.80	-0.69	-0.74	1128.1	1122.6	1129.8
6th	-0.38	-0.26	-0.34	0.40	0.28	0.34	1493.3	1510.0	1507.9
7th	1.95	2.04	2.02	-1.74	-2.01	-1.90	1644.8	1735.8	1693.0
8th	1.05	0.71	0.89	-0.29	0.28	-0.02	1744.9	1839.1	1790.9
9th	-0.92	0.00	-0.14	1.01	0.70	0.84	1768.4	1862.2	1811.9
10th	-0.46	-0.12	-0.13	0.12	0.10	0.12	1778.2	1863.3	1815.5

Table 4.26 Comparison of natural frequencies based on different spacings of girders of models in which weld was included for Model I

Model II weld was not included	Girders were **moved away**			Girders were **moved closer**			Girders were **not moved**		
	Using Mean Values - 3 S.D.	Using Mean Values + 3 S.D.	Using Mean Values	Using Mean Values - 3 S.D.	Using Mean Values + 3 S.D.	Using Mean Values	Using Mean Values - 3 S.D.	Using Mean Values + 3 S.D.	Using Mean Values
Natural frequencies	% differences of natural frequencies between this category and the category that the girders were not moved; others dimensions were the same			% differences of natural frequencies between this category and the category that the girders were not moved; others dimensions were the same			**Natural frequencies**		
1st	0.04	-0.11	0.02	0.01	-0.15	-0.02	580.44	585.66	583.40
2nd	0.01	-0.13	-0.01	0.04	-0.11	0.01	582.78	587.67	585.53
3rd	0.03	-0.05	0.05	-0.02	-0.07	0.01	1083.5	1099.9	1092.4
4th	0.00	-0.06	0.03	0.01	-0.05	0.04	1086.2	1102.1	1094.8
5th	0.84	0.79	0.86	-0.84	-0.81	-0.79	1124.6	1141.8	1133.7
6th	-0.45	-0.53	-0.28	0.39	0.25	0.43	1482.2	1517.4	1501.7
7th	1.88	1.67	1.99	-1.75	-2.03	-1.70	1619.0	1657.1	1641.7
8th	1.14	0.98	1.26	-0.62	-0.64	-0.51	1715.7	1752.3	1736.9
9th	-1.11	-1.33	-0.75	1.09	0.87	1.14	1748.2	1784.8	1769.5
10th	-0.61	-0.71	-0.35	0.16	-0.29	0.13	1757.9	1799.1	1782.1

Table 4.27 Comparison of natural frequencies based on different spacings of girders of models in which weld was not included for Model II

Model II weld was included	Girders were **moved away**			Girders were **moved closer**			Girders were **not moved**		
	Using Mean Values - 3 S.D.	Using Mean Values + 3 S.D.	Using Mean Values	Using Mean Values - 3 S.D.	Using Mean Values + 3 S.D.	Using Mean Values	Using Mean Values - 3 S.D.	Using Mean Values + 3 S.D.	Using Mean Values
Natural frequencies	% differences of natural frequencies between this category and the category that the girders were not moved; others dimensions were the same			% differences of natural frequencies between this category and the category that the girders were not moved; others dimensions were the same			**Natural frequencies**		
1st	0.02	0.02	0.02	-0.02	-0.02	-0.02	573.95	568.18	572.90
2nd	-0.01	-0.01	-0.01	0.01	0.01	0.01	576.26	570.19	575.15
3rd	0.02	0.10	0.02	-0.02	0.06	-0.02	1073.5	1081.7	1074.6
4th	0.00	-0.01	-0.01	0.01	0.00	0.00	1076.1	1082.8	1076.9
5th	0.88	0.70	0.75	-0.82	-0.71	-0.79	1125.2	1107.0	1123.2
6th	-0.41	-0.27	-0.39	0.42	0.28	0.29	1484.2	1484.3	1494.1
7th	1.96	2.01	1.96	-1.78	-1.98	-1.93	1629.8	1720.3	1682.6
8th	1.10	0.43	0.80	-0.42	-0.08	-0.16	1733.3	1821.0	1784.5
9th	-1.00	-0.07	-0.29	1.07	0.16	0.71	1760.4	1835.0	1805.2
10th	-0.71	0.13	-0.04	0.15	0.67	0.30	1767.0	1853.1	1809.9

Table 4.28 Comparison of natural frequencies based on different spacings of girders of models in which weld was included for Model II

CHAPTER 5

FREE VIBRATION ANALYSIS USING APPROXIMATE METHODS

5.1 INTRODUCTION AND SCOPE OF THIS ANALYSIS

The stiffened plates used in this investigation were fabricated using different sizes of T-section stiffeners to be attached to the plate panel in two mutually orthogonal directions, as shown in Figures 3.1 and 3.3. Due to this geometry, the stiffened plates were expected to behave similar to a homogeneous orthotropic plate. Thereafter, concepts of orthotropic plate were employed to analyze the free vibration behaviour of stiffened plates, and the results obtained using this method were compared with the results obtained using finite element method. This aspect forms one part of the study reported in this chapter.

Moreover, another approximate method using concepts of static analysis was also used to determine the approximate (lower order) natural frequencies of the stiffened plate. The natural frequencies obtained from this method were also compared with those obtained from finite element method. This aspect forms the second part of the study reported in this chapter.

5.2 ORTHOTROPIC PLATES

In this section, general concepts of an orthotropic plate are discussed first. Subsequently, the method of elastic equivalence will be employed for the stiffened plate. Calculation of flexural and torsional rigidities of a stiffened plate is presented later.

5.2.1 General concepts in orthotropic plates

Any material can be classified into two major types, either isotropic or anisotropic material. If a material has the same physical and mechanical properties in all directions or if material properties are independent of directions, that material is defined to be an isotropic material. On the other hand, a material possessing physical and mechanical properties that differ according to the specified directions is defined as an anisotropic material [36]. By definition, an orthotropic material is the material that has different material properties in three mutually perpendicular directions. If a material is an orthotropic material, the material is also an anisotropic material, and, sometimes, the terms "orthogonal-anisotropic" or "orthotropic" are used to denote the same [2], [37]. Orthotropic materials can be classified into two groups, viz., natural and technical orthotropic materials. Natural orthotropic materials have the property of orthotropy due to their intrinsic nature. On the other hand, technical or structural orthotropy includes systems which are reinforced to enhance the strength and stability, and arranged in appropriate geometrical configurations consisting of two or more different materials. Ribbed plates, orthogonally stiffened plate girders and reinforced or prestressed concrete slab floors are typical examples of structures in the technical orthotropy group [37].

The main focus of this study is on a stiffened plate which belongs to the technical orthotropic category. Elastic properties of a stiffened plate are different in mutually orthogonal directions, depending on the characteristics of the plate and the stiffeners. The properties could be expressed by the different flexural and torsional rigidities of the element.

Huber proposed the governing differential equation of orthotropic plate as shown in equation 5.1, and it is commonly known as Huber's equation [38].

$$D_x \frac{\partial^4 w}{\partial x^4} + 2H \frac{\partial^4 w}{\partial x^2 \partial y^2} + D_y \frac{\partial^4 w}{\partial y^4} = p(x, y) \tag{5.1}$$

where D_x is flexural rigidity in x-direction, D_y is flexural rigidity in y-direction, H is torsional rigidity, w or $w(x,y)$ is deflection as a function of x and y, and $p(x,y)$ is given load as a function of x and y

Huber's equation, given by equation (5.1), is a non-homogeneous partial differential equation. Therefore, the solution can be obtained by the superposition of two solutions that are homogeneous and particular solutions:

$$w = w_h + w_p \tag{5.2}$$

where w_h is a general solution of the corresponding homogeneous differential equation

$$D_x \frac{\partial^4 w_h}{\partial x^4} + 2H \frac{\partial^4 w_h}{\partial x^2 \partial y^2} + D_y \frac{\partial^4 w_h}{\partial y^4} = 0 \tag{5.3}$$

and w_p is a particular solution of the corresponding particular differential equation

$$D_x \frac{\partial^4 w_p}{\partial x^4} + 2H \frac{\partial^4 w_p}{\partial x^2 \partial y^2} + D_y \frac{\partial^4 w_p}{\partial y^4} = p(x, y) \tag{5.4}$$

Therefore, the addition of the two surfaces, $w_h + w_p$, provides a deflection surface for the actual loaded plate and satisfies all boundary conditions. A solution of the homogeneous equation can be obtained by using the solution first proposed by Levy and expressed in the general form as shown below in equation (5.5) [37]. However, the particular solution depends on the pattern of loading (whether concentrated, distributed or inertial), so no general solution will be shown here.

$$w_h = \sum_{m=1}^{\infty} A e^{\alpha y} \sin \frac{m\pi x}{a} \tag{5.5}$$

where A and α are constants [39], m is number of half sin and a is span in x direction. After substituting equation (5.5) into (5.3) and solving, the general solution can be written as follows [37],

$$w_h = \sum_{m=1}^{\infty} (A_1 e^{\alpha_1 y} + A_2 e^{\alpha_2 y} A_3 e^{\alpha_3 y} A_4 e^{\alpha_4 y}) \sin \frac{m\pi x}{a} \tag{5.6}$$

where

$$\alpha_1 = +\frac{m\pi}{a}\sqrt{\frac{1}{D_y}(H + \sqrt{H^2 - D_x D_y}}$$

$$\alpha_2 = +\frac{m\pi}{a}\sqrt{\frac{1}{D_y}(H - \sqrt{H^2 - D_x D_y}}$$

$$\alpha_3 = -\frac{m\pi}{a}\sqrt{\frac{1}{D_y}(H + \sqrt{H^2 - D_x D_y}}$$

$$\alpha_4 = -\frac{m\pi}{a}\sqrt{\frac{1}{D_y}(H - \sqrt{H^2 - D_x D_y}}$$

A_1, A_2, A_3 and A_4 can be determined from the boundary conditions.

5.2.2 Method of elastic equivalence

According to the theory of the elasticity of orthotropic plates, (applied to a stiffened plate), proposed and developed by Huber, the geometry of the stiffened plate, in which the stiffeners are attached in an orthogonal pattern, will be replaced by a homogeneous equivalent orthotropic plate, having a constant thickness. The stiffness or rigidity characteristics of the stiffened plate and modified equivalent orthotropic plate will be kept the same. Basically, the proposed method is used to estimate the overall bending deflections and bending stresses in the stiffened plate.

Thin plate theory is employed and the problem is treated as plane stress condition [37]. Therefore, for simplification purposes, the bending of the stiffened plate can be analyzed by substituting the plate-stiffener combination with an equivalent homogeneous orthotropic plate. This replacement of a stiffened plate with an equivalent orthotropic plate is called "method of elastic equivalence".

Even though the rigidity characteristics of both orthotropic and stiffened plate are the same, the application of this method is still limited. According to the analysis using this method and experimental data investigated, the requirements for the use of this method are [37]:

(1) The ratios of stiffener spacing to plate boundary dimensions are small enough to ensure approximate homogeneity of stiffness;

(2) It is assumed that the rigidities are uniformly distributed in both directions;

(3) Flexural and twisting rigidities do not depend on the boundary conditions of the plate or on the distribution of the vertical load;

(4) In case of steel stiffened plates it is assumed that both plate and stiffeners are fabricated of the same isotropic material, and

(5) A perfect bond exists between plate and stiffeners.

5.2.3 Calculation of flexural rigidities

Rigidity of any structure can be expressed in terms of elastic modulus and moment of inertia. An example of rigidity calculation of a simple stiffened plate is demonstrated below (this forms part of the stiffened plates that were used in this investigation). Assume a model as shown in Figure 5.1.

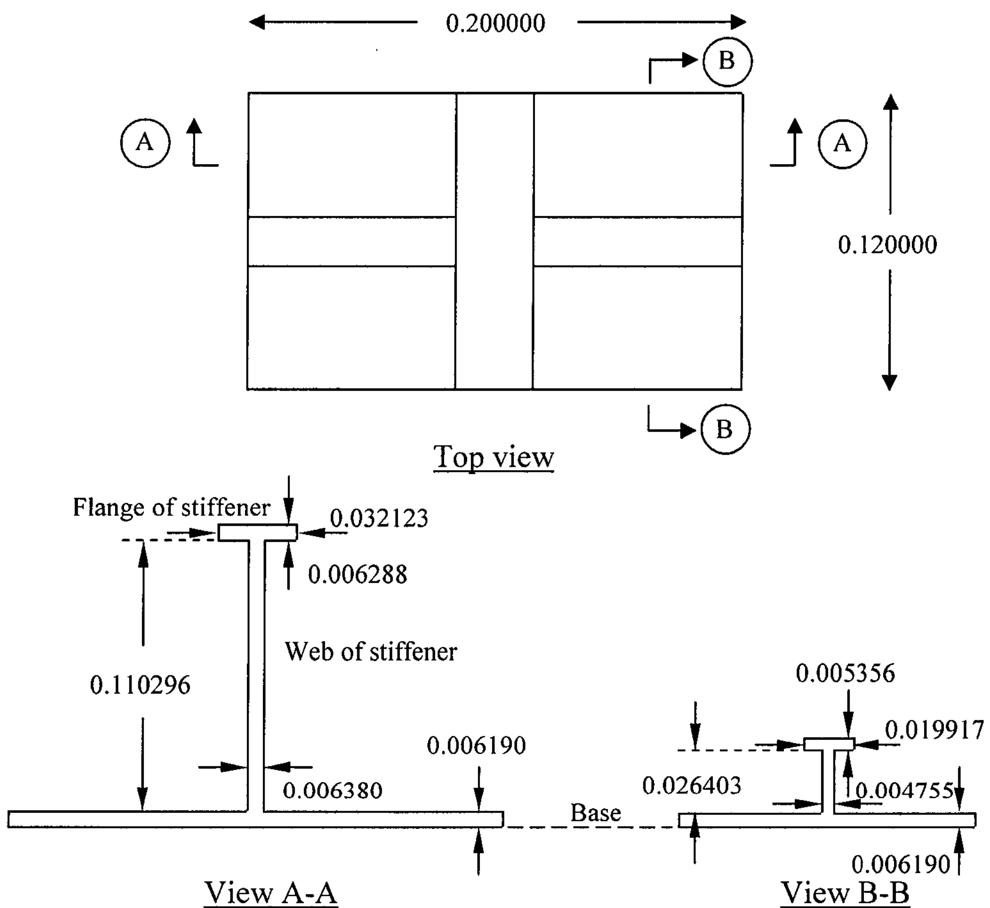


Figure 5.1 A simple stiffened plate (all units are in meters)

Calculation details of cross sectional view A-A and the variables used in calculation are given below:

A_{plate} = area of plate

A_{web} = area of web of stiffener

A_{flange} = area of flange of stiffener

$\sum A$ = total area of cross section

h_{plate} = distance from base to centroid of area of plate

h_{web} = distance from base to centroid of area of web of stiffener

h_{flange} = distance from base to centroid of area of flange of stiffener

$\sum Ah$ = summation of first moment of area with respect to base

$h_{N.A.}$ = distance from base to neutral axis of the whole section

ν = Poisson ratio, taken as 0.35 for Aluminum

E = elastic modulus, taken as 73.1E+09 for Aluminum

E' = modified elastic modulus for plate

I_{plate} = moment of inertia of plate with respect to its N.A.

I_{web} = moment of inertia of web of stiffener with respect to its N.A.

I_{flange} = moment of inertia of flange of stiffener with respect to its N.A.

$e_{plate_{N.A.}}$ = distance from centroid of plate to N.A. of the whole section

$e_{web_{N.A.}}$ = distance from centroid of web of stiffener to N.A. of the whole section

$e_{flange_{N.A.}}$ =distance from centroid of flange of stiffener to N.A. of the whole section

$D_{A\text{-}A}$ = flexural rigidity of the cross section of view A-A

Areas of each section are:

$$A_{plate} = 0.200000 \times 0.006190 = 0.001238 \qquad \text{m}^2$$

$$A_{web} = 0.006380 \times 0.110296 = 0.000704 \qquad \text{m}^2$$

$$A_{flange} = 0.032123 \times 0.006288 = 0.000202 \qquad \text{m}^2$$

$$\sum A = A_{plate} + A_{web} + A_{flange} \tag{5.7}$$

$$\sum A = 0.002144 \qquad \text{m}^2$$

Distances from base to centroid of each section are:

$$h_{plate} = \frac{0.006190}{2} = 0.003095 \qquad \text{m}$$

$$h_{web} = 0.006190 + \frac{0.110296}{2} = 0.061338 \qquad \text{m}$$

$$h_{flange} = 0.006190 + 0.110356 + \frac{0.006288}{2} = 0.119630 \qquad \text{m}$$

First moment of area with respect to base can be calculated as shown:

$$\sum Ah = A_{plate} \cdot h_{plate} + A_{web} \cdot h_{web} + A_{flange} \cdot h_{flange} \tag{5.8}$$

$$\sum Ah = 7.115845E-5 \qquad \text{m}^3$$

Distance from base to neutral axis of the whole section is:

$$h_{N.A.} = \frac{\sum Ah}{\sum A} \tag{5.9}$$

$$h_{N.A.} = \frac{7.115845E-5}{0.002144} = 0.033195 \qquad \text{m}$$

Based on concepts of method of elastic equivalence of stiffened plate [35], the plate panel is treated as a plate, and stiffeners are treated as beams. Therefore, elastic modulus used for the plate panel was elastic modulus used according to plate theory, and elastic modulus used for the stiffeners were elastic modulus used according to beam theory.

Assume that the stiffened plate was made of Aluminum; then elastic modulus of plate becomes:

$$E' = \frac{E}{1-\nu^2} \tag{5.10}$$

$$E' = \frac{73.1E+9}{1-0.35^2} = 8.330484E+10 \quad \text{N/m}^2$$

Moment of inertia of each section can be calculated as shown:

$$I_{plate} = \frac{0.200000 \times 0.006190^3}{12} = 3.952944E\text{-}09 \quad \text{m}^4$$

$$I_{web} = \frac{0.006380 \times 0.110296^3}{12} = 7.133764E\text{-}07 \quad \text{m}^4$$

$$I_{flange} = \frac{0.032123 \times 0.006288^3}{12} = 6.655374E\text{-}10 \quad \text{m}^4$$

Distances from centroid of each section to N.A. of the whole section are:

$$e_{plate_{N.A.}} = 0.033195 - \frac{0.006190}{2} = 0.030100 \quad \text{m}$$

$$e_{web_{N.A.}} = \left(0.006190 + \frac{0.110296}{2}\right) - 0.033195 = 0.028143 \quad \text{m}$$

$$e_{flange_{N.A.}} = \left(0.006190 + 0.110296 + \frac{0.006288}{2}\right) - 0.033195 = 0.086435 \quad \text{m}$$

Flexural rigidity of the whole section can be obtained from:

$$
\begin{aligned}
D_{A-A} &= E' \cdot I_{plate} + E' \cdot A_{plate} \cdot e^2_{plate_{N.A.}} \\
&+ E \cdot I_{web} + E \cdot A_{web} \cdot e^2_{web_{N.A.}} \\
&+ E \cdot I_{flange} + E \cdot A_{flange} \cdot e^2_{flange_{N.A.}}
\end{aligned}
\tag{5.11}
$$

$$D_{A-A} = 2.970178E + 05 \qquad \text{N.m}^2$$

Once the flexural rigidity is calculated, the orthotropic plate possessing a constant thickness will be obtained next. Assume that the cross section of the orthotropic plate has the same width as the stiffened plate's and has a thickness of 0.006190 in meter unit. Therefore, the moment of inertia of this section is already specified, and the calculation details are given below. According to the criteria that the flexural rigidity of the orthotropic and stiffened plate has to be the same, the elastic modulus of the orthotropic plate has to be modified. The modification is given below.

Assume

$I_{orthotropic}$ = moment of inertia of orthotropic plate with respect to its N.A.

$E_{orthotropic}$ = modified elastic modulus of the orthotropic plate

Moment of inertia of orthotropic plate with respect to its N.A. is:

$$I_{orthotropic} = \frac{0.200000 \times 0.006190^3}{12} = 3.952944E\text{-}09 \qquad \text{m}^4$$

According to plate theory, the flexural rigidity can be expressed as:

$$D = \frac{E \cdot I}{\left(1 - \nu^2\right)} \tag{5.12}$$

Therefore, modified elastic modulus of orthotropic plate can be expressed as:

$$E_{orthotropic} = \frac{D_{A-A} \cdot \left(1-\nu^2\right)}{I_{orthotropic}} \tag{5.13}$$

$$E_{orthotropic} = \frac{2.970178E+05\left(1-0.35^2\right)}{3.952944E-09} = 6.593392E+13 \quad \text{N/m}^2$$

Assume that this modified elastic modulus is called E_y, and the other one obtained from the other direction (view B-B) will be called E_x. The flexural rigidity and modified elastic modulus of cross section of view B-B can be obtained by following the same procedures and they are:

$$D_{B-B} = 9.249074E+03 \qquad \text{N.m}^2$$

$$E_x = 3.421948E+12 \qquad \text{N/m}^2$$

Once the flexural rigidities and modified moduli of elasticity in both directions of the orthotropic plate are obtained, the shear modulus and torsional rigidity of orthotropic plate [35] can be calculated using:

$$G_{xy} = \frac{E_x E_y}{E_x + (1+2\nu_{xy})E_y} \tag{5.14}$$

and

$$D_{xy} = \frac{G_{xy} t^3}{12} \tag{5.15}$$

where G_{xy} is the shear modulus, D_{xy} is the torsional rigidity, E_x and E_y are the modified moduli of elasticity in x- and y-direction, respectively, and ν_{xy} is Poisson ratio of orthotropic plate and can be obtained according to Betti's reciprocal theorem as expressed below:

$$\nu_{xy} = \frac{E_x}{E_y}\nu_{yx} \tag{5.16}$$

However, an assumption needs to be made in order to obtain ν_{xy}. Because there is only one relation with two unknowns, ν_{xy} and ν_{yx}, so one of the two unknown needs to be assigned a value. Additionally, the value of Poisson ratio should not be theoretically greater than 0.5. Thus, to reasonably assign values of Poisson ratio, one of two unknowns will be assigned the value of 0.35 which is the value of Poisson ratio of Aluminum, and the other one will be obtained depending on E_x and E_y; and it must be not greater than 0.35

For this simple stiffened plate, E_x is greater than E_y; hence, ν_{yx} will be assigned the value of 0.35 according to the statement above. Subsequently, ν_{xy}, shear modulus and torsional rigidity will be obtained as follow:

From equation (6.15),

$$\nu_{xy} = \frac{3.421948E+12}{6.593392E+13} \times 0.35 = 0.018165$$

From equation (5.13),

$$G_{xy} = \frac{(3.421948E+12) \times (6.593392E+13)}{(3.421948E+12) + [(1+2 \times 0.018165) \times (6.593392E+13)]} = 3.144510E+12$$

From equation (5.14),

$$D_{xy} = \frac{(3.144510E+12) \times 0.006190^3}{12} = 6.215036E+04 \qquad \text{N.m}^2$$

5.2.4 Modification of the stiffened plate under investigation to an equivalent orthotropic plate.

The geometry of stiffened plate is composed of a plate panel stiffened by T-section stiffeners in two directions, perpendicular to one other, as shown in Figure 3.1 and 3.3; therefore, the stiffened plate is modeled to have orthotropic properties. In order to transform the given stiffened plate to a plate with orthotropic properties and apply the method of elastic equivalence, contribution of flexural rigidities by each stiffener and the plate panel to the overall orthotropic plate behaviour should be considered properly.

The contribution of the individual stiffeners to the overall orthotropic behaviour is taken into account here by attributing that each stiffener contributed its flexural rigidity to the overall orthotropic behaviour equally around its location. In other words, a stiffener contributes to the flexural rigidity of a specified area having a width equal to the spacing between stiffeners. To visualize this more clearly, Figures 5.2 and 5.3 show the top view of the model; the contribution in rigidity of each stiffener to the plate is denoted by blue lines and color areas, respectively.

As a result, there are eight different zones or areas possessing different orthotropic properties as shown in Figures 5.2 and 5.3. Area A-1 is the simple plate panel; the elastic moduli in both directions of the area A-1 are assigned the same value as the modulus of the original plate panel. By following the procedure of rigidity calculation outlined earlier in Section 5.2.3, the rigidity and modified elastic moduli in both x- and y-direction of all areas could be obtained. However, it should be noted that ABAQUS is still used in this analysis to estimate the free vibration responses of the structure. Therefore, only variables required as inputs by the software were obtained.

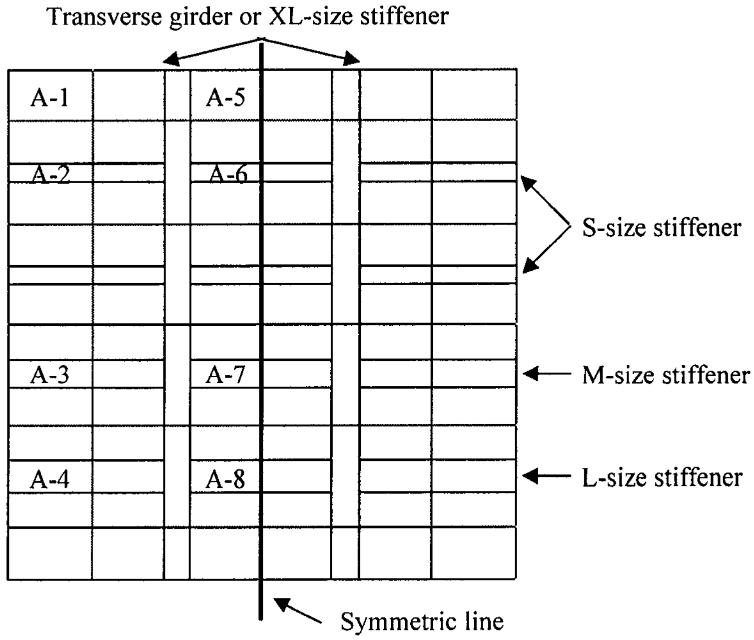


Figure 5.2 Contribution of each stiffener to overall orthotropic panel shown by blue lines

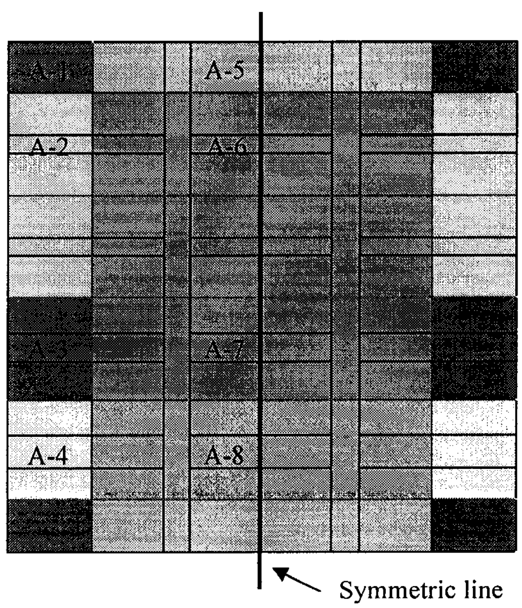


Figure 5.3 Contribution of each stiffener to overall orthotropic panel shown by colored areas

To assign the material property to orthotropic structure in ABAQUS [40], only the elastic or constitutive matrix needs to be specified. The constitutive matrix could be expressed in terms of the usual stress-strain relationship as shown below:

$$\begin{Bmatrix} \sigma_{11} \\ \sigma_{22} \\ \sigma_{33} \\ \sigma_{12} \\ \sigma_{13} \\ \sigma_{23} \end{Bmatrix} = \begin{bmatrix} D_{1111} & D_{1122} & D_{1133} & 0 & 0 & 0 \\ & D_{2222} & D_{2233} & 0 & 0 & 0 \\ & & D_{3333} & 0 & 0 & 0 \\ & & & D_{1212} & 0 & 0 \\ & symmetry & & & D_{1313} & 0 \\ & & & & & D_{2323} \end{bmatrix} \begin{Bmatrix} \varepsilon_{11} \\ \varepsilon_{22} \\ \varepsilon_{33} \\ \gamma_{12} \\ \gamma_{13} \\ \gamma_{23} \end{Bmatrix}$$

Where

$$D_{1111} = E_1(1-\nu_{23}\nu_{32})\beta$$

$$D_{2222} = E_2(1-\nu_{13}\nu_{31})\beta$$

$$D_{3333} = E_3(1-\nu_{12}\nu_{21})\beta$$

$$D_{1122} = E_1(\nu_{21}+\nu_{31}\nu_{23})\beta = E_2(\nu_{12}+\nu_{32}\nu_{13})\beta$$

$$D_{1133} = E_1(\nu_{31}+\nu_{21}\nu_{32})\beta = E_3(\nu_{13}+\nu_{12}\nu_{23})\beta$$

$$D_{2233} = E_2(\nu_{32}+\nu_{12}\nu_{31})\beta = E_3(\nu_{23}+\nu_{21}\nu_{13})\beta$$

$$D_{1212} = G_{12}$$

$$D_{1313} = G_{13}$$

$$D_{2323} = G_{23}$$

$$\beta = \frac{1}{1-\nu_{12}\nu_{21}-\nu_{23}\nu_{32}-\nu_{31}\nu_{13}-2\nu_{21}\nu_{32}\nu_{13}}$$

Rigidities, modified moduli of elasticity, shear moduli and Poisson ratio were obtained by the procedures outlined earlier in Section 5.2.3. All the variables that were required in the constitutive matrices of the areas A-1 to A-8 were obtained and are given in Table 5.1. The details of calculation of other variables are given in Appendix G.

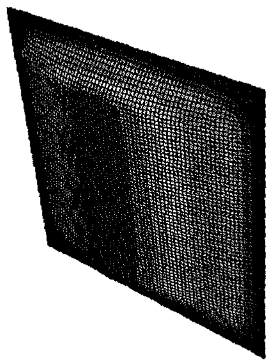
Area	Value of all variable filled in the constitutive matrices								
	D1111	D1122	D2222	D1133	D2323	D3333	D1212	D1313	D2323
A-1	1.1732E+11	6.3173E+10	1.1732E+11	6.3173E+10	6.3173E+10	1.1732E+11	2.7074E+10	2.7074E+10	2.7074E+10
A-2	3.4497E+12	3.9681E+10	8.3761E+10	3.9681E+10	2.9613E+10	8.3761E+10	7.0538E+10	7.0538E+10	2.7074E+10
A-3	7.2671E+12	3.9512E+10	8.3520E+10	3.9512E+10	2.9372E+10	8.3520E+10	7.1866E+10	7.1866E+10	2.7074E+10
A-4	1.0057E+13	3.9470E+10	8.3460E+10	3.9470E+10	2.9312E+10	8.3460E+10	7.2205E+10	7.2205E+10	2.7074E+10
A-5	8.3328E+10	3.9378E+10	6.5961E+13	2.9180E+10	3.9378E+10	8.3328E+10	7.2962E+10	2.7074E+10	7.2962E+10
A-6	3.4533E+12	1.2178E+12	6.6372E+13	2.6292E+10	3.4861E+10	7.3310E+10	3.1445E+12	7.0538E+10	7.2962E+10
A-7	7.3481E+12	2.5813E+12	6.6850E+13	2.6971E+10	3.5063E+10	7.3209E+10	6.1007E+12	7.1866E+10	7.2962E+10
A-8	1.0230E+13	3.5900E+12	6.7203E+13	2.7490E+10	3.5236E+10	7.3184E+10	7.9685E+12	7.2205E+10	7.2962E+10

Table 5.1 Variables that are required in the constitutive matrices

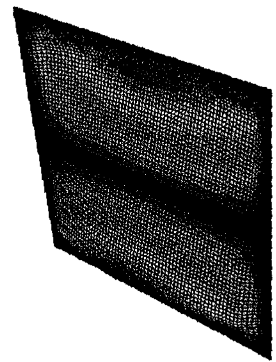
Once the constitutive matrices of all areas A-1 to A-8 were obtained, the orthotropic plate model was generated and analyzed using ABAQUS. Consequently, the dynamic responses of the orthotropic plate were obtained. The first ten natural frequencies of the orthotropic plate are given in Table 5.2, and the corresponding mode shapes are shown in Figure 5.4. Moreover, the natural frequencies (obtained by finite element analysis) of the stiffened plate are also included in Table 5.2, but only the fifth and sixth natural frequencies are included because they are the first two fundamental natural frequencies which are comparable with the first and second natural frequencies of the orthotropic plate.

Structures	**Natural frequency**									
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
Equivalent orthotropic plate	357.09	603.98	794.24	1115.6	1301.0	2225.4	2317.1	2317.1	2446.4	2629.4
Stiffened plate (FEM)	1135.2	1508.3	-	-	-	-	-	-	-	-
% difference	-68.54	-59.96	-	-	-	-	-	-	-	-

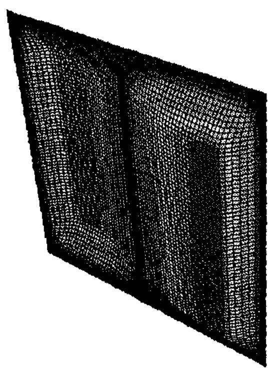
Table 5.2 Natural frequencies of orthotropic plate



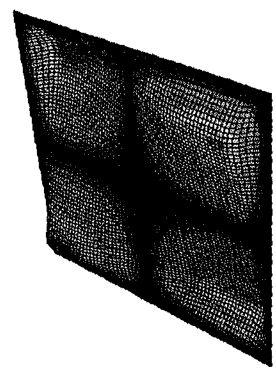
Mode shape 1



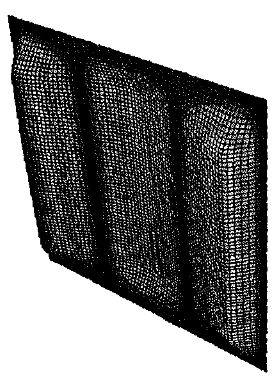
Mode shape 2



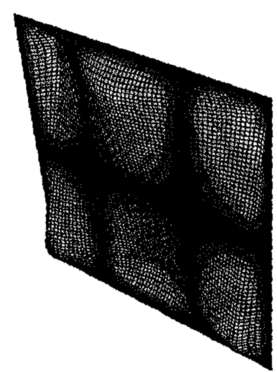
Mode shape 3



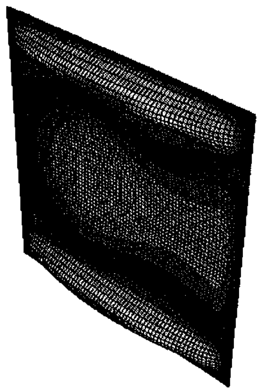
Mode shape 4



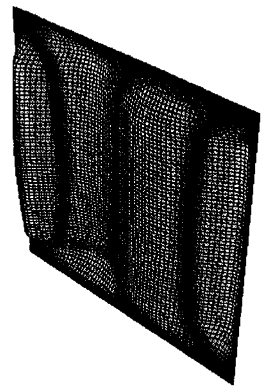
Mode shape 5



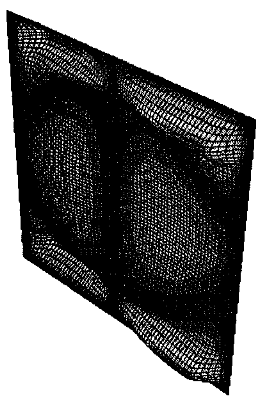
Mode shape 6



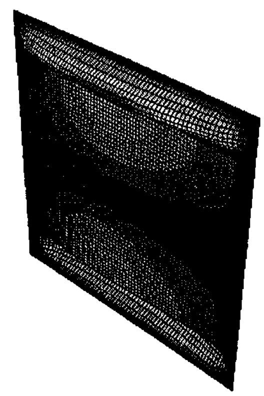
Mode shape 7



Mode shape 8



Mode shape 9



Mode shape 10

Figure 5.4 Ten mode shapes of orthotropic plate

The method of elastic equivalence does not seem to work well since so much difference occurs between the natural frequencies obtained from this method and finite element method. However, it does not mean that the method of elastic equivalence does not work at all. As stated, earlier in Section 5.2.2, that there are some requirements for the applications of this method, such as the spacings between the stiffeners must be close enough to be able to give a homogeneity of stiffness, and it is apparent that the spacings between the stiffeners of the stiffened plate used in this investigation do not seem to be small enough for that requirement; therefore, it is observed that the method of elastic equivalence is not applicable for this stiffened plate due to the large spacing between the stiffeners.

5.3 APPROXIMATE METHOD USING CONCEPTS OF STATIC ANALYSIS

5.3.1 General procedure to obtain fundamental natural frequencies

Normally, natural frequencies of structures are computed using mass and stiffness matrices. However, by using an approximate method that uses static analysis, fundamental natural frequencies can be approximately calculated. This kind of method was earlier proposed to obtain fundamental natural frequencies of a simple beam [41, 42]; moreover, this method was also applied to a simple plate [2]. But it is more difficult to work with a plate because the plate bends in two directions, and the equation that gives the deflection of the plate becomes more complex. Hence, concepts of the approximate method applied for beams will be demonstrated and used in this analysis. The general formulation to calculate the fundamental natural frequencies is given below as:

$$\omega_n = (\beta_n L)^2 \sqrt{\frac{EI}{\rho' L^4}} \tag{5.17}$$

where ω_n is the nth natural frequency; $(\beta_n L)$ is the coefficients of beam vibration; E is elastic modulus of beam; I is area moment of inertia of cross section of beam; ρ' is mass per unit length of beam and L is length of beam.

For different boundary conditions, coefficients of beam vibration can be obtained by following the same processes. Table 5.3 shows the coefficients computed from characteristic equations obtained for certain simple boundary conditions of a beam [41].

Boundary conditions	$\beta_1 L$ Fundamental mode	$\beta_2 L$ Second mode	$\beta_3 L$ Third mode
Cantilever	1.8751	4.6941	7.8548
Free-Free	4.7300	7.8532	10.9956
Fixed-Fixed	4.7300	7.8532	10.9956
Fixed-Hinged	3.9266	7.0686	10.2101
Hinged-Free	0	3.9266	7.0686

Table 5.3 Coefficients of beam vibration for certain simple boundary conditions

5.3.2 Application to the determination of natural frequencies of the stiffened plate.

The first ten natural frequencies of the stiffened plate were obtained earlier using the finite element method; only the first five natural frequencies will be approximately determined by the procedure illustrated here. Moreover, to apply these concepts to the stiffened plate, some appropriate assumptions were made. The assumptions in the approximate method were made mainly depending on the mode shapes of the actual stiffened plate as shown in Figure 4.10. Due to the complexity of assumptions, this approximate method was first applied to obtain the natural frequency of mode 5, and thereafter to modes 1, 2, 3 and 4 wherein assumptions became more complicated.

Define variables:

M = mass that participates in structure bending (kg)

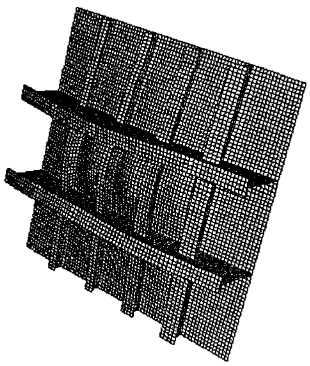
P = applied force (N)

δ	= deflection	(m)
k	= stiffness	(N / m)
E	= elastic modulus	(N / m^2)
I	= moment of inertia	(m^4)
L	= length of span	(m)
ρ'	= mass per length	(kg / m)
ω	= natural frequency	(Radian / s)
βL	= coefficient of beam vibration	

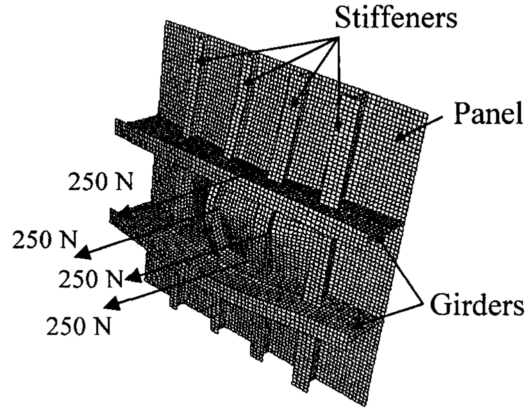
5.3.2.1 Approximate solution to determine the natural frequency of mode 5: Global bending mode

First assumption for this bending mode was to treat the stiffened plate as a beam with fixed-fixed end conditions. Then, forces were applied to make the stiffened plate deform in a pattern similar to that of mode shape 5 in Figure 4.10. The stiffness of this bending mode was obtained from the ratio of applied forces and deflection. Once the stiffness was obtained, equation (5.17) was employed to determine the natural frequency. All steps are explained clearly below:

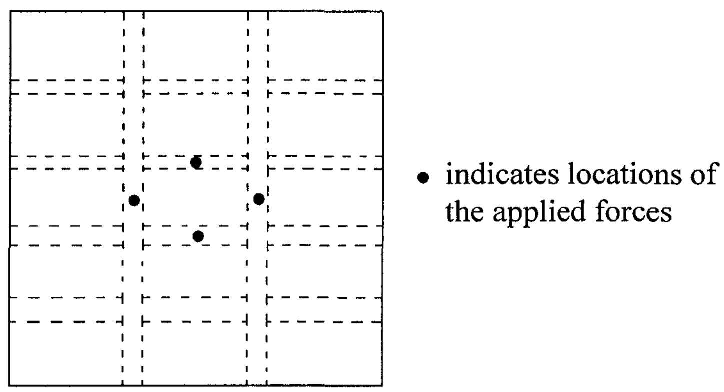
According to the deformation of mode shape 5 obtained by finite element method, four concentrated forces, each one with a magnitude of 250 N, were applied perpendicular to the plate panel at four points at the bottom of the stiffeners and girders as shown in Figure 5.5 to obtain a similar deformation. Figure 5.6 shows the deformed shape (side view) of the stiffened plate.



a) Mode shape 5 obtained from FEM

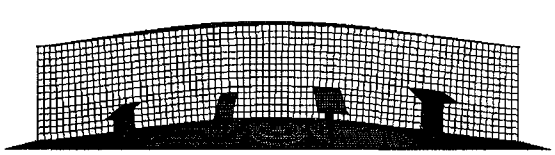


b) Static deformation under applied forces

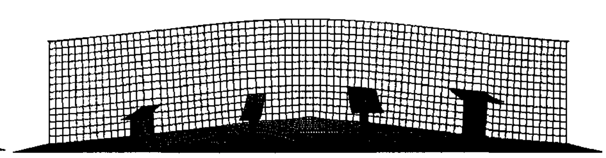


c) Locations of the applied forces on the bottom plate panel

Figure 5.5 a) Mode shape 5 obtained from finite element method; b) Deformation of stiffened plate under applied force, and c) Locations of the applied forces on the bottom of plate panel



a) Mode shape 5 obtained from FEM



b) Static deformation under applied forces

Figure 5.6 Side view of deformed shape of the stiffened plate

Because the contribution of stiffeners and girders to the stiffness of the whole body should be taken into account, it was considered to be reasonable to load through the webs of relevant stiffeners and girders. Hence, the locations where the forces were applied were determined to be the center of the stiffeners and girders, located closest to the middle of the panel. Another assumption was made by treating the stiffened plate as a fixed-fixed beam under a concentrated force at the middle of its span. As a result, the deflection of the fixed-fixed beam at mid-span where the concentrated force was applied could be computed using a formulation given below [36]:

$$\delta = \frac{PL^3}{192EI} \tag{5.18}$$

Since stiffness is the ratio of force and deflection, then the stiffness in this case can be found by rearranging equation (5.18) and expressing as:

$$k = \frac{P}{\delta} = \frac{192EI}{L^3} \tag{5.19}$$

However, it should be noticed that this was just an approximate method to determine stiffness of the stiffened plate to this bending mode, and the stiffness depended obviously on the deflection. Also, the locations at which deflections were to be measured in the deformed stiffened plate need to be assumed appropriately. As a result, deflections of the stiffened plate were measured from certain locations for certain reasonable cases; however, in the calculation details provided herein, only one case is illustrated.

The total applied force was,

$$P = 250 \times 4 = 1000 \qquad \text{N}$$

The average deflection measured at four spots, which were at the bottom of stiffeners and girders (where the forces were applied), was:

$$\delta = 6.3657E\text{-}06 \qquad \text{m}$$

The stiffness of the whole body could then be represented by the ratio of applied force and the measured deflection, and is given as:

$$k = \frac{P}{\delta} = \frac{1000}{6.3657E\text{-}06} = 1.5709E+08 \qquad \text{N / m}$$

Normally, the natural frequency can be obtained from,

$$\omega_n = \sqrt{\frac{k_n}{m_n}} \tag{5.20}$$

where ω_n denotes the nth natural frequency. The effective lumped mass, m_n, for this mode could be obtained by equating (5.17) and (5.20) as shown:

$$(\beta_n L)^2 \sqrt{\frac{EI}{\rho' L^4}} = \sqrt{\frac{k_n}{m_n}} \tag{5.21}$$

Based on the assumption made earlier, the stiffness can be expressed as in equation (5.19). Substituting equation (5.19) into equation (5.21), equation (5.21) becomes:

$$(\beta_n L)^2 \sqrt{\frac{EI}{\rho' L^4}} = \sqrt{\frac{192EI}{m_n L^3}} \tag{5.22}$$

Rearranging equation (5.22), the mass, m_n, can be obtained in the form,

$$m_n = 192 \frac{\rho' L}{(\beta_n L)^4} \tag{5.23}$$

Because the stiffened plate deformed in the pattern similar to the fundamental mode of a beam with fixed-fixed ends, the coefficient of beam vibration in Table 5.3 is taken as,

$$\beta_n L = \beta_l L = 4.730$$

Also, the total mass of the stiffened plate is expected to participate in this bending mode; therefore,

$$\rho' L = M = 11.76325 \qquad \text{kg}$$

Substituting the coefficient of beam vibration and mass participating into equation (5.23), the effective lumped mass of this bending mode can be obtained as:

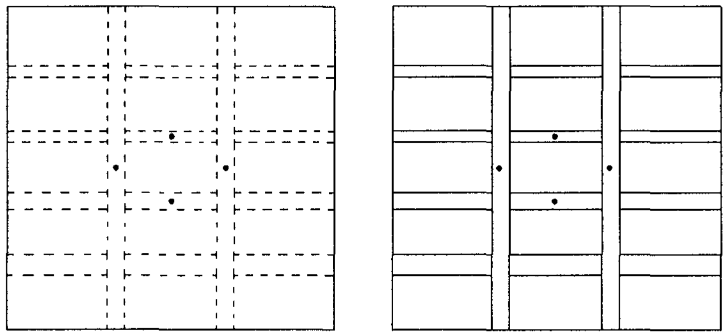
$$m_5 = \frac{192}{4.730^4} \times 11.76325 = 4.501244 \qquad \text{kg}$$

Once the stiffness and effective lumped mass are obtained, equation (5.20) is employed to calculate the natural frequency of mode shape 5, the first global bending mode of the stiffened plate, as shown below:

$$\omega_5 = \sqrt{\frac{k_5}{m_5}} = \sqrt{\frac{1.5709E+08}{4.501244}} = 5907.62 \qquad \text{radian/s}$$

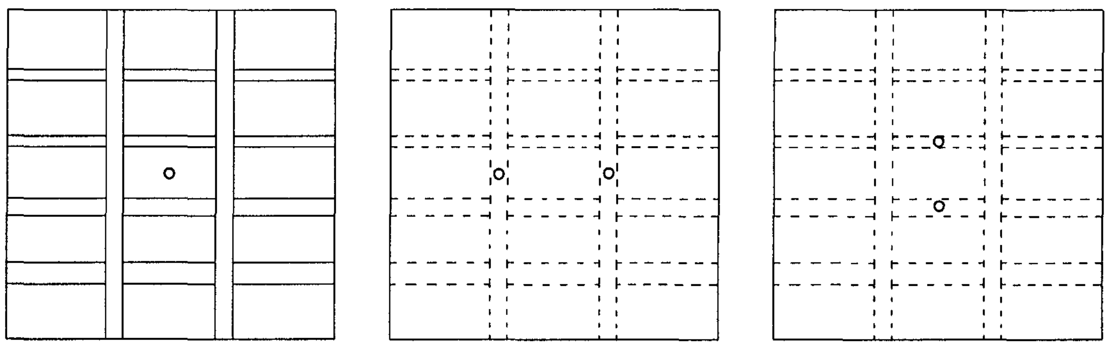
$$\omega_5 = 939.85 \qquad \text{Hz}$$

As mentioned earlier that the deflections of stiffened plate were measured at certain predefined points for certain reasonable cases. To observe the differences in these cases, the detailed results are given in Tables 5.4 and 5.5; moreover, % errors in Table 5.5 were made based on the fifth natural frequency, 1135.2 Hz, obtained using the finite element method. The locations of applied forces and measured deflections are shown precisely in Figure 5.7, which illustrates the area at the middle of the stiffened plate.

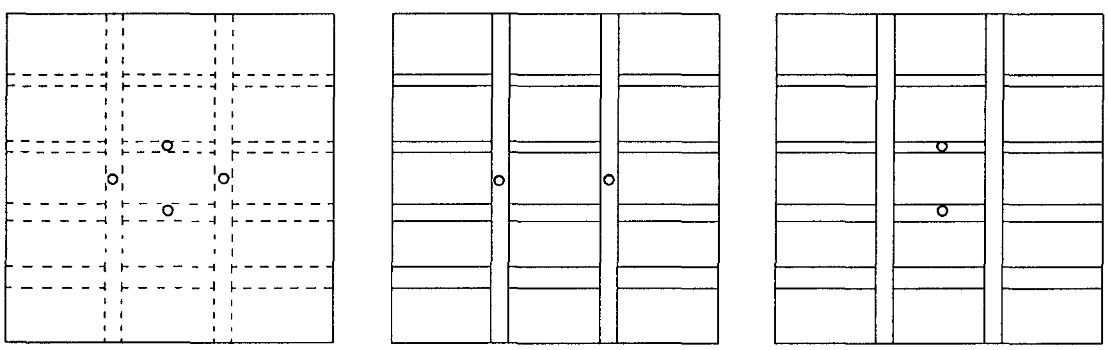


On panel On 4 flanges

a) Two cases of locations of the applied forces



Center of panel Bottom of girders only Bottom of stiffeners only



On panel On flanges of girders only On flanges of stiffeners only

b) Six cases of locations of the measured deflections

Figure 5.7 Details of where the forces were applied and deflections were measured

Case	**Locations of applied forces:** Figure 5.7 illustrates locations where loads were applied	**Locations of measured deflections:** Figure 5.7 illustrates locations where deflections were measured	Total applied force	Total mass of stiffened plate	Coefficient of beam vibration
			P	M	βL
			N	kg	
1	on panel	center of panel	1000	11.76325	4.730
2	on 4 flanges	center of panel	1000	11.76325	4.730
3	on panel *or* 4 flanges	bottom of girders only	1000	11.76325	4.730
4	on panel *or* 4 flanges	bottom of stiffeners only	1000	11.76325	4.730
5	on panel *or* 4 flanges	on panel	1000	11.76325	4.730
6	on panel	on flange of girders only	1000	11.76325	4.730
7	on 4 flanges	on flange of girders only	1000	11.76325	4.730
8	on panel	on flange of stiffeners only	1000	11.76325	4.730
9	on 4 flanges	on flange of stiffeners only	1000	11.76325	4.730

Table 5.4 Details of load cases and locations of measured deflections

Case	Displacement	Stiffness	Effective lumped mass	**Natural frequency**		error
	δ	k	m	ω	ω	
	m	N / m	kg	radian/s	Hz	%
1	1.0257E-05	9.7492E+07	4.512155	4648.28	739.50	-34.86
2	9.8487E-06	1.0154E+08	4.512155	4743.71	754.68	-33.52
3	4.7602E-06	2.1008E+08	4.512155	6823.35	1085.53	-4.38
4	7.9712E-06	1.2545E+08	4.512155	5272.88	838.87	-26.10
5	6.3657E-06	1.5709E+08	4.512155	5900.47	938.71	-17.31
6	4.7223E-06	2.1176E+08	4.512155	6850.62	1089.87	-3.99
7	5.4983E-06	1.8187E+08	4.512155	6348.83	1010.04	-11.03
8	9.6303E-06	1.0384E+08	4.512155	4797.20	763.19	-32.77
9	1.0180E-05	9.8236E+07	4.512155	4665.99	742.32	-34.61

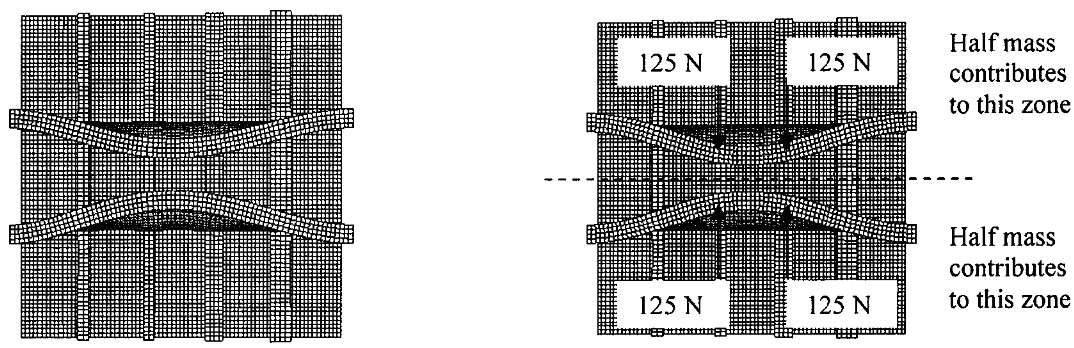
Table 5.5 The 5th natural frequency obtained by various cases of deflections

According to the definitions of locations illustrated in Figure 5.7, when four concentrated forces were applied at four locations on panel, at the bottom of the two girders and two stiffeners, and the deflections were measured at the top of flanges of those two girders and stiffeners, the natural frequencies were very close to 1135.2 Hz, obtained from finite element method. Moreover, when the four forces were applied at the four locations on panel and the deflections were measured at the center of the panel, the difference in natural frequencies was largest. This is due to the fact that the first situation represented more properly the stiffness and deformation characteristics of the stiffened plate than the second situation. As a result, the % differences in the fifth natural frequencies obtained from this method and finite element method ranged between -3.99 to -34.86 % from the different procedures shown in Figure 5.7 and Table 5.4.

5.3.2.2 Approximate solution to determine the natural frequency of mode 1: Local bending mode or transverse girders bending mode

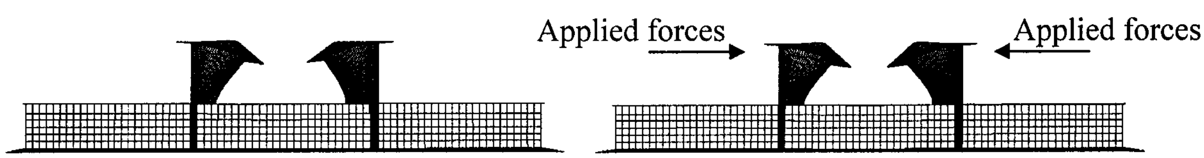
According to mode shape 1 obtained by finite element method and shown below in Figure 5.8 (a), the deformation appeared mainly to be due to the bending of two girders only, and the deformed shape observed from top view seemed like the first mode of a beam vibration with fixed-fixed ends. However, observation of the side view showed that the girder also bent like a cantilever beam as shown in Figure 5.9 (a).

Therefore, to obtain a similar deformed shape, static loads were applied at the top of girders in the horizontal direction parallel to the bottom plate panel. Because of the contribution of the bending stiffness of stiffeners to the bending stiffness of girders, two concentrated forces, each one with a magnitude of 125 N, were applied at the flanges of the girder above the intersection of the two middle stiffeners rather than applying one concentrated force with a magnitude of 250 N at the middle of each girder. Figures 5.8 (b) and 5.9 (b) show the applied forces and the deformed shape.



(a) Mode shape 1 obtained from FEM (b) Static deformation under applied forces

Figure 5.8 a) Mode shape 1 obtained from finite element method; and b) Deformation of stiffened plate under applied force



(a) Mode shape 5 obtained from FEM (b) Deformation under applied forces

Figure 5.9 Deformed shape of stiffened plate from side view

Furthermore, the bending stiffness of girders was expected to be a combination of stiffnesses of a beam with fixed-fixed ends and a cantilever beam. However, based on the coefficient of beam vibration available to be used in Table 5.3, there was no coefficient of that type of combination of stiffnesses, so an assumption was made that the coefficient of beam with fixed-fixed ends should be used because the beam with fixed-fixed ends seemed to dominate the behaviour of this bending. In addition, the behaviour of cantilever beam was later taken into account as part of the total mass expected to participate in this bending mode.

The deflections at four points where the forces were applied were measured in the same direction as the applied forces. The average deflection without considering positive and negative signs was taken, and it was obtained as:

$$\delta_{avareage} = 6.7383E\text{-}05 \qquad \text{m}$$

Since the bending of this mode (of the stiffened plate) was symmetric, the stiffened plate was separated into two halves for analysis. Consequently, only one half of the stiffened plate needs to be considered. The total applied force on one half was,

$$P = 125 + 125 = 250 \qquad \text{N}$$

In order to determine the total mass that was expected to contribute to this bending mode, appropriate assumptions were made. First of all, because only the main girders bent, only the masses of stiffeners and main girders were expected to participate in this action. The total mass participating in this vibratory motion was considered to be only masses of stiffeners and girders (the mass of bottom plate panel was not taken into account). Additionally, since the analysis had considered only one side of stiffened plate, the total mass should be divided by two. As a result, the maximum mass expected to participate in this bending mode was:

$$M = \frac{5.54597}{2} = 2.772985 \qquad \text{kg}$$

This mass was used as the total mass in the case where the behaviour of beam with fixed-fixed ends dominated the entire behaviour of girder bending. On the other hand, the effect of cantilever-beam behaviour as mentioned earlier was also expected to contribute to the vibratory motion. For this case, the mass contributing to this bending was determined to be 22.8 % of the total mass [43].

$$\hat{m} = 0.228\rho' L = 0.228M \tag{5.24}$$

Since the first case assumed that the behaviour of beam with fixed-fixed ends was dominant over the behaviour of cantilever beam, the total mass of 2.772985 kg. was used in this case. In contrast, the second case assumed that the cantilever behaviour of beam was significantly involved in the action, and the total mass used for this case should be the one represented in equation (5.24). Since $\rho' L$ was 2.772985 kg, the total mass used for the second case was:

$$\hat{m} = 0.228 \times 2.772985 = 0.6322406 \quad \text{kg.}$$

Once the needed variables were obtained, the first natural frequency of the stiffened plate for the two cases could be computed by applying the same procedures applied to compute the fifth natural frequency of the stiffened plate. Tables 5.6 and 5.7 show detailed results obtained from this investigation; moreover, % errors in Table 5.7 were made based on the first natural frequency, 587.10 Hz, obtained using the finite element method.

Case	**Beam types** that were anticipated to dominate the behaviour of bending	Force	Total mass	Coefficient of beam vibration
		P	M	βL
		N	kg	
1	Beam with fixed-fixed ends	250	2.772985	4.730
2	Cantilever beam	250	0.6322406	4.730

Table 5.6 Details of two cases anticipated to dominate this bending mode

Case	Displacement	Stiffness	Effective lumped mass	Natural frequency		error
	δ	k	m	ω	ω	
	m	N / m	kg	radian/s	Hz	%
1	6.7383E-05	3.7101E+06	1.061091	1867.6416	297.1248	-49.39
2	6.7383E-05	3.7101E+06	0.241929	3911.3450	622.2594	+5.99

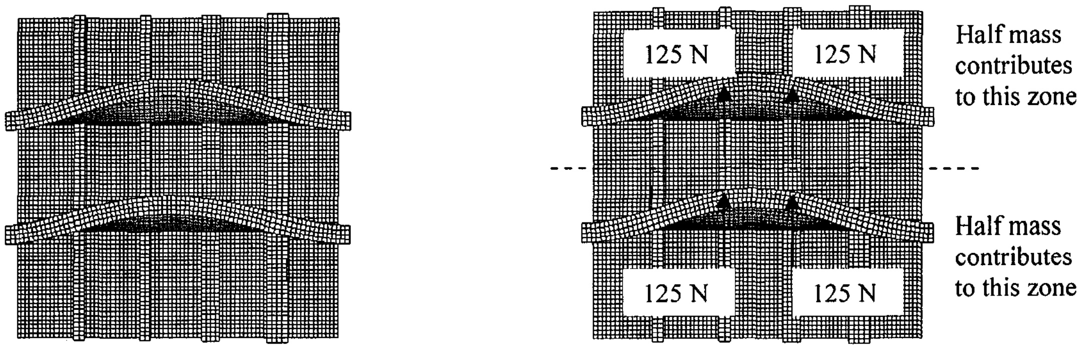
Table 5.7 The 1st natural frequency obtained by the two cases

It is seen that the combination of fixed-fixed beam and cantilever bending aspects seem to give better results than fixed-fixed beam aspect alone. In this case, the error is obtained as +5.99%.

5.3.2.3 Approximate solution to determine the natural frequency of mode 2: Local bending mode or transverse girders bending mode

The natural frequency of this mode was obtained in the same way as that used for the first natural frequency. A minor difference was the direction of forces that were applied. For the first mode, two forces were applied in one direction, and the other two were applied in the opposite direction. However, in this case, the four forces were applied in the same direction for this mode. Figure 5.10 shows the applied forces and deformed shape of the stiffened plate.

Deflections were also measured at four points where the forces were applied, and the average deflection due to these four forces was used. Moreover, two cases regarding the dominance of beam bending with fixed-fixed beam and beam bending with a combination of fixed-fixed beam and cantilever beam were considered as well. The detailed results from this study are shown in Tables 5.8 and 5.9; % errors in Table 5.9 were made based on the second natural frequency, 589.17 Hz, obtained using the finite element method.



(a) Mode shape 2 obtained from FEM (b) Deformation under applied forces

Figure 5.10 a) Mode shape 2 obtained from finite element method; and b) Deformation of stiffened plate under applied force

Case	**Beam types** that were anticipated to dominate the behaviour of bending	Force	Total mass	Coefficient of beam vibration
		P	M	βL
		N	kg	
1	Beam with fixed-fixed ends	250	2.772985	4.730
2	Cantilever beam	250	0.6322406	4.730

Table 5.8 Details of two cases anticipated to dominate this bending mode

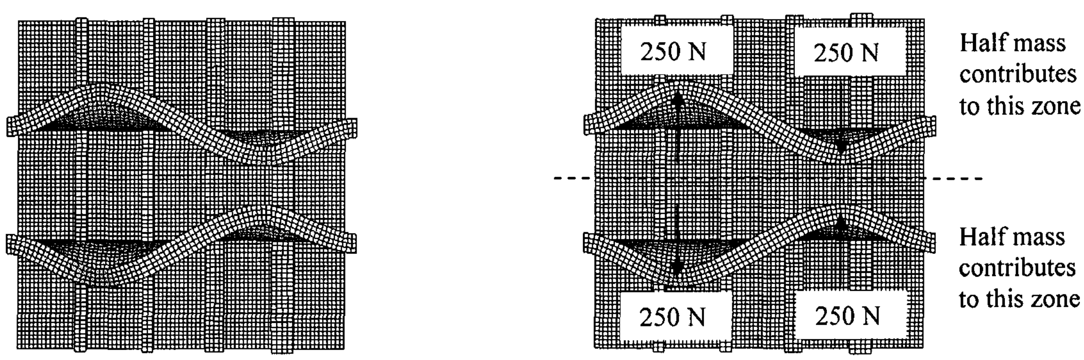
Case	Displacement	Stiffness	Effective lumped mass	**Natural frequency**		error
	δ	k	m	ω	ω	
	m	N / m	kg	radian/s	Hz	%
1	6.7099E-05	3.7258E+06	1.061091	1871.5864	297.7524	-49.46
2	6.7099E-05	3.7258E+06	0.241929	3919.6065	623.5738	+5.84

Table 5.9 The 2nd natural frequency obtained by the two cases

According to Tables 5.7 and 5.9, the natural frequencies obtained using the effective lumped mass of the cantilever beam seem to be closer to those obtained from finite element method than using the effective lumped mass of the fixed-fixed beam. In other words, the bending behaviour of cantilever beam seems to significantly affect these bending modes.

5.3.2.4 Approximate solution to determine the natural frequency of mode 3: Local bending mode or transverse girders bending mode

This case was a little bit different from the cases of the first and second natural frequencies. Four forces were applied at one-forth and three-forth of the girder span, as shown in Figure 5.11. Considering one of the two girders, two forces were applied at the top in the opposite direction in order to obtain a similar deformed shape as mode shape 3 obtained using finite element method.



(a) Mode shape 3 obtained from FEM (b) Deformation under applied forces

Figure 5.11 a) Mode shape 3 obtained from finite element method; and b) Deformation of stiffened plate under applied force

Deflections were still measured at four points where the forces were applied (in Figure 5.11), and the average deflection was again used. However, the coefficient of beam vibration had to be changed because the deformed shape of the girders was similar to the second bending mode shape of a beam with fixed-fixed ends; the coefficient for this case was 7.8532, according to Table 5.3. The stiffness that was used in equation (5.19) is also not valid for this case since that stiffness was used only for a beam with fixed-fixed ends under a concentrated load at its mid-span. Therefore, the stiffness of this bending mode had to be calculated, and it was derived using moment-area method. The derivation to obtain the stiffness used in this bending mode is given in Appendix H, and the formulation is given below.

$$k = \frac{15360EI}{61L^3} \tag{5.25}$$

Once the stiffness for this bending was obtained, it was substituted into equation (5.21). The effective lumped mass for this mode was then obtained, and the natural frequency was computed. Once again, the dominance between the lumped mass of a fixed-fixed beam and of a combination of fixed-fixed beam and cantilever beam were examined. The detailed results from this analysis are given in Tables 5.10 and 5.11; also, % errors in Table 5.11 were made based on the third natural frequency, 1097.9 Hz, obtained using finite element method.

In this case, the beam with fixed-fixed ends seems to give very good approximation to the third natural frequency of the stiffened plate structure. The error is obtained as -1.91%.

Case	Beam types that were anticipated to dominate the behaviour of bending	Force	Total mass	Coefficient of beam vibration
		P	M	βL
		N	kg	
1	Beam with fixed-fixed ends	250	2.772985	7.8532
2	Cantilever beam	250	0.6322406	7.8532

Table 5.10 Details of two cases anticipated to dominate this bending mode

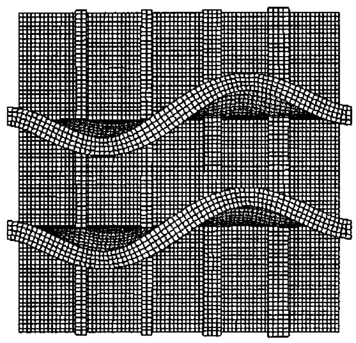
Case	Displacement	Stiffness	Effective lumped mass	**Natural frequency**		error
	δ	k	m	ω	ω	
	m	N / m	kg	radian/s	Hz	%
1	3.8972E-05	6.4148E+06	0.183417	6769.2271	1076.9225	-1.91
2	3.8972E-05	6.4148E+06	0.041819	14176.5861	2255.3600	+105.43

Table 5.11 The 3rd natural frequency obtained by the two cases

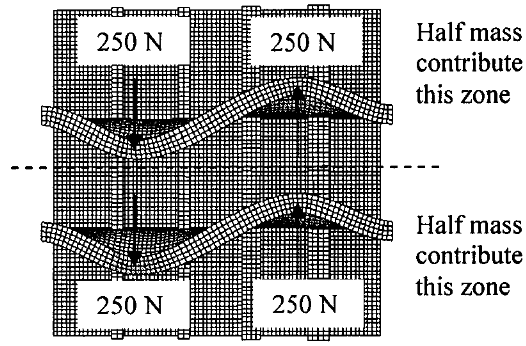
5.3.2.5 Approximate solution to determine the natural frequency of mode 4: Local bending mode or transverse girders bending mode

This case was also analyzed by the procedures similar to that in Section 5.3.2.4 to obtain the third natural frequency. Only the direction of two forces was changed as demonstrated in Figure 5.12. Tables 5.12 and 5.15 show the detailed results obtained for this investigation.

In modes 3 and 4, the natural frequencies obtained from this approximate method were closer to those obtained using finite element method when the effective lumped mass of the beam with fixed-fixed ends was used. So the bending behaviour of the beam with fixed-fixed ends seems to dominate over the cantilever beam for these modes.



a) Mode shape 4 obtained from FEM



b) Deformation under applied forces

Figure 5.12 a) Mode shape 4 obtained from finite element method; and b) Deformation of stiffened plate under applied force

Case	Types of beam that its lumped mass was anticipated to dominate the behaviour of bending	Force	Total mass	Coefficient of beam vibration
		P	M	βL
		N	kg	
1	Beam with fixed-fixed ends	250	2.772985	7.8532
2	Cantilever beam	250	0.6322406	7.8532

Table 5.12 Details of two cases anticipated to dominate this bending mode

Case	Displacement	Stiffness	Effective lumped mass	Natural frequency		error
	δ	k	m	ω	ω	
	m	N / m	kg	radian/s	Hz	%
1	3.9176E-05	6.3815E+06	0.183417	6751.6442	1074.1252	-2.17
2	3.9176E-05	6.3815E+06	0.041819	14139.7629	2249.5077	+104.89

Table 5.13 The 4th natural frequency obtained by the two cases

It should be mentioned that this approximate method provided just approximate solutions, and some assumptions had to be made along the way. However, the natural frequencies obtained using this approximate method seem to be acceptable and satisfactory.

5.4 SUMMARY OF RESULTS

The first ten natural frequencies of stiffened plates used in this investigation were obtained first using finite element method. Subsequently, two approximate methods, viz., the method of elastic equivalence and the method using concepts of static analysis, were applied to obtain the lower natural frequencies. When the method of elastic equivalence was used, the stiffened plate was considered as the equivalent orthotropic plate which had the same flexural and torsional rigidities as the original stiffened plate. Once the natural frequencies and mode shapes were obtained, only the first and second modes were considered to be comparable with the fifth and sixth modes of the original stiffened plate (obtained using finite element method). However, large % differences in natural frequencies were obtained by the use of this method over finite element method. This is attributed to the fact that the spacings between stiffeners were large. As a result, the equivalent orthotropic plate did not have the expected homogeneity; consequently, the use of orthotropic plate behaviour does not satisfy the requirements for the use of the method of elastic equivalence.

In addition, another approximate method used to obtain the natural frequencies of stiffened plate was applied. This method uses the concepts of static analysis by applying static loads to deform the stiffened plate in patterns similar to the mode shapes of interest. Only the first five natural frequencies were examined, and some assumptions were made along the way. The 5^{th} mode was calculated first, and the 1^{st}, 2^{nd}, 3^{rd} and 4^{th} were subsequently calculated. For the fifth mode, a number of cases of the locations of applied forces and measured deflection were analyzed. Furthermore, for the first to fourth modes, two cases that examined the dominance between the lumped mass of a fixed-fixed beam and the lumped mass of a combination of fixed-fixed beam and cantilever beam were studied.

As a result, it was found that the locations of applied forced and measured deflections influenced the fifth natural frequency considerably. Moreover, it was found that the lumped mass of the cantilever beam dominated in the first and second bending modes of the stiffened plate, and the lumped mass of the fixed-fixed beam dominated the third and fourth bending modes.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

This investigation focused on the analysis of the free vibration of stiffened plates due to the variation in dimensions of components of the stiffened plate and also due to the quality of weld, used to connect the various components together. All dimensions of the components of stiffened plate were measured using a digital micrometer and a vernier caliper. Moreover, the weld profiles were acquired using the microscribe digitizer, and Rhinoceros 3.0, the accompanying CAD software. Each cross section of the weld profile was transformed to an equivalent rectangular cross section, and the average of the transformed rectangular cross sections was used in the finite element analysis model.

Assuming normal probability for distribution (on dimensions of components of stiffened plates and weld parameters), the variation of a particular set of data was assumed to fall between the ranges of $\mu - 3\sigma$ and $\mu + 3\sigma$, giving a statistical certainty of 99.73%. Once all data of components of stiffened plate and weld profiles were measured, they were plotted to verify whether or not they were normally distributed. After plotting, it was observed that some data sets fitted very well in normal distribution while some others did not fit very well. In spite of the above limitation, all the data sets were assumed to be normally distributed, and the statistical criterion of 99.73 % of statistical certainty was assumed. The values of the obtained data were then classified into three categories which were a category of mean value (μ), a category of mean value – 3 S.D. ($\mu - 3\sigma$) and a category of mean value + 3 S.D. ($\mu + 3\sigma$). Also, the spacing between the two transverse girders was set to be: 200 mm for normal case, 195 and 205 mm for close and away girder cases, respectively.

Once all the needed data were obtained, finite element analysis models were generated. The models were categorized into two types which were the model without and the model with the weld profiles. Also, each type of model was generated using three different spacings of the girders, and each of them was generated using three different values of dimensions. Furthermore, to observe the changes in natural frequencies, all models were classified into four separate stages. From these analyses, the following results have been obtained.

1. It was observed that the minimum % difference between the expected and measured dimensions (using mean values) of components of stiffened plates was 0.028 % occurring at the height of S-size stiffener of Model I. The maximum % difference was 12.52 % occurring for the thickness of S-size flange of Model I, due to the taper of the flange.

2. Model I seemed to be welded better than Model II since the standard deviations of the width of the weld on panel and on web of girders of Model I were found to be 2.59 times less than those of Model II. The other standard deviations of dimensions of weld profiles of Model I and II seemed to be similar. Moreover, the uncertainties of industrial fabrication were found to be much smaller than those of fabrication by human intervention since the standard deviations of relevant dimensions of stiffened plate components were smaller than those of the components that

were cut (to be equal to the designed dimensions) from the original materials.

3. The % differences in natural frequencies, due to the inclusion of the weld profiles in the finite element analysis models, were found to vary in the range of -5.02 to 4.12 % for Model I and -4.50 to 3.14 % for Model II.

4. When the weld profiles were not modeled, the % differences in natural frequencies, due to the variation in dimensions of components of stiffened plates, were found to vary in the range of -3.19 to 3.74 % for Model I and -2.98 to 3.24 % for Model II. When the weld profiles were modeled, the % differences in natural frequencies, due to the variation in dimensions of components of stiffened plates, were found to vary in the range of -4.59 to 4.74 % for Model I and -4.27 to 5.04 % for Model II.

5. When the weld profiles were not modeled, the % differences in natural frequencies, due to the inaccurate placement of the main transverse girders on the stiffened plates, were found to vary in the range of -1.78 to 1.96 % for Model I and -2.03 to 1.99 % for Model II. When the weld profiles were modeled, the % differences in natural frequencies, due to the inaccurate placement of the main transverse girders on the stiffened plates, were found to vary in the range of -2.01 to 2.04 % for Model I and -1.98 to 2.01 % for Model II.

6. The determination of natural frequencies using the method of elastic equivalence by considering the stiffened plate as the equivalent

orthotropic plate did not work well due to the large spacings between the stiffeners.

7. The determination of first five natural frequencies of the stiffened plate by the approximate method using concepts of static analysis was successful, and it can be briefly concluded that

   7.1 For the first and second modes, it was observed that the girder bending stiffness was dominated by the fixed-fixed beam bending and the lumped mass was dominated by the cantilever beam bending. The difference between the natural frequencies obtained by this method and finite element method were 5.99 % and 5.84 %.

   7.2 For the third and fourth modes, it was observed that the girder bending stiffness and the lumped mass were dominated by the fixed-fixed beam bending. The difference between the natural frequencies obtained by this method and finite element method were -1.91 % and -2.17 %.

   7.3 For the fifth mode, the difference between the natural frequencies obtained by this method and finite element method were found to vary in the range of -34.86 % and -3.99 % depending on the locations of applied forces and measured deflections. Moreover, these locations were observed to be in the area around the middle of the stiffened plate.

In this investigation, a number of analyses have been carried out according to a well-designed plan; however, certain areas may require further exploration. Some of these ideas could not be carried out due to the limitation of facilities and time available, and some ideas required further studies which were not the main objectives of this investigation. Hence, future investigations can be carried out in the areas given below:

1. Even though the 4-node shell elements provided results very close to those obtained using 8-node shell elements, the 4-node shell elements were chosen for all analyses since it took much less time than 8-node shell elements. It is recommended to use 8-node shell elements if a better computer, which has much more potential and capability, is available.

2. It is of interest to generate the stiffened plates as a combination of 2-D shell elements for plate and 3-D continuum elements for weld regions and to compare the free vibration responses obtained from these models with those obtained using only shell elements.

3. The transformation of the weld cross sections to the equivalent rectangular cross sections was based on the location of centroid and area. It would be interesting to use local area moment of inertia along with the centroid and area in the transformation process.

4. Certain data sets, which did not fit well into normal distributions, were assumed to be normally distributed. It will be worthwhile to carry out an extreme probability analysis to examine the maximum variation in

frequencies that could occur due to rolling and welding fabrication processes.

5. It would be worthwhile to extend the analysis to a complete ship using the method of sub-structures (or super elements) to examine the actual variations in the free vibration response of a modeled or a prototype ship.

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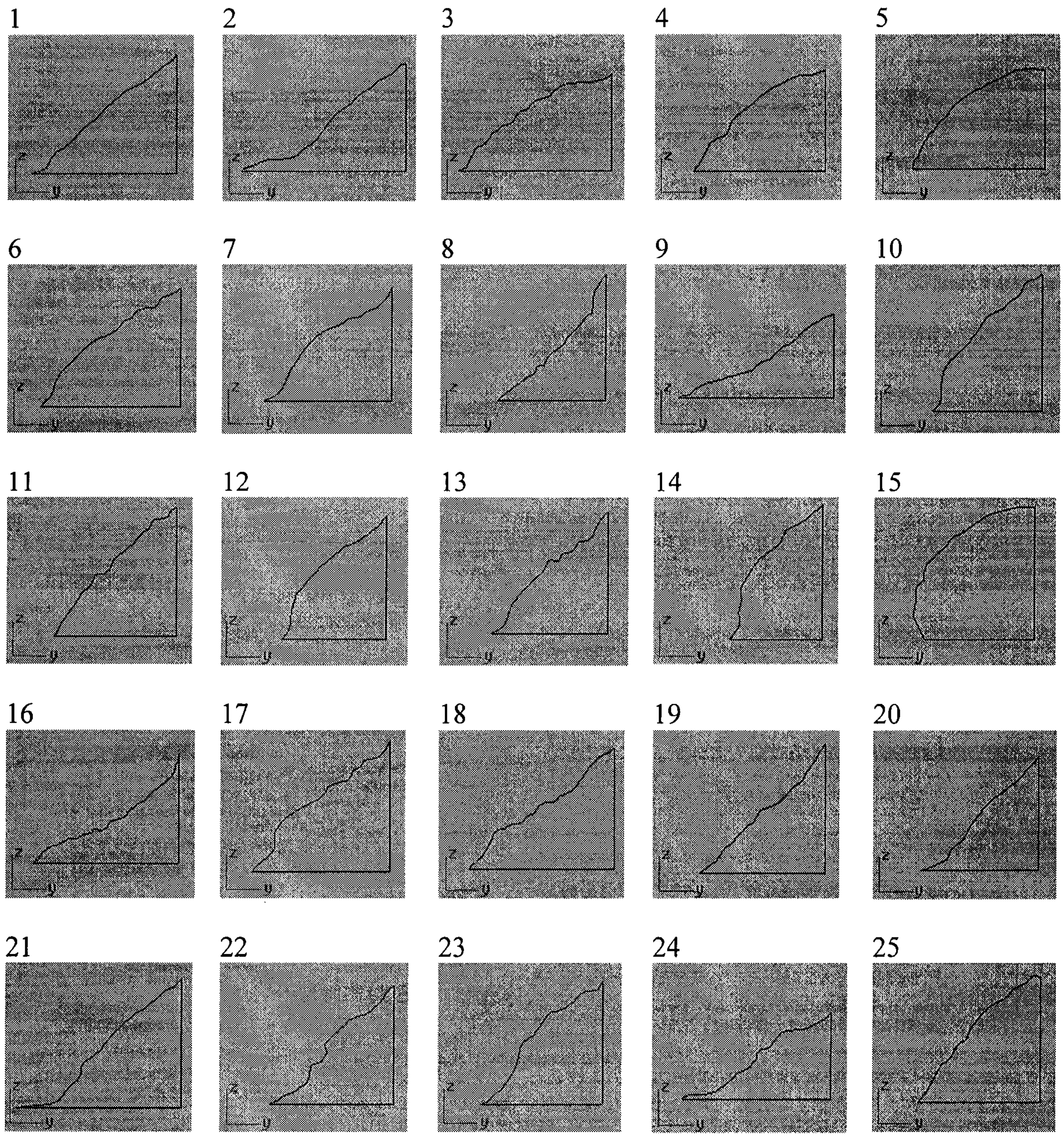
APPENDIX A

Examples of actual cross sections of weld profiles

50 from 854 examples of actual weld profiles between the plate panel and all stiffeners



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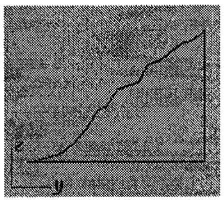

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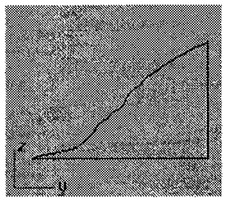

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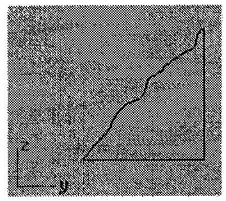

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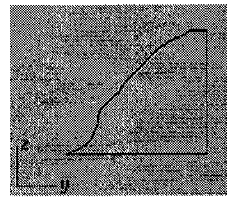

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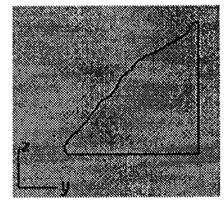

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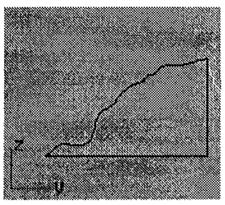

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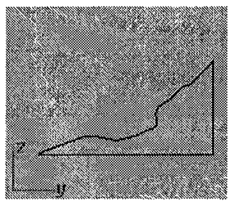

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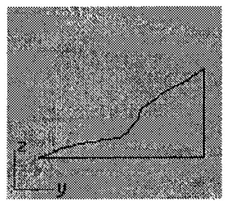

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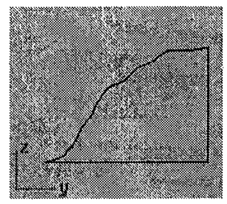

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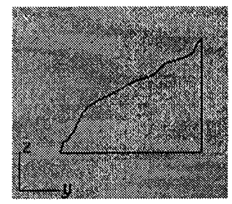

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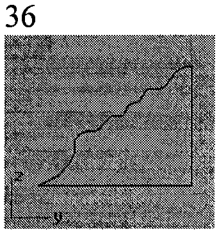

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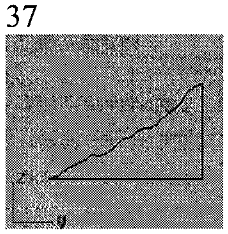

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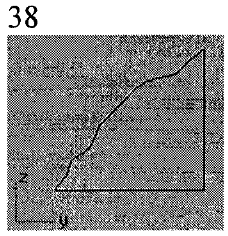

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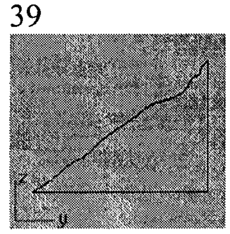

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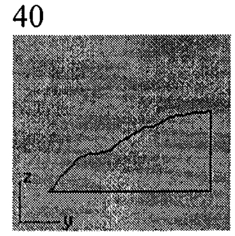

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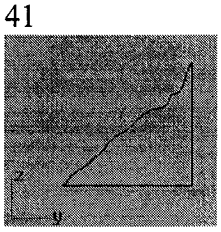

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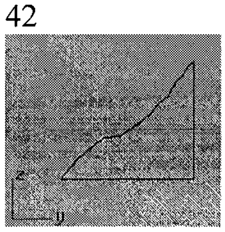

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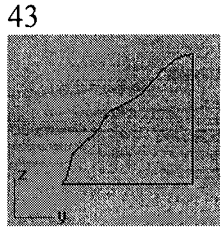

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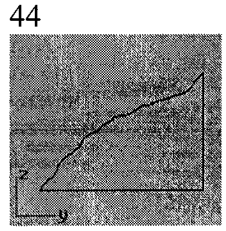

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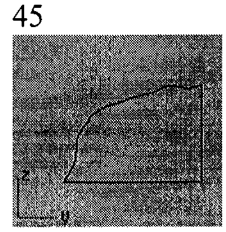

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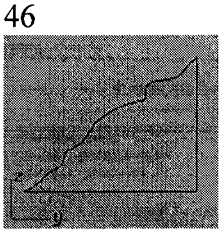

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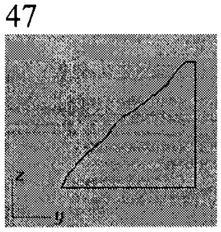

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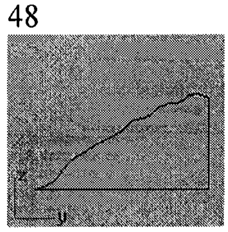

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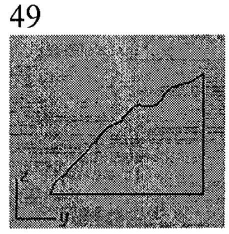

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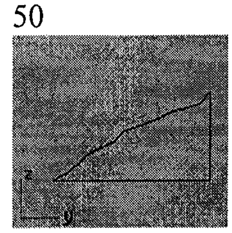
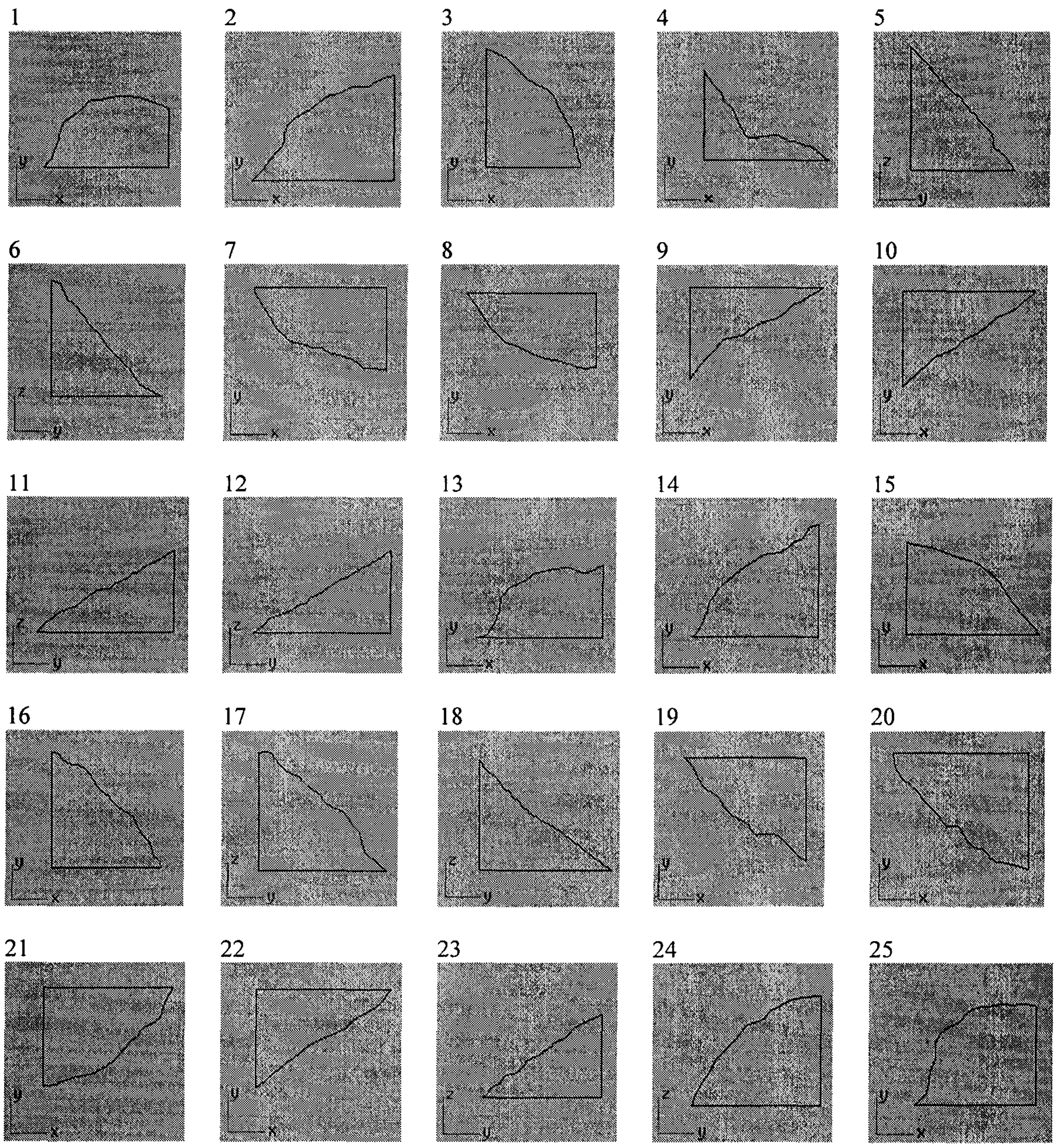


50 from 255 examples of actual weld profiles between the XL-size stiffeners (girders) and the other stiffeners



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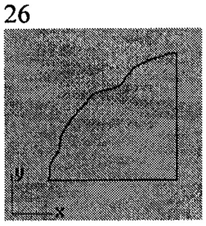

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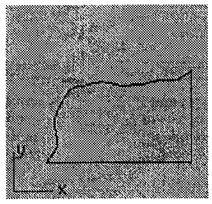

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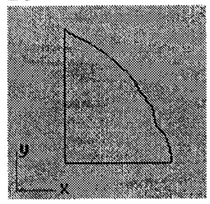

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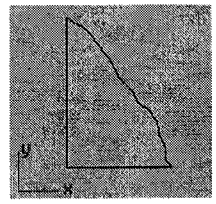

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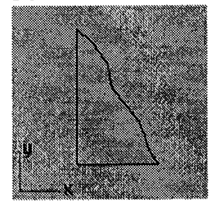

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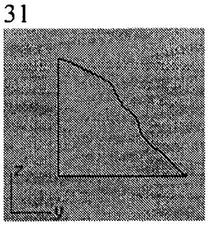

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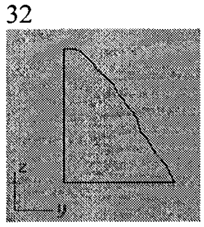

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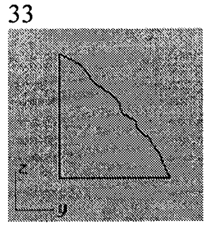

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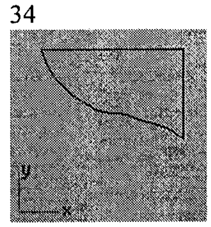

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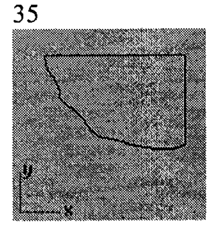

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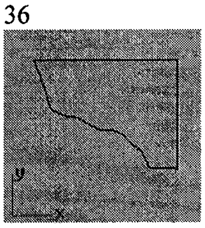

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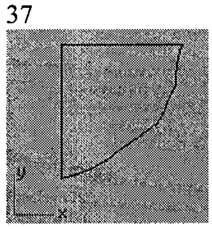

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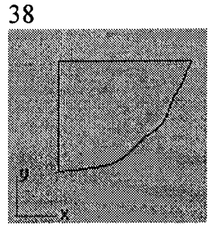

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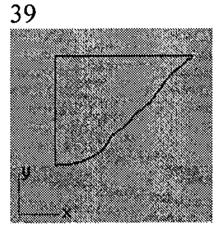

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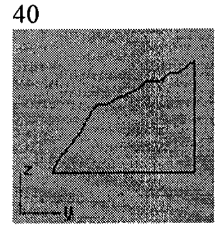

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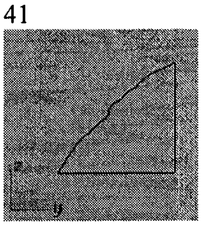

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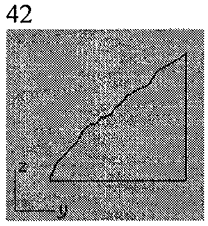

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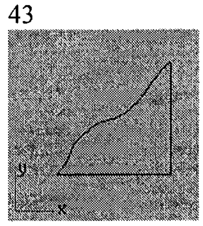

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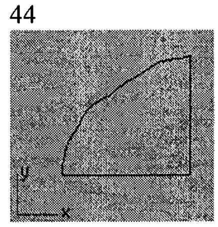

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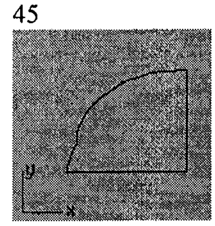

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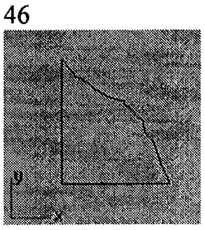

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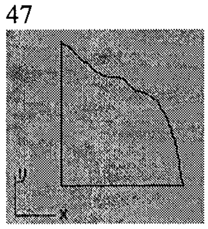

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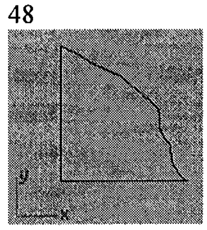

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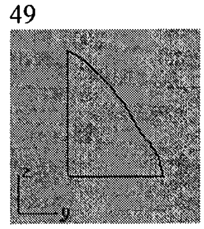

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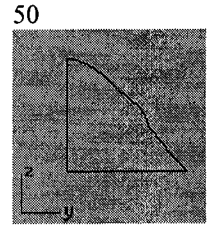

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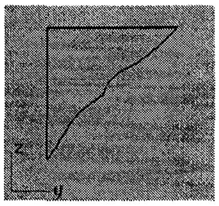
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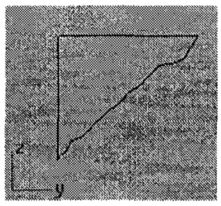
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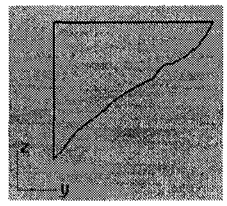
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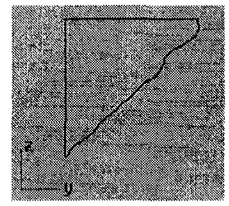
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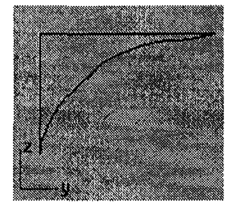
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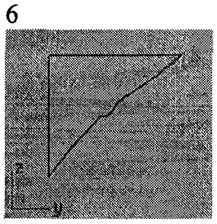
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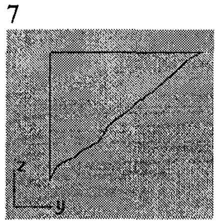
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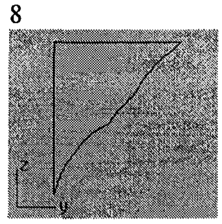
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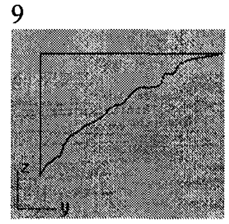
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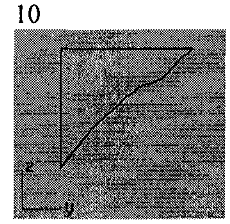
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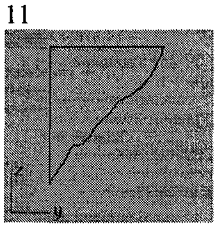
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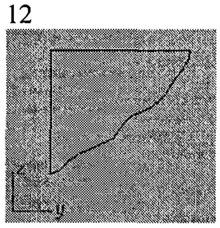
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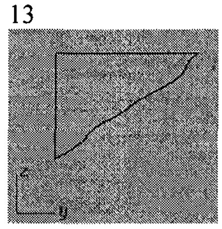
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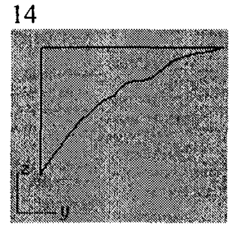
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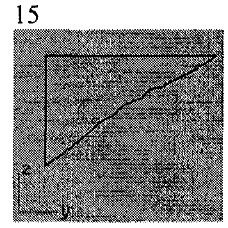
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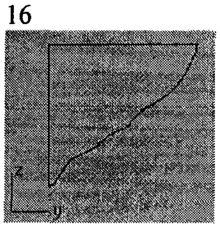
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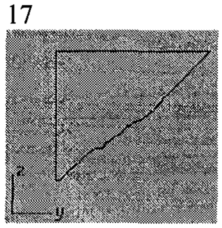
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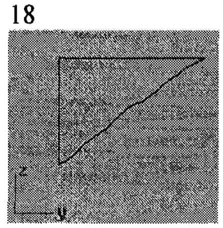
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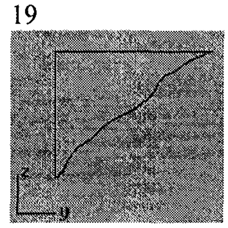
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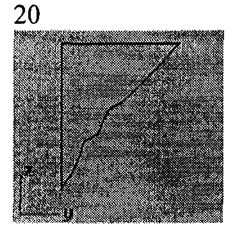
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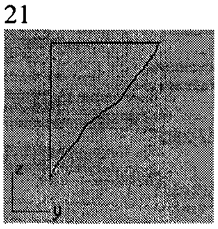
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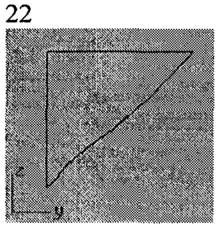
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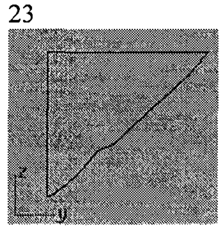
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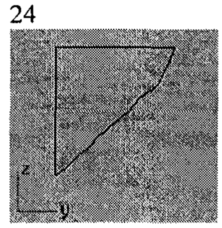
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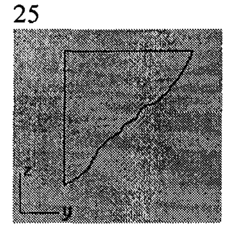

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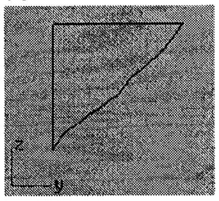

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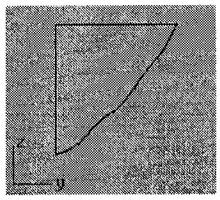

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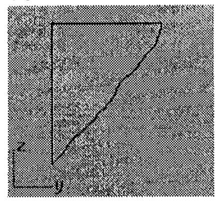

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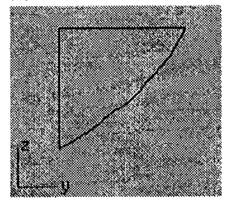

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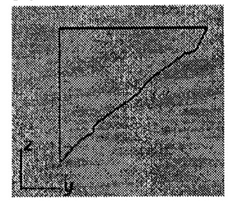

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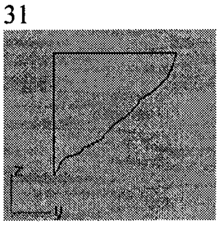

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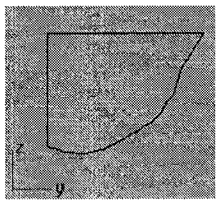

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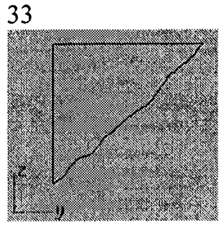

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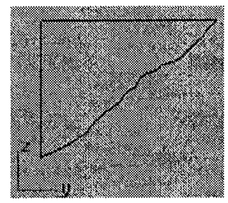

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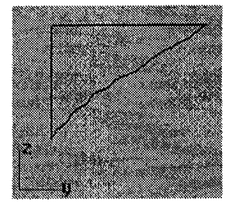

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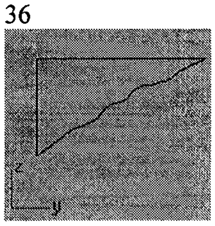

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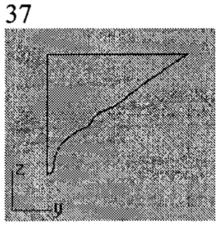

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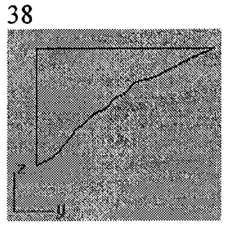

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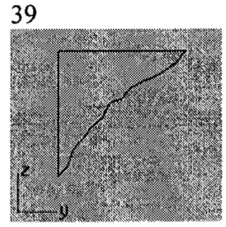

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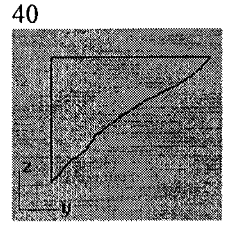

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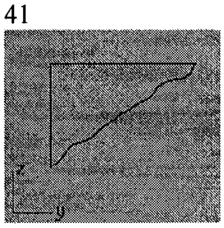

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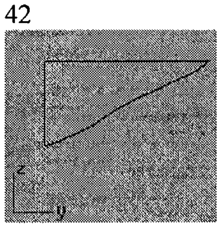

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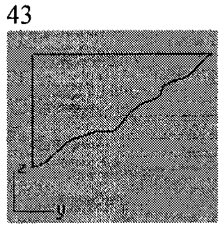

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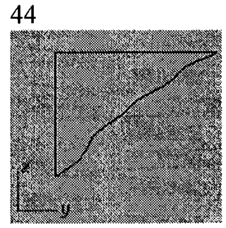

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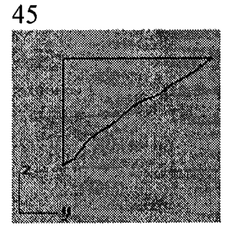

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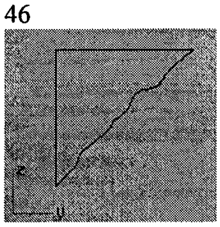

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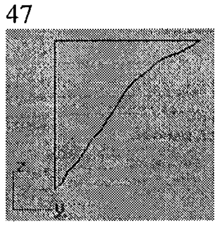

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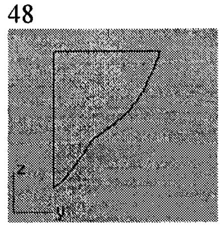

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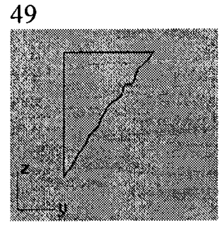

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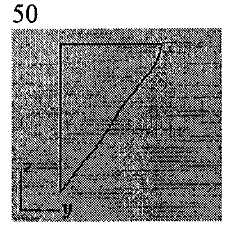


APPENDIX B

Tables of significant parameters of both weld cross section and equivalent modified cross sections (rectangular cross sections)

Model I: 415 weld profiles between the plate panel and all stiffeners

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	$mm.^2$	$mm.^3$	$mm.^4$	$mm.^4$	mm.	mm.	mm.	mm.	$mm.^2$	$mm.^3$	$mm.^4$	$mm.^4$
1	1.862	1.566	13.100	20.515	15.2468902 (+/- 3.3e-007)	32.126	2.091	1.566	3.132	4.183	13.100	20.515	10.709	32.126
2	2.222	1.711	16.938	28.981	26.1880409 (+/- 3.8e-007)	49.586	2.475	1.711	3.422	4.950	16.938	28.981	16.529	49.586
3	2.207	1.440	14.122	20.336	12.5805211 (+/- 4e-007)	29.283	2.452	1.440	2.880	4.903	14.122	20.336	9.761	29.283
4	2.342	1.894	19.719	37.348	30.4286693 (+/- 7e-007)	70.737	2.603	1.894	3.788	5.206	19.719	37.348	23.579	70.737
5	3.115	2.418	33.257	80.415	80.0034677 (+/- 8e-007)	194.445	3.438	2.418	4.836	6.877	33.257	80.415	64.815	194.445
6	2.460	2.008	22.042	44.260	38.913157 (+/- 6.1e-007)	88.875	2.744	2.008	4.016	5.489	22.042	44.260	29.625	88.875
7	2.166	1.842	17.676	32.559	25.2651385 (+/- 4.1e-007)	59.974	2.399	1.842	3.684	4.798	17.676	32.559	19.991	59.974
8	1.962	2.167	18.909	40.976	52.3505403 (+/- 4.9e-007)	88.795	2.181	2.167	4.334	4.363	18.909	40.976	29.598	88.795
9	3.479	1.943	30.177	58.634	63.9557814 (+/- 6.4e-007)	113.926	3.883	1.943	3.886	7.766	30.177	58.634	37.975	113.926
10	1.600	1.924	13.693	26.345	21.7808367 (+/- 3.5e-007)	50.688	1.779	1.924	3.848	3.558	13.693	26.345	16.896	50.688
11	1.697	1.781	13.558	24.147	19.9596309 (+/- 8.5e-007)	43.005	1.903	1.781	3.562	3.806	13.558	24.147	14.335	43.005
12	1.919	2.133	18.108	38.624	33.9331363 (+/- 4.7e-007)	82.386	2.122	2.133	4.266	4.245	18.108	38.624	27.462	82.386
13	1.910	1.913	16.341	31.260	27.2570057 (+/- 4.1e-007)	59.801	2.136	1.913	3.826	4.271	16.341	31.260	19.934	59.801
14	1.721	2.484	18.814	46.734	46.6123951 (+/- 5.5e-007)	116.087	1.894	2.484	4.968	3.787	18.814	46.734	38.696	116.087
15	2.501	2.749	29.642	81.486	82.6560601 (+/- 9.3e-007)	224.005	2.696	2.749	5.498	5.391	29.642	81.486	74.668	224.005
16	2.835	1.677	21.159	35.484	34.4105637 (+/- 6.7e-007)	59.506	3.154	1.677	3.354	6.309	21.159	35.484	19.835	59.506
17	1.937	1.723	14.885	25.647	19.4857622 (+/- 5e-007)	44.190	2.160	1.723	3.446	4.320	14.885	25.647	14.730	44.190
18	2.456	1.895	20.857	39.524	37.3065803 (+/- 6.2e-007)	74.898	2.752	1.895	3.790	5.503	20.857	39.524	24.966	74.898
19	1.944	1.894	16.523	31.295	30.2422234 (+/- 3.7e-007)	59.272	2.181	1.894	3.788	4.362	16.523	31.295	19.757	59.272
20	1.731	1.832	14.234	26.077	23.1159576 (+/- 4.6e-007)	47.772	1.942	1.832	3.664	3.885	14.234	26.077	15.924	47.772
21	2.220	2.134	21.228	45.301	45.6189634 (+/- 6.3e-007)	96.671	2.487	2.134	4.268	4.974	21.228	45.301	32.224	96.671
22	1.865	1.933	16.096	31.114	28.2901345 (+/- 5.5e-007)	60.143	2.082	1.933	3.866	4.163	16.096	31.114	20.048	60.143

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	$mm.^2$	$mm.^3$	$mm.^4$	$mm.^4$	mm.	mm.	mm.	mm.	$mm.^2$	$mm.^3$	$mm.^4$	$mm.^4$
23	1.992	**2.164**	**19.169**	**41.482**	39.0959454 (+/- 6.4e-007)	**89.766**	2.215	**2.164**	*4.328*	*4.429*	**19.169**	**41.482**	29.922	**89.766**
24	2.092	**1.372**	**12.799**	**17.560**	11.6048417 (+/- 6.1e-007)	**24.093**	2.332	**1.372**	*2.744*	*4.664*	**12.799**	**17.560**	8.031	**24.093**
25	1.709	**1.823**	**13.943**	**25.418**	20.8923392 (+/- 5.5e-007)	**46.337**	1.912	**1.823**	*3.646*	*3.824*	**13.943**	**25.418**	15.446	**46.337**
26	1.826	**1.567**	**12.828**	**20.101**	14.9345475 (+/- 4.6e-007)	**31.499**	2.047	**1.567**	*3.134*	*4.093*	**12.828**	**20.101**	10.500	**31.499**
27	2.129	**1.729**	**16.475**	**28.485**	24.0861223 (+/- 4.8e-007)	**49.251**	2.382	**1.729**	*3.458*	*4.764*	**16.475**	**28.485**	16.417	**49.251**
28	1.775	**1.835**	**14.617**	**26.822**	23.348952 (+/- 2.7e-007)	**49.219**	1.991	**1.835**	*3.670*	*3.983*	**14.617**	**26.822**	16.406	**49.219**
29	1.958	**2.025**	**17.634**	**35.709**	31.1121752 (+/- 6.5e-007)	**72.310**	2.177	**2.025**	*4.050*	*4.354*	**17.634**	**35.709**	24.103	**72.310**
30	2.085	**1.956**	**18.258**	**35.713**	31.6795452 (+/- 6.1e-007)	**69.854**	2.334	**1.956**	*3.912*	*4.667*	**18.258**	**35.713**	23.285	**69.854**
31	2.727	**1.915**	**23.330**	**44.677**	38.63806 (+/- 0.00033)	**85.556**	3.046	**1.915**	*3.830*	*6.091*	**23.330**	**44.677**	28.519	**85.556**
32	3.027	**1.604**	**20.955**	**33.612**	36.9412 (+/- 0.0013)	**53.913**	3.266	**1.604**	*3.208*	*6.532*	**20.955**	**33.612**	17.971	**53.913**
33	2.989	**1.812**	**23.757**	**43.048**	44.8608977 (+/- 5.8e-007)	**78.002**	3.278	**1.812**	*3.624*	*6.555*	**23.757**	**43.048**	26.001	**78.002**
34	2.368	**1.959**	**20.468**	**40.097**	32.7342125 (+/- 4.2e-007)	**78.550**	2.612	**1.959**	*3.918*	*5.224*	**20.468**	**40.097**	26.183	**78.550**
35	2.317	**1.623**	**16.738**	**27.166**	19.1324895 (+/- 2.6e-007)	**44.090**	2.578	**1.623**	*3.246*	*5.157*	**16.738**	**27.166**	14.697	**44.090**
36	1.867	**1.493**	**12.439**	**18.571**	12.516332 (+/- 3.1e-007)	**27.727**	2.083	**1.493**	*2.986*	*4.166*	**12.439**	**18.571**	9.242	**27.727**
37	2.529	**1.519**	**17.176**	**26.090**	22.1214685 (+/- 4.9e-007)	**39.631**	2.827	**1.519**	*3.038*	*5.654*	**17.176**	**26.090**	13.210	**39.631**
38	1.895	**1.735**	**14.648**	**25.414**	19.2815043 (+/- 2.6e-007)	**44.094**	2.111	**1.735**	*3.470*	*4.221*	**14.648**	**25.414**	14.698	**44.094**
39	2.020	**1.409**	**12.783**	**18.011**	12.523455 (+/- 2.5e-007)	**25.378**	2.268	**1.409**	*2.818*	*4.536*	**12.783**	**18.011**	8.459	**25.378**
40	2.569	**1.251**	**14.331**	**17.928**	9.85230402 (+/- 1.9e-007)	**22.428**	2.864	**1.251**	*2.502*	*5.728*	**14.331**	**17.928**	7.476	**22.428**
41	2.334	**1.928**	**20.179**	**38.905**	37.8993085 (+/- 1e-006)	**75.009**	2.617	**1.928**	*3.856*	*5.233*	**20.179**	**38.905**	25.003	**75.009**
42	2.427	**1.910**	**20.700**	**39.537**	41.3802011 (+/- 3.8e-007)	**75.516**	2.709	**1.910**	*3.820*	*5.419*	**20.700**	**39.537**	25.172	**75.516**
43	1.709	**1.676**	**12.813**	**21.475**	16.2672252 (+/- 4.5e-007)	**35.991**	1.911	**1.676**	*3.352*	*3.822*	**12.813**	**21.475**	11.997	**35.991**
44	2.165	**1.435**	**13.827**	**19.842**	12.2816036 (+/- 4.6e-007)	**28.473**	2.409	**1.435**	*2.870*	*4.818*	**13.827**	**19.842**	9.491	**28.473**
45	2.034	**1.457**	**12.737**	**18.558**	10.0320693 (+/- 2.3e-007)	**27.039**	2.185	**1.457**	*2.914*	*4.371*	**12.737**	**18.558**	9.013	**27.039**
46	1.665	**1.305**	**9.727**	**12.694**	7.62090334 (+/- 2.4e-007)	**16.565**	1.863	**1.305**	*2.610*	*3.727*	**9.727**	**12.694**	5.522	**16.565**
47	1.679	**1.568**	**11.834**	**18.556**	14.0005874 (+/- 2.5e-007)	**29.095**	1.887	**1.568**	*3.136*	*3.774*	**11.834**	**18.556**	9.698	**29.095**
48	2.596	**1.534**	**17.816**	**27.330**	18.9346534 (+/- 4.1e-007)	**41.924**	2.904	**1.534**	*3.068*	*5.807*	**17.816**	**27.330**	13.975	**41.924**

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}	mm.	mm.	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}
49	1.580	**1.210**	**8.550**	**10.346**	5.58950026 (+/- 2.5e-007)	**12.518**	1.767	**1.210**	*2.420*	*3.533*	**8.550**	**10.346**	4.173	**12.518**
50	1.566	**0.828**	**5.804**	**4.806**	1.8172805 (+/- 2.4e-007)	**3.979**	1.752	**0.828**	*1.656*	*3.505*	**5.804**	**4.806**	1.326	**3.979**
51	1.745	**1.206**	**9.350**	**11.276**	5.77346314 (+/- 4.8e-007)	**13.599**	1.938	**1.206**	*2.412*	*3.876*	**9.350**	**11.276**	4.533	**13.599**
52	1.700	**1.692**	**12.819**	**21.690**	15.9137231 (+/- 2.6e-007)	**36.699**	1.894	**1.692**	*3.384*	*3.788*	**12.819**	**21.690**	12.233	**36.699**
53	1.418	**2.117**	**13.372**	**28.309**	26.1680236 (+/- 4.8e-007)	**59.929**	1.579	**2.117**	*4.234*	*3.158*	**13.372**	**28.309**	19.976	**59.929**
54	1.653	**1.743**	**12.941**	**22.556**	20.2319319 (+/- 3.5e-007)	**39.315**	1.856	**1.743**	*3.486*	*3.712*	**12.941**	**22.556**	13.105	**39.315**
55	1.856	**2.232**	**18.584**	**41.479**	49.6117177 (+/- 4.1e-007)	**92.582**	2.082	**2.232**	*4.464*	*4.163*	**18.584**	**41.479**	30.861	**92.582**
56	1.798	**1.861**	**15.026**	**27.963**	24.7942542 (+/- 5e-007)	**52.040**	2.019	**1.861**	*3.722*	*4.037*	**15.026**	**27.963**	17.347	**52.040**
57	1.981	**1.673**	**14.810**	**24.777**	19.0874183 (+/- 4.5e-007)	**41.452**	2.213	**1.673**	*3.346*	*4.426*	**14.810**	**24.777**	13.817	**41.452**
58	1.950	**1.661**	**14.549**	**24.166**	18.9597902 (+/- 5.6e-007)	**40.140**	2.190	**1.661**	*3.322*	*4.380*	**14.549**	**24.166**	13.380	**40.140**
59	1.726	**1.636**	**12.664**	**20.718**	15.6371363 (+/- 4.7e-007)	**33.895**	1.935	**1.636**	*3.272*	*3.870*	**12.664**	**20.718**	11.298	**33.895**
60	1.637	**1.544**	**11.232**	**17.342**	11.3107776 (+/- 3e-007)	**26.776**	1.819	**1.544**	*3.088*	*3.637*	**11.232**	**17.342**	8.925	**26.776**
61	1.687	**2.030**	**15.298**	**31.055**	27.7406976 (+/- 2.8e-007)	**63.042**	1.884	**2.030**	*4.060*	*3.768*	**15.298**	**31.055**	21.014	**63.042**
62	2.566	**2.480**	**28.518**	**70.725**	85.5864025 (+/- 7.3e-007)	**175.397**	2.875	**2.480**	*4.960*	*5.750*	**28.518**	**70.725**	58.466	**175.397**
63	2.543	**2.095**	**23.435**	**49.096**	40.9628161 (+/- 8.5e-007)	**102.857**	2.797	**2.095**	*4.190*	*5.593*	**23.435**	**49.096**	34.286	**102.857**
64	2.359	**2.095**	**21.752**	**45.570**	38.8726925 (+/- 5.4e-007)	**95.470**	2.596	**2.095**	*4.190*	*5.191*	**21.752**	**45.570**	31.823	**95.470**
65	2.484	**2.058**	**22.422**	**46.144**	37.5848973 (+/- 6e-007)	**94.965**	2.724	**2.058**	*4.116*	*5.448*	**22.422**	**46.144**	31.655	**94.965**
66	2.066	**1.224**	**11.314**	**13.848**	7.67063546 (+/- 3.7e-007)	**16.950**	2.311	**1.224**	*2.448*	*4.622*	**11.314**	**13.848**	5.650	**16.950**
67	2.199	**0.940**	**9.075**	**8.531**	3.3158532 (+/- 3.6e-007)	**8.019**	2.414	**0.940**	*1.880*	*4.827*	**9.075**	**8.531**	2.673	**8.019**
68	1.897	**1.189**	**10.082**	**11.987**	6.33525237 (+/- 4.2e-007)	**14.253**	2.120	**1.189**	*2.378*	*4.240*	**10.082**	**11.987**	4.751	**14.253**
69	2.202	**1.340**	**13.236**	**17.736**	11.2607664 (+/- 5.6e-007)	**23.767**	2.469	**1.340**	*2.680*	*4.939*	**13.236**	**17.736**	7.922	**23.767**
70	1.939	**1.599**	**13.667**	**21.854**	21.688663 (+/- 2.6e-007)	**34.944**	2.137	**1.599**	*3.198*	*4.274*	**13.667**	**21.854**	11.648	**34.944**
71	2.218	**2.297**	**22.616**	**51.949**	50.3064799 (+/- 3.3e-007)	**119.327**	2.461	**2.297**	*4.594*	*4.923*	**22.616**	**51.949**	39.776	**119.327**
72	2.104	**1.354**	**12.753**	**17.268**	10.6752025 (+/- 4.2e-007)	**23.380**	2.355	**1.354**	*2.708*	*4.709*	**12.753**	**17.268**	7.793	**23.380**
73	2.042	**1.842**	**16.548**	**30.481**	22.521893 (+/- 1.8e-007)	**56.147**	2.246	**1.842**	*3.684*	*4.492*	**16.548**	**30.481**	18.716	**56.147**
74	2.235	**1.857**	**18.481**	**34.319**	27.6856691 (+/- 8.7e-008)	**63.731**	2.488	**1.857**	*3.714*	*4.976*	**18.481**	**34.319**	21.244	**63.731**

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}	mm.	mm.	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}
75	2.087	**1.718**	**15.896**	**27.309**	19.6899253 (+/- 1.6e-007)	**46.917**	2.313	**1.718**	*3.436*	*4.626*	**15.896**	**27.309**	15.639	**46.917**
76	2.277	**2.235**	**22.573**	**50.451**	47.2056987 (+/- 3.9e-007)	**112.757**	2.525	**2.235**	*4.470*	*5.050*	**22.573**	**50.451**	37.586	**112.757**
77	2.094	**2.095**	**19.680**	**41.230**	41.0070294 (+/- 1.9e-007)	**86.376**	2.348	**2.095**	*4.190*	*4.697*	**19.680**	**41.230**	28.792	**86.376**
78	2.087	**1.840**	**17.251**	**31.742**	27.9797675 (+/- 1.1e-007)	**58.405**	2.344	**1.840**	*3.680*	*4.688*	**17.251**	**31.742**	19.468	**58.405**
79	1.998	**1.822**	**16.112**	**29.356**	27.5134085 (+/- 1.6e-007)	**53.487**	2.211	**1.822**	*3.644*	*4.422*	**16.112**	**29.356**	17.829	**53.487**
80	1.811	**1.711**	**13.795**	**23.603**	17.4205015 (+/- 9.1e-008)	**40.385**	2.016	**1.711**	*3.422*	*4.031*	**13.795**	**23.603**	13.462	**40.385**
81	1.574	**1.551**	**10.972**	**17.018**	13.7456759 (+/- 9.6e-008)	**26.394**	1.769	**1.551**	*3.102*	*3.537*	**10.972**	**17.018**	8.798	**26.394**
82	1.712	**1.431**	**11.017**	**15.765**	11.1060003 (+/- 1.4e-007)	**22.560**	1.925	**1.431**	*2.862*	*3.849*	**11.017**	**15.765**	7.520	**22.560**
83	1.605	**1.553**	**11.175**	**17.355**	12.5720963 (+/- 1.6e-007)	**26.952**	1.799	**1.553**	*3.106*	*3.598*	**11.175**	**17.355**	8.984	**26.952**
84	2.246	**2.001**	**19.924**	**39.868**	33.4964737 (+/- 1.9e-007)	**79.776**	2.489	**2.001**	*4.002*	*4.979*	**19.924**	**39.868**	26.592	**79.776**
85	1.745	**1.951**	**15.301**	**29.852**	29.4574526 (+/- 1.7e-007)	**58.242**	1.961	**1.951**	*3.902*	*3.921*	**15.301**	**29.852**	19.414	**58.242**
86	1.681	**2.330**	**17.474**	**40.714**	41.5102728 (+/- 1.6e-007)	**94.865**	1.875	**2.330**	*4.660*	*3.750*	**17.474**	**40.714**	31.622	**94.865**
87	2.312	**2.357**	**24.068**	**56.728**	54.7919216 (+/- 2.3e-007)	**133.709**	2.553	**2.357**	*4.714*	*5.106*	**24.068**	**56.728**	44.570	**133.709**
88	2.050	**2.286**	**20.496**	**46.854**	41.926737 (+/- 1.3e-007)	**107.108**	2.241	**2.286**	*4.572*	*4.483*	**20.496**	**46.854**	35.703	**107.108**
89	1.986	**1.831**	**16.113**	**29.503**	22.5769818 (+/- 1e-006)	**54.020**	2.200	**1.831**	*3.662*	*4.400*	**16.113**	**29.503**	18.007	**54.020**
90	1.936	**1.577**	**13.579**	**21.414**	14.7997131 (+/- 1.4e-007)	**33.770**	2.153	**1.577**	*3.154*	*4.305*	**13.579**	**21.414**	11.257	**33.770**
91	2.076	**1.667**	**15.382**	**25.642**	18.0851366 (+/- 1e-007)	**42.745**	2.307	**1.667**	*3.334*	*4.614*	**15.382**	**25.642**	14.248	**42.745**
92	2.244	**1.872**	**18.807**	**35.207**	29.7359794 (+/- 2.5e-007)	**65.907**	2.512	**1.872**	*3.744*	*5.023*	**18.807**	**35.207**	21.969	**65.907**
93	2.165	**1.912**	**18.355**	**35.095**	28.3243666 (+/- 1.2e-007)	**67.101**	2.400	**1.912**	*3.824*	*4.800*	**18.355**	**35.095**	22.367	**67.101**
94	2.185	**1.723**	**16.830**	**28.998**	23.6422745 (+/- 1.9e-007)	**49.964**	2.442	**1.723**	*3.446*	*4.884*	**16.830**	**28.998**	16.655	**49.964**
95	1.810	**1.573**	**12.641**	**19.884**	13.359284 (+/- 2e-007)	**31.278**	2.009	**1.573**	*3.146*	*4.018*	**12.641**	**19.884**	10.426	**31.278**
96	2.219	**1.551**	**15.320**	**23.761**	15.7736925 (+/- 2.3e-007)	**36.854**	2.469	**1.551**	*3.102*	*4.939*	**15.320**	**23.761**	12.285	**36.854**
97	1.842	**1.501**	**12.270**	**18.417**	11.7828774 (+/- 1.2e-007)	**27.644**	2.044	**1.501**	*3.002*	*4.087*	**12.270**	**18.417**	9.215	**27.644**
98	2.422	**1.652**	**17.969**	**29.685**	24.5256463 (+/- 1.4e-007)	**49.039**	2.719	**1.652**	*3.304*	*5.439*	**17.969**	**29.685**	16.346	**49.039**
99	2.363	**1.546**	**16.241**	**25.109**	16.6928583 (+/- 2.2e-007)	**38.818**	2.626	**1.546**	*3.092*	*5.253*	**16.241**	**25.109**	12.939	**38.818**
100	2.631	**1.752**	**20.561**	**36.023**	30.0585271 (+/- 5.3e-007)	**63.112**	2.934	**1.752**	*3.504*	*5.868*	**20.561**	**36.023**	21.037	**63.112**

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}	mm.	mm.	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}
101	1.571	**2.375**	**16.698**	**39.658**	43.1131883 (+/- 1.5e-007)	**94.187**	1.758	**2.375**	*4.750*	*3.515*	**16.698**	**39.658**	31.396	**94.187**
102	2.030	**1.673**	**15.247**	**25.508**	22.3703305 (+/- 2e-007)	**42.675**	2.278	**1.673**	*3.346*	*4.557*	**15.247**	**25.508**	14.225	**42.675**
103	1.968	**1.969**	**17.350**	**34.162**	30.2412611 (+/- 1.1e-007)	**67.265**	2.203	**1.969**	*3.938*	*4.406*	**17.350**	**34.162**	22.422	**67.265**
104	2.601	**1.803**	**21.076**	**38.000**	33.9268821 (+/- 2.9e-007)	**68.514**	2.922	**1.803**	*3.606*	*5.845*	**21.076**	**38.000**	22.838	**68.514**
105	2.699	**2.379**	**28.532**	**67.878**	68.5600504 (+/- 2.8e-007)	**161.481**	2.998	**2.379**	*4.758*	*5.997*	**28.532**	**67.878**	53.827	**161.481**
106	2.004	**1.175**	**10.468**	**12.300**	6.22617437 (+/- 3.5e-007)	**14.452**	2.227	**1.175**	*2.350*	*4.454*	**10.468**	**12.300**	4.817	**14.452**
107	2.436	**1.415**	**15.260**	**21.593**	13.1830727 (+/- 1.7e-007)	**30.554**	2.696	**1.415**	*2.830*	*5.392*	**15.260**	**21.593**	10.185	**30.554**
108	1.955	**1.483**	**12.773**	**18.942**	17.3784851 (+/- 1.3e-007)	**28.092**	2.153	**1.483**	*2.966*	*4.306*	**12.773**	**18.942**	9.364	**28.092**
109	1.584	**1.712**	**12.161**	**20.820**	19.2635634 (+/- 1.5e-007)	**35.643**	1.776	**1.712**	*3.424*	*3.552*	**12.161**	**20.820**	11.881	**35.643**
110	1.763	**2.043**	**16.197**	**33.090**	33.9534899 (+/- 1.6e-007)	**67.604**	1.982	**2.043**	*4.086*	*3.964*	**16.197**	**33.090**	22.535	**67.604**
111	1.980	**1.599**	**14.184**	**22.680**	16.9201198 (+/- 1.9e-007)	**36.266**	2.218	**1.599**	*3.198*	*4.435*	**14.184**	**22.680**	12.089	**36.266**
112	1.935	**1.605**	**13.920**	**22.342**	19.4998647 (+/- 2.4e-007)	**35.858**	2.168	**1.605**	*3.210*	*4.336*	**13.920**	**22.342**	11.953	**35.858**
113	2.777	**1.536**	**19.113**	**29.358**	23.7648896 (+/- 4.9e-007)	**45.093**	3.111	**1.536**	*3.072*	*6.222*	**19.113**	**29.358**	15.031	**45.093**
114	1.793	**1.668**	**13.412**	**22.371**	17.9886513 (+/- 2.5e-007)	**37.315**	2.010	**1.668**	*3.336*	*4.020*	**13.412**	**22.371**	12.438	**37.315**
115	1.821	**1.813**	**14.729**	**26.704**	21.1880105 (+/- 1.2e-007)	**48.414**	2.031	**1.813**	*3.626*	*4.062*	**14.729**	**26.704**	16.138	**48.414**
116	1.998	**1.836**	**16.415**	**30.138**	24.9162124 (+/- 1.8e-007)	**55.333**	2.235	**1.836**	*3.672*	*4.470*	**16.415**	**30.138**	18.444	**55.333**
117	1.970	**1.782**	**15.615**	**27.826**	21.5696867 (+/- 1.1e-007)	**49.586**	2.191	**1.782**	*3.564*	*4.381*	**15.615**	**27.826**	16.529	**49.586**
118	1.693	**1.388**	**10.532**	**14.618**	10.9310792 (+/- 7.1e-008)	**20.290**	1.897	**1.388**	*2.776*	*3.794*	**10.532**	**14.618**	6.763	**20.290**
119	1.931	**1.803**	**15.587**	**28.103**	23.2997691 (+/- 3.4e-007)	**50.670**	2.161	**1.803**	*3.606*	*4.323*	**15.587**	**28.103**	16.890	**50.670**
120	1.597	**1.613**	**11.537**	**18.609**	13.7524365 (+/- 2.2e-007)	**30.017**	1.788	**1.613**	*3.226*	*3.576*	**11.537**	**18.609**	10.006	**30.017**
121	1.851	**1.803**	**14.858**	**26.789**	20.7598862 (+/- 2.9e-007)	**48.301**	2.060	**1.803**	*3.606*	*4.120*	**14.858**	**26.789**	16.100	**48.301**
122	1.694	**1.673**	**12.650**	**21.163**	15.9234817 (+/- 1.4e-007)	**35.406**	1.890	**1.673**	*3.346*	*3.781*	**12.650**	**21.163**	11.802	**35.406**
123	1.808	**2.087**	**16.945**	**35.364**	34.9971078 (+/- 3.7e-007)	**73.805**	2.030	**2.087**	*4.174*	*4.060*	**16.945**	**35.364**	24.602	**73.805**
124	1.837	**1.787**	**14.499**	**25.910**	19.1664024 (+/- 1.9e-007)	**46.301**	2.028	**1.787**	*3.574*	*4.057*	**14.499**	**25.910**	15.434	**46.301**
125	2.638	**1.586**	**18.676**	**29.620**	21.1822032 (+/- 2.6e-007)	**46.978**	2.944	**1.586**	*3.172*	*5.888*	**18.676**	**29.620**	15.659	**46.978**
126	1.887	**1.372**	**11.478**	**15.748**	13.0391293 (+/- 1.5e-007)	**21.606**	2.091	**1.372**	*2.744*	*4.183*	**11.478**	**15.748**	7.202	**21.606**

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}	mm.	mm.	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}
127	1.700	**1.552**	**11.823**	**18.349**	15.5160059 (+/- 2.7e-007)	**28.478**	1.904	**1.552**	*3.104*	*3.809*	**11.823**	**18.349**	9.493	**28.478**
128	2.755	**1.731**	**21.424**	**37.085**	32.4221867 (+/- 4.4e-007)	**64.194**	3.094	**1.731**	*3.462*	*6.188*	**21.424**	**37.085**	21.398	**64.194**
129	1.937	**1.372**	**11.931**	**16.369**	10.7775405 (+/- 2.1e-007)	**22.459**	2.174	**1.372**	*2.744*	*4.348*	**11.931**	**16.369**	7.486	**22.459**
130	2.151	**1.893**	**18.281**	**34.606**	32.2888479 (+/- 4.1e-007)	**65.509**	2.414	**1.893**	*3.786*	*4.829*	**18.281**	**34.606**	21.836	**65.509**
131	1.970	**1.741**	**14.918**	**25.972**	17.2709701 (+/- 3e-007)	**45.218**	2.142	**1.741**	*3.482*	*4.284*	**14.918**	**25.972**	15.073	**45.218**
132	1.644	**1.651**	**11.996**	**19.805**	13.4360766 (+/- 1.8e-007)	**32.699**	1.816	**1.651**	*3.302*	*3.633*	**11.996**	**19.805**	10.900	**32.699**
133	2.432	**1.939**	**20.895**	**40.515**	32.7329375 (+/- 2.5e-007)	**78.559**	2.694	**1.939**	*3.878*	*5.388*	**20.895**	**40.515**	26.186	**78.559**
134	2.068	**1.674**	**15.310**	**25.629**	17.8344848 (+/- 2.4e-007)	**42.903**	2.286	**1.674**	*3.348*	*4.573*	**15.310**	**25.629**	14.301	**42.903**
135	1.600	**1.559**	**11.137**	**17.363**	15.3009504 (+/- 1.2e-007)	**27.068**	1.786	**1.559**	*3.118*	*3.572*	**11.137**	**17.363**	9.023	**27.068**
136	2.708	**2.246**	**27.218**	**61.132**	61.7225109 (+/- 3.9e-007)	**137.302**	3.030	**2.246**	*4.492*	*6.059*	**27.218**	**61.132**	45.767	**137.302**
137	2.099	**1.774**	**16.627**	**29.496**	23.0827913 (+/- 7.6e-007)	**52.326**	2.343	**1.774**	*3.548*	*4.686*	**16.627**	**29.496**	17.442	**52.326**
138	1.834	**2.245**	**18.458**	**41.438**	43.0786846 (+/- 2.6e-007)	**93.029**	2.055	**2.245**	*4.490*	*4.111*	**18.458**	**41.438**	31.010	**93.029**
139	1.925	**1.987**	**17.177**	**34.131**	31.9222882 (+/- 2.3e-007)	**67.818**	2.161	**1.987**	*3.974*	*4.322*	**17.177**	**34.131**	22.606	**67.818**
140	3.090	**2.492**	**33.089**	**82.458**	75.9425775 (+/- 3e-006)	**205.485**	3.320	**2.492**	*4.984*	*6.639*	**33.089**	**82.458**	68.495	**205.485**
141	3.327	**2.730**	**39.413**	**107.597**	111.979346 (+/- 1.3e-006)	**293.741**	3.609	**2.730**	*5.460*	*7.218*	**39.413**	**107.597**	97.914	**293.741**
142	2.560	**1.758**	**19.644**	**34.534**	74.0663959 (+/- 2e-006)	**60.711**	2.794	**1.758**	*3.516*	*5.587*	**19.644**	**34.534**	20.237	**60.711**
143	2.625	**2.601**	**30.150**	**78.420**	83.2713995 (+/- 6.4e-007)	**203.971**	2.898	**2.601**	*5.202*	*5.796*	**30.150**	**78.420**	67.990	**203.971**
144	2.102	**2.392**	**22.163**	**53.014**	51.2260849 (+/- 4.7e-007)	**126.809**	2.316	**2.392**	*4.784*	*4.633*	**22.163**	**53.014**	42.270	**126.809**
145	1.986	**2.539**	**22.534**	**57.214**	64.3352554 (+/- 6e-007)	**145.266**	2.219	**2.539**	*5.078*	*4.438*	**22.534**	**57.214**	48.422	**145.266**
146	2.205	**2.130**	**20.717**	**44.127**	38.1053568 (+/- 3.9e-007)	**93.991**	2.432	**2.130**	*4.260*	*4.863*	**20.717**	**44.127**	31.330	**93.991**
147	2.081	**2.126**	**19.665**	**41.808**	37.7083361 (+/- 5.4e-007)	**88.883**	2.312	**2.126**	*4.252*	*4.625*	**19.665**	**41.808**	29.628	**88.883**
148	2.057	**2.352**	**21.237**	**49.949**	46.6320679 (+/- 5.5e-007)	**117.481**	2.257	**2.352**	*4.704*	*4.515*	**21.237**	**49.949**	39.160	**117.481**
149	2.416	**2.401**	**25.896**	**62.176**	65.6398022 (+/- 8.6e-007)	**149.285**	2.696	**2.401**	*4.802*	*5.393*	**25.896**	**62.176**	49.762	**149.285**
150	2.202	**2.090**	**20.683**	**43.227**	42.8180702 (+/- 6e-007)	**90.345**	2.474	**2.090**	*4.180*	*4.948*	**20.683**	**43.227**	30.115	**90.345**
151	2.685	**2.600**	**31.046**	**80.720**	89.242739 (+/- 4.2e-007)	**209.871**	2.985	**2.600**	*5.200*	*5.970*	**31.046**	**80.720**	69.957	**209.871**
152	2.261	**2.443**	**24.297**	**59.358**	57.945775 (+/- 5.3e-007)	**145.011**	2.486	**2.443**	*4.886*	*4.973*	**24.297**	**59.358**	48.337	**145.011**

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}	mm.	mm.	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}
153	2.031	1.797	16.192	29.097	22.5263167 (+/- 5.4e-007)	52.287	2.253	1.797	3.594	4.505	16.192	29.097	17.429	52.287
154	2.011	1.796	16.160	29.023	23.4590684 (+/- 5.7e-007)	52.126	2.249	1.796	3.592	4.499	16.160	29.023	17.375	52.126
155	2.133	1.940	18.211	35.329	27.8518106 (+/- 2.7e-007)	68.539	2.347	1.940	3.880	4.694	18.211	35.329	22.846	68.539
156	1.866	1.710	14.123	24.150	17.2211561 (+/- 2.8e-007)	41.297	2.065	1.710	3.420	4.130	14.123	24.150	13.766	41.297
157	1.907	2.321	19.548	45.371	42.9455353 (+/- 2.6e-007)	105.306	2.106	2.321	4.642	4.211	19.548	45.371	35.102	105.306
158	2.344	2.180	22.623	49.318	44.6193714 (+/- 6.9e-007)	107.514	2.594	2.180	4.360	5.189	22.623	49.318	35.838	107.514
159	2.366	2.190	21.838	47.825	36.7395855 (+/- 5.5e-007)	104.737	2.493	2.190	4.380	4.986	21.838	47.825	34.912	104.737
160	2.131	1.748	16.324	28.534	20.030326 (+/- 5.2e-007)	49.878	2.335	1.748	3.496	4.669	16.324	28.534	16.626	49.878
161	2.428	1.948	20.220	39.389	28.5920259 (+/- 4.6e-007)	76.729	2.595	1.948	3.896	5.190	20.220	39.389	25.576	76.729
162	3.395	3.453	49.696	171.600	208.973157 (+/- 1.2e-006)	592.536	3.598	3.453	6.906	7.196	49.696	171.600	197.512	592.536
163	2.426	1.488	15.880	23.629	14.4195535 (+/- 3.2e-007)	35.161	2.668	1.488	2.976	5.336	15.880	23.629	11.720	35.161
164	2.315	1.413	14.385	20.326	11.9645903 (+/- 3.8e-007)	28.721	2.545	1.413	2.826	5.090	14.385	20.326	9.574	28.721
165	1.787	1.929	15.295	29.504	24.0037662 (+/- 4.9e-007)	56.913	1.982	1.929	3.858	3.964	15.295	29.504	18.971	56.913
166	1.902	2.147	18.198	39.071	36.4097028 (+/- 4.1e-007)	83.886	2.119	2.147	4.294	4.238	18.198	39.071	27.962	83.886
167	1.955	2.138	18.524	39.604	35.2614995 (+/- 4.9e-007)	84.674	2.166	2.138	4.276	4.332	18.524	39.604	28.225	84.674
168	1.930	1.837	15.652	28.753	21.4938209 (+/- 3.8e-007)	52.819	2.130	1.837	3.674	4.260	15.652	28.753	17.606	52.819
169	2.007	2.008	18.071	36.287	34.6356931 (+/- 5.7e-007)	72.863	2.250	2.008	4.016	4.500	18.071	36.287	24.288	72.863
170	2.050	1.643	15.048	24.724	17.9728404 (+/- 5.7e-007)	40.621	2.290	1.643	3.286	4.579	15.048	24.724	13.540	40.621
171	1.857	1.525	12.681	19.339	16.0088306 (+/- 4e-007)	29.491	2.079	1.525	3.050	4.158	12.681	19.339	9.830	29.491
172	1.814	1.744	14.117	24.620	24.4271889 (+/- 2.9e-007)	42.937	2.024	1.744	3.488	4.047	14.117	24.620	14.312	42.937
173	2.070	1.405	13.013	18.283	14.162636 (+/- 3.5e-007)	25.688	2.315	1.405	2.810	4.631	13.013	18.283	8.563	25.688
174	3.214	2.644	35.921	94.975	89.197605 (+/- 7e-007)	251.114	3.396	2.644	5.288	6.793	35.921	94.975	83.705	251.114
175	2.144	1.908	18.235	34.792	29.0712701 (+/- 1.1e-006)	66.384	2.389	1.908	3.816	4.779	18.235	34.792	22.128	66.384
176	1.605	1.939	13.975	27.098	24.7824356 (+/- 3.3e-007)	52.542	1.802	1.939	3.878	3.604	13.975	27.098	17.514	52.542
177	2.131	2.371	22.359	53.013	52.0665005 (+/- 5.5e-007)	125.694	2.358	2.371	4.742	4.715	22.359	53.013	41.898	125.694
178	2.057	1.584	14.600	23.126	18.6804069 (+/- 3.8e-007)	36.632	2.304	1.584	3.168	4.609	14.600	23.126	12.211	36.632

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}	mm.	mm.	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}
179	2.158	1.730	16.531	28.599	20.5447477 (+/- 7.9e-007)	49.476	2.389	1.730	3.460	4.778	16.531	28.599	16.492	49.476
180	3.297	2.543	34.795	88.484	77.9494125 (+/- 6.4e-006)	225.014	3.421	2.543	5.086	6.841	34.795	88.484	75.005	225.014
181	2.599	1.651	18.899	31.202	20.9515813 (+/- 6e-007)	51.515	2.862	1.651	3.302	5.724	18.899	31.202	17.172	51.515
182	1.908	1.505	12.849	19.338	14.0999082 (+/- 2.7e-007)	29.103	2.134	1.505	3.010	4.269	12.849	19.338	9.701	29.103
183	1.998	2.121	18.699	39.661	34.1562445 (+/- 3.1e-007)	84.120	2.204	2.121	4.242	4.408	18.699	39.661	28.040	84.120
184	2.071	1.837	16.995	31.220	25.2673846 (+/- 2.7e-007)	57.351	2.313	1.837	3.674	4.626	16.995	31.220	19.117	57.351
185	2.248	1.655	16.699	27.637	21.3202799 (+/- 5.5e-007)	45.739	2.523	1.655	3.310	5.045	16.699	27.637	15.246	45.739
186	2.270	1.833	18.585	34.066	27.6146209 (+/- 4.7e-007)	62.444	2.535	1.833	3.666	5.070	18.585	34.066	20.815	62.444
187	2.583	1.850	21.130	39.091	29.6885425 (+/- 7e-007)	72.317	2.855	1.850	3.700	5.711	21.130	39.091	24.106	72.317
188	2.728	2.122	25.465	54.037	45.7794937 (+/- 6e-007)	114.666	3.000	2.122	4.244	6.000	25.465	54.037	38.222	114.666
189	2.516	2.314	25.092	58.063	49.7805976 (+/- 1.2e-006)	134.358	2.711	2.314	4.628	5.422	25.092	58.063	44.786	134.358
190	2.259	2.428	24.277	58.945	76.371139 (+/- 8.3e-007)	143.117	2.500	2.428	4.856	4.999	24.277	58.945	47.706	143.117
191	2.643	2.112	24.813	52.405	47.8637544 (+/- 5.1e-007)	110.679	2.937	2.112	4.224	5.874	24.813	52.405	36.893	110.679
192	2.825	1.670	20.895	34.895	24.2966647 (+/- 4.6e-007)	58.274	3.128	1.670	3.340	6.256	20.895	34.895	19.425	58.274
193	2.877	2.100	26.021	54.644	42.6492974 (+/- 1.5e-006)	114.753	3.098	2.100	4.200	6.195	26.021	54.644	38.251	114.753
194	2.877	1.556	19.710	30.669	19.928762 (+/- 9.2e-007)	47.721	3.167	1.556	3.112	6.334	19.710	30.669	15.907	47.721
195	2.953	1.738	22.158	38.511	25.6722079 (+/- 9.3e-007)	66.931	3.187	1.738	3.476	6.375	22.158	38.511	22.310	66.931
196	2.395	1.584	16.857	26.701	17.9194908 (+/- 3.9e-007)	42.295	2.661	1.584	3.168	5.321	16.857	26.701	14.098	42.295
197	2.824	1.854	23.200	43.013	33.3366159 (+/- 7.4e-007)	79.746	3.128	1.854	3.708	6.257	23.200	43.013	26.582	79.746
198	2.056	2.119	19.425	41.162	38.186138 (+/- 8.3e-007)	87.221	2.292	2.119	4.238	4.584	19.425	41.162	29.074	87.221
199	3.186	2.043	28.244	57.702	46.6364085 (+/- 3.7e-007)	117.886	3.456	2.043	4.086	6.912	28.244	57.702	39.295	117.886
200	2.901	2.044	26.343	53.845	47.6171169 (+/- 5.5e-007)	110.059	3.222	2.044	4.088	6.444	26.343	53.845	36.686	110.059
201	1.916	1.800	15.480	27.864	26.7262028 (+/- 2e-007)	50.155	2.150	1.800	3.600	4.300	15.480	27.864	16.718	50.155
202	1.976	2.323	20.407	47.405	46.8094195 (+/- 2.9e-007)	110.123	2.196	2.323	4.646	4.392	20.407	47.405	36.708	110.123
203	2.703	2.365	28.043	66.322	61.9496112 (+/- 5.2e-007)	156.851	2.964	2.365	4.730	5.929	28.043	66.322	52.284	156.851
204	2.488	2.453	27.301	66.969	73.3880552 (+/- 4.1e-007)	164.276	2.782	2.453	4.906	5.565	27.301	66.969	54.759	164.276

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}	mm.	mm.	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}
205	2.815	2.527	31.373	79.280	81.0702607 (+/- 4e-007)	200.339	3.104	2.527	5.054	6.208	31.373	79.280	66.780	200.339
206	2.768	2.243	27.729	62.196	61.3339737 (+/- 7.7e-007)	139.506	3.091	2.243	4.486	6.181	27.729	62.196	46.502	139.506
207	2.675	2.065	24.793	51.198	49.3190383 (+/- 4.7e-007)	105.723	3.002	2.065	4.130	6.003	24.793	51.198	35.241	105.723
208	2.472	1.913	21.237	40.626	36.4309114 (+/- 5e-007)	77.718	2.775	1.913	3.826	5.551	21.237	40.626	25.906	77.718
209	2.371	2.017	21.448	43.261	40.1801225 (+/- 2.6e-007)	87.257	2.658	2.017	4.034	5.317	21.448	43.261	29.086	87.257
210	2.409	2.370	25.575	60.613	66.4258031 (+/- 4.1e-007)	143.652	2.698	2.370	4.740	5.396	25.575	60.613	47.884	143.652
211	2.227	2.258	22.554	50.927	52.7777022 (+/- 2.2e-007)	114.993	2.497	2.258	4.516	4.994	22.554	50.927	38.331	114.993
212	2.417	2.175	23.630	51.395	54.0081839 (+/- 4.8e-007)	111.785	2.716	2.175	4.350	5.432	23.630	51.395	37.262	111.785
213	2.430	2.537	27.608	70.041	80.4606317 (+/- 4.1e-007)	177.695	2.721	2.537	5.074	5.441	27.608	70.041	59.232	177.695
214	2.567	2.642	31.120	82.219	89.045234 (+/- 2.2e-007)	217.223	2.945	2.642	5.284	5.889	31.120	82.219	72.408	217.223
215	2.204	2.037	19.882	40.500	34.825054 (+/- 2.8e-007)	82.498	2.440	2.037	4.074	4.880	19.882	40.500	27.499	82.498
216	2.010	1.720	15.523	26.700	22.630334 (+/- 2.5e-007)	45.923	2.256	1.720	3.440	4.513	15.523	26.700	15.308	45.923
217	1.775	1.815	14.363	26.069	20.5748142 (+/- 1.8e-007)	47.315	1.978	1.815	3.630	3.957	14.363	26.069	15.772	47.315
218	1.947	1.860	16.152	30.043	24.3426723 (+/- 2.1e-007)	55.879	2.171	1.860	3.720	4.342	16.152	30.043	18.626	55.879
219	2.353	1.842	19.362	35.665	29.081501 (+/- 3.7e-007)	65.695	2.628	1.842	3.684	5.256	19.362	35.665	21.898	65.695
220	2.590	2.387	27.766	66.277	80.8221598 (+/- 4.1e-007)	158.204	2.908	2.387	4.774	5.816	27.766	66.277	52.735	158.204
221	2.250	1.631	16.305	26.593	18.4416061 (+/- 1.1e-007)	43.374	2.499	1.631	3.262	4.998	16.305	26.593	14.458	43.374
222	2.262	1.915	18.917	36.226	27.295201 (+/- 7.4e-007)	69.373	2.470	1.915	3.830	4.939	18.917	36.226	23.124	69.373
223	2.449	2.049	21.785	44.637	35.0224987 (+/- 2.8e-007)	91.462	2.658	2.049	4.098	5.316	21.785	44.637	30.487	91.462
224	2.380	1.986	21.067	41.839	36.7820448 (+/- 4.3e-007)	83.092	2.652	1.986	3.972	5.304	21.067	41.839	27.697	83.092
225	2.654	2.399	26.881	64.488	54.5071999 (+/- 2.5e-007)	154.706	2.801	2.399	4.798	5.603	26.881	64.488	51.569	154.706
226	2.749	2.060	24.739	50.962	42.1213368 (+/- 3.3e-007)	104.982	3.002	2.060	4.120	6.005	24.739	50.962	34.994	104.982
227	2.012	2.050	18.537	38.001	39.3119632 (+/- 3.2e-007)	77.902	2.261	2.050	4.100	4.521	18.537	38.001	25.967	77.902
228	2.170	1.665	16.240	27.040	22.2374205 (+/- 2e-007)	45.021	2.438	1.665	3.330	4.877	16.240	27.040	15.007	45.021
229	2.142	1.648	15.869	26.152	21.2562372 (+/- 1.5e-007)	43.099	2.407	1.648	3.296	4.815	15.869	26.152	14.366	43.099
230	2.086	2.019	18.908	38.175	38.5713076 (+/- 2.3e-007)	77.076	2.341	2.019	4.038	4.683	18.908	38.175	25.692	77.076

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}	mm.	mm.	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}
231	2.225	2.188	21.894	47.904	52.2116748 (+/- 3.8e-007)	104.814	2.502	2.188	4.376	5.003	21.894	47.904	34.938	104.814
232	1.994	1.944	17.428	33.880	32.7230028 (+/- 3.4e-007)	65.863	2.241	1.944	3.888	4.483	17.428	33.880	21.954	65.863
233	1.904	1.943	16.475	32.011	36.0033409 (+/- 2e-007)	62.197	2.120	1.943	3.886	4.240	16.475	32.011	20.732	62.197
234	2.018	2.027	18.378	37.252	39.2989805 (+/- 2.7e-007)	75.510	2.267	2.027	4.054	4.533	18.378	37.252	25.170	75.510
235	2.052	1.974	18.199	35.925	34.2595281 (+/- 2.3e-007)	70.916	2.305	1.974	3.948	4.610	18.199	35.925	23.639	70.916
236	2.277	1.901	19.455	36.984	35.8092614 (+/- 3e-007)	70.306	2.559	1.901	3.802	5.117	19.455	36.984	23.435	70.306
237	1.734	1.684	13.054	21.983	20.0282712 (+/- 2.1e-007)	37.019	1.938	1.684	3.368	3.876	13.054	21.983	12.340	37.019
238	2.203	1.971	19.464	38.364	34.6567852 (+/- 3.9e-007)	75.615	2.469	1.971	3.942	4.938	19.464	38.364	25.205	75.615
239	2.164	1.922	18.701	35.943	35.2804068 (+/- 3e-007)	69.083	2.432	1.922	3.844	4.865	18.701	35.943	23.028	69.083
240	2.154	1.877	18.085	33.946	28.3343712 (+/- 3.4e-007)	63.716	2.409	1.877	3.754	4.818	18.085	33.946	21.239	63.716
241	2.284	2.170	22.064	47.879	44.5114998 (+/- 3.4e-007)	103.897	2.542	2.170	4.340	5.084	22.064	47.879	34.632	103.897
242	2.857	1.460	18.471	26.968	18.1381857 (+/- 4.7e-007)	39.373	3.163	1.460	2.920	6.326	18.471	26.968	13.124	39.373
243	2.203	1.587	15.694	24.906	19.0680338 (+/- 3.4e-007)	39.526	2.472	1.587	3.174	4.945	15.694	24.906	13.175	39.526
244	2.268	1.823	18.487	33.702	28.266843 (+/- 5e-007)	61.438	2.535	1.823	3.646	5.070	18.487	33.702	20.479	61.438
245	2.404	1.718	18.094	31.085	21.0327984 (+/- 2e-007)	53.405	2.633	1.718	3.436	5.266	18.094	31.085	17.802	53.405
246	2.680	1.763	21.204	37.383	30.9456249 (+/- 1.3e-007)	65.906	3.007	1.763	3.526	6.014	21.204	37.383	21.969	65.906
247	1.720	2.166	16.735	36.248	37.3104052 (+/- 5e-007)	78.513	1.932	2.166	4.332	3.863	16.735	36.248	26.171	78.513
248	1.759	2.273	17.971	40.848	46.0772907 (+/- 3.1e-007)	92.848	1.977	2.273	4.546	3.953	17.971	40.848	30.949	92.848
249	2.180	2.179	21.316	46.448	47.5014005 (+/- 2.8e-007)	101.209	2.446	2.179	4.358	4.891	21.316	46.448	33.736	101.209
250	2.210	2.149	21.335	45.849	46.3359521 (+/- 2.8e-007)	98.529	2.482	2.149	4.298	4.964	21.335	45.849	32.843	98.529
251	2.220	2.101	20.861	43.829	41.0363228 (+/- 3.6e-007)	92.085	2.482	2.101	4.202	4.965	20.861	43.829	30.695	92.085
252	2.604	1.810	21.147	38.276	32.3785511 (+/- 4.3e-007)	69.280	2.921	1.810	3.620	5.842	21.147	38.276	23.093	69.280
253	2.458	1.790	19.643	35.161	27.7277414 (+/- 2.1e-007)	62.938	2.743	1.790	3.580	5.487	19.643	35.161	20.979	62.938
254	2.663	2.250	26.424	59.454	54.3234743 (+/- 2.7e-007)	133.772	2.936	2.250	4.500	5.872	26.424	59.454	44.591	133.772
255	3.099	2.417	32.986	79.727	78.8109993 (+/- 2.7e-007)	192.701	3.412	2.417	4.834	6.824	32.986	79.727	64.234	192.701
256	2.941	2.285	29.742	67.960	66.4318157 (+/- 3.2e-007)	155.290	3.254	2.285	4.570	6.508	29.742	67.960	51.763	155.290

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}	mm.	mm.	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}
257	2.114	**1.799**	**17.067**	**30.704**	25.6684025 (+/- 2.1e-007)	**55.236**	2.372	**1.799**	*3.598*	*4.743*	**17.067**	**30.704**	18.412	**55.236**
258	1.949	**2.114**	**18.525**	**39.162**	41.5885305 (+/- 2.6e-007)	**82.788**	2.191	**2.114**	*4.228*	*4.382*	**18.525**	**39.162**	27.596	**82.788**
259	2.092	**2.052**	**19.166**	**39.329**	35.7288527 (+/- 4.4e-007)	**80.702**	2.335	**2.052**	*4.104*	*4.670*	**19.166**	**39.329**	26.901	**80.702**
260	2.660	**2.084**	**24.829**	**51.744**	49.486971 (+/- 4.7e-007)	**107.834**	2.979	**2.084**	*4.168*	*5.957*	**24.829**	**51.744**	35.945	**107.834**
261	2.191	**2.191**	**21.559**	**47.236**	50.197785 (+/- 4.9e-007)	**103.494**	2.460	**2.191**	*4.382*	*4.920*	**21.559**	**47.236**	34.498	**103.494**
262	2.406	**1.667**	**17.908**	**29.853**	22.0534955 (+/- 2.9e-007)	**49.764**	2.686	**1.667**	*3.334*	*5.371*	**17.908**	**29.853**	16.588	**49.764**
263	2.698	**2.008**	**24.096**	**48.385**	41.4232124 (+/- 4e-007)	**97.157**	3.000	**2.008**	*4.016*	*6.000*	**24.096**	**48.385**	32.386	**97.157**
264	3.101	**1.636**	**22.397**	**36.641**	24.6618392 (+/- 5e-007)	**59.945**	3.423	**1.636**	*3.272*	*6.845*	**22.397**	**36.641**	19.982	**59.945**
265	2.915	**1.862**	**24.257**	**45.167**	37.0824333 (+/- 5e-007)	**84.100**	3.257	**1.862**	*3.724*	*6.514*	**24.257**	**45.167**	28.033	**84.100**
266	2.474	**1.351**	**15.018**	**20.289**	13.5367684 (+/- 2.8e-007)	**27.411**	2.779	**1.351**	*2.702*	*5.558*	**15.018**	**20.289**	9.137	**27.411**
267	2.939	**1.862**	**23.619**	**43.979**	31.9196836 (+/- 4.4e-007)	**81.888**	3.171	**1.862**	*3.724*	*6.342*	**23.619**	**43.979**	27.296	**81.888**
268	3.042	**1.610**	**21.701**	**34.939**	23.6669166 (+/- 5.2e-007)	**56.251**	3.370	**1.610**	*3.220*	*6.739*	**21.701**	**34.939**	18.750	**56.251**
269	2.414	**1.578**	**16.888**	**26.649**	17.7066518 (+/- 1.4e-007)	**42.053**	2.676	**1.578**	*3.156*	*5.351*	**16.888**	**26.649**	14.018	**42.053**
270	2.294	**1.700**	**17.456**	**29.675**	25.1157185 (+/- 3.3e-007)	**50.448**	2.567	**1.700**	*3.400*	*5.134*	**17.456**	**29.675**	16.816	**50.448**
271	2.546	**2.341**	**26.377**	**61.749**	59.8811285 (+/- 3.4e-007)	**144.553**	2.817	**2.341**	*4.682*	*5.634*	**26.377**	**61.749**	48.184	**144.553**
272	2.345	**1.732**	**18.224**	**31.564**	25.3771841 (+/- 2.3e-007)	**54.669**	2.630	**1.732**	*3.464*	*5.261*	**18.224**	**31.564**	18.223	**54.669**
273	1.805	**2.248**	**18.239**	**41.001**	47.6819118 (+/- 2.8e-007)	**92.171**	2.028	**2.248**	*4.496*	*4.057*	**18.239**	**41.001**	30.724	**92.171**
274	2.061	**1.821**	**16.872**	**30.724**	26.9165541 (+/- 2.1e-007)	**55.948**	2.316	**1.821**	*3.642*	*4.633*	**16.872**	**30.724**	18.649	**55.948**
275	1.777	**1.783**	**14.192**	**25.304**	20.6475129 (+/- 2.1e-007)	**45.118**	1.990	**1.783**	*3.566*	*3.980*	**14.192**	**25.304**	15.039	**45.118**
276	2.201	**1.656**	**16.291**	**26.978**	20.0202871 (+/- 4e-007)	**44.675**	2.459	**1.656**	*3.312*	*4.919*	**16.291**	**26.978**	14.892	**44.675**
277	2.346	**1.675**	**17.576**	**29.440**	22.1599987 (+/- 1.5e-007)	**49.312**	2.623	**1.675**	*3.350*	*5.247*	**17.576**	**29.440**	16.437	**49.312**
278	2.062	**1.531**	**14.131**	**21.635**	14.9825846 (+/- 3.1e-007)	**33.123**	2.307	**1.531**	*3.062*	*4.615*	**14.131**	**21.635**	11.041	**33.123**
279	2.065	**1.890**	**17.512**	**33.098**	28.8558842 (+/- 3.3e-007)	**62.555**	2.316	**1.890**	*3.780*	*4.633*	**17.512**	**33.098**	20.852	**62.555**
280	1.839	**1.995**	**16.495**	**32.908**	33.414485 (+/- 2.7e-007)	**65.651**	2.067	**1.995**	*3.990*	*4.134*	**16.495**	**32.908**	21.884	**65.651**
281	1.862	**1.946**	**16.213**	**31.550**	28.5179771 (+/- 2.2e-007)	**61.397**	2.083	**1.946**	*3.892*	*4.166*	**16.213**	**31.550**	20.466	**61.397**
282	1.957	**2.062**	**18.136**	**37.396**	37.40646 (+/- 1.6e-007)	**77.111**	2.199	**2.062**	*4.124*	*4.398*	**18.136**	**37.396**	25.704	**77.111**

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}	mm.	mm.	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}
283	2.261	1.608	16.334	26.265	21.0092979 (+/- 1.9e-007)	42.234	2.539	1.608	3.216	5.079	16.334	26.265	14.078	42.234
284	2.663	1.752	20.901	36.619	29.1238494 (+/- 1.7e-007)	64.156	2.982	1.752	3.504	5.965	20.901	36.619	21.385	64.156
285	2.650	2.836	32.282	91.552	96.1874813 (+/- 4e-007)	259.641	2.846	2.836	5.672	5.691	32.282	91.552	86.547	259.641
286	2.573	2.864	32.197	92.212	102.368395 (+/- 2e-007)	264.096	2.810	2.864	5.728	5.621	32.197	92.212	88.032	264.096
287	1.718	1.632	12.566	20.508	15.3057484 (+/- 1.2e-007)	33.469	1.925	1.632	3.264	3.850	12.566	20.508	11.156	33.469
288	2.198	2.026	19.763	40.040	34.063425 (+/- 3.3e-007)	81.121	2.439	2.026	4.052	4.877	19.763	40.040	27.040	81.121
289	2.463	1.916	20.887	40.019	31.6558307 (+/- 2.7e-007)	76.677	2.725	1.916	3.832	5.451	20.887	40.019	25.559	76.677
290	1.887	2.010	16.959	34.088	30.3333999 (+/- 1.3e-007)	68.516	2.109	2.010	4.020	4.219	16.959	34.088	22.839	68.516
291	2.058	1.870	17.091	31.960	25.1792474 (+/- 1.9e-007)	59.766	2.285	1.870	3.740	4.570	17.091	31.960	19.922	59.766
292	2.298	2.046	20.805	42.567	36.0030894 (+/- 2.7e-007)	87.092	2.542	2.046	4.092	5.084	20.805	42.567	29.031	87.092
293	2.281	2.092	21.117	44.177	38.4399213 (+/- 2.6e-007)	92.418	2.524	2.092	4.184	5.047	21.117	44.177	30.806	92.418
294	2.524	1.802	20.111	36.240	27.2277016 (+/- 1.6e-007)	65.305	2.790	1.802	3.604	5.580	20.111	36.240	21.768	65.305
295	2.063	1.881	17.198	32.349	25.3286224 (+/- 2.1e-007)	60.849	2.286	1.881	3.762	4.572	17.198	32.349	20.283	60.849
296	2.151	1.934	18.111	35.027	26.0444036 (+/- 2.9e-007)	67.742	2.341	1.934	3.868	4.682	18.111	35.027	22.581	67.742
297	2.784	2.342	28.171	65.976	59.089057 (+/- 3.4e-006)	154.517	3.007	2.342	4.684	6.014	28.171	65.976	51.506	154.517
298	3.219	3.131	43.495	136.183	158.325943 (+/- 3.2e-007)	426.388	3.473	3.131	6.262	6.946	43.495	136.183	142.129	426.388
299	2.569	1.754	19.941	34.977	26.7526492 (+/- 4.8e-007)	61.349	2.842	1.754	3.508	5.684	19.941	34.977	20.450	61.349
300	2.257	1.665	16.726	27.849	21.2516388 (+/- 2e-007)	46.368	2.511	1.665	3.330	5.023	16.726	27.849	15.456	46.368
301	2.550	1.328	15.191	20.174	12.6338932 (+/- 2.9e-007)	26.791	2.860	1.328	2.656	5.720	15.191	20.174	8.930	26.791
302	2.701	1.200	14.571	17.485	10.8782298 (+/- 2.3e-007)	20.982	3.036	1.200	2.400	6.071	14.571	17.485	6.994	20.982
303	2.327	1.380	14.407	19.882	13.5946055 (+/- 2e-007)	27.437	2.610	1.380	2.760	5.220	14.407	19.882	9.146	27.437
304	2.353	1.445	15.256	22.045	15.2878551 (+/- 1.1e-007)	31.855	2.639	1.445	2.890	5.279	15.256	22.045	10.618	31.855
305	3.487	1.963	30.624	60.115	55.5689292 (+/- 6e-007)	118.006	3.900	1.963	3.926	7.800	30.624	60.115	39.335	118.006
306	2.257	1.941	19.678	38.195	36.2697226 (+/- 3e-007)	74.136	2.535	1.941	3.882	5.069	19.678	38.195	24.712	74.136
307	2.393	1.945	20.845	40.544	35.7428796 (+/- 2e-007)	78.857	2.679	1.945	3.890	5.359	20.845	40.544	26.286	78.857
308	2.131	1.805	17.274	31.180	28.6372636 (+/- 1.9e-007)	56.279	2.393	1.805	3.610	4.785	17.274	31.180	18.760	56.279

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}	mm.	mm.	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}
309	1.980	1.801	15.863	28.569	30.2546177 (+/- 1.8e-007)	51.453	2.202	1.801	3.602	4.404	15.863	28.569	17.151	51.453
310	2.111	1.841	17.481	32.183	28.5538281 (+/- 1.5e-007)	59.248	2.374	1.841	3.682	4.748	17.481	32.183	19.749	59.248
311	2.017	1.700	15.408	26.194	23.2408652 (+/- 3e-007)	44.529	2.266	1.700	3.400	4.532	15.408	26.194	14.843	44.529
312	1.950	1.901	16.672	31.693	30.4584588 (+/- 1.9e-007)	60.249	2.193	1.901	3.802	4.385	16.672	31.693	20.083	60.249
313	2.219	1.722	17.181	29.586	25.3384424 (+/- 6.1e-007)	50.947	2.494	1.722	3.444	4.989	17.181	29.586	16.982	50.947
314	1.789	1.977	15.905	31.444	31.7724654 (+/- 1.9e-007)	62.165	2.011	1.977	3.954	4.023	15.905	31.444	20.722	62.165
315	1.510	2.331	15.740	36.690	38.1647859 (+/- 2.5e-007)	85.524	1.688	2.331	4.662	3.376	15.740	36.690	28.508	85.524
316	1.698	2.200	16.692	36.722	36.4512242 (+/- 1.4e-007)	80.789	1.897	2.200	4.400	3.794	16.692	36.722	26.930	80.789
317	2.780	2.623	32.328	84.796	92.9331351 (+/- 3.9e-007)	222.421	3.081	2.623	5.246	6.162	32.328	84.796	74.140	222.421
318	2.420	1.807	19.269	34.819	25.6809085 (+/- 2.9e-007)	62.918	2.666	1.807	3.614	5.332	19.269	34.819	20.973	62.918
319	2.255	1.896	19.176	36.358	32.7795036 (+/- 2.4e-007)	68.934	2.528	1.896	3.792	5.057	19.176	36.358	22.978	68.934
320	2.189	2.284	22.413	51.191	55.4626713 (+/- 2e-007)	116.921	2.453	2.284	4.568	4.907	22.413	51.191	38.974	116.921
321	2.626	2.121	24.409	51.771	43.502093 (+/- 8.1e-007)	109.807	2.877	2.121	4.242	5.754	24.409	51.771	36.602	109.807
322	1.900	2.096	17.899	37.516	38.0721245 (+/- 2.1e-007)	78.634	2.135	2.096	4.192	4.270	17.899	37.516	26.211	78.634
323	2.481	1.701	18.953	32.239	27.9097877 (+/- 2.9e-007)	54.839	2.786	1.701	3.402	5.571	18.953	32.239	18.280	54.839
324	1.933	1.657	14.401	23.862	20.1902707 (+/- 1.6e-007)	39.540	2.173	1.657	3.314	4.346	14.401	23.862	13.180	39.540
325	2.769	2.125	26.384	56.066	54.5346406 (+/- 2.5e-007)	119.140	3.104	2.125	4.250	6.208	26.384	56.066	39.713	119.140
326	1.824	2.150	17.619	37.881	39.0451179 (+/- 1.5e-007)	81.444	2.049	2.150	4.300	4.097	17.619	37.881	27.148	81.444
327	1.811	1.648	13.401	22.085	17.7950418 (+/- 9.9e-008)	36.396	2.033	1.648	3.296	4.066	13.401	22.085	12.132	36.396
328	2.029	1.833	16.702	30.615	26.6007543 (+/- 2.6e-007)	56.117	2.278	1.833	3.666	4.556	16.702	30.615	18.706	56.117
329	2.012	1.842	16.659	30.686	28.9873011 (+/- 2.8e-007)	56.523	2.261	1.842	3.684	4.522	16.659	30.686	18.841	56.523
330	1.939	2.118	18.465	39.109	41.4273351 (+/- 1.4e-007)	82.833	2.180	2.118	4.236	4.359	18.465	39.109	27.611	82.833
331	2.553	2.600	29.364	76.346	84.7977052 (+/- 1.3e-007)	198.501	2.823	2.600	5.200	5.647	29.364	76.346	66.167	198.501
332	2.363	3.194	33.730	107.734	193.655964 (+/- 3.7e-007)	344.101	2.640	3.194	6.388	5.280	33.730	107.734	114.700	344.101
333	1.314	2.265	13.335	30.204	34.5783779 (+/- 1.7e-007)	68.412	1.472	2.265	4.530	2.944	13.335	30.204	22.804	68.412
334	1.356	1.475	8.914	13.148	11.2080755 (+/- 1.3e-007)	19.394	1.511	1.475	2.950	3.022	8.914	13.148	6.465	19.394

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}	mm.	mm.	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}
335	1.667	**1.405**	**10.534**	**14.800**	10.224641 (+/- 1.6e-007)	**20.794**	1.874	**1.405**	*2.810*	*3.749*	**10.534**	**14.800**	6.931	**20.794**
336	1.534	**1.667**	**11.498**	**19.167**	16.1395921 (+/- 1.4e-007)	**31.952**	1.724	**1.667**	*3.334*	*3.449*	**11.498**	**19.167**	10.651	**31.952**
337	1.761	**1.849**	**14.613**	**27.019**	26.6342736 (+/- 2e-007)	**49.959**	1.976	**1.849**	*3.698*	*3.952*	**14.613**	**27.019**	16.653	**49.959**
338	2.603	**2.170**	**24.323**	**52.781**	42.5797788 (+/- 2.6e-007)	**114.535**	2.802	**2.170**	*4.340*	*5.604*	**24.323**	**52.781**	38.178	**114.535**
339	1.955	**1.983**	**17.405**	**34.514**	32.0209308 (+/- 1.3e-007)	**68.441**	2.194	**1.983**	*3.966*	*4.389*	**17.405**	**34.514**	22.814	**68.441**
340	1.761	**1.712**	**13.376**	**22.900**	16.58873 (+/- 2e-007)	**39.204**	1.953	**1.712**	*3.424*	*3.907*	**13.376**	**22.900**	13.068	**39.204**
341	2.239	**1.843**	**18.525**	**34.142**	29.3855354 (+/- 2.4e-007)	**62.923**	2.513	**1.843**	*3.686*	*5.026*	**18.525**	**34.142**	20.974	**62.923**
342	2.322	**1.755**	**18.269**	**32.062**	25.7786071 (+/- 2.4e-007)	**56.269**	2.602	**1.755**	*3.510*	*5.205*	**18.269**	**32.062**	18.756	**56.269**
343	2.292	**1.622**	**16.689**	**27.070**	20.5721897 (+/- 3.3e-007)	**43.907**	2.572	**1.622**	*3.244*	*5.145*	**16.689**	**27.070**	14.636	**43.907**
344	2.414	**1.686**	**18.198**	**30.682**	23.0536205 (+/- 2.1e-007)	**51.730**	2.698	**1.686**	*3.372*	*5.397*	**18.198**	**30.682**	17.243	**51.730**
345	2.445	**1.719**	**18.386**	**31.606**	21.576423 (+/- 4.6e-007)	**54.330**	2.674	**1.719**	*3.438*	*5.348*	**18.386**	**31.606**	18.110	**54.330**
346	2.093	**1.318**	**12.402**	**16.346**	10.7757053 (+/- 2.8e-007)	**21.544**	2.352	**1.318**	*2.636*	*4.705*	**12.402**	**16.346**	7.181	**21.544**
347	2.162	**1.503**	**14.490**	**21.778**	14.2535041 (+/- 3.1e-007)	**32.733**	2.410	**1.503**	*3.006*	*4.820*	**14.490**	**21.778**	10.911	**32.733**
348	2.759	**1.399**	**17.095**	**23.916**	13.9323373 (+/- 5.3e-007)	**33.458**	3.055	**1.399**	*2.798*	*6.110*	**17.095**	**23.916**	11.153	**33.458**
349	2.130	**1.414**	**13.351**	**18.878**	11.23014 (+/- 2.9e-007)	**26.694**	2.361	**1.414**	*2.828*	*4.721*	**13.351**	**18.878**	8.898	**26.694**
350	2.184	**1.509**	**14.748**	**22.255**	15.0765824 (+/- 5.4e-007)	**33.582**	2.443	**1.509**	*3.018*	*4.887*	**14.748**	**22.255**	11.194	**33.582**
351	2.397	**1.695**	**17.897**	**30.335**	20.7507847 (+/- 4.7e-007)	**51.419**	2.640	**1.695**	*3.390*	*5.279*	**17.897**	**30.335**	17.140	**51.419**
352	2.076	**1.652**	**15.209**	**25.125**	17.35511 (+/- 2.9e-007)	**41.507**	2.302	**1.652**	*3.304*	*4.603*	**15.209**	**25.125**	13.836	**41.507**
353	2.247	**1.752**	**17.301**	**30.311**	21.1861415 (+/- 3.2e-007)	**53.105**	2.469	**1.752**	*3.504*	*4.938*	**17.301**	**30.311**	17.702	**53.105**
354	2.348	**1.851**	**18.844**	**34.880**	24.6568549 (+/- 9.6e-007)	**64.563**	2.545	**1.851**	*3.702*	*5.090*	**18.844**	**34.880**	21.521	**64.563**
355	2.246	**1.786**	**17.555**	**31.353**	21.88722 (+/- 2.2e-007)	**55.997**	2.457	**1.786**	*3.572*	*4.915*	**17.555**	**31.353**	18.666	**55.997**
356	2.172	**1.706**	**16.151**	**27.554**	18.2712405 (+/- 4.6e-007)	**47.006**	2.367	**1.706**	*3.412*	*4.734*	**16.151**	**27.554**	15.669	**47.006**
357	2.223	**1.981**	**19.373**	**38.378**	30.4143693 (+/- 3.5e-007)	**76.027**	2.445	**1.981**	*3.962*	*4.890*	**19.373**	**38.378**	25.342	**76.027**
358	3.319	**2.639**	**37.877**	**99.957**	99.7866959 (+/- 7.9e-007)	**263.788**	3.588	**2.639**	*5.278*	*7.176*	**37.877**	**99.957**	87.929	**263.788**
359	2.462	**2.362**	**24.915**	**58.849**	53.9457135 (+/- 5.1e-007)	**139.002**	2.637	**2.362**	*4.724*	*5.274*	**24.915**	**58.849**	46.334	**139.002**
360	2.516	**2.593**	**28.858**	**74.829**	79.7094888 (+/- 6.8e-007)	**194.031**	2.782	**2.593**	*5.186*	*5.565*	**28.858**	**74.829**	64.677	**194.031**

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}	mm.	mm.	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}
361	2.523	2.593	27.938	72.443	67.3046773 (+/- 5.3e-007)	187.845	2.694	2.593	5.186	5.387	27.938	72.443	62.615	187.845
362	1.618	1.325	9.640	12.773	8.5258745 (+/- 2.2e-007)	16.924	1.819	1.325	2.650	3.638	9.640	12.773	5.641	16.924
363	2.111	2.116	19.863	42.030	38.1525513 (+/- 3.9e-007)	88.936	2.347	2.116	4.232	4.694	19.863	42.030	29.645	88.936
364	1.889	1.888	15.995	30.199	28.7433724 (+/- 2.6e-007)	57.015	2.118	1.888	3.776	4.236	15.995	30.199	19.005	57.015
365	1.868	1.897	15.910	30.181	27.6455458 (+/- 4.5e-007)	57.254	2.097	1.897	3.794	4.193	15.910	30.181	19.085	57.254
366	2.023	1.937	17.397	33.698	27.5012226 (+/- 4.1e-007)	65.273	2.245	1.937	3.874	4.491	17.397	33.698	21.758	65.273
367	2.517	1.727	19.176	33.117	23.331903 (+/- 5.1e-007)	57.193	2.776	1.727	3.454	5.552	19.176	33.117	19.064	57.193
368	3.083	2.175	28.293	61.537	48.4503506 (+/- 6e-007)	133.844	3.252	2.175	4.350	6.504	28.293	61.537	44.615	133.844
369	2.473	1.858	20.521	38.128	32.206387 (+/- 2.2e-007)	70.842	2.761	1.858	3.716	5.522	20.521	38.128	23.614	70.842
370	2.202	1.899	18.362	34.869	26.3904685 (+/- 4.6e-007)	66.217	2.417	1.899	3.798	4.835	18.362	34.869	22.072	66.217
371	2.581	1.986	22.540	44.764	35.4570765 (+/- 3.6e-007)	88.902	2.837	1.986	3.972	5.675	22.540	44.764	29.634	88.902
372	2.720	2.206	26.475	58.404	52.7421781 (+/- 1.1e-006)	128.839	3.000	2.206	4.412	6.001	26.475	58.404	42.946	128.839
373	3.138	2.987	40.224	120.149	129.848395 (+/- 4.4e-007)	358.885	3.367	2.987	5.974	6.733	40.224	120.149	119.628	358.885
374	2.512	1.692	18.728	31.688	22.1484425 (+/- 5.3e-007)	53.616	2.767	1.692	3.384	5.534	18.728	31.688	17.872	53.616
375	2.769	1.890	23.059	43.582	49.6694035 (+/- 6e-007)	82.369	3.050	1.890	3.780	6.100	23.059	43.582	27.456	82.369
376	2.150	1.761	16.827	29.632	22.135671 (+/- 4.1e-007)	52.183	2.389	1.761	3.522	4.778	16.827	29.632	17.394	52.183
377	2.343	1.798	18.682	33.590	25.259098 (+/- 3.3e-007)	60.395	2.598	1.798	3.596	5.195	18.682	33.590	20.132	60.395
378	2.680	2.264	26.294	59.530	51.742974 (+/- 5.8e-007)	134.775	2.903	2.264	4.528	5.807	26.294	59.530	44.925	134.775
379	2.256	1.872	18.323	34.301	24.2941701 (+/- 4e-007)	64.211	2.447	1.872	3.744	4.894	18.323	34.301	21.404	64.211
380	2.859	1.607	19.449	31.255	18.4246305 (+/- 4e-007)	50.226	3.026	1.607	3.214	6.051	19.449	31.255	16.742	50.226
381	2.397	1.890	20.043	37.881	29.5340906 (+/- 4.7e-007)	71.596	2.651	1.890	3.780	5.302	20.043	37.881	23.865	71.596
382	2.548	2.646	29.580	78.269	81.5382764 (+/- 5.1e-007)	207.099	2.795	2.646	5.292	5.590	29.580	78.269	69.033	207.099
383	3.029	2.289	28.815	65.958	52.7767633 (+/- 2e-006)	150.977	3.147	2.289	4.578	6.294	28.815	65.958	50.326	150.977
384	2.443	2.617	28.442	74.433	83.178863 (+/- 2.5e-007)	194.790	2.717	2.617	5.234	5.434	28.442	74.433	64.930	194.790
385	2.168	1.803	17.504	31.560	31.1838985 (+/- 1.9e-007)	56.902	2.427	1.803	3.606	4.854	17.504	31.560	18.967	56.902
386	2.283	1.423	14.478	20.602	13.0765756 (+/- 2.7e-007)	29.317	2.544	1.423	2.846	5.087	14.478	20.602	9.772	29.317

	Original cross section						**Modified cross section (Rectangular cross section)**							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}	mm.	mm.	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}
387	2.717	**1.565**	**19.074**	**29.851**	21.706233 (+/- 6.3e-007)	**46.717**	3.047	**1.565**	*3.130*	*6.094*	**19.074**	**29.851**	15.572	**46.717**
388	2.311	**1.247**	**12.920**	**16.111**	11.0637343 (+/- 1.5e-007)	**20.091**	2.590	**1.247**	*2.494*	*5.180*	**12.920**	**16.111**	6.697	**20.091**
389	1.959	**1.257**	**11.050**	**13.890**	8.49113942 (+/- 3.1e-007)	**17.460**	2.198	**1.257**	*2.514*	*4.395*	**11.050**	**13.890**	5.820	**17.460**
390	2.091	**1.562**	**14.441**	**22.557**	14.6921859 (+/- 2.4e-007)	**35.234**	2.311	**1.562**	*3.124*	*4.623*	**14.441**	**22.557**	11.745	**35.234**
391	2.001	**1.360**	**12.234**	**16.638**	11.3648357 (+/- 1.4e-007)	**22.628**	2.249	**1.360**	*2.720*	*4.498*	**12.234**	**16.638**	7.543	**22.628**
392	1.959	**1.532**	**13.387**	**20.509**	13.73515 (+/- 3.2e-007)	**31.420**	2.185	**1.532**	*3.064*	*4.369*	**13.387**	**20.509**	10.473	**31.420**
393	2.551	**1.614**	**18.499**	**29.857**	23.7042013 (+/- 4.7e-007)	**48.190**	2.865	**1.614**	*3.228*	*5.731*	**18.499**	**29.857**	16.063	**48.190**
394	1.515	**2.373**	**16.154**	**38.333**	46.4366467 (+/- 2.8e-007)	**90.965**	1.702	**2.373**	*4.746*	*3.404*	**16.154**	**38.333**	30.322	**90.965**
395	2.238	**2.193**	**21.896**	**48.018**	46.480947 (+/- 3.9e-007)	**105.303**	2.496	**2.193**	*4.386*	*4.992*	**21.896**	**48.018**	35.101	**105.303**
396	1.906	**1.516**	**12.988**	**19.690**	14.9755644 (+/- 4e-007)	**29.850**	2.142	**1.516**	*3.032*	*4.284*	**12.988**	**19.690**	9.950	**29.850**
397	2.005	**1.669**	**15.043**	**25.107**	20.8004227 (+/- 2.3e-007)	**41.903**	2.253	**1.669**	*3.338*	*4.507*	**15.043**	**25.107**	13.968	**41.903**
398	2.163	**1.723**	**16.655**	**28.697**	21.982643 (+/- 3.7e-007)	**49.444**	2.417	**1.723**	*3.446*	*4.833*	**16.655**	**28.697**	16.481	**49.444**
399	1.971	**2.006**	**17.748**	**35.602**	33.4930564 (+/- 3.3e-007)	**71.419**	2.212	**2.006**	*4.012*	*4.424*	**17.748**	**35.602**	23.806	**71.419**
400	2.860	**2.229**	**27.999**	**62.410**	55.5099977 (+/- 5.7e-007)	**139.111**	3.140	**2.229**	*4.458*	*6.281*	**27.999**	**62.410**	46.370	**139.111**
401	1.881	**2.181**	**18.374**	**40.074**	39.8924651 (+/- 2.7e-007)	**87.401**	2.106	**2.181**	*4.362*	*4.212*	**18.374**	**40.074**	29.134	**87.401**
402	2.148	**2.196**	**20.813**	**45.705**	41.0235352 (+/- 2.9e-007)	**100.369**	2.369	**2.196**	*4.392*	*4.739*	**20.813**	**45.705**	33.456	**100.369**
403	2.647	**2.502**	**28.398**	**71.052**	65.6074973 (+/- 3.6e-007)	**177.772**	2.838	**2.502**	*5.004*	*5.675*	**28.398**	**71.052**	59.257	**177.772**
404	2.203	**1.963**	**18.917**	**37.134**	28.9811254 (+/- 3.6e-007)	**72.894**	2.409	**1.963**	*3.926*	*4.818*	**18.917**	**37.134**	24.298	**72.894**
405	1.783	**1.796**	**14.237**	**25.570**	19.7021953 (+/- 3.2e-007)	**45.923**	1.982	**1.796**	*3.592*	*3.964*	**14.237**	**25.570**	15.308	**45.923**
406	1.978	**1.666**	**14.747**	**24.569**	18.3995985 (+/- 3e-007)	**40.931**	2.213	**1.666**	*3.332*	*4.426*	**14.747**	**24.569**	13.644	**40.931**
407	2.283	**1.669**	**16.622**	**27.742**	17.8896298 (+/- 4.1e-007)	**46.302**	2.490	**1.669**	*3.338*	*4.980*	**16.622**	**27.742**	15.434	**46.302**
408	2.417	**1.452**	**15.459**	**22.446**	13.1293179 (+/- 1.9e-007)	**32.592**	2.662	**1.452**	*2.904*	*5.323*	**15.459**	**22.446**	10.864	**32.592**
409	2.446	**1.558**	**16.912**	**26.349**	17.1938724 (+/- 5e-007)	**41.052**	2.714	**1.558**	*3.116*	*5.427*	**16.912**	**26.349**	13.684	**41.052**
410	2.214	**1.673**	**16.224**	**27.143**	17.8341922 (+/- 1.9e-007)	**45.410**	2.424	**1.673**	*3.346*	*4.849*	**16.224**	**27.143**	15.137	**45.410**
411	2.766	**1.625**	**19.481**	**31.657**	19.8925728 (+/- 3.1e-007)	**51.442**	2.997	**1.625**	*3.250*	*5.994*	**19.481**	**31.657**	17.147	**51.442**
412	2.210	**1.962**	**19.292**	**37.851**	31.849372 (+/- 2.5e-007)	**74.263**	2.458	**1.962**	*3.924*	*4.916*	**19.292**	**37.851**	24.754	**74.263**

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}	mm.	mm.	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}
413	2.329	**1.690**	**17.442**	**29.477**	20.9500621 (+/- 2.7e-007)	**49.816**	2.580	**1.690**	*3.380*	*5.160*	**17.442**	**29.477**	16.605	**49.816**
414	2.990	**1.928**	**25.636**	**49.426**	40.9267899 (+/- 4.2e-007)	**95.294**	3.324	**1.928**	*3.856*	*6.648*	**25.636**	**49.426**	31.765	**95.294**
415	2.334	**1.952**	**20.289**	**39.604**	33.2351885 (+/- 2.4e-007)	**77.307**	2.598	**1.952**	*3.904*	*5.197*	**20.289**	**39.604**	25.769	**77.307**
							Sum		1571.01	2050.15				
							Mean		3.786	4.940				

Model I: 119 weld profiles between the XL-size stiffeners (girders) and the other stiffeners

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	$mm.^2$	$mm.^3$	$mm.^4$	$mm.^4$	mm.	mm.	mm.	mm.	$mm.^2$	$mm.^3$	$mm.^4$	$mm.^4$
1	2.456	1.426	14.581	20.793	10.922676 (+/- 1.5e-006)	29.650	2.556	1.426	2.852	5.113	14.581	20.793	9.883	29.650
2	1.957	1.506	12.970	19.533	20.1117177 (+/- 5.4e-007)	29.416	2.153	1.506	3.012	4.306	12.970	19.533	9.805	29.416
3	1.771	2.134	16.735	35.712	31.601373 (+/- 1.2e-006)	76.210	1.961	2.134	4.268	3.921	16.735	35.712	25.403	76.210
4	2.781	1.697	19.894	33.760	40.4339134 (+/- 1.6e-006)	57.291	2.931	1.697	3.394	5.862	19.894	33.760	19.097	57.291
5	1.687	1.962	14.872	29.179	27.2433817 (+/- 1.4e-007)	57.249	1.895	1.962	3.924	3.790	14.872	29.179	19.083	57.249
6	1.581	1.830	13.008	23.805	22.5905578 (+/- 2.1e-007)	43.562	1.777	1.830	3.660	3.554	13.008	23.805	14.521	43.562
7	1.994	1.204	10.548	12.700	6.1269291 (+/- 1.7e-006)	15.291	2.190	1.204	2.408	4.380	10.548	12.700	5.097	15.291
8	1.962	1.150	9.922	11.410	5.2784623 (+/- 9.8e-007)	13.122	2.157	1.150	2.300	4.314	9.922	11.410	4.374	13.122
9	1.664	1.012	7.533	7.623	4.1504493 (+/- 1e-006)	7.715	1.861	1.012	2.024	3.722	7.533	7.623	2.572	7.715
10	1.707	1.143	8.777	10.032	5.8341351 (+/- 7.4e-007)	11.467	1.920	1.143	2.286	3.839	8.777	10.032	3.822	11.467
11	2.241	1.241	12.497	15.509	9.4218258 (+/- 2.4e-007)	19.246	2.518	1.241	2.482	5.035	12.497	15.509	6.415	19.246
12	2.712	1.572	19.172	30.138	23.9419668 (+/- 2e-007)	47.378	3.049	1.572	3.144	6.098	19.172	30.138	15.793	47.378
13	2.356	1.446	14.500	20.967	11.325897 (+/- 1.5e-006)	30.318	2.507	1.446	2.892	5.014	14.500	20.967	10.106	30.318
14	1.441	1.232	7.875	9.702	5.0568857 (+/- 6.4e-007)	11.953	1.598	1.232	2.464	3.196	7.875	9.702	3.984	11.953
15	1.914	1.379	11.663	16.083	9.2275051 (+/- 1.1e-006)	22.179	2.114	1.379	2.758	4.229	11.663	16.083	7.393	22.179
16	1.534	1.603	10.998	17.630	12.6710283 (+/- 9.6e-007)	28.261	1.715	1.603	3.206	3.430	10.998	17.630	9.420	28.261
17	2.134	2.054	19.599	40.256	37.1941082 (+/- 2.3e-007)	82.687	2.385	2.054	4.108	4.771	19.599	40.256	27.562	82.687
18	2.096	1.631	15.356	25.046	21.5764268 (+/- 4.1e-007)	40.849	2.354	1.631	3.262	4.708	15.356	25.046	13.616	40.849
19	1.714	1.375	10.509	14.450	8.7837208 (+/- 9.7e-007)	19.869	1.911	1.375	2.750	3.821	10.509	14.450	6.623	19.869
20	1.970	1.664	14.630	24.344	17.8738518 (+/- 1.4e-006)	40.509	2.198	1.664	3.328	4.396	14.630	24.344	13.503	40.509
21	2.348	1.802	18.729	33.750	25.4386474 (+/- 8.8e-007)	60.817	2.598	1.802	3.604	5.197	18.729	33.750	20.272	60.817
22	1.759	1.164	9.200	10.709	6.238329 (+/- 9.9e-007)	12.465	1.976	1.164	2.328	3.952	9.200	10.709	4.155	12.465
23	1.937	1.330	11.588	15.412	9.98568264 (+/- 2.3e-007)	20.498	2.178	1.330	2.660	4.356	11.588	15.412	6.833	20.498

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	$mm.^2$	$mm.^3$	$mm.^4$	$mm.^4$	mm.	mm.	mm.	mm.	$mm.^2$	$mm.^3$	$mm.^4$	$mm.^4$
24	1.888	**1.654**	**13.843**	**22.896**	15.9388267 (+/- 1.6e-007)	**37.871**	2.092	**1.654**	*3.308*	*4.185*	**13.843**	**22.896**	12.624	**37.871**
25	2.295	**2.059**	**20.133**	**41.454**	31.6226876 (+/- 1.5e-006)	**85.353**	2.445	**2.059**	*4.118*	*4.889*	**20.133**	**41.454**	28.451	**85.353**
26	1.781	**1.708**	**13.439**	**22.954**	16.0877271 (+/- 9.1e-007)	**39.205**	1.967	**1.708**	*3.416*	*3.934*	**13.439**	**22.954**	13.068	**39.205**
27	2.233	**1.323**	**12.214**	**16.159**	7.3928807 (+/- 1.4e-006)	**21.379**	2.308	**1.323**	*2.646*	*4.616*	**12.214**	**16.159**	7.126	**21.379**
28	1.459	**1.761**	**11.405**	**20.084**	14.8662037 (+/- 6.5e-007)	**35.368**	1.619	**1.761**	*3.522*	*3.238*	**11.405**	**20.084**	11.789	**35.368**
29	1.291	**1.868**	**10.789**	**20.154**	17.0477414 (+/- 7.1e-007)	**37.647**	1.444	**1.868**	*3.736*	*2.888*	**10.789**	**20.154**	12.549	**37.647**
30	1.172	**2.052**	**10.789**	**22.139**	21.9226528 (+/- 6.8e-007)	**45.429**	1.314	**2.052**	*4.104*	*2.629*	**10.789**	**22.139**	15.143	**45.429**
31	1.833	**1.897**	**15.510**	**29.422**	25.5959041 (+/- 1.7e-007)	**55.814**	2.044	**1.897**	*3.794*	*4.088*	**15.510**	**29.422**	18.605	**55.814**
32	1.703	**2.209**	**16.843**	**37.206**	37.7137288 (+/- 2.4e-007)	**82.188**	1.906	**2.209**	*4.418*	*3.812*	**16.843**	**37.206**	27.396	**82.188**
33	1.741	**1.910**	**14.910**	**28.478**	24.9907059 (+/- 2.7e-007)	**54.393**	1.952	**1.910**	*3.820*	*3.903*	**14.910**	**28.478**	18.131	**54.393**
34	1.599	**0.901**	**6.349**	**5.720**	2.0864748 (+/- 6.1e-007)	**5.154**	1.762	**0.901**	*1.802*	*3.523*	**6.349**	**5.720**	1.718	**5.154**
35	1.647	**1.128**	**8.043**	**9.073**	3.9580892 (+/- 7.7e-007)	**10.234**	1.783	**1.128**	*2.256*	*3.565*	**8.043**	**9.073**	3.411	**10.234**
36	1.612	**1.140**	**8.136**	**9.275**	4.5827726 (+/- 5.9e-007)	**10.574**	1.784	**1.140**	*2.280*	*3.568*	**8.136**	**9.275**	3.525	**10.574**
37	1.723	**1.860**	**14.046**	**26.126**	19.0801914 (+/- 7.6e-007)	**48.594**	1.888	**1.860**	*3.720*	*3.776*	**14.046**	**26.126**	16.198	**48.594**
38	1.845	**1.619**	**13.074**	**21.167**	13.6904258 (+/- 7.4e-007)	**34.269**	2.019	**1.619**	*3.238*	*4.038*	**13.074**	**21.167**	11.423	**34.269**
39	1.632	**1.467**	**10.701**	**15.698**	10.5115136 (+/- 4.4e-007)	**23.030**	1.824	**1.467**	*2.934*	*3.647*	**10.701**	**15.698**	7.677	**23.030**
40	1.908	**1.400**	**11.824**	**16.554**	9.66399101 (+/- 2.5e-007)	**23.175**	2.111	**1.400**	*2.800*	*4.223*	**11.824**	**16.554**	7.725	**23.175**
41	1.812	**1.741**	**14.130**	**24.600**	19.6319186 (+/- 1.4e-007)	**42.829**	2.029	**1.741**	*3.482*	*4.058*	**14.130**	**24.600**	14.276	**42.829**
42	2.116	**1.897**	**18.008**	**34.161**	30.2196877 (+/- 1.8e-007)	**64.804**	2.373	**1.897**	*3.794*	*4.746*	**18.008**	**34.161**	21.601	**64.804**
43	1.803	**1.600**	**12.868**	**20.589**	16.175743 (+/- 1.7e-006)	**32.942**	2.011	**1.600**	*3.200*	*4.021*	**12.868**	**20.589**	10.981	**32.942**
44	1.451	**1.336**	**8.547**	**11.419**	6.1698604 (+/- 1.6e-006)	**15.256**	1.599	**1.336**	*2.672*	*3.199*	**8.547**	**11.419**	5.085	**15.256**
45	1.765	**1.535**	**11.732**	**18.009**	10.538439 (+/- 1.3e-006)	**27.643**	1.911	**1.535**	*3.070*	*3.821*	**11.732**	**18.009**	9.214	**27.643**
46	1.804	**1.870**	**14.939**	**27.936**	21.7873379 (+/- 1.1e-006)	**52.240**	1.997	**1.870**	*3.740*	*3.994*	**14.939**	**27.936**	17.413	**52.240**
47	1.750	**1.832**	**14.022**	**25.688**	18.4670244 (+/- 1.4e-006)	**47.061**	1.913	**1.832**	*3.664*	*3.827*	**14.022**	**25.688**	15.687	**47.061**
48	1.686	**1.829**	**13.552**	**24.787**	18.19216 (+/- 2e-006)	**45.335**	1.852	**1.829**	*3.658*	*3.705*	**13.552**	**24.787**	15.112	**45.335**
49	1.523	**1.984**	**13.528**	**26.840**	23.992229 (+/- 6.1e-008)	**53.250**	1.705	**1.984**	*3.968*	*3.409*	**13.528**	**26.840**	17.750	**53.250**

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	$mm.^2$	$mm.^3$	$mm.^4$	$mm.^4$	mm.	mm.	mm.	mm.	$mm.^2$	$mm.^3$	$mm.^4$	$mm.^4$
50	1.806	1.832	14.795	27.104	22.3521629 (+/- 2.8e-008)	49.655	2.019	1.832	3.664	4.038	14.795	27.104	16.552	49.655
51	2.146	2.020	19.458	39.305	36.9645675 (+/- 1.2e-007)	79.396	2.408	2.020	4.040	4.816	19.458	39.305	26.465	79.396
52	1.653	1.558	11.442	17.827	12.0529882 (+/- 8.6e-007)	27.774	1.836	1.558	3.116	3.672	11.442	17.827	9.258	27.774
53	1.557	1.270	8.812	11.191	6.150283 (+/- 8.6e-007)	14.213	1.735	1.270	2.540	3.469	8.812	11.191	4.738	14.213
54	1.646	1.479	10.776	15.938	9.92153263 (+/- 6.7e-007)	23.572	1.822	1.479	2.958	3.643	10.776	15.938	7.857	23.572
55	1.636	1.331	9.764	12.996	7.99669012 (+/- 8e-007)	17.298	1.834	1.331	2.662	3.668	9.764	12.996	5.766	17.298
56	1.745	0.905	6.987	6.323	2.423675 (+/- 5.1e-007)	5.723	1.930	0.905	1.810	3.860	6.987	6.323	1.908	5.723
57	2.011	0.909	8.150	7.408	2.992771 (+/- 7.8e-007)	6.734	2.241	0.909	1.818	4.483	8.150	7.408	2.245	6.734
58	1.635	1.871	13.681	25.597	21.4318872 (+/- 8.4e-008)	47.892	1.828	1.871	3.742	3.656	13.681	25.597	15.964	47.892
59	1.663	1.626	12.118	19.704	14.8326963 (+/- 6.7e-008)	32.038	1.863	1.626	3.252	3.726	12.118	19.704	10.679	32.038
60	1.795	1.787	14.097	25.191	18.0962665 (+/- 1.3e-007)	45.017	1.972	1.787	3.574	3.944	14.097	25.191	15.006	45.017
61	1.947	1.515	13.092	19.834	12.5820441 (+/- 1.9e-008)	30.049	2.160	1.515	3.030	4.321	13.092	19.834	10.016	30.049
62	1.887	1.394	11.327	15.790	8.22099696 (+/- 3.5e-009)	22.011	2.031	1.394	2.788	4.063	11.327	15.790	7.337	22.011
63	2.331	1.735	17.655	30.631	20.7060319 (+/- 1e-008)	53.146	2.544	1.735	3.470	5.088	17.655	30.631	17.715	53.146
64	2.227	1.408	13.612	19.166	10.6867543 (+/- 1.3e-008)	26.985	2.417	1.408	2.816	4.834	13.612	19.166	8.995	26.985
65	1.624	2.000	14.422	28.844	24.3371338 (+/- 9.6e-008)	57.688	1.803	2.000	4.000	3.606	14.422	28.844	19.229	57.688
66	1.661	1.877	13.990	26.259	23.9258252 (+/- 6.6e-008)	49.289	1.863	1.877	3.754	3.727	13.990	26.259	16.430	49.289
67	1.888	1.552	13.071	20.286	13.8143535 (+/- 1.1e-007)	31.484	2.106	1.552	3.104	4.211	13.071	20.286	10.495	31.484
68	1.756	1.469	11.584	17.017	11.9561175 (+/- 1.1e-008)	24.998	1.971	1.469	2.938	3.943	11.584	17.017	8.333	24.998
69	2.021	1.608	14.129	22.719	13.9936464 (+/- 1e-008)	36.533	2.197	1.608	3.216	4.393	14.129	22.719	12.178	36.533
70	1.369	1.092	6.713	7.331	4.20732888 (+/- 1e-009)	8.005	1.537	1.092	2.184	3.074	6.713	7.331	2.668	8.005
71	1.980	1.760	15.604	27.463	21.7439714 (+/- 7.8e-008)	48.335	2.216	1.760	3.520	4.433	15.604	27.463	16.112	48.335
72	1.660	1.886	14.037	26.474	23.9521424 (+/- 9.1e-008)	49.930	1.861	1.886	3.772	3.721	14.037	26.474	16.643	49.930
73	1.691	2.052	15.346	31.490	26.5981986 (+/- 4e-008)	64.617	1.870	2.052	4.104	3.739	15.346	31.490	21.539	64.617
74	1.965	1.335	11.131	14.860	7.18112021 (+/- 1e-009)	19.838	2.084	1.335	2.670	4.169	11.131	14.860	6.613	19.838
75	1.722	1.179	9.021	10.636	5.47064383 (+/- 2.6e-009)	12.540	1.913	1.179	2.358	3.826	9.021	10.636	4.180	12.540

	Original cross section: Centroid to vertical axis	Original cross section: Centroid to horizontal axis	Original cross section: Area	Original cross section: First moment of area	Original cross section: Local moment of inertia	Original cross section: Second moment of area	Modified cross section (Rectangular cross section): Centroid to vertical axis	Modified cross section (Rectangular cross section): Centroid to horizontal axis	Modified cross section (Rectangular cross section): Dimension h	Modified cross section (Rectangular cross section): Dimension b	Modified cross section (Rectangular cross section): Area	Modified cross section (Rectangular cross section): First moment of area	Modified cross section (Rectangular cross section): Local moment of inertia	Modified cross section (Rectangular cross section): Second moment of area
	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}	mm.	mm.	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}
76	1.610	1.848	13.236	24.460	19.3112346 (+/- 1e-008)	45.202	1.791	1.848	3.696	3.581	13.236	24.460	15.067	45.202
77	1.841	1.383	11.426	15.802	10.3195283 (+/- 7.7e-008)	21.854	2.065	1.383	2.766	4.131	11.426	15.802	7.285	21.854
78	1.369	1.743	10.724	18.692	16.9827306 (+/- 1.3e-007)	32.580	1.538	1.743	3.486	3.076	10.724	18.692	10.860	32.580
79	1.701	1.363	10.381	14.149	8.7576173 (+/- 7.4e-009)	19.285	1.904	1.363	2.726	3.808	10.381	14.149	6.428	19.285
80	1.491	1.420	9.512	13.507	9.07823895 (+/- 1.2e-008)	19.180	1.675	1.420	2.840	3.349	9.512	13.507	6.393	19.180
81	1.870	1.693	13.930	23.583	16.7887474 (+/- 2e-008)	39.927	2.057	1.693	3.386	4.114	13.930	23.583	13.309	39.927
82	1.358	1.905	11.407	21.730	16.7262001 (+/- 1e-008)	41.396	1.497	1.905	3.810	2.994	11.407	21.730	13.799	41.396
83	1.907	1.600	13.600	21.760	15.202686 (+/- 5.4e-008)	34.816	2.125	1.600	3.200	4.250	13.600	21.760	11.605	34.816
84	1.730	1.676	12.991	21.773	16.5634909 (+/- 8.1e-008)	36.491	1.938	1.676	3.352	3.876	12.991	21.773	12.164	36.491
85	1.913	1.801	15.392	27.721	22.5740066 (+/- 1.6e-008)	49.926	2.137	1.801	3.602	4.273	15.392	27.721	16.642	49.926
86	1.633	1.572	11.303	17.768	11.3457138 (+/- 4.2e-008)	27.932	1.798	1.572	3.144	3.595	11.303	17.768	9.311	27.932
87	1.502	1.460	9.798	14.305	9.27956717 (+/- 1.4e-008)	20.885	1.678	1.460	2.920	3.355	9.798	14.305	6.962	20.885
88	2.140	1.736	16.166	28.064	19.3752844 (+/- 1e-008)	48.719	2.328	1.736	3.472	4.656	16.166	28.064	16.240	48.719
89	2.055	1.562	13.684	21.374	12.2852652 (+/- 1e-008)	33.387	2.190	1.562	3.124	4.380	13.684	21.374	11.129	33.387
90	1.540	1.185	7.969	9.443	4.36268405 (+/- 6.9e-009)	11.190	1.681	1.185	2.370	3.362	7.969	9.443	3.730	11.190
91	1.819	1.651	13.471	22.241	16.9392796 (+/- 6.2e-008)	36.719	2.040	1.651	3.302	4.080	13.471	22.241	12.240	36.719
92	1.530	1.477	10.153	14.996	10.6737036 (+/- 4.7e-008)	22.149	1.719	1.477	2.954	3.437	10.153	14.996	7.383	22.149
93	1.988	1.593	14.242	22.688	18.4713083 (+/- 7.5e-008)	36.141	2.235	1.593	3.186	4.470	14.242	22.688	12.047	36.141
94	1.765	1.371	10.579	14.504	7.86814845 (+/- 1.5e-008)	19.885	1.929	1.371	2.742	3.858	10.579	14.504	6.628	19.885
95	1.864	1.405	11.432	16.062	8.89503242 (+/- 9.8e-008)	22.567	2.034	1.405	2.810	4.068	11.432	16.062	7.522	22.567
96	1.790	1.335	10.637	14.200	8.19014246 (+/- 1.2e-008)	18.958	1.992	1.335	2.670	3.984	10.637	14.200	6.319	18.958
97	2.304	1.641	15.723	25.801	16.0066119 (+/- 2.7e-008)	42.340	2.395	1.641	3.282	4.791	15.723	25.801	14.113	42.340
98	1.851	1.241	8.703	10.800	4.44277123 (+/- 1.5e-007)	13.403	1.753	1.241	2.482	3.506	8.703	10.800	4.468	13.403
99	1.799	1.811	14.457	26.182	20.0354997 (+/- 5.7e-008)	47.415	1.996	1.811	3.622	3.991	14.457	26.182	15.805	47.415
100	1.770	1.697	13.495	22.901	18.381784 (+/- 5.7e-008)	38.863	1.988	1.697	3.394	3.976	13.495	22.901	12.954	38.863
101	1.802	1.720	13.888	23.887	18.6694263 (+/- 8.1e-008)	41.086	2.019	1.720	3.440	4.037	13.888	23.887	13.695	41.086

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}	mm.	mm.	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}
102	2.144	1.571	14.618	22.965	13.932997 (+/- 1e-008)	36.078	2.326	1.571	3.142	4.652	14.618	22.965	12.026	36.078
103	1.774	1.244	9.848	12.251	6.76534706 (+/- 4.1e-007)	15.240	1.979	1.244	2.488	3.958	9.848	12.251	5.080	15.240
104	1.815	1.665	13.397	22.306	15.6166005 (+/- 1e-008)	37.139	2.012	1.665	3.330	4.023	13.397	22.306	12.380	37.139
105	2.069	1.522	13.883	21.130	12.9583775 (+/- 1e-008)	32.160	2.280	1.522	3.044	4.561	13.883	21.130	10.720	32.160
106	1.848	1.614	12.979	20.948	12.9771165 (+/- 1e-008)	33.810	2.010	1.614	3.228	4.021	12.979	20.948	11.270	33.810
107	2.297	2.612	26.808	70.022	94.4824488 (+/- 5e-008)	182.899	2.566	2.612	5.224	5.132	26.808	70.022	60.966	182.899
108	1.864	2.038	16.797	34.232	28.9996658 (+/- 2.9e-008)	69.765	2.060	2.038	4.076	4.121	16.797	34.232	23.255	69.765
109	1.450	1.889	12.262	23.163	20.4189251 (+/- 3e-008)	43.755	1.623	1.889	3.778	3.246	12.262	23.163	14.585	43.755
110	1.709	1.829	13.954	25.522	20.6681787 (+/- 7.1e-007)	46.679	1.907	1.829	3.658	3.815	13.954	25.522	15.560	46.679
111	1.955	2.020	17.495	35.340	29.7829581 (+/- 1.8e-008)	71.387	2.165	2.020	4.040	4.330	17.495	35.340	23.796	71.387
112	1.389	1.537	9.531	14.649	9.97451743 (+/- 4.2e-008)	22.516	1.550	1.537	3.074	3.101	9.531	14.649	7.505	22.516
113	2.256	1.518	15.298	23.222	15.522972 (+/- 1e-008)	35.252	2.519	1.518	3.036	5.039	15.298	23.222	11.751	35.252
114	2.082	2.095	19.440	40.727	37.0548736 (+/- 4.1e-008)	85.323	2.320	2.095	4.190	4.640	19.440	40.727	28.441	85.323
115	1.816	2.051	16.650	34.149	31.5471015 (+/- 2.7e-008)	70.040	2.029	2.051	4.102	4.059	16.650	34.149	23.347	70.040
116	1.674	1.552	11.651	18.082	12.9928281 (+/- 1e-008)	28.064	1.877	1.552	3.104	3.754	11.651	18.082	9.355	28.064
117	1.603	2.219	15.823	35.111	33.2512705 (+/- 3.4e-008)	77.912	1.783	2.219	4.438	3.565	15.823	35.111	25.971	77.912
118	1.944	2.236	19.286	43.123	40.9273046 (+/- 4e-008)	96.424	2.156	2.236	4.472	4.313	19.286	43.123	32.141	96.424
119	2.210	1.903	18.667	35.523	28.607623 (+/- 5.5e-008)	67.601	2.452	1.903	3.806	4.905	18.667	35.523	22.534	67.601
							Sum		385.18	480.67				
							Mean		3.237	4.039				

Model I: 165 weld profiles between flanges and webs of the longitudinal girders

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}	mm.	mm.	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}
1	1.817	1.699	13.831	23.499	21.9630066 (+/- 3.8e-008)	39.925	2.035	1.699	3.398	4.070	13.831	23.499	13.308	39.925
2	1.687	1.378	10.439	14.385	10.2519214 (+/- 5.1e-008)	19.822	1.894	1.378	2.756	3.788	10.439	14.385	6.607	19.822
3	1.957	1.464	12.862	18.830	14.0156503 (+/- 1.4e-008)	27.567	2.196	1.464	2.928	4.393	12.862	18.830	9.189	27.567
4	1.661	1.610	12.019	19.351	15.1445107 (+/- 1.3e-008)	31.154	1.866	1.610	3.220	3.733	12.019	19.351	10.385	31.154
5	2.229	1.529	14.449	22.093	24.2319539 (+/- 3.7e-008)	33.779	2.362	1.529	3.058	4.725	14.449	22.093	11.260	33.779
6	1.531	1.360	9.339	12.701	9.35894711 (+/- 3e-008)	17.273	1.717	1.360	2.720	3.433	9.339	12.701	5.758	17.273
7	1.747	1.500	11.787	17.681	13.238647 (+/- 4.5e-008)	26.521	1.965	1.500	3.000	3.929	11.787	17.681	8.840	26.521
8	1.480	1.682	11.173	18.793	15.9596416 (+/- 1e-008)	31.610	1.661	1.682	3.364	3.321	11.173	18.793	10.537	31.610
9	1.813	1.298	10.527	13.664	9.88285849 (+/- 2e-008)	17.736	2.028	1.298	2.596	4.055	10.527	13.664	5.912	17.736
10	1.872	1.591	13.338	21.221	18.4287799 (+/- 1e-008)	33.762	2.096	1.591	3.182	4.192	13.338	21.221	11.254	33.762
11	1.446	1.531	9.938	15.215	11.5073291 (+/- 1.4e-008)	23.294	1.623	1.531	3.062	3.246	9.938	15.215	7.765	23.294
12	1.830	1.531	12.529	19.182	13.1771686 (+/- 1e-008)	29.367	2.046	1.531	3.062	4.092	12.529	19.182	9.789	29.367
13	1.767	1.240	9.841	12.203	7.48709155 (+/- 4.9e-009)	15.132	1.984	1.240	2.480	3.968	9.841	12.203	5.044	15.132
14	1.736	1.269	9.732	12.350	9.6413481 (+/- 3.7e-008)	15.672	1.917	1.269	2.538	3.835	9.732	12.350	5.224	15.672
15	2.415	1.518	16.432	24.944	20.6146426 (+/- 2.3e-008)	37.865	2.706	1.518	3.036	5.412	16.432	24.944	12.622	37.865
16	1.618	1.344	9.733	13.081	8.08494333 (+/- 7.1e-009)	17.581	1.810	1.344	2.688	3.621	9.733	13.081	5.860	17.581
17	1.864	1.532	12.824	19.646	14.2694247 (+/- 3.4e-008)	30.098	2.093	1.532	3.064	4.185	12.824	19.646	10.033	30.098
18	1.642	1.221	9.013	11.005	6.93532549 (+/- 4e-009)	13.437	1.845	1.221	2.442	3.691	9.013	11.005	4.479	13.437
19	1.677	1.354	10.187	13.793	9.6807043 (+/- 2.5e-008)	18.676	1.881	1.354	2.708	3.762	10.187	13.793	6.225	18.676
20	1.600	1.856	13.286	24.659	25.503899 (+/- 3e-008)	45.767	1.790	1.856	3.712	3.579	13.286	24.659	15.256	45.767
21	1.699	1.884	14.323	26.985	25.0559624 (+/- 1.4e-008)	50.839	1.901	1.884	3.768	3.801	14.323	26.985	16.946	50.839
22	1.782	1.582	12.672	20.047	15.4422211 (+/- 1.7e-008)	31.715	2.003	1.582	3.164	4.005	12.672	20.047	10.572	31.715
23	1.939	1.701	14.827	25.221	20.9789719 (+/- 1.2e-008)	42.900	2.179	1.701	3.402	4.358	14.827	25.221	14.300	42.900

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}	mm.	mm.	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}
24	1.922	1.940	16.724	32.445	29.1575314 (+/- 4.2e-008)	62.942	2.155	1.940	3.880	4.310	16.724	32.445	20.981	62.942
25	1.988	1.953	17.429	34.039	32.8411997 (+/- 3.8e-008)	66.478	2.231	1.953	3.906	4.462	17.429	34.039	22.159	66.478
26	2.001	1.831	16.463	30.144	26.2556669 (+/- 4.1e-008)	55.193	2.248	1.831	3.662	4.496	16.463	30.144	18.398	55.193
27	1.557	1.724	12.027	20.735	16.2650907 (+/- 1.6e-008)	35.746	1.744	1.724	3.448	3.488	12.027	20.735	11.915	35.746
28	1.729	2.102	16.335	34.336	34.4060864 (+/- 1.7e-007)	72.175	1.943	2.102	4.204	3.886	16.335	34.336	24.058	72.175
29	2.017	1.927	17.394	33.518	28.8774471 (+/- 2e-008)	64.590	2.257	1.927	3.854	4.513	17.394	33.518	21.530	64.590
30	1.789	1.517	12.200	18.507	14.2038997 (+/- 1.7e-008)	28.076	2.011	1.517	3.034	4.021	12.200	18.507	9.359	28.076
31	1.973	1.741	15.395	26.803	21.3741244 (+/- 1.3e-008)	46.663	2.211	1.741	3.482	4.421	15.395	26.803	15.554	46.663
32	2.696	2.218	25.983	57.630	50.4465455 (+/- 4.6e-008)	127.824	2.929	2.218	4.436	5.857	25.983	57.630	42.608	127.824
33	1.476	1.349	8.947	12.070	7.87628137 (+/- 3.5e-008)	16.282	1.658	1.349	2.698	3.316	8.947	12.070	5.427	16.282
34	1.672	1.325	9.953	13.188	8.71049309 (+/- 4.7e-009)	17.474	1.878	1.325	2.650	3.756	9.953	13.188	5.825	17.474
35	1.798	1.191	9.610	11.446	7.2903843 (+/- 2.6e-008)	13.632	2.017	1.191	2.382	4.034	9.610	11.446	4.544	13.632
36	1.920	1.098	9.459	10.386	6.07328347 (+/- 4.6e-009)	11.404	2.154	1.098	2.196	4.307	9.459	10.386	3.801	11.404
37	1.593	1.229	8.751	10.755	7.29165166 (+/- 7.3e-009)	13.218	1.780	1.229	2.458	3.560	8.751	10.755	4.406	13.218
38	1.856	1.294	10.780	13.949	10.2833406 (+/- 3.1e-007)	18.050	2.083	1.294	2.588	4.165	10.780	13.949	6.017	18.050
39	1.737	1.606	12.414	19.937	18.7533191 (+/- 1.4e-008)	32.019	1.932	1.606	3.212	3.865	12.414	19.937	10.673	32.019
40	1.893	1.352	11.472	15.510	11.3236895 (+/- 2.8e-008)	20.970	2.121	1.352	2.704	4.243	11.472	15.510	6.990	20.970
41	1.716	1.150	8.863	10.192	6.02993675 (+/- 8.4e-009)	11.721	1.927	1.150	2.300	3.853	8.863	10.192	3.907	11.721
42	1.944	1.013	8.857	8.972	4.59930441 (+/- 1e-008)	9.089	2.186	1.013	2.026	4.372	8.857	8.972	3.030	9.089
43	1.810	1.104	8.961	9.893	5.16498484 (+/- 7.3e-009)	10.922	2.029	1.104	2.208	4.058	8.961	9.893	3.641	10.922
44	1.714	1.384	10.619	14.697	11.259025 (+/- 4e-008)	20.340	1.918	1.384	2.768	3.836	10.619	14.697	6.780	20.340
45	1.738	1.189	9.271	11.023	7.05713677 (+/- 3.1e-008)	13.107	1.949	1.189	2.378	3.899	9.271	11.023	4.369	13.107
46	1.552	1.533	10.680	16.372	13.2304981 (+/- 1.5e-008)	25.099	1.742	1.533	3.066	3.483	10.680	16.372	8.366	25.099
47	1.174	1.349	7.054	9.516	7.27064492 (+/- 4.9e-009)	12.837	1.307	1.349	2.698	2.615	7.054	9.516	4.279	12.837
48	1.378	1.613	9.959	16.064	12.1286021 (+/- 1e-008)	25.911	1.544	1.613	3.226	3.087	9.959	16.064	8.637	25.911
49	1.276	1.781	10.208	18.180	16.9232557 (+/- 6.6e-008)	32.379	1.433	1.781	3.562	2.866	10.208	18.180	10.793	32.379

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}	mm.	mm.	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}
50	1.256	**1.752**	**9.893**	**17.333**	14.8600514 (+/- 1e-008)	**30.367**	1.412	**1.752**	*3.504*	*2.823*	**9.893**	**17.333**	10.122	**30.367**
51	1.222	**1.873**	**10.263**	**19.223**	17.911763 (+/- 1e-008)	**36.004**	1.370	**1.873**	*3.746*	*2.740*	**10.263**	**19.223**	12.001	**36.004**
52	1.913	**1.671**	**14.340**	**23.962**	19.0285972 (+/- 1e-008)	**40.041**	2.145	**1.671**	*3.342*	*4.291*	**14.340**	**23.962**	13.347	**40.041**
53	1.474	**1.720**	**11.375**	**19.565**	15.6087192 (+/- 1e-008)	**33.652**	1.653	**1.720**	*3.440*	*3.307*	**11.375**	**19.565**	11.217	**33.652**
54	1.531	**1.664**	**11.444**	**19.043**	15.8887744 (+/- 1e-008)	**31.687**	1.719	**1.664**	*3.328*	*3.439*	**11.444**	**19.043**	10.562	**31.687**
55	1.652	**1.574**	**11.638**	**18.318**	13.0681953 (+/- 1.1e-008)	**28.833**	1.848	**1.574**	*3.148*	*3.697*	**11.638**	**18.318**	9.611	**28.833**
56	1.440	**1.892**	**12.057**	**22.812**	18.2792663 (+/- 2.8e-008)	**43.160**	1.593	**1.892**	*3.784*	*3.186*	**12.057**	**22.812**	14.387	**43.160**
57	1.592	**1.699**	**12.155**	**20.651**	17.6183651 (+/- 1e-008)	**35.087**	1.789	**1.699**	*3.398*	*3.577*	**12.155**	**20.651**	11.696	**35.087**
58	1.892	**1.782**	**15.117**	**26.938**	25.835616 (+/- 3.2e-008)	**48.004**	2.121	**1.782**	*3.564*	*4.242*	**15.117**	**26.938**	16.001	**48.004**
59	1.741	**1.567**	**12.258**	**19.208**	15.4428378 (+/- 1.4e-008)	**30.099**	1.956	**1.567**	*3.134*	*3.911*	**12.258**	**19.208**	10.033	**30.099**
60	1.859	**1.508**	**12.584**	**18.977**	13.8504628 (+/- 1e-008)	**28.617**	2.086	**1.508**	*3.016*	*4.172*	**12.584**	**18.977**	9.539	**28.617**
61	1.683	**1.596**	**11.968**	**19.101**	17.705649 (+/- 1e-008)	**30.485**	1.875	**1.596**	*3.192*	*3.749*	**11.968**	**19.101**	10.162	**30.485**
62	1.908	**1.905**	**16.289**	**31.031**	31.8397904 (+/- 1e-008)	**59.113**	2.138	**1.905**	*3.810*	*4.275*	**16.289**	**31.031**	19.704	**59.113**
63	2.196	**1.706**	**16.751**	**28.577**	21.6843326 (+/- 1e-008)	**48.753**	2.455	**1.706**	*3.412*	*4.909*	**16.751**	**28.577**	16.251	**48.753**
64	2.123	**1.733**	**16.440**	**28.491**	22.0528289 (+/- 7.5e-008)	**49.374**	2.372	**1.733**	*3.466*	*4.743*	**16.440**	**28.491**	16.458	**49.374**
65	2.077	**1.827**	**16.991**	**31.043**	25.7535579 (+/- 1e-008)	**56.715**	2.325	**1.827**	*3.654*	*4.650*	**16.991**	**31.043**	18.905	**56.715**
66	2.047	**2.390**	**21.848**	**52.217**	54.7900162 (+/- 3.2e-008)	**124.798**	2.285	**2.390**	*4.780*	*4.571*	**21.848**	**52.217**	41.599	**124.798**
67	2.454	**2.172**	**23.953**	**52.026**	53.5001373 (+/- 2.9e-008)	**113.000**	2.757	**2.172**	*4.344*	*5.514*	**23.953**	**52.026**	37.667	**113.000**
68	1.773	**1.488**	**11.839**	**17.616**	14.0426764 (+/- 1e-008)	**26.213**	1.989	**1.488**	*2.976*	*3.978*	**11.839**	**17.616**	8.738	**26.213**
69	1.866	**1.449**	**12.155**	**17.613**	12.4968181 (+/- 1e-008)	**25.521**	2.097	**1.449**	*2.898*	*4.194*	**12.155**	**17.613**	8.507	**25.521**
70	1.596	**1.613**	**11.578**	**18.675**	14.9874723 (+/- 1e-008)	**30.123**	1.794	**1.613**	*3.226*	*3.589*	**11.578**	**18.675**	10.041	**30.123**
71	1.567	**1.830**	**12.854**	**23.523**	20.2575134 (+/- 6.2e-008)	**43.047**	1.756	**1.830**	*3.660*	*3.512*	**12.854**	**23.523**	14.349	**43.047**
72	2.360	**1.806**	**19.149**	**34.583**	30.8353644 (+/- 1.1e-008)	**62.457**	2.651	**1.806**	*3.612*	*5.301*	**19.149**	**34.583**	20.819	**62.457**
73	1.964	**1.452**	**12.763**	**18.532**	14.4417456 (+/- 1.3e-008)	**26.908**	2.197	**1.452**	*2.904*	*4.395*	**12.763**	**18.532**	8.969	**26.908**
74	1.827	**1.423**	**11.654**	**16.584**	11.2407047 (+/- 1e-008)	**23.599**	2.047	**1.423**	*2.846*	*4.095*	**11.654**	**16.584**	7.866	**23.599**
75	1.570	**1.393**	**9.830**	**13.693**	9.8377444 (+/- 1.1e-008)	**19.075**	1.764	**1.393**	*2.786*	*3.528*	**9.830**	**13.693**	6.358	**19.075**

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}	mm.	mm.	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}
76	1.620	1.323	9.616	12.722	9.00595063 (+/- 2.2e-008)	16.831	1.817	1.323	2.646	3.634	9.616	12.722	5.610	16.831
77	1.848	1.524	12.658	19.291	14.7072605 (+/- 1.5e-008)	29.399	2.076	1.524	3.048	4.153	12.658	19.291	9.800	29.399
78	2.031	1.588	14.437	22.926	16.4489339 (+/- 5.4e-008)	36.406	2.273	1.588	3.176	4.546	14.437	22.926	12.135	36.406
79	1.947	1.558	13.558	21.123	14.6609312 (+/- 1e-008)	32.910	2.176	1.558	3.116	4.351	13.558	21.123	10.970	32.910
80	1.874	1.610	13.559	21.830	16.7904895 (+/- 1e-008)	35.146	2.105	1.610	3.220	4.211	13.559	21.830	11.715	35.146
81	1.664	1.834	13.648	25.030	25.8119842 (+/- 1.5e-008)	45.906	1.860	1.834	3.668	3.721	13.648	25.030	15.302	45.906
82	1.839	2.060	17.028	35.078	34.3691632 (+/- 5.4e-008)	72.260	2.067	2.060	4.120	4.133	17.028	35.078	24.087	72.260
83	1.772	2.044	16.247	33.209	31.3562943 (+/- 1.4e-008)	67.879	1.987	2.044	4.088	3.974	16.247	33.209	22.626	67.879
84	2.412	1.870	20.249	37.866	34.163392 (+/- 3.7e-008)	70.809	2.707	1.870	3.740	5.414	20.249	37.866	23.603	70.809
85	1.801	1.416	11.441	16.200	11.8691102 (+/- 1e-008)	22.940	2.020	1.416	2.832	4.040	11.441	16.200	7.647	22.940
86	1.409	1.195	7.533	9.002	6.0514355 (+/- 8.6e-009)	10.757	1.576	1.195	2.390	3.152	7.533	9.002	3.586	10.757
87	1.245	1.749	9.674	16.920	17.7930515 (+/- 1.2e-007)	29.593	1.383	1.749	3.498	2.766	9.674	16.920	9.864	29.593
88	1.558	1.486	10.394	15.445	10.9973718 (+/- 1.4e-008)	22.952	1.749	1.486	2.972	3.497	10.394	15.445	7.651	22.952
89	1.285	1.838	10.604	19.490	16.9860207 (+/- 1e-008)	35.823	1.442	1.838	3.676	2.885	10.604	19.490	11.941	35.823
90	1.091	1.540	7.526	11.590	9.69648251 (+/- 1e-009)	17.849	1.222	1.540	3.080	2.444	7.526	11.590	5.950	17.849
91	1.476	2.062	13.574	27.990	25.4518461 (+/- 3.5e-008)	57.715	1.646	2.062	4.124	3.291	13.574	27.990	19.238	57.715
92	1.232	1.432	7.910	11.327	8.93024568 (+/- 1e-009)	16.220	1.381	1.432	2.864	2.762	7.910	11.327	5.407	16.220
93	1.560	1.731	12.081	20.912	16.1815494 (+/- 1e-008)	36.199	1.745	1.731	3.462	3.490	12.081	20.912	12.066	36.199
94	1.593	1.704	12.182	20.758	16.6272486 (+/- 1e-008)	35.372	1.787	1.704	3.408	3.575	12.182	20.758	11.791	35.372
95	1.725	1.663	12.897	21.448	17.0464206 (+/- 1e-008)	35.668	1.939	1.663	3.326	3.878	12.897	21.448	11.889	35.668
96	1.380	1.663	10.296	17.122	13.121638 (+/- 1.4e-008)	28.474	1.548	1.663	3.326	3.096	10.296	17.122	9.491	28.474
97	1.559	1.442	10.074	14.527	9.90100479 (+/- 9.5e-008)	20.948	1.747	1.442	2.884	3.493	10.074	14.527	6.983	20.948
98	1.636	1.501	11.041	16.573	12.01459 (+/- 1.6e-008)	24.875	1.839	1.501	3.002	3.678	11.041	16.573	8.292	24.875
99	1.625	1.376	10.043	13.819	9.87360839 (+/- 9.3e-009)	19.015	1.825	1.376	2.752	3.649	10.043	13.819	6.338	19.015
100	1.398	1.359	8.538	11.603	7.6852541 (+/- 4.4e-009)	15.769	1.571	1.359	2.718	3.141	8.538	11.603	5.256	15.769
101	1.592	1.104	7.720	8.523	5.91393127 (+/- 1.8e-008)	9.409	1.748	1.104	2.208	3.496	7.720	8.523	3.136	9.409

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}	mm.	mm.	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}
102	1.518	1.373	9.365	12.858	8.53958504 (+/- 1.2e-008)	17.654	1.705	1.373	2.746	3.410	9.365	12.858	5.885	17.654
103	1.422	1.168	7.465	8.719	4.88461257 (+/- 1e-009)	10.184	1.598	1.168	2.336	3.196	7.465	8.719	3.395	10.184
104	1.337	1.338	8.038	10.755	7.01195449 (+/- 5e-009)	14.390	1.502	1.338	2.676	3.004	8.038	10.755	4.797	14.390
105	1.541	1.596	10.953	17.481	12.4220738 (+/- 1.2e-008)	27.900	1.716	1.596	3.192	3.431	10.953	17.481	9.300	27.900
106	1.428	1.306	8.370	10.931	6.83705099 (+/- 4.2e-008)	14.276	1.602	1.306	2.612	3.204	8.370	10.931	4.759	14.276
107	1.179	1.408	7.461	10.505	7.60078264 (+/- 1.5e-008)	14.791	1.325	1.408	2.816	2.650	7.461	10.505	4.930	14.791
108	1.435	1.489	9.522	14.178	12.0770023 (+/- 2e-008)	21.111	1.599	1.489	2.978	3.197	9.522	14.178	7.037	21.111
109	1.453	1.401	9.141	12.807	9.52827384 (+/- 2.5e-008)	17.942	1.631	1.401	2.802	3.262	9.141	12.807	5.981	17.942
110	1.433	1.584	10.202	16.160	13.4522076 (+/- 1e-008)	25.597	1.610	1.584	3.168	3.220	10.202	16.160	8.532	25.597
111	1.561	1.562	10.956	17.113	13.4529266 (+/- 1.8e-008)	26.731	1.754	1.562	3.124	3.507	10.956	17.113	8.910	26.731
112	1.733	1.536	11.972	18.389	14.1254139 (+/- 2.3e-008)	28.245	1.949	1.536	3.072	3.897	11.972	18.389	9.415	28.245
113	2.310	2.040	21.173	43.193	42.3533092 (+/- 2.4e-008)	88.114	2.595	2.040	4.080	5.189	21.173	43.193	29.371	88.114
114	1.915	1.554	13.342	20.733	16.9687454 (+/- 1.1e-008)	32.220	2.146	1.554	3.108	4.293	13.342	20.733	10.740	32.220
115	1.816	1.573	12.802	20.138	16.8745643 (+/- 1e-008)	31.676	2.035	1.573	3.146	4.069	12.802	20.138	10.559	31.676
116	2.394	1.906	20.425	38.930	33.6693654 (+/- 1e-008)	74.201	2.679	1.906	3.812	5.358	20.425	38.930	24.734	74.201
117	2.675	2.296	27.353	62.802	62.2249537 (+/- 3.9e-008)	144.195	2.978	2.296	4.592	5.957	27.353	62.802	48.065	144.195
118	2.097	1.637	15.302	25.049	17.8596863 (+/- 4.9e-007)	41.006	2.337	1.637	3.274	4.674	15.302	25.049	13.669	41.006
119	1.871	1.557	13.083	20.370	15.0308076 (+/- 1e-008)	31.716	2.101	1.557	3.114	4.201	13.083	20.370	10.572	31.716
120	1.858	1.524	12.723	19.390	14.1476714 (+/- 1.5e-008)	29.550	2.087	1.524	3.048	4.174	12.723	19.390	9.850	29.550
121	2.007	1.508	13.589	20.492	14.9996424 (+/- 7.5e-008)	30.902	2.253	1.508	3.016	4.506	13.589	20.492	10.301	30.902
122	2.006	1.354	12.176	16.486	11.0595398 (+/- 1.4e-008)	22.322	2.248	1.354	2.708	4.496	12.176	16.486	7.441	22.322
123	1.981	1.204	10.718	12.904	7.69531503 (+/- 1e-009)	15.537	2.225	1.204	2.408	4.451	10.718	12.904	5.179	15.537
124	1.976	1.629	14.471	23.573	19.5664601 (+/- 6.5e-008)	38.401	2.221	1.629	3.258	4.442	14.471	23.573	12.800	38.401
125	1.786	1.523	12.184	18.556	15.4212888 (+/- 1e-008)	28.261	2.000	1.523	3.046	4.000	12.184	18.556	9.420	28.261
126	1.710	1.566	12.031	18.841	15.1675053 (+/- 1.2e-007)	29.504	1.921	1.566	3.132	3.841	12.031	18.841	9.835	29.504
127	1.677	1.548	11.631	18.005	14.9463592 (+/- 1e-008)	27.871	1.878	1.548	3.096	3.757	11.631	18.005	9.290	27.871

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}	mm.	mm.	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}
128	1.829	**1.399**	**11.487**	**16.070**	11.553195 (+/- 1e-008)	**22.482**	2.053	**1.399**	*2.798*	*4.105*	**11.487**	**16.070**	7.494	**22.482**
129	1.885	**1.296**	**10.960**	**14.204**	9.91309259 (+/- 7.6e-009)	**18.409**	2.114	**1.296**	*2.592*	*4.228*	**10.960**	**14.204**	6.136	**18.409**
130	1.281	**1.359**	**7.778**	**10.570**	7.96019455 (+/- 1e-008)	**14.365**	1.431	**1.359**	*2.718*	*2.862*	**7.778**	**10.570**	4.788	**14.365**
131	1.124	**1.730**	**8.716**	**15.079**	13.7475857 (+/- 1e-008)	**26.086**	1.260	**1.730**	*3.460*	*2.519*	**8.716**	**15.079**	8.695	**26.086**
132	1.384	**1.229**	**7.633**	**9.381**	5.94446725 (+/- 3.5e-009)	**11.529**	1.553	**1.229**	*2.458*	*3.105*	**7.633**	**9.381**	3.843	**11.529**
133	1.576	**1.375**	**9.736**	**13.387**	8.99537126 (+/- 1.1e-008)	**18.407**	1.770	**1.375**	*2.750*	*3.540*	**9.736**	**13.387**	6.136	**18.407**
134	1.462	**0.998**	**6.560**	**6.547**	3.35687677 (+/- 1.1e-009)	**6.534**	1.643	**0.998**	*1.996*	*3.287*	**6.560**	**6.547**	2.178	**6.534**
135	1.567	**0.946**	**6.647**	**6.288**	3.05697776 (+/- 1e-009)	**5.949**	1.757	**0.946**	*1.892*	*3.513*	**6.647**	**6.288**	1.983	**5.949**
136	1.581	**1.224**	**8.695**	**10.643**	6.6800916 (+/- 3e-009)	**13.027**	1.776	**1.224**	*2.448*	*3.552*	**8.695**	**10.643**	4.342	**13.027**
137	2.023	**1.376**	**12.503**	**17.204**	11.1498135 (+/- 1e-008)	**23.673**	2.272	**1.376**	*2.752*	*4.543*	**12.503**	**17.204**	7.891	**23.673**
138	1.561	**1.619**	**11.342**	**18.363**	13.9518247 (+/- 1e-008)	**29.729**	1.751	**1.619**	*3.238*	*3.503*	**11.342**	**18.363**	9.910	**29.729**
139	1.816	**1.329**	**10.682**	**14.196**	7.97157642 (+/- 1.9e-009)	**18.867**	2.009	**1.329**	*2.658*	*4.019*	**10.682**	**14.196**	6.289	**18.867**
140	1.520	**1.819**	**12.416**	**22.585**	21.7093458 (+/- 1e-008)	**41.082**	1.706	**1.819**	*3.638*	*3.413*	**12.416**	**22.585**	13.694	**41.082**
141	1.704	**2.121**	**16.179**	**34.316**	38.7076924 (+/- 2.4e-008)	**72.784**	1.907	**2.121**	*4.242*	*3.814*	**16.179**	**34.316**	24.261	**72.784**
142	1.271	**1.263**	**7.121**	**8.994**	6.86499602 (+/- 2.1e-009)	**11.359**	1.410	**1.263**	*2.526*	*2.819*	**7.121**	**8.994**	3.786	**11.359**
143	1.683	**1.666**	**12.594**	**20.982**	18.1697304 (+/- 1.7e-008)	**34.955**	1.890	**1.666**	*3.332*	*3.780*	**12.594**	**20.982**	11.652	**34.955**
144	1.227	**1.590**	**8.680**	**13.801**	12.9034429 (+/- 3.6e-007)	**21.944**	1.365	**1.590**	*3.180*	*2.730*	**8.680**	**13.801**	7.315	**21.944**
145	2.411	**1.700**	**18.401**	**31.282**	25.3907796 (+/- 1.1e-008)	**53.179**	2.706	**1.700**	*3.400*	*5.412*	**18.401**	**31.282**	17.726	**53.179**
146	1.717	**1.553**	**11.975**	**18.597**	13.9154573 (+/- 1.1e-008)	**28.881**	1.928	**1.553**	*3.106*	*3.855*	**11.975**	**18.597**	9.627	**28.881**
147	1.635	**2.015**	**14.784**	**29.790**	31.7757104 (+/- 6.3e-008)	**60.026**	1.834	**2.015**	*4.030*	*3.668*	**14.784**	**29.790**	20.009	**60.026**
148	1.586	**1.479**	**10.543**	**15.593**	11.9189859 (+/- 1.3e-008)	**23.062**	1.782	**1.479**	*2.958*	*3.564*	**10.543**	**15.593**	7.687	**23.062**
149	1.584	**1.318**	**9.381**	**12.364**	7.81467915 (+/- 1e-009)	**16.296**	1.779	**1.318**	*2.636*	*3.559*	**9.381**	**12.364**	5.432	**16.296**
150	1.573	**1.332**	**9.386**	**12.502**	7.79981769 (+/- 3.7e-009)	**16.653**	1.762	**1.332**	*2.664*	*3.523*	**9.386**	**12.502**	5.551	**16.653**
151	1.494	**1.040**	**6.964**	**7.243**	4.14985546 (+/- 1e-009)	**7.532**	1.674	**1.040**	*2.080*	*3.348*	**6.964**	**7.243**	2.511	**7.532**
152	1.517	**1.304**	**8.896**	**11.600**	7.53401945 (+/- 1e-009)	**15.127**	1.706	**1.304**	*2.608*	*3.411*	**8.896**	**11.600**	5.042	**15.127**
153	1.208	**1.536**	**8.332**	**12.798**	10.4610165 (+/- 1e-008)	**19.658**	1.356	**1.536**	3.072	2.712	**8.332**	**12.798**	6.553	**19.658**

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	$mm.^2$	$mm.^3$	$mm.^4$	$mm.^4$	mm.	mm.	mm.	mm.	$mm.^2$	$mm.^3$	$mm.^4$	$mm.^4$
154	1.047	**1.645**	**7.733**	**12.721**	10.7314665 (+/- 1.1e-008)	**20.926**	1.175	**1.645**	*3.290*	*2.350*	**7.733**	**12.721**	6.975	**20.926**
155	1.598	**1.335**	**9.598**	**12.813**	8.47802456 (+/- 1.1e-008)	**17.106**	1.797	**1.335**	*2.670*	*3.595*	**9.598**	**12.813**	5.702	**17.106**
156	2.153	**1.231**	**11.843**	**14.579**	10.0325469 (+/- 1e-008)	**17.946**	2.405	**1.231**	*2.462*	*4.810*	**11.843**	**14.579**	5.982	**17.946**
157	2.011	**1.456**	**13.139**	**19.130**	13.0918039 (+/- 1e-008)	**27.854**	2.256	**1.456**	*2.912*	*4.512*	**13.139**	**19.130**	9.285	**27.854**
158	1.709	**1.553**	**11.907**	**18.492**	15.459378 (+/- 1.3e-008)	**28.717**	1.917	**1.553**	*3.106*	*3.834*	**11.907**	**18.492**	9.572	**28.717**
159	1.833	**1.563**	**12.866**	**20.110**	16.3168408 (+/- 1e-008)	**31.431**	2.058	**1.563**	*3.126*	*4.116*	**12.866**	**20.110**	10.477	**31.431**
160	1.891	**1.714**	**14.560**	**24.956**	22.3525385 (+/- 1e-008)	**42.774**	2.124	**1.714**	*3.428*	*4.247*	**14.560**	**24.956**	14.258	**42.774**
161	1.833	**1.449**	**11.774**	**17.061**	14.7835749 (+/- 1e-008)	**24.721**	2.031	**1.449**	*2.898*	*4.063*	**11.774**	**17.061**	8.240	**24.721**
162	1.472	**1.391**	**9.207**	**12.807**	8.97096213 (+/- 1.1e-008)	**17.814**	1.655	**1.391**	*2.782*	*3.309*	**9.207**	**12.807**	5.938	**17.814**
163	2.674	**1.140**	**12.532**	**14.286**	12.9154481 (+/- 8.3e-008)	**16.287**	2.748	**1.140**	*2.280*	*5.496*	**12.532**	**14.286**	5.429	**16.287**
164	1.822	**1.492**	**12.001**	**17.905**	16.5167043 (+/- 1e-008)	**26.715**	2.011	**1.492**	*2.984*	*4.022*	**12.001**	**17.905**	8.905	**26.715**
165	1.323	**1.049**	**6.224**	**6.529**	3.61906645 (+/- 2.5e-009)	**6.849**	1.483	**1.049**	*2.098*	*2.967*	**6.224**	**6.529**	2.283	**6.849**
							Sum		510.32	635.92				
							Mean		3.093	3.854				

Model II: 439 weld profiles between the plate panel and all stiffeners

	Original cross section						**Modified cross section (Rectangular cross section)**							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}	mm.	mm.	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}
1	2.948	**2.623**	**34.285**	**89.930**	98.1499 (+/- 0.0042)	**235.885**	3.268	**2.623**	*5.246*	*6.535*	**34.285**	**89.930**	78.628	**235.885**
2	3.377	**2.522**	**37.727**	**95.147**	135.656 (+/- 0.011)	**239.962**	3.740	**2.522**	*5.044*	*7.480*	**37.727**	**95.147**	79.987	**239.962**
3	1.952	**2.099**	**18.147**	**38.091**	33.2667 (+/- 0.0024)	**79.952**	2.161	**2.099**	*4.198*	*4.323*	**18.147**	**38.091**	26.651	**79.952**
4	1.926	**1.934**	**16.530**	**31.969**	26.1251 (+/- 0.0018)	**61.828**	2.137	**1.934**	*3.868*	*4.274*	**16.530**	**31.969**	20.609	**61.828**
5	2.298	**1.828**	**18.895**	**34.540**	31.4482 (+/- 0.0017)	**63.139**	2.584	**1.828**	*3.656*	*5.168*	**18.895**	**34.540**	21.046	**63.139**
6	2.432	**1.587**	**17.342**	**27.522**	21.554 (+/- 0.0027)	**43.677**	2.732	**1.587**	*3.174*	*5.464*	**17.342**	**27.522**	14.559	**43.677**
7	1.456	**1.716**	**11.019**	**18.909**	20.34 (+/- 0.13)	**32.447**	1.605	**1.716**	*3.432*	*3.211*	**11.019**	**18.909**	10.816	**32.447**
8	1.860	**1.631**	**13.629**	**22.229**	18.319 (+/- 0.001)	**36.255**	2.089	**1.631**	*3.262*	*4.178*	**13.629**	**22.229**	12.085	**36.255**
9	1.929	**2.059**	**17.690**	**36.424**	41.657 (+/- 0.038)	**74.996**	2.148	**2.059**	*4.118*	*4.296*	**17.690**	**36.424**	24.999	**74.996**
10	2.058	**1.512**	**13.965**	**21.115**	16.696 (+/- 0.0041)	**31.926**	2.309	**1.512**	*3.024*	*4.618*	**13.965**	**21.115**	10.642	**31.926**
11	2.131	**1.512**	**14.187**	**21.451**	20.023 (+/- 0.0035)	**32.434**	2.346	**1.512**	*3.024*	*4.691*	**14.187**	**21.451**	10.811	**32.434**
12	1.847	**1.396**	**11.545**	**16.117**	12.3376 (+/- 0.0011)	**22.499**	2.068	**1.396**	*2.792*	*4.135*	**11.545**	**16.117**	7.500	**22.499**
13	1.905	**1.475**	**12.419**	**18.318**	16.636 (+/- 0.0028)	**27.019**	2.105	**1.475**	*2.950*	*4.210*	**12.419**	**18.318**	9.006	**27.019**
14	2.819	**1.743**	**21.749**	**37.909**	28.039 (+/- 0.0051)	**66.075**	3.119	**1.743**	*3.486*	*6.239*	**21.749**	**37.909**	22.025	**66.075**
15	2.509	**1.631**	**18.158**	**29.616**	26.91 (+/- 0.02)	**48.303**	2.783	**1.631**	*3.262*	*5.567*	**18.158**	**29.616**	16.101	**48.303**
16	2.632	**2.045**	**23.675**	**48.415**	61.615 (+/- 0.024)	**99.009**	2.894	**2.045**	*4.090*	*5.789*	**23.675**	**48.415**	33.003	**99.009**
17	1.852	**1.797**	**14.943**	**26.853**	25.3594 (+/- 0.0011)	**48.254**	2.079	**1.797**	*3.594*	*4.158*	**14.943**	**26.853**	16.085	**48.254**
18	1.668	**1.715**	**12.186**	**20.899**	20.779 (+/- 0.0026)	**35.842**	1.776	**1.715**	*3.430*	*3.553*	**12.186**	**20.899**	11.947	**35.842**
19	1.566	**1.811**	**12.635**	**22.882**	24.037 (+/- 0.0076)	**41.439**	1.744	**1.811**	*3.622*	*3.488*	**12.635**	**22.882**	13.813	**41.439**
20	1.270	**1.527**	**8.657**	**13.219**	11.517 (+/- 0.0017)	**20.186**	1.417	**1.527**	*3.054*	*2.835*	**8.657**	**13.219**	6.729	**20.186**
21	1.576	**1.195**	**8.341**	**9.967**	7.1144 (+/- 0.0045)	**11.911**	1.745	**1.195**	*2.390*	*3.490*	**8.341**	**9.967**	3.970	**11.911**
22	2.510	**1.403**	**15.320**	**21.494**	11.867 (+/- 0.0025)	**30.156**	2.730	**1.403**	*2.806*	*5.460*	**15.320**	**21.494**	10.052	**30.156**
23	3.129	**1.616**	**22.671**	**36.636**	27.7476 (+/- 0.0014)	**59.204**	3.507	**1.616**	*3.232*	*7.015*	**22.671**	**36.636**	19.735	**59.204**

	Original cross section						**Modified cross section (Rectangular cross section)**							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}	mm.	mm.	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}
24	2.415	**1.465**	**15.807**	**23.157**	19.2374 (+/- 0.0011)	**33.925**	2.697	**1.465**	*2.930*	*5.395*	**15.807**	**23.157**	11.308	**33.925**
25	2.502	**2.461**	**26.161**	**64.382**	111.02 (+/- 0.072)	**158.445**	2.658	**2.461**	*4.922*	*5.315*	**26.161**	**64.382**	52.815	**158.445**
26	1.621	**1.026**	**7.389**	**7.581**	4.6204 (+/- 0.00052)	**7.778**	1.800	**1.026**	*2.052*	*3.601*	**7.389**	**7.581**	2.593	**7.778**
27	1.932	**1.100**	**9.341**	**10.275**	7.0329 (+/- 0.0016)	**11.303**	2.123	**1.100**	*2.200*	*4.246*	**9.341**	**10.275**	3.768	**11.303**
28	1.513	**1.087**	**7.094**	**7.711**	5.8867 (+/- 0.0023)	**8.382**	1.632	**1.087**	*2.174*	*3.263*	**7.094**	**7.711**	2.794	**8.382**
29	1.946	**2.682**	**23.397**	**62.751**	78.0925 (+/- 0.004)	**168.298**	2.181	**2.682**	*5.364*	*4.362*	**23.397**	**62.751**	56.099	**168.298**
30	3.272	**2.366**	**34.411**	**81.416**	82.4541 (+/- 0.0014)	**192.631**	3.636	**2.366**	*4.732*	*7.272*	**34.411**	**81.416**	64.210	**192.631**
31	2.218	**1.445**	**14.392**	**20.796**	14.837 (+/- 0.0026)	**30.051**	2.490	**1.445**	*2.890*	*4.980*	**14.392**	**20.796**	10.017	**30.051**
32	1.779	**1.397**	**11.087**	**15.489**	12.3816 (+/- 0.00042)	**21.637**	1.984	**1.397**	*2.794*	*3.968*	**11.087**	**15.489**	7.212	**21.637**
33	1.678	**1.246**	**9.248**	**11.523**	8.8241 (+/- 0.0019)	**14.358**	1.856	**1.246**	*2.492*	*3.711*	**9.248**	**11.523**	4.786	**14.358**
34	1.611	**1.723**	**12.472**	**21.489**	18.849108 (+/- 4.3e-007)	**37.026**	1.810	**1.723**	*3.446*	*3.619*	**12.472**	**21.489**	12.342	**37.026**
35	1.587	**1.403**	**9.957**	**13.970**	8.89139531 (+/- 2.3e-007)	**19.599**	1.774	**1.403**	*2.806*	*3.548*	**9.957**	**13.970**	6.533	**19.599**
36	1.608	**1.597**	**11.539**	**18.428**	14.8694757 (+/- 2.7e-007)	**29.429**	1.806	**1.597**	*3.194*	*3.613*	**11.539**	**18.428**	9.810	**29.429**
37	1.767	**1.507**	**11.959**	**18.022**	13.0190058 (+/- 3.2e-007)	**27.159**	1.984	**1.507**	*3.014*	*3.968*	**11.959**	**18.022**	9.053	**27.159**
38	2.562	**2.913**	**33.124**	**96.490**	132.520938 (+/- 1e-006)	**281.076**	2.843	**2.913**	*5.826*	*5.686*	**33.124**	**96.490**	93.692	**281.076**
39	2.045	**1.935**	**17.747**	**34.340**	31.4788952 (+/- 1.1e-006)	**66.449**	2.293	**1.935**	*3.870*	*4.586*	**17.747**	**34.340**	22.150	**66.449**
40	1.905	**3.086**	**26.794**	**82.686**	112.0927 (+/- 0.0011)	**255.170**	2.171	**3.086**	*6.172*	*4.341*	**26.794**	**82.686**	85.057	**255.170**
41	2.093	**1.452**	**13.243**	**19.229**	18.7130173 (+/- 2e-007)	**27.920**	2.280	**1.452**	*2.904*	*4.560*	**13.243**	**19.229**	9.307	**27.920**
42	2.201	**1.488**	**14.673**	**21.833**	17.2035112 (+/- 2.4e-007)	**32.488**	2.465	**1.488**	*2.976*	*4.930*	**14.673**	**21.833**	10.829	**32.488**
43	2.798	**1.760**	**20.932**	**36.840**	38.5234509 (+/- 1.5e-006)	**64.839**	2.973	**1.760**	*3.520*	*5.947*	**20.932**	**36.840**	21.613	**64.839**
44	2.558	**2.016**	**23.025**	**46.418**	41.2098881 (+/- 4.8e-007)	**93.579**	2.855	**2.016**	*4.032*	*5.711*	**23.025**	**46.418**	31.193	**93.579**
45	2.136	**1.646**	**15.694**	**25.832**	18.9406126 (+/- 3.9e-007)	**42.520**	2.384	**1.646**	*3.292*	*4.767*	**15.694**	**25.832**	14.173	**42.520**
46	2.491	**2.166**	**23.582**	**51.079**	42.9775998 (+/- 4.6e-007)	**110.636**	2.722	**2.166**	*4.332*	*5.444*	**23.582**	**51.079**	36.879	**110.636**
47	2.479	**1.827**	**19.665**	**35.928**	25.4122763 (+/- 2.2e-007)	**65.640**	2.691	**1.827**	*3.654*	*5.382*	**19.665**	**35.928**	21.880	**65.640**
48	2.449	**1.665**	**18.279**	**30.435**	25.3455637 (+/- 3.6e-007)	**50.674**	2.745	**1.665**	*3.330*	*5.489*	**18.279**	**30.435**	16.891	**50.674**
49	2.524	**1.709**	**19.386**	**33.131**	27.739681 (+/- 6.1e-007)	**56.620**	2.836	**1.709**	*3.418*	*5.672*	**19.386**	**33.131**	18.873	**56.620**

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	$mm.^2$	$mm.^3$	$mm.^4$	$mm.^4$	mm.	mm.	mm.	mm.	$mm.^2$	$mm.^3$	$mm.^4$	$mm.^4$
50	3.889	1.639	28.048	45.971	30.7291572 (+/- 9.5e-007)	75.346	4.278	1.639	3.278	8.556	28.048	45.971	25.115	75.346
51	1.756	1.789	14.099	25.223	22.0090037 (+/- 3.5e-007)	45.124	1.970	1.789	3.578	3.940	14.099	25.223	15.041	45.124
52	1.885	1.911	16.127	30.819	26.6920734 (+/- 4.8e-007)	58.895	2.110	1.911	3.822	4.220	16.127	30.819	19.632	58.895
53	1.963	1.714	14.867	25.482	27.87657 (+/- 0.00026)	43.676	2.168	1.714	3.428	4.337	14.867	25.482	14.559	43.676
54	1.765	1.965	15.528	30.513	27.4681946 (+/- 6.6e-007)	59.957	1.976	1.965	3.930	3.951	15.528	30.513	19.986	59.957
55	2.038	2.272	20.779	47.210	54.0139457 (+/- 5.5e-007)	107.261	2.286	2.272	4.544	4.573	20.779	47.210	35.754	107.261
56	2.241	1.495	14.913	22.295	19.3564794 (+/- 5.4e-007)	33.331	2.494	1.495	2.990	4.988	14.913	22.295	11.110	33.331
57	1.907	1.501	12.037	18.068	19.858104 (+/- 7.5e-006)	27.119	2.005	1.501	3.002	4.010	12.037	18.068	9.040	27.119
58	2.346	1.869	18.766	35.074	49.89981 (+/- 0.0003)	65.553	2.510	1.869	3.738	5.020	18.766	35.074	21.851	65.553
59	1.789	1.476	11.698	17.266	14.9336405 (+/- 5.9e-007)	25.485	1.981	1.476	2.952	3.963	11.698	17.266	8.495	25.485
60	3.021	1.137	15.373	17.479	10.7283981 (+/- 5e-007)	19.874	3.380	1.137	2.274	6.760	15.373	17.479	6.625	19.874
61	3.714	1.986	32.976	65.490	60.0715556 (+/- 7.8e-007)	130.064	4.151	1.986	3.972	8.302	32.976	65.490	43.355	130.064
62	2.397	1.309	12.527	16.398	18.4109653 (+/- 5.5e-007)	21.465	2.392	1.309	2.618	4.785	12.527	16.398	7.155	21.465
63	3.362	1.852	27.501	50.932	38.6306774 (+/- 7.6e-007)	94.326	3.712	1.852	3.704	7.425	27.501	50.932	31.442	94.326
64	3.194	2.211	31.650	69.978	75.6318206 (+/- 9.4e-007)	154.722	3.579	2.211	4.422	7.157	31.650	69.978	51.574	154.722
65	2.084	1.207	11.069	13.360	6.69732522 (+/- 2.4e-007)	16.126	2.293	1.207	2.414	4.585	11.069	13.360	5.375	16.126
66	1.950	1.341	11.723	15.721	11.4601242 (+/- 2.7e-007)	21.081	2.185	1.341	2.682	4.371	11.723	15.721	7.027	21.081
67	2.246	1.385	13.832	19.157	11.3215438 (+/- 4e-007)	26.533	2.497	1.385	2.770	4.994	13.832	19.157	8.844	26.533
68	2.211	1.573	15.512	24.400	16.9512446 (+/- 5e-007)	38.382	2.465	1.573	3.146	4.931	15.512	24.400	12.794	38.382
69	1.941	1.326	11.527	15.285	9.41854884 (+/- 2.8e-007)	20.268	2.173	1.326	2.652	4.347	11.527	15.285	6.756	20.268
70	2.508	1.764	19.807	34.940	31.0768 (+/- 0.0023)	61.633	2.807	1.764	3.528	5.614	19.807	34.940	20.544	61.633
71	2.809	1.960	24.452	47.926	40.3760354 (+/- 3.1e-007)	93.935	3.119	1.960	3.920	6.238	24.452	47.926	31.312	93.935
72	2.520	1.870	20.495	38.326	28.1608 (+/- 0.0017)	71.669	2.740	1.870	3.740	5.480	20.495	38.326	23.890	71.669
73	2.618	2.037	23.096	47.047	64.889 (+/- 0.057)	95.834	2.835	2.037	4.074	5.669	23.096	47.047	31.945	95.834
74	3.000	2.029	27.328	55.449	57.3426 (+/- 0.0048)	112.505	3.367	2.029	4.058	6.734	27.328	55.449	37.502	112.505
75	3.007	1.756	23.343	40.990	29.5601 (+/- 0.0013)	71.979	3.323	1.756	3.512	6.647	23.343	40.990	23.993	71.979

	Original cross section						**Modified cross section (Rectangular cross section)**							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}	mm.	mm.	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}
76	3.592	**2.625**	**41.672**	**109.389**	117.5 (+/- 0.14)	**287.146**	3.969	**2.625**	*5.250*	*7.938*	**41.672**	**109.389**	95.715	**287.146**
77	2.692	**1.997**	**24.037**	**48.002**	44.055 (+/- 0.0053)	**95.860**	3.009	**1.997**	*3.994*	*6.018*	**24.037**	**48.002**	31.953	**95.860**
78	2.799	**1.626**	**20.055**	**32.609**	22.01 (+/- 0.0031)	**53.023**	3.083	**1.626**	*3.252*	*6.167*	**20.055**	**32.609**	17.674	**53.023**
79	2.059	**1.852**	**17.019**	**31.519**	33.4463 (+/- 0.0024)	**58.374**	2.297	**1.852**	*3.704*	*4.595*	**17.019**	**31.519**	19.458	**58.374**
80	1.628	**1.425**	**10.255**	**14.613**	13.2 (+/- 0.13)	**20.824**	1.799	**1.425**	*2.850*	*3.598*	**10.255**	**14.613**	6.941	**20.824**
81	1.502	**0.996**	**6.641**	**6.614**	3.8471 (+/- 0.0013)	**6.588**	1.667	**0.996**	*1.992*	*3.334*	**6.641**	**6.614**	2.196	**6.588**
82	1.631	**1.314**	**9.403**	**12.356**	10.44 (+/- 0.075)	**16.235**	1.789	**1.314**	*2.628*	*3.578*	**9.403**	**12.356**	5.412	**16.235**
83	2.868	**1.710**	**21.956**	**37.545**	33.4848 (+/- 0.00089)	**64.202**	3.210	**1.710**	*3.420*	*6.420*	**21.956**	**37.545**	21.401	**64.202**
84	3.718	**1.857**	**30.811**	**57.216**	60.17 (+/- 0.15)	**106.250**	4.148	**1.857**	*3.714*	*8.296*	**30.811**	**57.216**	35.417	**106.250**
85	2.728	**2.563**	**31.281**	**80.173**	93.7549 (+/- 0.0033)	**205.484**	3.051	**2.563**	*5.126*	*6.102*	**31.281**	**80.173**	68.495	**205.484**
86	2.516	**1.871**	**21.055**	**39.394**	40.748 (+/- 0.0045)	**73.706**	2.813	**1.871**	*3.742*	*5.627*	**21.055**	**39.394**	24.569	**73.706**
87	1.577	**1.366**	**9.655**	**13.189**	9.5962 (+/- 0.001)	**18.016**	1.767	**1.366**	*2.732*	*3.534*	**9.655**	**13.189**	6.005	**18.016**
88	1.646	**1.080**	**7.990**	**8.629**	4.857 (+/- 0.0064)	**9.320**	1.850	**1.080**	*2.160*	*3.699*	**7.990**	**8.629**	3.107	**9.320**
89	1.692	**1.319**	**9.787**	**12.909**	10.897 (+/- 0.002)	**17.027**	1.855	**1.319**	*2.638*	*3.710*	**9.787**	**12.909**	5.676	**17.027**
90	3.064	**1.984**	**27.221**	**54.006**	51.7822 (+/- 0.0039)	**107.149**	3.430	**1.984**	*3.968*	*6.860*	**27.221**	**54.006**	35.716	**107.149**
91	2.626	**1.884**	**22.009**	**41.465**	33.3359 (+/- 0.003)	**78.120**	2.921	**1.884**	*3.768*	*5.841*	**22.009**	**41.465**	26.040	**78.120**
92	2.856	**1.474**	**18.829**	**27.754**	18.542 (+/- 0.003)	**40.909**	3.194	**1.474**	*2.948*	*6.387*	**18.829**	**27.754**	13.636	**40.909**
93	3.140	**1.320**	**17.675**	**23.331**	11.412 (+/- 0.0031)	**30.797**	3.348	**1.320**	*2.640*	*6.695*	**17.675**	**23.331**	10.266	**30.797**
94	2.998	**1.800**	**23.674**	**42.613**	48.025 (+/- 0.0031)	**76.704**	3.288	**1.800**	*3.600*	*6.576*	**23.674**	**42.613**	25.568	**76.704**
95	1.727	**2.121**	**16.423**	**34.833**	39.8933 (+/- 0.003)	**73.881**	1.936	**2.121**	*4.242*	*3.872*	**16.423**	**34.833**	24.627	**73.881**
96	1.495	**2.073**	**13.907**	**28.829**	30.394 (+/- 0.023)	**59.763**	1.677	**2.073**	*4.146*	*3.354*	**13.907**	**28.829**	19.921	**59.763**
97	1.558	**1.740**	**12.149**	**21.139**	19.9624 (+/- 0.00048)	**36.782**	1.746	**1.740**	*3.480*	*3.491*	**12.149**	**21.139**	12.261	**36.782**
98	3.120	**2.186**	**30.457**	**66.579**	64.235 (+/- 0.012)	**145.542**	3.483	**2.186**	*4.372*	*6.966*	**30.457**	**66.579**	48.514	**145.542**
99	2.283	**2.804**	**28.452**	**79.779**	96.989 (+/- 0.018)	**223.701**	2.537	**2.804**	*5.608*	*5.073*	**28.452**	**79.779**	74.567	**223.701**
100	2.163	**1.979**	**19.239**	**38.074**	36.704 (+/- 0.019)	**75.348**	2.430	**1.979**	*3.958*	*4.861*	**19.239**	**38.074**	25.116	**75.348**
101	2.039	**1.640**	**14.985**	**24.575**	18.4526 (+/- 0.0013)	**40.304**	2.284	**1.640**	*3.280*	*4.569*	**14.985**	**24.575**	13.435	**40.304**

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	$mm.^2$	$mm.^3$	$mm.^4$	$mm.^4$	mm.	mm.	mm.	mm.	$mm.^2$	$mm.^3$	$mm.^4$	$mm.^4$
102	1.846	**1.647**	**13.672**	**22.518**	18.395 (+/- 0.0027)	**37.087**	2.075	**1.647**	*3.294*	*4.151*	**13.672**	**22.518**	12.362	**37.087**
103	2.003	**2.181**	**19.597**	**42.741**	43.2267 (+/- 0.0038)	**93.218**	2.246	**2.181**	*4.362*	*4.493*	**19.597**	**42.741**	31.073	**93.218**
104	1.576	**2.550**	**17.694**	**45.120**	46.368 (+/- 0.033)	**115.055**	1.735	**2.550**	*5.100*	*3.469*	**17.694**	**45.120**	38.352	**115.055**
105	2.093	**1.919**	**18.002**	**34.546**	31.3785197 (+/- 2.8e-007)	**66.293**	2.345	**1.919**	*3.838*	*4.690*	**18.002**	**34.546**	22.098	**66.293**
106	1.804	**2.156**	**17.441**	**37.603**	37.562594 (+/- 3.4e-007)	**81.072**	2.022	**2.156**	*4.312*	*4.045*	**17.441**	**37.603**	27.024	**81.072**
107	1.919	**2.388**	**20.800**	**49.670**	55.5495 (+/- 0.0009)	**118.613**	2.178	**2.388**	*4.776*	*4.355*	**20.800**	**49.670**	39.538	**118.613**
108	2.548	**2.310**	**26.202**	**60.527**	59.8707623 (+/- 3.6e-007)	**139.816**	2.836	**2.310**	*4.620*	*5.671*	**26.202**	**60.527**	46.605	**139.816**
109	3.280	**2.256**	**31.383**	**70.800**	58.4210967 (+/- 1.4e-006)	**159.725**	3.478	**2.256**	*4.512*	*6.955*	**31.383**	**70.800**	53.242	**159.725**
110	3.813	**2.703**	**43.827**	**118.464**	118.117325 (+/- 5e-007)	**320.209**	4.054	**2.703**	*5.406*	*8.107*	**43.827**	**118.464**	106.736	**320.209**
111	4.495	**3.313**	**59.511**	**197.160**	217.492791 (+/- 1.4e-006)	**653.191**	4.491	**3.313**	*6.626*	*8.981*	**59.511**	**197.160**	217.730	**653.191**
112	2.282	**1.653**	**16.741**	**27.673**	27.334225 (+/- 5.7e-007)	**45.743**	2.532	**1.653**	*3.306*	*5.064*	**16.741**	**27.673**	15.248	**45.743**
113	2.489	**1.700**	**18.865**	**32.071**	31.5462378 (+/- 5.6e-007)	**54.520**	2.774	**1.700**	*3.400*	*5.549*	**18.865**	**32.071**	18.173	**54.520**
114	2.269	**1.572**	**15.979**	**25.119**	21.244 (+/- 0.0042)	**39.487**	2.541	**1.572**	*3.144*	*5.082*	**15.979**	**25.119**	13.162	**39.487**
115	2.517	**1.421**	**16.064**	**22.827**	15.3321 (+/- 0.00034)	**32.437**	2.826	**1.421**	*2.842*	*5.652*	**16.064**	**22.827**	10.812	**32.437**
116	2.837	**1.765**	**22.442**	**39.610**	35.5624988 (+/- 4.3e-007)	**69.912**	3.179	**1.765**	*3.530*	*6.358*	**22.442**	**39.610**	23.304	**69.912**
117	2.395	**1.860**	**19.764**	**36.761**	28.6833442 (+/- 2.8e-007)	**68.376**	2.656	**1.860**	*3.720*	*5.313*	**19.764**	**36.761**	22.792	**68.376**
118	1.897	**1.590**	**13.523**	**21.502**	14.9046 (+/- 0.00031)	**34.187**	2.126	**1.590**	*3.180*	*4.253*	**13.523**	**21.502**	11.396	**34.187**
119	2.603	**2.568**	**29.633**	**76.098**	83.9471712 (+/- 5.4e-007)	**195.418**	2.885	**2.568**	*5.136*	*5.770*	**29.633**	**76.098**	65.139	**195.418**
120	2.695	**2.645**	**31.728**	**83.921**	95.3996807 (+/- 4.1e-007)	**221.970**	2.999	**2.645**	*5.290*	*5.998*	**31.728**	**83.921**	73.990	**221.970**
121	1.763	**1.175**	**9.297**	**10.924**	6.61561577 (+/- 1.2e-007)	**12.836**	1.978	**1.175**	*2.350*	*3.956*	**9.297**	**10.924**	4.279	**12.836**
122	1.906	**1.240**	**10.825**	**13.423**	8.65095 (+/- 0.00026)	**16.645**	2.182	**1.240**	*2.480*	*4.365*	**10.825**	**13.423**	5.548	**16.645**
123	1.942	**1.093**	**9.449**	**10.328**	6.63466145 (+/- 2.7e-007)	**11.288**	2.161	**1.093**	*2.186*	*4.323*	**9.449**	**10.328**	3.763	**11.288**
124	2.688	**1.325**	**13.890**	**18.404**	25.3675 (+/- 0.002)	**24.386**	2.621	**1.325**	*2.650*	*5.242*	**13.890**	**18.404**	8.129	**24.386**
125	3.253	**1.979**	**28.164**	**55.737**	43.5810199 (+/- 1.1e-006)	**110.303**	3.558	**1.979**	*3.958*	*7.116*	**28.164**	**55.737**	36.768	**110.303**
126	2.779	**1.798**	**21.596**	**38.830**	44.3219 (+/- 0.00081)	**69.816**	3.003	**1.798**	*3.596*	*6.006*	**21.596**	**38.830**	23.272	**69.816**
127	2.810	**2.027**	**25.498**	**51.684**	60.5842 (+/- 0.0019)	**104.764**	3.145	**2.027**	*4.054*	*6.290*	**25.498**	**51.684**	34.921	**104.764**

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}	mm.	mm.	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}
128	2.441	**1.488**	**16.275**	**24.217**	19.4364048 (+/- 3.4e-007)	**36.035**	2.734	**1.488**	*2.976*	*5.469*	**16.275**	**24.217**	12.012	**36.035**
129	2.991	**1.301**	**17.290**	**22.494**	12.9691816 (+/- 4.1e-007)	**29.265**	3.322	**1.301**	*2.602*	*6.645*	**17.290**	**22.494**	9.755	**29.265**
130	2.164	**1.654**	**16.096**	**26.623**	21.9067959 (+/- 4.7e-007)	**44.034**	2.433	**1.654**	*3.308*	*4.866*	**16.096**	**26.623**	14.678	**44.034**
131	4.109	**1.709**	**31.434**	**53.721**	49.7576451 (+/- 5.3e-007)	**91.809**	4.598	**1.709**	*3.418*	*9.197*	**31.434**	**53.721**	30.603	**91.809**
132	3.304	**1.979**	**29.142**	**57.672**	50.31607 (+/- 6.4e-007)	**114.133**	3.681	**1.979**	*3.958*	*7.363*	**29.142**	**57.672**	38.044	**114.133**
133	3.338	**1.826**	**27.071**	**49.432**	40.2574385 (+/- 8.2e-007)	**90.262**	3.706	**1.826**	*3.652*	*7.413*	**27.071**	**49.432**	30.087	**90.262**
134	3.398	**1.892**	**28.584**	**54.081**	44.75134 (+/- 0.00043)	**102.321**	3.777	**1.892**	*3.784*	*7.554*	**28.584**	**54.081**	34.107	**102.321**
135	2.704	**1.687**	**19.990**	**33.723**	36.7376 (+/- 0.00058)	**56.891**	2.962	**1.687**	*3.374*	*5.925*	**19.990**	**33.723**	18.964	**56.891**
136	2.928	**1.505**	**19.749**	**29.722**	20.8877891 (+/- 4.5e-007)	**44.732**	3.281	**1.505**	*3.010*	*6.561*	**19.749**	**29.722**	14.911	**44.732**
137	2.857	**1.435**	**18.276**	**26.226**	17.903209 (+/- 3e-007)	**37.634**	3.184	**1.435**	*2.870*	*6.368*	**18.276**	**26.226**	12.545	**37.634**
138	2.049	**1.554**	**14.291**	**22.208**	17.4947521 (+/- 2.9e-007)	**34.512**	2.299	**1.554**	*3.108*	*4.598*	**14.291**	**22.208**	11.504	**34.512**
139	2.075	**1.807**	**16.826**	**30.405**	25.8824083 (+/- 4.1e-007)	**54.941**	2.328	**1.807**	*3.614*	*4.656*	**16.826**	**30.405**	18.314	**54.941**
140	2.834	**2.028**	**25.698**	**52.116**	47.1480295 (+/- 7.1e-007)	**105.690**	3.168	**2.028**	*4.056*	*6.336*	**25.698**	**52.116**	35.230	**105.690**
141	2.169	**1.607**	**15.536**	**24.966**	17.5289098 (+/- 6e-007)	**40.121**	2.417	**1.607**	*3.214*	*4.834*	**15.536**	**24.966**	13.374	**40.121**
142	2.261	**1.737**	**17.555**	**30.493**	23.4342912 (+/- 5.1e-007)	**52.966**	2.527	**1.737**	*3.474*	*5.053*	**17.555**	**30.493**	17.655	**52.966**
143	2.322	**1.724**	**17.851**	**30.775**	23.0540145 (+/- 4e-007)	**53.056**	2.589	**1.724**	*3.448*	*5.177*	**17.851**	**30.775**	17.685	**53.056**
144	2.148	**1.667**	**16.005**	**26.680**	24.3162369 (+/- 4.7e-007)	**44.476**	2.400	**1.667**	*3.334*	*4.801*	**16.005**	**26.680**	14.825	**44.476**
145	2.674	**1.937**	**23.128**	**44.799**	40.0589675 (+/- 1e-006)	**86.776**	2.985	**1.937**	*3.874*	*5.970*	**23.128**	**44.799**	28.925	**86.776**
146	2.391	**1.856**	**19.785**	**36.721**	29.9045875 (+/- 4.8e-007)	**68.154**	2.665	**1.856**	*3.712*	*5.330*	**19.785**	**36.721**	22.718	**68.154**
147	2.261	**1.531**	**15.500**	**23.731**	16.6869991 (+/- 3.9e-007)	**36.331**	2.531	**1.531**	*3.062*	*5.062*	**15.500**	**23.731**	12.110	**36.331**
148	3.013	**1.693**	**21.830**	**36.958**	24.2040759 (+/- 8.5e-007)	**62.570**	3.224	**1.693**	*3.386*	*6.447*	**21.830**	**36.958**	20.857	**62.570**
149	2.997	**2.176**	**27.470**	**59.775**	49.5815213 (+/- 1.4e-006)	**130.070**	3.156	**2.176**	*4.352*	*6.312*	**27.470**	**59.775**	43.357	**130.070**
150	2.551	**2.349**	**25.592**	**60.116**	51.7875999 (+/- 9e-007)	**141.212**	2.724	**2.349**	*4.698*	*5.447*	**25.592**	**60.116**	47.071	**141.212**
151	2.197	**2.861**	**27.385**	**78.348**	85.9379662 (+/- 7.7e-007)	**224.155**	2.393	**2.861**	*5.722*	*4.786*	**27.385**	**78.348**	74.718	**224.155**
152	1.830	**2.141**	**17.594**	**37.669**	38.123667 (+/- 4.2e-007)	**80.649**	2.054	**2.141**	*4.282*	*4.109*	**17.594**	**37.669**	26.883	**80.649**
153	2.057	**2.365**	**21.829**	**51.626**	64.9485566 (+/- 7.6e-007)	**122.095**	2.308	**2.365**	*4.730*	*4.615*	**21.829**	**51.626**	40.698	**122.095**

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	$mm.^2$	$mm.^3$	$mm.^4$	$mm.^4$	mm.	mm.	mm.	mm.	$mm.^2$	$mm.^3$	$mm.^4$	$mm.^4$
154	2.483	2.103	23.436	49.286	51.5312138 (+/- 1.3e-006)	103.648	2.786	2.103	4.206	5.572	23.436	49.286	34.549	103.648
155	1.968	1.706	14.928	25.467	24.8749701 (+/- 3.4e-007)	43.447	2.188	1.706	3.412	4.375	14.928	25.467	14.482	43.447
156	2.287	1.251	12.833	16.054	10.7508859 (+/- 4.2e-007)	20.084	2.565	1.251	2.502	5.129	12.833	16.054	6.695	20.084
157	2.678	2.326	26.454	61.532	102.325091 (+/- 7.3e-007)	143.123	2.843	2.326	4.652	5.687	26.454	61.532	47.708	143.123
158	2.282	1.912	19.595	37.466	34.0169509 (+/- 6e-007)	71.634	2.562	1.912	3.824	5.124	19.595	37.466	23.878	71.634
159	2.102	1.734	16.356	28.361	24.8679 (+/- 0.00035)	49.179	2.358	1.734	3.468	4.716	16.356	28.361	16.393	49.179
160	2.019	1.739	15.643	27.203	26.2122922 (+/- 3.9e-007)	47.306	2.249	1.739	3.478	4.498	15.643	27.203	15.769	47.306
161	2.052	1.719	15.852	27.250	23.9486 (+/- 5.6e-007)	46.842	2.305	1.719	3.438	4.611	15.852	27.250	15.614	46.842
162	2.047	1.871	18.491	34.597	36.477 (+/- 0.0012)	64.730	2.471	1.871	3.742	4.941	18.491	34.597	21.577	64.730
163	1.595	1.653	11.818	19.535	17.7366405 (+/- 5.4e-007)	32.292	1.787	1.653	3.306	3.575	11.818	19.535	10.764	32.292
164	1.554	1.622	11.305	18.337	15.883409 (+/- 2.7e-007)	29.742	1.742	1.622	3.244	3.485	11.305	18.337	9.914	29.742
165	1.716	1.543	11.896	18.356	14.6037558 (+/- 4.6e-007)	28.323	1.927	1.543	3.086	3.855	11.896	18.356	9.441	28.323
166	1.968	1.360	11.765	16.000	13.9590196 (+/- 5.5e-007)	21.761	2.163	1.360	2.720	4.325	11.765	16.000	7.254	21.761
167	2.175	1.615	15.786	25.494	21.1325208 (+/- 4.7e-007)	41.173	2.444	1.615	3.230	4.887	15.786	25.494	13.724	41.173
168	2.322	1.412	14.673	20.718	16.2119898 (+/- 4.9e-007)	29.254	2.598	1.412	2.824	5.196	14.673	20.718	9.751	29.254
169	2.171	1.523	14.586	22.214	21.003561 (+/- 7.1e-007)	33.833	2.394	1.523	3.046	4.789	14.586	22.214	11.278	33.833
170	2.617	2.045	24.028	49.137	49.4211868 (+/- 7.6e-007)	100.486	2.937	2.045	4.090	5.875	24.028	49.137	33.495	100.486
171	2.356	1.538	16.214	24.937	18.8894599 (+/- 7.6e-007)	38.353	2.636	1.538	3.076	5.271	16.214	24.937	12.784	38.353
172	1.905	2.199	18.774	41.284	41.5419546 (+/- 6e-007)	90.784	2.134	2.199	4.398	4.269	18.774	41.284	30.261	90.784
173	2.223	1.633	16.294	26.608	60.6512306 (+/- 1.8e-006)	43.451	2.494	1.633	3.266	4.989	16.294	26.608	14.484	43.451
174	2.417	1.725	18.661	32.190	26.1739045 (+/- 7.4e-007)	55.528	2.704	1.725	3.450	5.409	18.661	32.190	18.509	55.528
175	2.211	1.793	17.372	31.148	22.4529305 (+/- 6.3e-007)	55.848	2.422	1.793	3.586	4.844	17.372	31.148	18.616	55.848
176	2.418	1.831	19.819	36.289	30.9359724 (+/- 4.8e-007)	66.444	2.706	1.831	3.662	5.412	19.819	36.289	22.148	66.444
177	1.926	1.954	16.999	33.216	34.5985 (+/- 0.00061)	64.904	2.175	1.954	3.908	4.350	16.999	33.216	21.635	64.904
178	1.791	1.651	13.049	21.544	18.8228 (+/- 0.00038)	35.569	1.976	1.651	3.302	3.952	13.049	21.544	11.856	35.569
179	1.948	2.310	20.215	46.697	53.8830158 (+/- 6.2e-007)	107.869	2.188	2.310	4.620	4.376	20.215	46.697	35.956	107.869

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}	mm.	mm.	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}
180	1.683	**2.039**	**15.423**	**31.447**	31.2944413 (+/- 6.6e-007)	**64.121**	1.891	**2.039**	*4.078*	*3.782*	**15.423**	**31.447**	21.374	**64.121**
181	2.198	**2.261**	**22.281**	**50.377**	61.9815777 (+/- 7.1e-007)	**113.903**	2.464	**2.261**	*4.522*	*4.927*	**22.281**	**50.377**	37.968	**113.903**
182	1.680	**1.878**	**14.128**	**26.532**	26.160186 (+/- 9.7e-007)	**49.828**	1.881	**1.878**	*3.756*	*3.761*	**14.128**	**26.532**	16.609	**49.828**
183	2.364	**2.595**	**27.085**	**70.286**	76.4286492 (+/- 7.2e-007)	**182.391**	2.609	**2.595**	*5.190*	*5.219*	**27.085**	**70.286**	60.797	**182.391**
184	3.160	**2.406**	**31.733**	**76.350**	64.9600453 (+/- 1.6e-006)	**183.697**	3.297	**2.406**	*4.812*	*6.595*	**31.733**	**76.350**	61.232	**183.697**
185	2.673	**2.121**	**23.694**	**50.255**	37.8876038 (+/- 8.8e-007)	**106.591**	2.793	**2.121**	*4.242*	*5.586*	**23.694**	**50.255**	35.530	**106.591**
186	2.086	**1.903**	**17.355**	**33.027**	40.9577994 (+/- 6.1e-007)	**62.850**	2.280	**1.903**	*3.806*	*4.560*	**17.355**	**33.027**	20.950	**62.850**
187	1.952	**1.825**	**15.985**	**29.173**	28.1786701 (+/- 4.2e-007)	**53.240**	2.190	**1.825**	*3.650*	*4.379*	**15.985**	**29.173**	17.747	**53.240**
188	1.990	**1.736**	**15.482**	**26.877**	24.5838184 (+/- 6.4e-007)	**46.658**	2.230	**1.736**	*3.472*	*4.459*	**15.482**	**26.877**	15.553	**46.658**
189	2.177	**1.971**	**19.266**	**37.973**	37.1858549 (+/- 7.7e-007)	**74.845**	2.444	**1.971**	*3.942*	*4.887*	**19.266**	**37.973**	24.948	**74.845**
190	2.349	**2.186**	**23.092**	**50.479**	57.1598189 (+/- 6.7e-007)	**110.347**	2.641	**2.186**	*4.372*	*5.282*	**23.092**	**50.479**	36.782	**110.347**
191	2.215	**2.203**	**21.810**	**48.047**	59.8179634 (+/- 8.3e-007)	**105.848**	2.475	**2.203**	*4.406*	*4.950*	**21.810**	**48.047**	35.283	**105.848**
192	2.183	**2.259**	**21.895**	**49.461**	68.2598 (+/- 0.0005)	**111.732**	2.423	**2.259**	*4.518*	*4.846*	**21.895**	**49.461**	37.244	**111.732**
193	2.022	**2.597**	**23.547**	**61.152**	84.9128836 (+/- 9.4e-007)	**158.811**	2.267	**2.597**	*5.194*	*4.534*	**23.547**	**61.152**	52.937	**158.811**
194	1.797	**2.614**	**21.038**	**54.993**	66.2591749 (+/- 1.4e-006)	**143.753**	2.012	**2.614**	*5.228*	*4.024*	**21.038**	**54.993**	47.918	**143.753**
195	2.166	**2.556**	**24.867**	**63.560**	77.9677775 (+/- 9.1e-007)	**162.459**	2.432	**2.556**	*5.112*	*4.864*	**24.867**	**63.560**	54.153	**162.459**
196	1.605	**1.702**	**12.266**	**20.877**	17.8234794 (+/- 4e-007)	**35.532**	1.802	**1.702**	*3.404*	*3.603*	**12.266**	**20.877**	11.844	**35.532**
197	1.553	**1.637**	**11.295**	**18.490**	17.7850712 (+/- 3.9e-007)	**30.268**	1.725	**1.637**	*3.274*	*3.450*	**11.295**	**18.490**	10.089	**30.268**
198	1.745	**1.786**	**14.009**	**25.020**	22.4432078 (+/- 2.3e-007)	**44.686**	1.961	**1.786**	*3.572*	*3.922*	**14.009**	**25.020**	14.895	**44.686**
199	1.551	**1.548**	**10.783**	**16.692**	13.3365699 (+/- 3.1e-007)	**25.839**	1.741	**1.548**	*3.096*	*3.483*	**10.783**	**16.692**	8.613	**25.839**
200	1.479	**1.634**	**10.608**	**17.333**	18.6383 (+/- 0.00021)	**28.323**	1.623	**1.634**	*3.268*	*3.246*	**10.608**	**17.333**	9.441	**28.323**
201	1.947	**1.821**	**15.932**	**29.012**	25.4711378 (+/- 6e-007)	**52.831**	2.187	**1.821**	*3.642*	*4.375*	**15.932**	**29.012**	17.610	**52.831**
202	2.580	**1.885**	**21.863**	**41.212**	37.3825974 (+/- 5.9e-007)	**77.684**	2.900	**1.885**	*3.770*	*5.799*	**21.863**	**41.212**	25.895	**77.684**
203	2.823	**2.501**	**31.612**	**79.062**	134.4004 (+/- 0.00098)	**197.733**	3.160	**2.501**	*5.002*	*6.320*	**31.612**	**79.062**	65.911	**197.733**
204	2.079	**2.244**	**20.775**	**46.619**	61.21822 (+/- 0.00052)	**104.613**	2.315	**2.244**	*4.488*	*4.629*	**20.775**	**46.619**	34.871	**104.613**
205	2.343	**2.300**	**24.046**	**55.306**	56.7669489 (+/- 8.1e-007)	**127.203**	2.614	**2.300**	*4.600*	*5.227*	**24.046**	**55.306**	42.401	**127.203**

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	$mm.^2$	$mm.^3$	$mm.^4$	$mm.^4$	mm.	mm.	mm.	mm.	$mm.^2$	$mm.^3$	$mm.^4$	$mm.^4$
206	2.149	2.498	24.053	60.084	77.1638899 (+/- 5.7e-007)	150.091	2.407	2.498	4.996	4.814	24.053	60.084	50.030	150.091
207	1.466	1.821	11.884	21.641	17.4853755 (+/- 2.4e-007)	39.408	1.632	1.821	3.642	3.263	11.884	21.641	13.136	39.408
208	1.532	2.193	14.981	32.853	31.3762635 (+/- 1.7e-007)	72.047	1.708	2.193	4.386	3.416	14.981	32.853	24.016	72.047
209	1.603	1.849	13.326	24.640	23.3062987 (+/- 1.9e-007)	45.559	1.802	1.849	3.698	3.604	13.326	24.640	15.186	45.559
210	1.619	1.981	14.246	28.221	24.1295904 (+/- 2.7e-007)	55.906	1.798	1.981	3.962	3.596	14.246	28.221	18.635	55.906
211	1.553	1.971	13.617	26.839	22.8775248 (+/- 1.4e-007)	52.900	1.727	1.971	3.942	3.454	13.617	26.839	17.633	52.900
212	1.575	2.009	14.052	28.230	24.3045523 (+/- 1.6e-007)	56.715	1.749	2.009	4.018	3.497	14.052	28.230	18.905	56.715
213	1.507	1.637	11.024	18.046	16.6941848 (+/- 2.1e-007)	29.542	1.684	1.637	3.274	3.367	11.024	18.046	9.847	29.542
214	1.435	1.818	11.672	21.220	20.7382632 (+/- 3e-007)	38.577	1.605	1.818	3.636	3.210	11.672	21.220	12.859	38.577
215	1.922	2.089	18.062	37.732	39.5591387 (+/- 4.4e-007)	78.821	2.162	2.089	4.178	4.323	18.062	37.732	26.274	78.821
216	2.074	2.000	18.628	37.256	37.9739699 (+/- 4.4e-007)	74.512	2.329	2.000	4.000	4.657	18.628	37.256	24.837	74.512
217	1.648	1.730	12.809	22.160	20.001558 (+/- 1.6e-007)	38.336	1.851	1.730	3.460	3.702	12.809	22.160	12.779	38.336
218	1.810	1.990	16.180	32.198	33.8404218 (+/- 3.6e-007)	64.074	2.033	1.990	3.980	4.065	16.180	32.198	21.358	64.074
219	1.732	2.055	16.000	32.880	35.1143593 (+/- 3.2e-007)	67.568	1.946	2.055	4.110	3.893	16.000	32.880	22.523	67.568
220	2.587	1.788	20.737	37.078	35.534257 (+/- 3.1e-007)	66.295	2.899	1.788	3.576	5.799	20.737	37.078	22.098	66.295
221	2.043	1.858	16.790	31.196	33.9716291 (+/- 5e-007)	57.962	2.259	1.858	3.716	4.518	16.790	31.196	19.321	57.962
222	1.565	1.783	12.466	22.227	18.0316614 (+/- 2.4e-007)	39.631	1.748	1.783	3.566	3.496	12.466	22.227	13.210	39.631
223	1.891	1.426	11.999	17.111	13.2035471 (+/- 3.9e-007)	24.400	2.104	1.426	2.852	4.207	11.999	17.111	8.133	24.400
224	2.659	2.163	25.735	55.665	68.2842126 (+/- 5e-007)	120.403	2.974	2.163	4.326	5.949	25.735	55.665	40.134	120.403
225	1.945	1.574	13.705	21.572	18.8130733 (+/- 2.9e-007)	33.954	2.177	1.574	3.148	4.354	13.705	21.572	11.318	33.954
226	1.810	1.899	15.429	29.300	28.9626469 (+/- 3.8e-007)	55.640	2.031	1.899	3.798	4.062	15.429	29.300	18.547	55.640
227	2.026	1.954	17.767	34.717	35.3224321 (+/- 3.1e-007)	67.836	2.273	1.954	3.908	4.546	17.767	34.717	22.612	67.836
228	1.926	1.816	15.535	28.212	30.0536472 (+/- 4.2e-007)	51.232	2.139	1.816	3.632	4.277	15.535	28.212	17.077	51.232
229	1.763	2.050	16.236	33.284	34.0881147 (+/- 3.6e-007)	68.232	1.980	2.050	4.100	3.960	16.236	33.284	22.744	68.232
230	1.803	2.015	16.321	32.887	34.165849 (+/- 2.7e-007)	66.267	2.025	2.015	4.030	4.050	16.321	32.887	22.089	66.267
231	1.742	1.763	13.785	24.303	22.4372211 (+/- 3.7e-007)	42.846	1.955	1.763	3.526	3.910	13.785	24.303	14.282	42.846

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}	mm.	mm.	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}
232	1.744	**1.946**	**15.216**	**29.610**	30.7011911 (+/- 3.3e-007)	**57.622**	1.955	**1.946**	*3.892*	*3.910*	**15.216**	**29.610**	19.207	**57.622**
233	1.673	**1.982**	**14.814**	**29.361**	32.6951305 (+/- 2.4e-007)	**58.194**	1.869	**1.982**	*3.964*	*3.737*	**14.814**	**29.361**	19.398	**58.194**
234	1.664	**1.846**	**13.765**	**25.410**	25.7942363 (+/- 2.6e-007)	**46.907**	1.864	**1.846**	*3.692*	*3.728*	**13.765**	**25.410**	15.636	**46.907**
235	1.613	**2.182**	**15.753**	**34.373**	41.0788828 (+/- 3.1e-007)	**75.002**	1.805	**2.182**	*4.364*	*3.610*	**15.753**	**34.373**	25.001	**75.002**
236	1.965	**1.458**	**12.826**	**18.700**	14.28091 (+/- 3.7e-007)	**27.265**	2.199	**1.458**	*2.916*	*4.398*	**12.826**	**18.700**	9.088	**27.265**
237	2.229	**1.929**	**19.327**	**37.282**	35.9681754 (+/- 4.4e-007)	**71.917**	2.505	**1.929**	*3.858*	*5.010*	**19.327**	**37.282**	23.972	**71.917**
238	1.704	**1.368**	**10.390**	**14.214**	11.1738364 (+/- 3.4e-007)	**19.444**	1.899	**1.368**	*2.736*	*3.798*	**10.390**	**14.214**	6.481	**19.444**
239	2.220	**1.550**	**15.368**	**23.820**	16.5289587 (+/- 1.6e-007)	**36.922**	2.479	**1.550**	*3.100*	*4.957*	**15.368**	**23.820**	12.307	**36.922**
240	1.876	**1.275**	**10.646**	**13.574**	9.73741226 (+/- 3.3e-007)	**17.306**	2.087	**1.275**	*2.550*	*4.175*	**10.646**	**13.574**	5.769	**17.306**
241	2.204	**1.376**	**13.557**	**18.654**	13.1200542 (+/- 5.7e-007)	**25.668**	2.463	**1.376**	*2.752*	*4.926*	**13.557**	**18.654**	8.556	**25.668**
242	2.173	**1.470**	**14.237**	**20.928**	13.6457691 (+/- 2.3e-007)	**30.765**	2.421	**1.470**	*2.940*	*4.843*	**14.237**	**20.928**	10.255	**30.765**
243	2.095	**1.432**	**13.421**	**19.219**	12.2826803 (+/- 1.7e-007)	**27.521**	2.343	**1.432**	*2.864*	*4.686*	**13.421**	**19.219**	9.174	**27.521**
244	2.161	**1.294**	**12.524**	**16.206**	9.57934124 (+/- 1.9e-007)	**20.971**	2.420	**1.294**	*2.588*	*4.839*	**12.524**	**16.206**	6.990	**20.971**
245	1.538	**1.721**	**11.894**	**20.470**	17.929945 (+/- 2.4e-007)	**35.228**	1.728	**1.721**	*3.442*	*3.456*	**11.894**	**20.470**	11.743	**35.228**
246	1.727	**1.667**	**12.900**	**21.504**	19.2658232 (+/- 2.6e-007)	**35.848**	1.935	**1.667**	*3.334*	*3.869*	**12.900**	**21.504**	11.949	**35.848**
247	2.521	**1.726**	**19.315**	**33.338**	33.2569405 (+/- 4.7e-007)	**57.541**	2.798	**1.726**	*3.452*	*5.595*	**19.315**	**33.338**	19.180	**57.541**
248	2.467	**1.435**	**15.871**	**22.775**	15.9911865 (+/- 1.8e-007)	**32.682**	2.765	**1.435**	*2.870*	*5.530*	**15.871**	**22.775**	10.894	**32.682**
249	2.430	**1.751**	**19.106**	**33.455**	36.3765402 (+/- 5.1e-007)	**58.579**	2.728	**1.751**	*3.502*	*5.456*	**19.106**	**33.455**	19.526	**58.579**
250	1.972	**1.954**	**17.277**	**33.759**	30.7787804 (+/- 3.2e-007)	**65.966**	2.210	**1.954**	*3.908*	*4.421*	**17.277**	**33.759**	21.989	**65.966**
251	2.025	**1.882**	**17.061**	**32.109**	33.0159041 (+/- 4e-007)	**60.429**	2.266	**1.882**	*3.764*	*4.533*	**17.061**	**32.109**	20.143	**60.429**
252	1.905	**1.981**	**16.922**	**33.522**	35.3887599 (+/- 5.2e-007)	**66.408**	2.136	**1.981**	*3.962*	*4.271*	**16.922**	**33.522**	22.136	**66.408**
253	2.048	**2.205**	**20.190**	**44.519**	54.0525722 (+/- 6.1e-007)	**98.164**	2.289	**2.205**	*4.410*	*4.578*	**20.190**	**44.519**	32.721	**98.164**
254	1.999	**2.276**	**20.441**	**46.524**	53.2115793 (+/- 3.4e-007)	**105.888**	2.245	**2.276**	*4.552*	*4.491*	**20.441**	**46.524**	35.296	**105.888**
255	1.930	**2.270**	**19.663**	**44.635**	53.6154513 (+/- 4.1e-007)	**101.321**	2.166	**2.270**	*4.540*	*4.331*	**19.663**	**44.635**	33.774	**101.321**
256	1.741	**2.006**	**15.663**	**31.420**	30.9922079 (+/- 2.7e-007)	**63.028**	1.952	**2.006**	*4.012*	*3.904*	**15.663**	**31.420**	21.009	**63.028**
257	1.681	**2.060**	**15.543**	**32.019**	34.5587212 (+/- 4.9e-007)	**65.958**	1.886	**2.060**	*4.120*	*3.773*	**15.543**	**32.019**	21.986	**65.958**

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}	mm.	mm.	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}
258	1.729	2.057	15.970	32.850	33.8005477 (+/- 2.5e-007)	67.573	1.941	2.057	4.114	3.882	15.970	32.850	22.524	67.573
259	1.912	2.261	19.362	43.777	54.7027128 (+/- 3.7e-007)	98.981	2.141	2.261	4.522	4.282	19.362	43.777	32.994	98.981
260	1.886	2.070	17.544	36.316	38.1121088 (+/- 2.8e-007)	75.174	2.119	2.070	4.140	4.238	17.544	36.316	25.058	75.174
261	2.002	2.215	19.842	43.950	53.4922478 (+/- 3.6e-007)	97.349	2.240	2.215	4.430	4.479	19.842	43.950	32.450	97.349
262	1.973	1.609	14.177	22.811	20.8781097 (+/- 3.2e-007)	36.703	2.203	1.609	3.218	4.406	14.177	22.811	12.234	36.703
263	1.852	1.592	13.191	21.000	17.709187 (+/- 2.1e-007)	33.432	2.071	1.592	3.184	4.143	13.191	21.000	11.144	33.432
264	2.099	1.646	15.394	25.339	24.2050501 (+/- 3.1e-007)	41.707	2.338	1.646	3.292	4.676	15.394	25.339	13.902	41.707
265	1.992	1.385	12.370	17.132	12.8055462 (+/- 2.3e-007)	23.728	2.233	1.385	2.770	4.466	12.370	17.132	7.909	23.728
266	1.994	1.654	14.806	24.489	21.2260536 (+/- 3.6e-007)	40.505	2.238	1.654	3.308	4.476	14.806	24.489	13.502	40.505
267	1.540	1.620	11.143	18.052	16.1960903 (+/- 4.3e-007)	29.244	1.720	1.620	3.240	3.439	11.143	18.052	9.748	29.244
268	1.966	1.864	16.438	30.640	30.6732503 (+/- 2.5e-007)	57.114	2.205	1.864	3.728	4.409	16.438	30.640	19.038	57.114
269	1.985	1.645	14.644	24.089	19.4753831 (+/- 3.7e-007)	39.627	2.226	1.645	3.290	4.451	14.644	24.089	13.209	39.627
270	2.114	1.900	18.039	34.274	33.6182484 (+/- 4.1e-007)	65.121	2.374	1.900	3.800	4.747	18.039	34.274	21.707	65.121
271	1.931	2.139	18.556	39.691	42.8989263 (+/- 8.4e-007)	84.900	2.169	2.139	4.278	4.338	18.556	39.691	28.300	84.900
272	2.152	2.046	19.768	40.445	39.7410138 (+/- 3.7e-007)	82.751	2.415	2.046	4.092	4.831	19.768	40.445	27.584	82.751
273	1.634	1.523	11.110	16.921	13.4293329 (+/- 2.9e-007)	25.770	1.824	1.523	3.046	3.647	11.110	16.921	8.590	25.770
274	1.751	2.065	16.249	33.554	34.32181 (+/- 3.3e-007)	69.289	1.967	2.065	4.130	3.934	16.249	33.554	23.096	69.289
275	2.360	1.779	18.391	32.718	37.9724221 (+/- 5e-007)	58.205	2.584	1.779	3.558	5.169	18.391	32.718	19.402	58.205
276	2.227	2.275	22.743	51.740	57.3261421 (+/- 3.7e-007)	117.709	2.499	2.275	4.550	4.998	22.743	51.740	39.236	117.709
277	1.944	1.641	13.825	22.687	25.6497669 (+/- 3.9e-007)	37.229	2.106	1.641	3.282	4.212	13.825	22.687	12.410	37.229
278	2.133	2.576	24.655	63.511	83.2177708 (+/- 4.2e-007)	163.605	2.393	2.576	5.152	4.786	24.655	63.511	54.535	163.605
279	2.443	1.690	18.543	31.338	25.9542097 (+/- 5.4e-007)	52.961	2.743	1.690	3.380	5.486	18.543	31.338	17.654	52.961
280	1.841	1.991	16.012	31.880	41.6202418 (+/- 2.9e-007)	63.473	2.011	1.991	3.982	4.021	16.012	31.880	21.158	63.473
281	1.700	1.882	14.193	26.711	29.9684053 (+/- 3.1e-007)	50.271	1.885	1.882	3.764	3.771	14.193	26.711	16.757	50.271
282	2.210	2.160	21.444	46.319	52.5523228 (+/- 4.1e-007)	100.049	2.482	2.160	4.320	4.964	21.444	46.319	33.350	100.049
283	1.985	2.512	22.401	56.271	71.6694042 (+/- 4.1e-007)	141.354	2.229	2.512	5.024	4.459	22.401	56.271	47.118	141.354

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}	mm.	mm.	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}
284	1.395	1.972	12.264	24.185	26.535801 (+/- 2.1e-007)	47.692	1.555	1.972	3.944	3.110	12.264	24.185	15.897	47.692
285	1.582	3.009	21.162	63.676	82.5431887 (+/- 4.6e-007)	191.602	1.758	3.009	6.018	3.516	21.162	63.676	63.867	191.602
286	1.627	2.502	18.136	45.376	49.449941 (+/- 3.9e-007)	113.531	1.812	2.502	5.004	3.624	18.136	45.376	37.844	113.531
287	1.408	1.725	10.889	18.784	16.068949 (+/- 2e-007)	32.402	1.578	1.725	3.450	3.156	10.889	18.784	10.801	32.402
288	1.725	2.426	18.761	45.514	52.8279087 (+/- 1.1e-006)	110.417	1.933	2.426	4.852	3.867	18.761	45.514	36.806	110.417
289	1.506	1.894	12.336	23.364	16.9246065 (+/- 1.4e-007)	44.252	1.628	1.894	3.788	3.257	12.336	23.364	14.751	44.252
290	1.492	1.880	12.607	23.701	22.6107523 (+/- 3.1e-007)	44.558	1.676	1.880	3.760	3.353	12.607	23.701	14.853	44.558
291	1.979	2.265	20.042	45.395	46.3438724 (+/- 5e-007)	102.820	2.212	2.265	4.530	4.424	20.042	45.395	34.273	102.820
292	1.309	1.802	10.577	19.060	18.3034 (+/- 0.00036)	34.346	1.467	1.802	3.604	2.935	10.577	19.060	11.449	34.346
293	1.565	1.920	13.279	25.496	20.3503513 (+/- 2.2e-007)	48.952	1.729	1.920	3.840	3.458	13.279	25.496	16.317	48.952
294	1.729	1.731	13.366	23.137	20.3145115 (+/- 2.6e-007)	40.049	1.930	1.731	3.462	3.861	13.366	23.137	13.350	40.049
295	1.926	1.963	16.995	33.361	31.3234753 (+/- 2e-007)	65.488	2.164	1.963	3.926	4.329	16.995	33.361	21.829	65.488
296	2.297	2.250	23.177	52.148	53.9076762 (+/- 4e-007)	117.334	2.575	2.250	4.500	5.150	23.177	52.148	39.111	117.334
297	2.347	2.219	23.398	51.920	54.5431922 (+/- 2.8e-007)	115.211	2.636	2.219	4.438	5.272	23.398	51.920	38.404	115.211
298	2.403	1.842	19.868	36.597	33.3913676 (+/- 2.8e-007)	67.411	2.697	1.842	3.684	5.393	19.868	36.597	22.470	67.411
299	2.353	2.193	23.007	50.454	63.4612 (+/- 2.8e-007)	110.646	2.623	2.193	4.386	5.246	23.007	50.454	36.882	110.646
300	2.046	1.816	16.700	30.327	26.8405152 (+/- 3.1e-007)	55.074	2.299	1.816	3.632	4.598	16.700	30.327	18.358	55.074
301	1.868	1.699	14.057	23.883	24.72656 (+/- 2e-007)	40.577	2.068	1.699	3.398	4.137	14.057	23.883	13.526	40.577
302	1.961	1.837	16.129	29.629	24.6410107 (+/- 2.6e-007)	54.428	2.195	1.837	3.674	4.390	16.129	29.629	18.143	54.428
303	2.504	2.323	26.153	60.753	71.6618344 (+/- 4.2e-007)	141.130	2.815	2.323	4.646	5.629	26.153	60.753	47.043	141.130
304	2.397	1.922	20.564	39.524	43.0043923 (+/- 2.6e-007)	75.965	2.675	1.922	3.844	5.350	20.564	39.524	25.322	75.965
305	2.307	2.230	23.039	51.377	63.0266736 (+/- 2.7e-007)	114.571	2.583	2.230	4.460	5.166	23.039	51.377	38.190	114.571
306	3.560	1.978	29.518	58.387	91.7667297 (+/- 5.3e-007)	115.489	3.731	1.978	3.956	7.462	29.518	58.387	38.496	115.489
307	2.058	1.983	18.288	36.265	35.2702486 (+/- 3.7e-007)	71.914	2.306	1.983	3.966	4.611	18.288	36.265	23.971	71.914
308	1.655	1.918	14.231	27.295	25.3062338 (+/- 3.4e-007)	52.352	1.855	1.918	3.836	3.710	14.231	27.295	17.451	52.352
309	1.995	2.220	19.426	43.126	38.0357724 (+/- 3e-007)	95.739	2.188	2.220	4.440	4.375	19.426	43.126	31.913	95.739

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}	mm.	mm.	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}
310	1.865	**2.670**	**22.399**	**59.805**	79.3005068 (+/- 5.8e-007)	**159.680**	2.097	**2.670**	*5.340*	*4.195*	**22.399**	**59.805**	53.227	**159.680**
311	1.887	**2.353**	**19.978**	**47.008**	56.3954543 (+/- 4.8e-007)	**110.610**	2.123	**2.353**	*4.706*	*4.245*	**19.978**	**47.008**	36.870	**110.610**
312	1.776	**2.334**	**18.614**	**43.445**	52.3409658 (+/- 3.9e-007)	**101.401**	1.994	**2.334**	*4.668*	*3.988*	**18.614**	**43.445**	33.800	**101.401**
313	1.559	**2.290**	**16.049**	**36.752**	41.7636592 (+/- 2.1e-007)	**84.163**	1.752	**2.290**	*4.580*	*3.504*	**16.049**	**36.752**	28.054	**84.163**
314	1.485	**2.548**	**17.001**	**43.319**	53.7239862 (+/- 2.8e-007)	**110.376**	1.668	**2.548**	*5.096*	*3.336*	**17.001**	**43.319**	36.792	**110.376**
315	1.515	**2.574**	**17.533**	**45.130**	58.4187151 (+/- 4.2e-007)	**116.164**	1.703	**2.574**	*5.148*	*3.406*	**17.533**	**45.130**	38.721	**116.164**
316	1.411	**2.450**	**15.530**	**38.049**	46.6401718 (+/- 2.1e-007)	**93.219**	1.585	**2.450**	*4.900*	*3.169*	**15.530**	**38.049**	31.073	**93.219**
317	1.380	**2.032**	**12.561**	**25.524**	28.3720464 (+/- 3.1e-007)	**51.865**	1.545	**2.032**	*4.064*	*3.091*	**12.561**	**25.524**	17.288	**51.865**
318	1.560	**2.020**	**14.149**	**28.581**	30.4883244 (+/- 3e-007)	**57.734**	1.751	**2.020**	*4.040*	*3.502*	**14.149**	**28.581**	19.245	**57.734**
319	1.480	**1.972**	**13.111**	**25.855**	25.7378724 (+/- 2.6e-007)	**50.986**	1.662	**1.972**	*3.944*	*3.324*	**13.111**	**25.855**	16.995	**50.986**
320	1.249	**1.875**	**10.453**	**19.599**	20.3187665 (+/- 1.5e-007)	**36.749**	1.394	**1.875**	*3.750*	*2.787*	**10.453**	**19.599**	12.250	**36.749**
321	1.240	**2.178**	**12.112**	**26.380**	30.7792412 (+/- 1.6e-007)	**57.456**	1.390	**2.178**	*4.356*	*2.781*	**12.112**	**26.380**	19.152	**57.456**
322	1.988	**2.234**	**19.968**	**44.609**	50.0834301 (+/- 2e-007)	**99.655**	2.235	**2.234**	*4.468*	*4.469*	**19.968**	**44.609**	33.218	**99.655**
323	2.118	**1.615**	**15.343**	**24.779**	21.4494329 (+/- 3.9e-007)	**40.018**	2.375	**1.615**	*3.230*	*4.750*	**15.343**	**24.779**	13.339	**40.018**
324	2.242	**2.228**	**22.341**	**49.776**	60.171709 (+/- 3.5e-007)	**110.900**	2.507	**2.228**	*4.456*	*5.014*	**22.341**	**49.776**	36.967	**110.900**
325	1.982	**1.593**	**14.124**	**22.500**	17.5148119 (+/- 5.9e-007)	**35.842**	2.217	**1.593**	*3.186*	*4.433*	**14.124**	**22.500**	11.947	**35.842**
326	2.083	**1.882**	**17.563**	**33.054**	34.0526779 (+/- 4.6e-007)	**62.207**	2.333	**1.882**	*3.764*	*4.666*	**17.563**	**33.054**	20.736	**62.207**
327	1.975	**1.617**	**14.346**	**23.197**	18.2555334 (+/- 1.9e-007)	**37.510**	2.218	**1.617**	*3.234*	*4.436*	**14.346**	**23.197**	12.503	**37.510**
328	2.130	**1.900**	**17.641**	**33.518**	38.692213 (+/- 3.7e-007)	**63.684**	2.321	**1.900**	*3.800*	*4.642*	**17.641**	**33.518**	21.228	**63.684**
329	1.947	**1.746**	**15.189**	**26.520**	25.2601596 (+/- 3.4e-007)	**46.304**	2.175	**1.746**	*3.492*	*4.350*	**15.189**	**26.520**	15.435	**46.304**
330	1.571	**1.823**	**12.872**	**23.466**	21.295955 (+/- 2.4e-007)	**42.778**	1.765	**1.823**	*3.646*	*3.530*	**12.872**	**23.466**	14.259	**42.778**
331	1.614	**1.875**	**13.606**	**25.511**	24.8374057 (+/- 2.1e-007)	**47.834**	1.814	**1.875**	*3.750*	*3.628*	**13.606**	**25.511**	15.945	**47.834**
332	1.722	**2.018**	**15.602**	**31.485**	33.9318612 (+/- 2.2e-007)	**63.536**	1.933	**2.018**	*4.036*	*3.866*	**15.602**	**31.485**	21.179	**63.536**
333	1.446	**2.016**	**13.053**	**26.315**	33.4316 (+/- 0.00053)	**53.051**	1.619	**2.016**	*4.032*	*3.237*	**13.053**	**26.315**	17.684	**53.051**
334	1.497	**1.599**	**10.723**	**17.146**	14.9200323 (+/- 1.6e-007)	**27.417**	1.677	**1.599**	*3.198*	*3.353*	**10.723**	**17.146**	9.139	**27.417**
335	1.862	**1.897**	**15.858**	**30.083**	29.8105914 (+/- 4.1e-007)	**57.067**	2.090	**1.897**	*3.794*	*4.180*	**15.858**	**30.083**	19.022	**57.067**

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}	mm.	mm.	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}
336	2.217	**1.479**	**14.662**	**21.685**	17.801168 (+/- 6.5e-007)	**32.072**	2.478	**1.479**	*2.958*	*4.957*	**14.662**	**21.685**	10.691	**32.072**
337	2.355	**2.016**	**21.351**	**43.044**	43.3154122 (+/- 4.4e-007)	**86.776**	2.648	**2.016**	*4.032*	*5.295*	**21.351**	**43.044**	28.925	**86.776**
338	2.158	**2.525**	**24.470**	**61.787**	75.7956211 (+/- 5.4e-007)	**156.012**	2.423	**2.525**	*5.050*	*4.846*	**24.470**	**61.787**	52.004	**156.012**
339	1.863	**1.896**	**15.881**	**30.110**	28.2344391 (+/- 4.7e-007)	**57.089**	2.094	**1.896**	*3.792*	*4.188*	**15.881**	**30.110**	19.030	**57.089**
340	2.119	**1.579**	**14.955**	**23.614**	19.6945362 (+/- 3.9e-007)	**37.286**	2.368	**1.579**	*3.158*	*4.736*	**14.955**	**23.614**	12.429	**37.286**
341	1.921	**1.956**	**16.090**	**31.472**	43.58068 (+/- 0.00033)	**61.559**	2.056	**1.956**	*3.912*	*4.113*	**16.090**	**31.472**	20.520	**61.559**
342	2.302	**2.359**	**24.408**	**57.578**	67.1388802 (+/- 5.3e-007)	**135.828**	2.587	**2.359**	*4.718*	*5.173*	**24.408**	**57.578**	45.276	**135.828**
343	2.061	**1.869**	**17.277**	**32.291**	31.3963282 (+/- 4e-007)	**60.351**	2.311	**1.869**	*3.738*	*4.622*	**17.277**	**32.291**	20.117	**60.351**
344	2.639	**2.163**	**25.653**	**55.487**	58.3981641 (+/- 6.9e-007)	**120.019**	2.965	**2.163**	*4.326*	*5.930*	**25.653**	**55.487**	40.006	**120.019**
345	1.806	**2.109**	**17.055**	**35.969**	40.7257622 (+/- 2.8e-007)	**75.859**	2.022	**2.109**	*4.218*	*4.043*	**17.055**	**35.969**	25.286	**75.859**
346	1.556	**1.753**	**12.233**	**21.444**	20.4171339 (+/- 3.2e-007)	**37.592**	1.745	**1.753**	*3.506*	*3.489*	**12.233**	**21.444**	12.531	**37.592**
347	1.878	**2.004**	**16.987**	**34.042**	43.5731948 (+/- 3.7e-007)	**68.220**	2.119	**2.004**	*4.008*	*4.238*	**16.987**	**34.042**	22.740	**68.220**
348	2.665	**1.934**	**22.609**	**43.726**	54.8785338 (+/- 6.2e-007)	**84.566**	2.923	**1.934**	*3.868*	*5.845*	**22.609**	**43.726**	28.189	**84.566**
349	2.385	**1.792**	**18.874**	**33.822**	36.6688667 (+/- 4.7e-007)	**60.609**	2.633	**1.792**	*3.584*	*5.266*	**18.874**	**33.822**	20.203	**60.609**
350	2.142	**2.231**	**21.273**	**47.460**	62.0935019 (+/- 4.3e-007)	**105.883**	2.384	**2.231**	*4.462*	*4.768*	**21.273**	**47.460**	35.294	**105.883**
351	2.210	**2.381**	**23.641**	**56.289**	69.9448653 (+/- 4.9e-007)	**134.025**	2.482	**2.381**	*4.762*	*4.965*	**23.641**	**56.289**	44.675	**134.025**
352	2.190	**1.815**	**17.765**	**32.243**	33.0302463 (+/- 7.2e-007)	**58.522**	2.447	**1.815**	*3.630*	*4.894*	**17.765**	**32.243**	19.507	**58.522**
353	2.259	**1.928**	**19.572**	**37.735**	37.8253794 (+/- 3.9e-007)	**72.753**	2.538	**1.928**	*3.856*	*5.076*	**19.572**	**37.735**	24.251	**72.753**
354	1.892	**1.781**	**15.014**	**26.740**	27.1058464 (+/- 3.2e-007)	**47.624**	2.108	**1.781**	*3.562*	*4.215*	**15.014**	**26.740**	15.875	**47.624**
355	2.114	**1.960**	**18.536**	**36.331**	39.6189776 (+/- 6.4e-007)	**71.208**	2.364	**1.960**	*3.920*	*4.729*	**18.536**	**36.331**	23.736	**71.208**
356	2.351	**2.179**	**22.995**	**50.106**	58.5536938 (+/- 7.2e-007)	**109.181**	2.638	**2.179**	*4.358*	*5.277*	**22.995**	**50.106**	36.394	**109.181**
357	2.101	**1.965**	**18.350**	**36.058**	40.6625928 (+/- 3.8e-007)	**70.853**	2.335	**1.965**	*3.930*	*4.669*	**18.350**	**36.058**	23.618	**70.853**
358	2.668	**2.097**	**24.861**	**52.134**	64.1831287 (+/- 7e-007)	**109.324**	2.964	**2.097**	*4.194*	*5.928*	**24.861**	**52.134**	36.441	**109.324**
359	2.528	**2.580**	**29.304**	**75.604**	93.8166027 (+/- 5.8e-007)	**195.059**	2.840	**2.580**	*5.160*	*5.679*	**29.304**	**75.604**	65.020	**195.059**
360	2.198	**1.694**	**16.616**	**28.148**	27.1494941 (+/- 1.6e-007)	**47.682**	2.452	**1.694**	*3.388*	*4.904*	**16.616**	**28.148**	15.894	**47.682**
361	2.149	**1.687**	**16.274**	**27.454**	24.3504933 (+/- 4.4e-007)	**46.315**	2.412	**1.687**	*3.374*	*4.823*	**16.274**	**27.454**	15.438	**46.315**

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	$mm.^2$	$mm.^3$	$mm.^4$	$mm.^4$	mm.	mm.	mm.	mm.	$mm.^2$	$mm.^3$	$mm.^4$	$mm.^4$
362	2.084	1.551	14.516	22.514	18.1841352 (+/- 4.5e-007)	34.920	2.340	1.551	3.102	4.680	14.516	22.514	11.640	34.920
363	2.138	1.762	16.864	29.714	27.8298342 (+/- 3.7e-007)	52.357	2.393	1.762	3.524	4.785	16.864	29.714	17.452	52.357
364	2.245	1.692	17.072	28.886	25.0825623 (+/- 3.9e-007)	48.875	2.522	1.692	3.384	5.045	17.072	28.886	16.292	48.875
365	2.754	1.809	22.368	40.464	37.9850023 (+/- 2.9e-007)	73.199	3.091	1.809	3.618	6.182	22.368	40.464	24.400	73.199
366	2.556	2.526	28.632	72.324	78.2866707 (+/- 4.6e-007)	182.692	2.834	2.526	5.052	5.667	28.632	72.324	60.897	182.692
367	2.141	2.016	19.080	38.465	32.1882914 (+/- 2.5e-007)	77.546	2.366	2.016	4.032	4.732	19.080	38.465	25.849	77.546
368	2.136	1.717	16.471	28.281	23.9630701 (+/- 5e-007)	48.558	2.398	1.717	3.434	4.796	16.471	28.281	16.186	48.558
369	2.016	1.712	15.363	26.301	19.7728299 (+/- 3.6e-007)	45.028	2.243	1.712	3.424	4.487	15.363	26.301	15.009	45.028
370	1.875	1.762	14.644	25.803	19.2118887 (+/- 3.2e-007)	45.464	2.078	1.762	3.524	4.156	14.644	25.803	15.155	45.464
371	2.350	1.620	17.006	27.550	20.1099746 (+/- 4e-007)	44.631	2.624	1.620	3.240	5.249	17.006	27.550	14.877	44.631
372	2.439	1.431	15.636	22.375	14.6671812 (+/- 3.7e-007)	32.019	2.732	1.431	2.862	5.463	15.636	22.375	10.673	32.019
373	2.150	1.839	17.716	32.580	27.9512054 (+/- 4.3e-007)	59.914	2.408	1.839	3.678	4.817	17.716	32.580	19.971	59.914
374	2.052	1.963	17.736	34.816	27.8396658 (+/- 4.5e-007)	68.343	2.259	1.963	3.926	4.518	17.736	34.816	22.781	68.343
375	1.774	1.844	14.700	27.107	23.8987439 (+/- 3.8e-007)	49.985	1.993	1.844	3.688	3.986	14.700	27.107	16.662	49.985
376	2.190	1.994	19.474	38.831	33.7403189 (+/- 4e-007)	77.429	2.442	1.994	3.988	4.883	19.474	38.831	25.810	77.429
377	2.561	2.279	26.196	59.701	64.0002781 (+/- 7.9e-007)	136.058	2.874	2.279	4.558	5.747	26.196	59.701	45.353	136.058
378	2.351	1.948	20.386	39.712	33.5071443 (+/- 8.5e-007)	77.359	2.616	1.948	3.896	5.233	20.386	39.712	25.786	77.359
379	2.227	1.798	17.974	32.317	28.9085586 (+/- 6.5e-007)	58.106	2.499	1.798	3.596	4.998	17.974	32.317	19.369	58.106
380	2.000	1.787	16.035	28.655	24.5131368 (+/- 4.3e-007)	51.206	2.243	1.787	3.574	4.487	16.035	28.655	17.069	51.206
381	2.386	1.976	21.083	41.660	46.0362537 (+/- 5.8e-007)	82.320	2.667	1.976	3.952	5.335	21.083	41.660	27.440	82.320
382	2.594	2.140	24.919	53.327	54.4266735 (+/- 6.2e-007)	114.119	2.911	2.140	4.280	5.822	24.919	53.327	38.040	114.119
383	2.191	1.678	16.460	27.620	25.0720698 (+/- 4.8e-007)	46.346	2.452	1.678	3.356	4.905	16.460	27.620	15.449	46.346
384	2.138	1.741	16.724	29.116	26.6551895 (+/- 3.4e-007)	50.692	2.401	1.741	3.482	4.803	16.724	29.116	16.897	50.692
385	3.767	2.062	34.824	71.807	70.2866256 (+/- 7.9e-007)	148.066	4.222	2.062	4.124	8.444	34.824	71.807	49.355	148.066
386	2.215	2.133	20.450	43.620	34.998171 (+/- 3.6e-007)	93.041	2.397	2.133	4.266	4.794	20.450	43.620	31.014	93.041
387	2.349	2.352	24.583	57.819	58.2944776 (+/- 4.5e-007)	135.991	2.613	2.352	4.704	5.226	24.583	57.819	45.330	135.991
388	1.895	2.173	18.237	39.629	35.6448794 (+/- 4.7e-007)	86.114	2.098	2.173	4.346	4.196	18.237	39.629	28.705	86.114

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}	mm.	mm.	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}
389	1.941	**1.770**	**15.439**	**27.327**	23.8598753 (+/- 4.2e-007)	**48.369**	2.181	**1.770**	*3.540*	*4.361*	**15.439**	**27.327**	16.123	**48.369**
390	1.866	**1.944**	**16.125**	**31.347**	25.9054123 (+/- 5.5e-007)	**60.939**	2.074	**1.944**	*3.888*	*4.147*	**16.125**	**31.347**	20.313	**60.939**
391	1.824	**1.847**	**15.075**	**27.844**	23.2014938 (+/- 4.7e-007)	**51.427**	2.040	**1.847**	*3.694*	*4.081*	**15.075**	**27.844**	17.142	**51.427**
392	2.025	**1.989**	**17.971**	**35.744**	31.123319 (+/- 4e-007)	**71.095**	2.259	**1.989**	*3.978*	*4.518*	**17.971**	**35.744**	23.698	**71.095**
393	1.964	**2.081**	**17.319**	**36.041**	32.7818356 (+/- 5.5e-007)	**75.001**	2.081	**2.081**	*4.162*	*4.161*	**17.319**	**36.041**	25.000	**75.001**
394	1.625	**1.970**	**14.102**	**27.781**	22.0998594 (+/- 4.2e-007)	**54.728**	1.790	**1.970**	*3.940*	*3.579*	**14.102**	**27.781**	18.243	**54.728**
395	1.965	**1.961**	**17.316**	**33.957**	32.1200294 (+/- 4.6e-007)	**66.589**	2.208	**1.961**	*3.922*	*4.415*	**17.316**	**33.957**	22.196	**66.589**
396	1.787	**1.728**	**13.880**	**23.985**	21.6090959 (+/- 4.9e-007)	**41.445**	2.008	**1.728**	*3.456*	*4.016*	**13.880**	**23.985**	13.815	**41.445**
397	1.885	**1.791**	**15.159**	**27.150**	25.6202415 (+/- 3.3e-007)	**48.625**	2.116	**1.791**	*3.582*	*4.232*	**15.159**	**27.150**	16.208	**48.625**
398	2.110	**1.868**	**17.664**	**32.996**	33.2097652 (+/- 9.2e-007)	**61.637**	2.364	**1.868**	*3.736*	*4.728*	**17.664**	**32.996**	20.546	**61.637**
399	2.025	**1.830**	**16.595**	**30.369**	25.4256568 (+/- 3.8e-007)	**55.575**	2.267	**1.830**	*3.660*	*4.534*	**16.595**	**30.369**	18.525	**55.575**
400	1.675	**1.680**	**12.647**	**21.247**	17.217169 (+/- 4.2e-007)	**35.695**	1.882	**1.680**	*3.360*	*3.764*	**12.647**	**21.247**	11.898	**35.695**
401	1.640	**1.729**	**12.655**	**21.880**	19.4708979 (+/- 4.9e-007)	**37.831**	1.830	**1.729**	*3.458*	*3.660*	**12.655**	**21.880**	12.610	**37.831**
402	1.843	**1.791**	**14.614**	**26.174**	19.5713986 (+/- 4.7e-007)	**46.877**	2.040	**1.791**	*3.582*	*4.080*	**14.614**	**26.174**	15.626	**46.877**
403	2.798	**1.863**	**23.354**	**43.509**	44.2445938 (+/- 7e-007)	**81.056**	3.134	**1.863**	*3.726*	*6.268*	**23.354**	**43.509**	27.019	**81.056**
404	1.788	**1.827**	**14.678**	**26.817**	23.1466046 (+/- 3.4e-007)	**48.994**	2.008	**1.827**	*3.654*	*4.017*	**14.678**	**26.817**	16.331	**48.994**
405	1.520	**1.821**	**12.435**	**22.644**	19.7464961 (+/- 2.6e-007)	**41.235**	1.707	**1.821**	*3.642*	*3.414*	**12.435**	**22.644**	13.745	**41.235**
406	1.363	**1.489**	**9.102**	**13.553**	10.8664906 (+/- 3.9e-007)	**20.180**	1.528	**1.489**	*2.978*	*3.056*	**9.102**	**13.553**	6.727	**20.180**
407	1.444	**1.715**	**11.130**	**19.088**	17.2120235 (+/- 3.1e-007)	**32.736**	1.622	**1.715**	*3.430*	*3.245*	**11.130**	**19.088**	10.912	**32.736**
408	3.506	**2.023**	**30.874**	**62.458**	49.4199847 (+/- 2.5e-006)	**126.353**	3.815	**2.023**	*4.046*	*7.631*	**30.874**	**62.458**	42.118	**126.353**
409	3.509	**1.826**	**28.458**	**51.964**	41.6045655 (+/- 9.5e-007)	**94.887**	3.896	**1.826**	*3.652*	*7.792*	**28.458**	**51.964**	31.629	**94.887**
410	4.391	**2.140**	**41.830**	**89.516**	82.7111788 (+/- 1.3e-006)	**191.565**	4.887	**2.140**	*4.280*	*9.773*	**41.830**	**89.516**	63.855	**191.565**
411	2.556	**2.150**	**24.427**	**52.518**	47.9745606 (+/- 6.1e-007)	**112.914**	2.840	**2.150**	*4.300*	*5.681*	**24.427**	**52.518**	37.638	**112.914**
412	2.833	**1.947**	**24.385**	**47.478**	38.4699951 (+/- 5.3e-007)	**92.439**	3.131	**1.947**	*3.894*	*6.262*	**24.385**	**47.478**	30.813	**92.439**
413	2.406	**1.608**	**17.216**	**27.683**	19.2884336 (+/- 5.3e-007)	**44.515**	2.677	**1.608**	*3.216*	*5.353*	**17.216**	**27.683**	14.838	**44.515**
414	2.352	**1.542**	**16.093**	**24.815**	16.4533935 (+/- 4.9e-007)	**38.265**	2.609	**1.542**	*3.084*	*5.218*	**16.093**	**24.815**	12.755	**38.265**
415	1.980	**2.089**	**18.324**	**38.279**	33.3697305 (+/- 4.9e-007)	**79.964**	2.193	**2.089**	*4.178*	*4.386*	**18.324**	**38.279**	26.655	**79.964**

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	$mm.^2$	$mm.^3$	$mm.^4$	$mm.^4$	mm.	mm.	mm.	mm.	$mm.^2$	$mm.^3$	$mm.^4$	$mm.^4$
416	1.995	**1.541**	**13.728**	**21.155**	14.4328555 (+/- 4.6e-007)	**32.600**	2.227	**1.541**	*3.082*	*4.454*	**13.728**	**21.155**	10.867	**32.600**
417	2.611	**1.918**	**22.346**	**42.860**	39.2886255 (+/- 7.9e-007)	**82.205**	2.913	**1.918**	*3.836*	*5.825*	**22.346**	**42.860**	27.402	**82.205**
418	2.418	**1.651**	**17.861**	**29.489**	23.1816812 (+/- 4.8e-007)	**48.686**	2.705	**1.651**	*3.302*	*5.409*	**17.861**	**29.489**	16.229	**48.686**
419	2.407	**1.594**	**17.255**	**27.504**	22.0638019 (+/- 4.8e-007)	**43.842**	2.706	**1.594**	*3.188*	*5.412*	**17.255**	**27.504**	14.614	**43.842**
420	3.165	**2.280**	**32.253**	**73.537**	77.9655959 (+/- 6.6e-007)	**167.664**	3.537	**2.280**	*4.560*	*7.073*	**32.253**	**73.537**	55.888	**167.664**
421	2.843	**2.038**	**25.753**	**52.485**	45.5546553 (+/- 6.5e-007)	**106.964**	3.159	**2.038**	*4.076*	*6.318*	**25.753**	**52.485**	35.655	**106.964**
422	3.408	**1.974**	**29.621**	**58.472**	46.7143237 (+/- 5.7e-007)	**115.423**	3.751	**1.974**	*3.948*	*7.503*	**29.621**	**58.472**	38.474	**115.423**
423	3.348	**1.799**	**26.897**	**48.388**	38.7627957 (+/- 6.3e-007)	**87.049**	3.738	**1.799**	*3.598*	*7.476*	**26.897**	**48.388**	29.016	**87.049**
424	2.978	**1.894**	**25.224**	**47.774**	40.7366303 (+/- 8.4e-007)	**90.484**	3.329	**1.894**	*3.788*	*6.659*	**25.224**	**47.774**	30.161	**90.484**
425	2.864	**1.550**	**19.747**	**30.608**	20.440488 (+/- 5e-007)	**47.442**	3.185	**1.550**	*3.100*	*6.370*	**19.747**	**30.608**	15.814	**47.442**
426	3.017	**1.898**	**25.645**	**48.674**	45.5161738 (+/- 6.8e-007)	**92.384**	3.378	**1.898**	*3.796*	*6.756*	**25.645**	**48.674**	30.795	**92.384**
427	3.188	**1.665**	**23.748**	**39.540**	29.6262425 (+/- 4.4e-007)	**65.835**	3.566	**1.665**	*3.330*	*7.132*	**23.748**	**39.540**	21.945	**65.835**
428	3.056	**1.680**	**22.957**	**38.568**	35.616879 (+/- 5.4e-007)	**64.794**	3.416	**1.680**	*3.360*	*6.832*	**22.957**	**38.568**	21.598	**64.794**
429	2.802	**1.718**	**21.596**	**37.102**	33.9134762 (+/- 6e-007)	**63.741**	3.143	**1.718**	*3.436*	*6.285*	**21.596**	**37.102**	21.247	**63.741**
430	2.994	**1.788**	**22.190**	**39.676**	57.5242588 (+/- 8.2e-007)	**70.940**	3.103	**1.788**	*3.576*	*6.205*	**22.190**	**39.676**	23.647	**70.940**
431	2.938	**1.906**	**25.089**	**47.820**	41.7111441 (+/- 1.1e-006)	**91.144**	3.291	**1.906**	*3.812*	*6.582*	**25.089**	**47.820**	30.381	**91.144**
432	2.576	**1.632**	**18.752**	**30.603**	28.5895528 (+/- 9.1e-007)	**49.945**	2.873	**1.632**	*3.264*	*5.745*	**18.752**	**30.603**	16.648	**49.945**
433	2.428	**1.536**	**16.674**	**25.611**	21.2891651 (+/- 5.4e-007)	**39.339**	2.714	**1.536**	*3.072*	*5.428*	**16.674**	**25.611**	13.113	**39.339**
434	2.818	**1.461**	**18.322**	**26.768**	16.7867556 (+/- 5.9e-007)	**39.109**	3.135	**1.461**	*2.922*	*6.270*	**18.322**	**26.768**	13.036	**39.109**
435	3.155	**1.890**	**26.129**	**49.384**	37.0298737 (+/- 6.4e-007)	**93.335**	3.456	**1.890**	*3.780*	*6.912*	**26.129**	**49.384**	31.112	**93.335**
436	2.774	**1.466**	**17.708**	**25.960**	15.2345054 (+/- 5.7e-007)	**38.057**	3.020	**1.466**	*2.932*	*6.040*	**17.708**	**25.960**	12.686	**38.057**
437	3.354	**1.461**	**20.521**	**29.981**	16.4851931 (+/- 6.5e-007)	**43.803**	3.511	**1.461**	*2.922*	*7.023*	**20.521**	**29.981**	14.601	**43.803**
438	2.480	**1.595**	**17.723**	**28.268**	23.1091807 (+/- 5.3e-007)	**45.088**	2.778	**1.595**	*3.190*	*5.556*	**17.723**	**28.268**	15.029	**45.088**
439	3.055	**1.681**	**23.070**	**38.781**	34.8998 (+/- 0.00051)	**65.190**	3.431	**1.681**	*3.362*	*6.862*	**23.070**	**38.781**	21.730	**65.190**
							Sum		1645.89	2144.06				
							Mean		3.749	4.884				

Model II: 136 weld profiles between the XL-size stiffeners (girders) and the other stiffeners

	Original cross section						**Modified cross section (Rectangular cross section)**							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	$mm.^2$	$mm.^3$	$mm.^4$	$mm.^4$	mm.	mm.	mm.	mm.	$mm.^2$	$mm.^3$	$mm.^4$	$mm.^4$
1	1.982	**1.935**	**17.230**	**33.340**	31.6728972 (+/- 1.8e-006)	**64.513**	2.226	**1.935**	*3.870*	*4.452*	**17.230**	**33.340**	21.504	**64.513**
2	1.489	**1.419**	**9.490**	**13.466**	9.8963157 (+/- 1.6e-006)	**19.109**	1.672	**1.419**	*2.838*	*3.344*	**9.490**	**13.466**	6.370	**19.109**
3	1.814	**1.350**	**10.916**	**14.737**	11.137428 (+/- 1.9e-006)	**19.894**	2.021	**1.350**	*2.700*	*4.043*	**10.916**	**14.737**	6.631	**19.894**
4	2.251	**1.967**	**19.817**	**38.980**	35.2246418 (+/- 2.8e-006)	**76.674**	2.519	**1.967**	*3.934*	*5.037*	**19.817**	**38.980**	25.558	**76.674**
5	1.933	**1.675**	**14.514**	**24.311**	20.917375 (+/- 2.8e-006)	**40.721**	2.166	**1.675**	*3.350*	*4.333*	**14.514**	**24.311**	13.574	**40.721**
6	1.826	**1.467**	**12.019**	**17.632**	12.092127 (+/- 2.1e-006)	**25.866**	2.048	**1.467**	*2.934*	*4.096*	**12.019**	**17.632**	8.622	**25.866**
7	2.315	**1.860**	**19.326**	**35.946**	31.2774946 (+/- 2.9e-007)	**66.860**	2.598	**1.860**	*3.720*	*5.195*	**19.326**	**35.946**	22.287	**66.860**
8	1.624	**2.468**	**17.869**	**44.101**	47.3707297 (+/- 4.3e-007)	**108.841**	1.810	**2.468**	*4.936*	*3.620*	**17.869**	**44.101**	36.280	**108.841**
9	1.940	**1.678**	**14.576**	**24.459**	18.5287262 (+/- 2.5e-007)	**41.041**	2.172	**1.678**	*3.356*	*4.343*	**14.576**	**24.459**	13.680	**41.041**
10	2.509	**1.647**	**18.417**	**30.333**	21.661559 (+/- 2.3e-006)	**49.958**	2.796	**1.647**	*3.294*	*5.591*	**18.417**	**30.333**	16.653	**49.958**
11	2.289	**1.427**	**14.671**	**20.936**	14.541812 (+/- 1.9e-006)	**29.875**	2.570	**1.427**	*2.854*	*5.141*	**14.671**	**20.936**	9.958	**29.875**
12	2.010	**1.176**	**10.605**	**12.471**	7.207645 (+/- 1.6e-006)	**14.666**	2.254	**1.176**	*2.352*	*4.509*	**10.605**	**12.471**	4.889	**14.666**
13	2.211	**1.638**	**16.155**	**26.462**	19.059471 (+/- 2.7e-006)	**43.345**	2.466	**1.638**	*3.276*	*4.931*	**16.155**	**26.462**	14.448	**43.345**
14	1.831	**1.490**	**12.270**	**18.282**	13.627916 (+/- 7.1e-007)	**27.241**	2.059	**1.490**	*2.980*	*4.117*	**12.270**	**18.282**	9.080	**27.241**
15	1.554	**1.709**	**11.843**	**20.240**	15.0171512 (+/- 2.7e-007)	**34.590**	1.732	**1.709**	*3.418*	*3.465*	**11.843**	**20.240**	11.530	**34.590**
16	1.315	**1.672**	**9.886**	**16.529**	22.9043243 (+/- 1.5e-006)	**27.637**	1.478	**1.672**	*3.344*	*2.956*	**9.886**	**16.529**	9.212	**27.637**
17	1.908	**2.163**	**17.821**	**38.547**	53.7132153 (+/- 5.7e-007)	**83.377**	2.060	**2.163**	*4.326*	*4.120*	**17.821**	**38.547**	27.792	**83.377**
18	2.452	**2.350**	**25.738**	**60.484**	62.530235 (+/- 3e-006)	**142.138**	2.738	**2.350**	*4.700*	*5.476*	**25.738**	**60.484**	47.379	**142.138**
19	1.580	**1.862**	**13.214**	**24.604**	21.7025716 (+/- 1.5e-006)	**45.814**	1.774	**1.862**	*3.724*	*3.548*	**13.214**	**24.604**	15.271	**45.814**
20	1.388	**1.865**	**11.631**	**21.692**	19.6983357 (+/- 8.1e-007)	**40.455**	1.559	**1.865**	*3.730*	*3.118*	**11.631**	**21.692**	13.485	**40.455**
21	2.486	**2.175**	**24.089**	**52.394**	49.2908536 (+/- 2.8e-006)	**113.956**	2.769	**2.175**	*4.350*	*5.538*	**24.089**	**52.394**	37.985	**113.956**
22	1.802	**1.467**	**11.721**	**17.195**	14.721432 (+/- 1.8e-006)	**25.225**	1.997	**1.467**	*2.934*	*3.995*	**11.721**	**17.195**	8.408	**25.225**
23	1.722	**1.438**	**11.056**	**15.899**	10.076237 (+/- 1.3e-006)	**22.862**	1.922	**1.438**	*2.876*	*3.844*	**11.056**	**15.899**	7.621	**22.862**

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	$mm.^2$	$mm.^3$	$mm.^4$	$mm.^4$	mm.	mm.	mm.	mm.	$mm.^2$	$mm.^3$	$mm.^4$	$mm.^4$
24	1.516	2.983	20.302	60.561	95.98688 (+/- 0.00034)	180.653	1.701	2.983	5.966	3.403	20.302	60.561	60.218	180.653
25	1.815	1.917	15.634	29.970	27.675998 (+/- 3.8e-007)	57.453	2.039	1.917	3.834	4.078	15.634	29.970	19.151	57.453
26	1.982	1.799	15.771	28.372	30.932437 (+/- 4.7e-007)	51.041	2.192	1.799	3.598	4.383	15.771	28.372	17.014	51.041
27	2.167	1.473	14.137	20.824	12.738514 (+/- 1.3e-006)	30.673	2.399	1.473	2.946	4.799	14.137	20.824	10.224	30.673
28	1.974	1.603	13.905	22.290	14.3066488 (+/- 1.3e-006)	35.730	2.169	1.603	3.206	4.337	13.905	22.290	11.910	35.730
29	2.188	1.888	18.050	34.078	25.032694 (+/- 2.5e-006)	64.340	2.390	1.888	3.776	4.780	18.050	34.078	21.447	64.340
30	2.013	1.802	16.290	29.355	24.7770961 (+/- 1.1e-006)	52.897	2.260	1.802	3.604	4.520	16.290	29.355	17.632	52.897
31	1.602	1.514	10.880	16.472	11.5308444 (+/- 7e-007)	24.939	1.797	1.514	3.028	3.593	10.880	16.472	8.313	24.939
32	1.844	1.933	15.996	30.920	31.6674225 (+/- 3.9e-007)	59.769	2.069	1.933	3.866	4.138	15.996	30.920	19.923	59.769
33	1.761	1.772	13.998	24.804	20.8076357 (+/- 2.5e-007)	43.953	1.975	1.772	3.544	3.950	13.998	24.804	14.651	43.953
34	2.033	1.915	17.506	33.524	32.9714223 (+/- 3.1e-007)	64.198	2.285	1.915	3.830	4.571	17.506	33.524	21.399	64.198
35	1.991	2.088	18.686	39.016	39.6599865 (+/- 1.6e-006)	81.466	2.237	2.088	4.176	4.475	18.686	39.016	27.155	81.466
36	1.502	1.713	11.515	19.725	18.4284628 (+/- 1.4e-006)	33.789	1.681	1.713	3.426	3.361	11.515	19.725	11.263	33.789
37	1.410	1.945	12.317	23.957	22.5999515 (+/- 1.3e-006)	46.596	1.583	1.945	3.890	3.166	12.317	23.957	15.532	46.596
38	2.130	1.305	12.466	16.268	9.9121142 (+/- 1.2e-006)	21.230	2.388	1.305	2.610	4.776	12.466	16.268	7.077	21.230
39	1.998	1.314	11.709	15.386	8.7961645 (+/- 1e-006)	20.217	2.228	1.314	2.628	4.455	11.709	15.386	6.739	20.217
40	2.138	1.469	13.915	20.441	12.7250924 (+/- 1.2e-006)	30.028	2.368	1.469	2.938	4.736	13.915	20.441	10.009	30.028
41	2.043	1.839	16.868	31.020	28.8290975 (+/- 3.4e-007)	57.046	2.293	1.839	3.678	4.586	16.868	31.020	19.015	57.046
42	1.676	1.725	12.984	22.397	20.0825303 (+/- 2.6e-007)	38.636	1.882	1.725	3.450	3.763	12.984	22.397	12.879	38.636
43	2.095	1.704	16.050	27.349	23.4228378 (+/- 2.5e-007)	46.603	2.355	1.704	3.408	4.710	16.050	27.349	15.534	46.603
44	1.965	1.278	11.261	14.392	9.0263064 (+/- 9.6e-007)	18.392	2.203	1.278	2.556	4.406	11.261	14.392	6.131	18.392
45	1.985	1.544	13.721	21.185	14.8037018 (+/- 1.2e-006)	32.710	2.222	1.544	3.088	4.443	13.721	21.185	10.903	32.710
46	2.092	1.791	16.554	29.648	21.9213711 (+/- 9e-007)	53.100	2.311	1.791	3.582	4.621	16.554	29.648	17.700	53.100
47	1.567	2.229	15.692	34.977	37.4627725 (+/- 1e-006)	77.965	1.760	2.229	4.458	3.520	15.692	34.977	25.988	77.965
48	1.331	2.101	12.517	26.298	24.851463 (+/- 9.9e-007)	55.253	1.489	2.101	4.202	2.979	12.517	26.298	18.418	55.253
49	1.235	1.955	10.849	21.210	21.119981 (+/- 6.3e-007)	41.465	1.387	1.955	3.910	2.775	10.849	21.210	13.822	41.465

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	$mm.^2$	$mm.^3$	$mm.^4$	$mm.^4$	mm.	mm.	mm.	mm.	$mm.^2$	$mm.^3$	$mm.^4$	$mm.^4$
50	2.273	1.541	15.709	24.208	20.1165307 (+/- 1.9e-007)	37.304	2.549	1.541	3.082	5.097	15.709	24.208	12.435	37.304
51	1.623	1.285	9.371	12.042	8.04907426 (+/- 8.3e-008)	15.474	1.823	1.285	2.570	3.646	9.371	12.042	5.158	15.474
52	1.655	1.523	11.255	17.141	14.3108873 (+/- 1.5e-007)	26.106	1.848	1.523	3.046	3.695	11.255	17.141	8.702	26.106
53	2.399	2.308	24.864	57.386	63.9013271 (+/- 2.9e-006)	132.447	2.693	2.308	4.616	5.386	24.864	57.386	44.149	132.447
54	1.395	1.310	8.175	10.709	7.4804223 (+/- 1.3e-006)	14.029	1.560	1.310	2.620	3.120	8.175	10.709	4.676	14.029
55	1.429	1.678	10.752	18.042	14.335082 (+/- 1.6e-006)	30.274	1.602	1.678	3.356	3.204	10.752	18.042	10.091	30.274
56	2.481	1.877	20.344	38.186	28.116835 (+/- 2.8e-006)	71.675	2.710	1.877	3.754	5.419	20.344	38.186	23.892	71.675
57	2.176	1.833	17.680	32.407	24.774429 (+/- 3.1e-006)	59.403	2.411	1.833	3.666	4.823	17.680	32.407	19.801	59.403
58	1.969	1.829	16.128	29.498	24.985609 (+/- 2.8e-006)	53.952	2.204	1.829	3.658	4.409	16.128	29.498	17.984	53.952
59	2.107	2.076	19.605	40.700	38.542076 (+/- 3.2e-007)	84.493	2.361	2.076	4.152	4.722	19.605	40.700	28.164	84.493
60	2.406	2.021	21.869	44.197	45.0891552 (+/- 2.5e-007)	89.323	2.705	2.021	4.042	5.410	21.869	44.197	29.774	89.323
61	2.035	1.843	16.819	30.997	26.5747844 (+/- 2.4e-007)	57.128	2.281	1.843	3.686	4.563	16.819	30.997	19.043	57.128
62	2.411	1.699	18.142	30.823	21.7981141 (+/- 2e-006)	52.369	2.670	1.699	3.398	5.339	18.142	30.823	17.456	52.369
63	2.338	1.730	18.164	31.424	25.8476717 (+/- 1.6e-006)	54.363	2.625	1.730	3.460	5.250	18.164	31.424	18.121	54.363
64	2.638	1.926	22.488	43.312	34.4392335 (+/- 2.3e-006)	83.419	2.919	1.926	3.852	5.838	22.488	43.312	27.806	83.419
65	1.641	2.262	16.527	37.384	36.3059929 (+/- 2.5e-006)	84.563	1.827	2.262	4.524	3.653	16.527	37.384	28.188	84.563
66	1.660	1.890	14.100	26.649	25.0202198 (+/- 1.9e-006)	50.367	1.865	1.890	3.780	3.730	14.100	26.649	16.789	50.367
67	1.405	1.668	10.522	17.551	14.2859254 (+/- 1.3e-006)	29.275	1.577	1.668	3.336	3.154	10.522	17.551	9.758	29.275
68	1.687	1.614	12.146	19.604	13.7740514 (+/- 9.7e-008)	31.640	1.881	1.614	3.228	3.763	12.146	19.604	10.547	31.640
69	1.572	1.991	13.981	27.836	24.3907488 (+/- 2e-007)	55.422	1.756	1.991	3.982	3.511	13.981	27.836	18.474	55.422
70	2.021	1.656	15.035	24.898	19.575368 (+/- 2.8e-007)	41.231	2.270	1.656	3.312	4.540	15.035	24.898	13.744	41.231
71	1.987	1.716	15.280	26.220	21.0868054 (+/- 1.7e-008)	44.994	2.226	1.716	3.432	4.452	15.280	26.220	14.998	44.994
72	1.939	1.649	14.379	23.711	18.9444289 (+/- 2.5e-008)	39.099	2.180	1.649	3.298	4.360	14.379	23.711	13.033	39.099
73	1.816	1.758	14.266	25.080	24.8581126 (+/- 1.4e-008)	44.090	2.029	1.758	3.516	4.057	14.266	25.080	14.697	44.090
74	2.272	1.704	17.207	29.321	21.3738235 (+/- 2.2e-008)	49.963	2.525	1.704	3.408	5.049	17.207	29.321	16.654	49.963
75	2.574	1.640	18.959	31.093	25.1571142 (+/- 1e-007)	50.992	2.890	1.640	3.280	5.780	18.959	31.093	16.997	50.992

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}	mm.	mm.	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}
76	1.865	**1.684**	**13.900**	**23.408**	16.3698427 (+/- 1.2e-007)	**39.418**	2.064	**1.684**	*3.368*	*4.127*	**13.900**	**23.408**	13.139	**39.418**
77	1.707	**1.830**	**13.763**	**25.186**	18.5982736 (+/- 9.4e-008)	**46.091**	1.880	**1.830**	*3.660*	*3.760*	**13.763**	**25.186**	15.364	**46.091**
78	1.885	**1.821**	**15.384**	**28.014**	23.2890086 (+/- 9.7e-008)	**51.014**	2.112	**1.821**	*3.642*	*4.224*	**15.384**	**28.014**	17.005	**51.014**
79	2.107	**1.937**	**18.134**	**35.126**	28.709815 (+/- 1e-008)	**68.038**	2.340	**1.937**	*3.874*	*4.681*	**18.134**	**35.126**	22.679	**68.038**
80	1.941	**2.054**	**17.811**	**36.584**	32.9930732 (+/- 1.9e-008)	**75.143**	2.168	**2.054**	*4.108*	*4.336*	**17.811**	**36.584**	25.048	**75.143**
81	1.952	**2.195**	**19.172**	**42.083**	41.1939169 (+/- 6.5e-008)	**92.371**	2.184	**2.195**	*4.390*	*4.367*	**19.172**	**42.083**	30.790	**92.371**
82	1.591	**2.056**	**14.692**	**30.207**	29.6565544 (+/- 1.8e-007)	**62.105**	1.786	**2.056**	*4.112*	*3.573*	**14.692**	**30.207**	20.702	**62.105**
83	1.555	**1.917**	**13.383**	**25.655**	23.2264249 (+/- 4.1e-008)	**49.181**	1.745	**1.917**	*3.834*	*3.491*	**13.383**	**25.655**	16.394	**49.181**
84	1.638	**1.977**	**14.506**	**28.678**	26.2146085 (+/- 7.2e-008)	**56.697**	1.834	**1.977**	*3.954*	*3.669*	**14.506**	**28.678**	18.899	**56.697**
85	2.207	**1.706**	**16.882**	**28.801**	26.2172535 (+/- 3.2e-007)	**49.134**	2.474	**1.706**	*3.412*	*4.948*	**16.882**	**28.801**	16.378	**49.134**
86	1.490	**2.184**	**14.594**	**31.873**	32.3698414 (+/- 9.6e-008)	**69.611**	1.671	**2.184**	*4.368*	*3.341*	**14.594**	**31.873**	23.204	**69.611**
87	1.795	**2.416**	**19.006**	**45.918**	43.5904128 (+/- 1.3e-007)	**110.939**	1.967	**2.416**	*4.832*	*3.933*	**19.006**	**45.918**	36.980	**110.939**
88	2.269	**1.631**	**16.597**	**27.070**	20.8259338 (+/- 2.4e-008)	**44.151**	2.544	**1.631**	*3.262*	*5.088*	**16.597**	**27.070**	14.717	**44.151**
89	1.693	**1.638**	**12.429**	**20.359**	15.6523278 (+/- 2.7e-008)	**33.348**	1.897	**1.638**	*3.276*	*3.794*	**12.429**	**20.359**	11.116	**33.348**
90	2.558	**1.809**	**20.571**	**37.213**	28.8569553 (+/- 5.1e-008)	**67.318**	2.843	**1.809**	*3.618*	*5.686*	**20.571**	**37.213**	22.439	**67.318**
91	2.601	**1.524**	**17.567**	**26.772**	17.0433254 (+/- 2.8e-008)	**40.801**	2.882	**1.524**	*3.048*	*5.763*	**17.567**	**26.772**	13.600	**40.801**
92	1.964	**1.492**	**13.057**	**19.481**	16.4121118 (+/- 1.4e-007)	**29.066**	2.188	**1.492**	*2.984*	*4.376*	**13.057**	**19.481**	9.689	**29.066**
93	1.526	**2.091**	**14.145**	**29.577**	26.0861352 (+/- 1.3e-007)	**61.846**	1.691	**2.091**	*4.182*	*3.382*	**14.145**	**29.577**	20.615	**61.846**
94	2.576	**1.714**	**19.830**	**33.989**	29.8704448 (+/- 1.3e-007)	**58.256**	2.892	**1.714**	*3.428*	*5.785*	**19.830**	**33.989**	19.419	**58.256**
95	2.121	**1.556**	**14.772**	**22.985**	16.0417051 (+/- 8.7e-008)	**35.765**	2.373	**1.556**	*3.112*	*4.747*	**14.772**	**22.985**	11.922	**35.765**
96	1.885	**1.517**	**12.715**	**19.289**	12.4326849 (+/- 1.7e-008)	**29.261**	2.095	**1.517**	*3.034*	*4.191*	**12.715**	**19.289**	9.754	**29.261**
97	1.950	**1.661**	**14.482**	**24.055**	17.963304 (+/- 3.6e-008)	**39.955**	2.180	**1.661**	*3.322*	*4.359*	**14.482**	**24.055**	13.318	**39.955**
98	1.610	**2.326**	**16.793**	**39.061**	42.2501754 (+/- 7.1e-008)	**90.855**	1.805	**2.326**	*4.652*	*3.610*	**16.793**	**39.061**	30.285	**90.855**
99	4.659	**1.513**	**31.528**	**47.702**	40.41838 (+/- 0.0003)	**72.173**	5.210	**1.513**	*3.026*	*10.419*	**31.528**	**47.702**	24.058	**72.173**
100	4.856	**1.595**	**34.431**	**54.917**	41.2345219 (+/- 3.8e-007)	**87.593**	5.397	**1.595**	*3.190*	*10.793*	**34.431**	**54.917**	29.198	**87.593**
101	5.040	**1.524**	**33.904**	**51.670**	39.911 (+/- 0.00075)	**78.745**	5.562	**1.524**	*3.048*	*11.123*	**33.904**	**51.670**	26.248	**78.745**

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}	mm.	mm.	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}
102	2.143	1.332	12.751	16.984	10.2385906 (+/- 8.7e-008)	22.623	2.393	1.332	2.664	4.786	12.751	16.984	7.541	22.623
103	1.820	1.593	12.970	20.661	15.0726284 (+/- 1.3e-007)	32.913	2.035	1.593	3.186	4.071	12.970	20.661	10.971	32.913
104	1.748	1.677	13.163	22.074	18.0286508 (+/- 3.7e-008)	37.019	1.962	1.677	3.354	3.925	13.163	22.074	12.340	37.019
105	2.152	1.812	17.448	31.616	25.9068434 (+/- 5.4e-008)	57.288	2.407	1.812	3.624	4.815	17.448	31.616	19.096	57.288
106	2.417	1.586	16.818	26.673	17.3268811 (+/- 8.3e-008)	42.304	2.651	1.586	3.172	5.302	16.818	26.673	14.101	42.304
107	2.504	1.832	20.380	37.336	29.2256573 (+/- 5.5e-007)	68.400	2.781	1.832	3.664	5.562	20.380	37.336	22.800	68.400
108	1.891	2.244	18.868	42.340	40.4287874 (+/- 9.4e-008)	95.010	2.102	2.244	4.488	4.204	18.868	42.340	31.670	95.010
109	2.096	1.869	17.587	32.870	33.0903267 (+/- 1.2e-007)	61.434	2.352	1.869	3.738	4.705	17.587	32.870	20.478	61.434
110	1.962	2.031	17.826	36.205	33.6421278 (+/- 4.8e-007)	73.532	2.194	2.031	4.062	4.388	17.826	36.205	24.511	73.532
111	1.924	2.023	17.360	35.119	30.9622164 (+/- 2.5e-007)	71.046	2.145	2.023	4.046	4.291	17.360	35.119	23.682	71.046
112	1.801	2.499	19.668	49.150	47.6758101 (+/- 1.8e-008)	122.827	1.968	2.499	4.998	3.935	19.668	49.150	40.942	122.827
113	2.101	1.569	14.815	23.245	17.6204521 (+/- 5.1e-008)	36.471	2.361	1.569	3.138	4.721	14.815	23.245	12.157	36.471
114	1.760	1.678	13.257	22.245	19.6671596 (+/- 1.3e-008)	37.328	1.975	1.678	3.356	3.950	13.257	22.245	12.443	37.328
115	1.688	1.753	13.281	23.282	19.3120235 (+/- 1e-008)	40.813	1.894	1.753	3.506	3.788	13.281	23.282	13.604	40.813
116	5.726	1.604	40.165	64.425	42.384013 (+/- 5.6e-007)	103.337	6.260	1.604	3.208	12.520	40.165	64.425	34.446	103.337
117	4.655	1.534	31.120	47.738	36.0300519 (+/- 3.9e-007)	73.230	5.072	1.534	3.068	10.143	31.120	47.738	24.410	73.230
118	4.392	1.381	26.927	37.186	27.4212505 (+/- 2.6e-007)	51.354	4.875	1.381	2.762	9.749	26.927	37.186	17.118	51.354
119	2.032	1.782	16.275	29.002	25.5893762 (+/- 4.5e-008)	51.682	2.283	1.782	3.564	4.566	16.275	29.002	17.227	51.682
120	1.644	1.827	13.492	24.650	21.7530156 (+/- 7e-008)	45.035	1.846	1.827	3.654	3.692	13.492	24.650	15.012	45.035
121	1.725	1.948	15.101	29.417	29.574063 (+/- 1.9e-008)	57.304	1.938	1.948	3.896	3.876	15.101	29.417	19.101	57.304
122	2.211	1.538	15.205	23.385	16.06201 (+/- 1.5e-008)	35.967	2.472	1.538	3.076	4.943	15.205	23.385	11.989	35.967
123	1.754	1.686	13.283	22.395	18.1992582 (+/- 1.9e-008)	37.758	1.970	1.686	3.372	3.939	13.283	22.395	12.586	37.758
124	1.999	2.154	18.929	40.773	35.2348881 (+/- 3.2e-007)	87.825	2.197	2.154	4.308	4.394	18.929	40.773	29.275	87.825
125	2.492	2.374	25.744	61.116	55.7598263 (+/- 1.1e-007)	145.090	2.711	2.374	4.748	5.422	25.744	61.116	48.363	145.090
126	2.864	2.853	35.248	100.563	106.183752 (+/- 3.8e-007)	286.905	3.089	2.853	5.706	6.177	35.248	100.563	95.635	286.905
127	2.258	2.226	22.532	50.156	51.950937 (+/- 7.3e-008)	111.648	2.531	2.226	4.452	5.061	22.532	50.156	37.216	111.648

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}	mm.	mm.	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}
128	2.476	**2.014**	**21.885**	**44.076**	35.6374309 (+/- 4.2e-008)	**88.770**	2.717	**2.014**	*4.028*	*5.433*	**21.885**	**44.076**	29.590	**88.770**
129	2.149	**1.817**	**17.349**	**31.523**	24.2820748 (+/- 4.3e-008)	**57.278**	2.387	**1.817**	*3.634*	*4.774*	**17.349**	**31.523**	19.093	**57.278**
130	2.310	**1.782**	**18.007**	**32.088**	22.4688067 (+/- 2.9e-008)	**57.182**	2.526	**1.782**	*3.564*	*5.052*	**18.007**	**32.088**	19.061	**57.182**
131	2.145	**1.984**	**19.089**	**37.873**	34.8676206 (+/- 7.7e-008)	**75.139**	2.405	**1.984**	*3.968*	*4.811*	**19.089**	**37.873**	25.046	**75.139**
132	2.083	**1.624**	**15.210**	**24.701**	19.4458735 (+/- 4.5e-008)	**40.114**	2.341	**1.624**	*3.248*	*4.683*	**15.210**	**24.701**	13.371	**40.114**
133	2.229	**1.049**	**10.371**	**10.879**	4.93176544 (+/- 4.5e-009)	**11.412**	2.472	**1.049**	*2.098*	*4.943*	**10.371**	**10.879**	3.804	**11.412**
134	1.536	**1.761**	**12.157**	**21.408**	18.4163736 (+/- 8e-008)	**37.700**	1.726	**1.761**	*3.522*	*3.452*	**12.157**	**21.408**	12.567	**37.700**
135	1.824	**2.215**	**17.872**	**39.586**	36.2101377 (+/- 2.3e-007)	**87.684**	2.017	**2.215**	*4.430*	*4.034*	**17.872**	**39.586**	29.228	**87.684**
136	2.145	**2.123**	**20.241**	**42.972**	38.7041378 (+/- 8.8e-008)	**91.229**	2.384	**2.123**	*4.246*	*4.767*	**20.241**	**42.972**	30.410	**91.229**
							Sum		489.33	632.55				
							Mean		3.598	4.651				

Model II: 134 weld profiles between flanges and webs of the longitudinal girders

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}	mm.	mm.	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}
1	1.510	1.114	6.516	7.259	8.4239819 (+/- 1e-008)	8.086	1.462	1.114	2.228	2.925	6.516	7.259	2.695	8.086
2	1.505	1.382	9.133	12.622	11.1213302 (+/- 1e-008)	17.443	1.652	1.382	2.764	3.304	9.133	12.622	5.814	17.443
3	1.855	1.547	12.291	19.014	20.3034342 (+/- 1.2e-008)	29.415	1.986	1.547	3.094	3.973	12.291	19.014	9.805	29.415
4	1.786	1.653	13.079	21.620	21.4000386 (+/- 1.9e-008)	35.737	1.978	1.653	3.306	3.956	13.079	21.620	11.912	35.737
5	1.283	1.416	7.905	11.193	10.5465957 (+/- 1e-008)	15.850	1.396	1.416	2.832	2.791	7.905	11.193	5.283	15.850
6	1.223	1.054	5.760	6.071	3.6061276 (+/- 7.1e-009)	6.399	1.366	1.054	2.108	2.732	5.760	6.071	2.133	6.399
7	1.254	1.279	7.034	8.996	7.462981 (+/- 2.8e-005)	11.507	1.375	1.279	2.558	2.750	7.034	8.996	3.836	11.507
8	1.521	1.550	10.492	16.263	14.8273109 (+/- 2.1e-008)	25.207	1.692	1.550	3.100	3.385	10.492	16.263	8.402	25.207
9	1.603	1.740	12.488	21.729	20.8774189 (+/- 1.1e-008)	37.809	1.794	1.740	3.480	3.589	12.488	21.729	12.603	37.809
10	1.877	1.400	11.708	16.391	13.233723 (+/- 4.7e-008)	22.948	2.091	1.400	2.800	4.181	11.708	16.391	7.649	22.948
11	1.906	1.052	8.999	9.467	5.09454442 (+/- 4.4e-008)	9.959	2.139	1.052	2.104	4.277	8.999	9.467	3.320	9.959
12	2.408	1.432	15.471	22.154	17.0791096 (+/- 1.6e-008)	31.725	2.701	1.432	2.864	5.402	15.471	22.154	10.575	31.725
13	2.156	1.462	14.081	20.586	17.0605151 (+/- 8.2e-008)	30.097	2.408	1.462	2.924	4.816	14.081	20.586	10.032	30.097
14	2.134	1.355	12.944	17.539	13.2047779 (+/- 2.1e-008)	23.766	2.388	1.355	2.710	4.776	12.944	17.539	7.922	23.766
15	1.428	1.409	8.980	12.653	10.2843149 (+/- 1.8e-008)	17.828	1.593	1.409	2.818	3.187	8.980	12.653	5.943	17.828
16	1.311	1.294	7.403	9.579	8.0724487 (+/- 5.2e-008)	12.396	1.430	1.294	2.588	2.861	7.403	9.579	4.132	12.396
17	1.499	1.353	9.017	12.200	9.66416957 (+/- 3.9e-008)	16.507	1.666	1.353	2.706	3.332	9.017	12.200	5.502	16.507
18	1.510	1.456	9.820	14.298	11.9683927 (+/- 1e-008)	20.818	1.686	1.456	2.912	3.372	9.820	14.298	6.939	20.818
19	1.799	1.857	14.999	27.853	27.5313461 (+/- 5.5e-008)	51.723	2.019	1.857	3.714	4.039	14.999	27.853	17.241	51.723
20	1.643	1.491	10.999	16.400	12.8923123 (+/- 9.3e-008)	24.452	1.844	1.491	2.982	3.688	10.999	16.400	8.151	24.452
21	1.879	1.719	14.358	24.681	25.1985803 (+/- 1.1e-007)	42.427	2.088	1.719	3.438	4.176	14.358	24.681	14.142	42.427
22	1.794	1.501	12.093	18.152	14.4583185 (+/- 1.2e-008)	27.246	2.014	1.501	3.002	4.028	12.093	18.152	9.082	27.246
23	1.377	1.216	7.472	9.086	4.93688988 (+/- 1.1e-008)	11.049	1.536	1.216	2.432	3.072	7.472	9.086	3.683	11.049

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}	mm.	mm.	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}
24	1.602	**1.348**	**9.710**	**13.089**	8.78660598 (+/- 2.8e-009)	**17.644**	1.801	**1.348**	*2.696*	*3.602*	**9.710**	**13.089**	5.881	**17.644**
25	1.439	**1.295**	**8.353**	**10.817**	7.50997304 (+/- 1.9e-008)	**14.008**	1.613	**1.295**	*2.590*	*3.225*	**8.353**	**10.817**	4.669	**14.008**
26	1.321	**1.451**	**8.554**	**12.412**	10.0924694 (+/- 2.4e-008)	**18.010**	1.474	**1.451**	*2.902*	*2.948*	**8.554**	**12.412**	6.003	**18.010**
27	1.435	**1.507**	**9.654**	**14.549**	12.4543757 (+/- 1e-008)	**21.925**	1.602	**1.507**	*3.014*	*3.203*	**9.654**	**14.549**	7.308	**21.925**
28	1.601	**1.646**	**11.849**	**19.503**	16.5375164 (+/- 1.8e-008)	**32.103**	1.800	**1.646**	*3.292*	*3.599*	**11.849**	**19.503**	10.701	**32.103**
29	1.469	**1.386**	**9.145**	**12.675**	8.90399358 (+/- 1.5e-008)	**17.568**	1.650	**1.386**	*2.772*	*3.299*	**9.145**	**12.675**	5.856	**17.568**
30	1.510	**1.360**	**9.153**	**12.448**	9.7471039 (+/- 1.1e-008)	**16.929**	1.683	**1.360**	*2.720*	*3.365*	**9.153**	**12.448**	5.643	**16.929**
31	1.334	**1.264**	**7.505**	**9.486**	6.98831967 (+/- 7.4e-009)	**11.991**	1.484	**1.264**	*2.528*	*2.969*	**7.505**	**9.486**	3.997	**11.991**
32	1.583	**1.298**	**9.188**	**11.926**	8.838979 (+/- 4.6e-005)	**15.480**	1.770	**1.298**	*2.596*	*3.539*	**9.188**	**11.926**	5.160	**15.480**
33	1.766	**1.109**	**8.750**	**9.704**	6.09491738 (+/- 5.1e-009)	**10.761**	1.972	**1.109**	*2.218*	*3.945*	**8.750**	**9.704**	3.587	**10.761**
34	2.060	**1.135**	**10.386**	**11.788**	7.84396924 (+/- 1.4e-008)	**13.380**	2.288	**1.135**	*2.270*	*4.575*	**10.386**	**11.788**	4.460	**13.380**
35	1.401	**1.103**	**6.759**	**7.455**	5.34629836 (+/- 2.4e-008)	**8.223**	1.532	**1.103**	*2.206*	*3.064*	**6.759**	**7.455**	2.741	**8.223**
36	1.498	**0.940**	**6.208**	**5.836**	3.43380301 (+/- 1.1e-008)	**5.485**	1.651	**0.940**	*1.880*	*3.302*	**6.208**	**5.836**	1.828	**5.485**
37	1.381	**1.163**	**6.992**	**8.132**	6.35364513 (+/- 5.3e-009)	**9.457**	1.503	**1.163**	*2.326*	*3.006*	**6.992**	**8.132**	3.152	**9.457**
38	1.454	**1.303**	**8.347**	**10.876**	8.97714731 (+/- 1.9e-009)	**14.172**	1.601	**1.303**	*2.606*	*3.203*	**8.347**	**10.876**	4.724	**14.172**
39	1.238	**1.066**	**5.881**	**6.269**	3.79357793 (+/- 6.1e-008)	**6.683**	1.379	**1.066**	*2.132*	*2.758*	**5.881**	**6.269**	2.228	**6.683**
40	1.593	**1.093**	**7.771**	**8.494**	5.31207895 (+/- 1.3e-008)	**9.284**	1.777	**1.093**	*2.186*	*3.555*	**7.771**	**8.494**	3.095	**9.284**
41	1.341	**1.185**	**7.093**	**8.405**	5.64447015 (+/- 3.7e-009)	**9.960**	1.496	**1.185**	*2.370*	*2.993*	**7.093**	**8.405**	3.320	**9.960**
42	1.195	**1.270**	**6.699**	**8.508**	6.68187273 (+/- 4.6e-009)	**10.805**	1.319	**1.270**	*2.540*	*2.637*	**6.699**	**8.508**	3.602	**10.805**
43	1.372	**1.364**	**8.343**	**11.380**	8.87176797 (+/- 1.4e-008)	**15.522**	1.529	**1.364**	*2.728*	*3.058*	**8.343**	**11.380**	5.174	**15.522**
44	1.305	**1.188**	**6.928**	**8.230**	5.51842332 (+/- 6.9e-008)	**9.778**	1.458	**1.188**	*2.376*	*2.916*	**6.928**	**8.230**	3.259	**9.778**
45	2.005	**2.181**	**19.633**	**42.820**	49.9037257 (+/- 1.3e-008)	**93.389**	2.250	**2.181**	*4.362*	*4.501*	**19.633**	**42.820**	31.130	**93.389**
46	1.575	**1.274**	**8.890**	**11.326**	8.61678912 (+/- 3.4e-009)	**14.429**	1.745	**1.274**	*2.548*	*3.489*	**8.890**	**11.326**	4.810	**14.429**
47	1.474	**1.208**	**7.864**	**9.500**	7.11342988 (+/- 7.9e-009)	**11.476**	1.627	**1.208**	*2.416*	*3.255*	**7.864**	**9.500**	3.825	**11.476**
48	1.105	**1.205**	**5.908**	**7.119**	5.11738453 (+/- 4.7e-009)	**8.579**	1.226	**1.205**	*2.410*	*2.451*	**5.908**	**7.119**	2.860	**8.579**

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	$mm.^2$	$mm.^3$	$mm.^4$	$mm.^4$	mm.	mm.	mm.	mm.	$mm.^2$	$mm.^3$	$mm.^4$	$mm.^4$
49	1.556	**1.389**	**9.483**	**13.172**	11.7301235 (+/- 1e-008)	**18.296**	1.707	**1.389**	*2.778*	*3.414*	**9.483**	**13.172**	6.099	**18.296**
50	1.252	**1.282**	**7.213**	**9.247**	6.20852634 (+/- 3.6e-009)	**11.855**	1.407	**1.282**	*2.564*	*2.813*	**7.213**	**9.247**	3.952	**11.855**
51	1.458	**1.513**	**9.891**	**14.965**	12.4693643 (+/- 1.3e-008)	**22.642**	1.634	**1.513**	*3.026*	*3.269*	**9.891**	**14.965**	7.547	**22.642**
52	1.339	**1.572**	**9.462**	**14.874**	11.3054929 (+/- 1e-008)	**23.382**	1.505	**1.572**	*3.144*	*3.010*	**9.462**	**14.874**	7.794	**23.382**
53	1.261	**1.358**	**7.696**	**10.451**	7.27951668 (+/- 2.8e-009)	**14.193**	1.417	**1.358**	*2.716*	*2.834*	**7.696**	**10.451**	4.731	**14.193**
54	1.822	**1.263**	**10.203**	**12.886**	9.66157731 (+/- 1.5e-008)	**16.276**	2.020	**1.263**	*2.526*	*4.039*	**10.203**	**12.886**	5.425	**16.276**
55	1.401	**1.315**	**8.276**	**10.883**	7.59831405 (+/- 5.8e-009)	**14.311**	1.573	**1.315**	*2.630*	*3.147*	**8.276**	**10.883**	4.770	**14.311**
56	1.335	**1.276**	**7.596**	**9.692**	7.15025188 (+/- 1.9e-008)	**12.368**	1.488	**1.276**	*2.552*	*2.976*	**7.596**	**9.692**	4.123	**12.368**
57	1.308	**1.041**	**6.096**	**6.346**	3.66533191 (+/- 3.2e-008)	**6.606**	1.464	**1.041**	*2.082*	*2.928*	**6.096**	**6.346**	2.202	**6.606**
58	1.479	**1.190**	**7.795**	**9.276**	6.67715599 (+/- 5.3e-008)	**11.038**	1.638	**1.190**	*2.380*	*3.275*	**7.795**	**9.276**	3.679	**11.038**
59	1.512	**0.930**	**6.297**	**5.856**	2.99518296 (+/- 1.1e-008)	**5.446**	1.693	**0.930**	*1.860*	*3.385*	**6.297**	**5.856**	1.815	**5.446**
60	1.452	**1.066**	**6.960**	**7.419**	3.9577927 (+/- 6.5e-009)	**7.909**	1.632	**1.066**	*2.132*	*3.265*	**6.960**	**7.419**	2.636	**7.909**
61	1.598	**0.906**	**6.502**	**5.891**	2.71793511 (+/- 1.6e-008)	**5.337**	1.794	**0.906**	*1.812*	*3.588*	**6.502**	**5.891**	1.779	**5.337**
62	1.788	**1.001**	**8.044**	**8.052**	3.99459611 (+/- 6.5e-008)	**8.060**	2.009	**1.001**	*2.002*	*4.018*	**8.044**	**8.052**	2.687	**8.060**
63	1.534	**1.092**	**7.527**	**8.219**	4.63605372 (+/- 5.2e-009)	**8.976**	1.723	**1.092**	*2.184*	*3.446*	**7.527**	**8.219**	2.992	**8.976**
64	1.062	**1.302**	**6.158**	**8.018**	5.96951536 (+/- 3.2e-008)	**10.439**	1.182	**1.302**	*2.604*	*2.365*	**6.158**	**8.018**	3.480	**10.439**
65	1.213	**1.191**	**6.376**	**7.594**	5.63085082 (+/- 4.5e-008)	**9.044**	1.338	**1.191**	*2.382*	*2.677*	**6.376**	**7.594**	3.015	**9.044**
66	1.111	**1.294**	**6.438**	**8.331**	5.64847743 (+/- 4.9e-008)	**10.780**	1.244	**1.294**	*2.588*	*2.488*	**6.438**	**8.331**	3.593	**10.780**
67	1.013	**1.168**	**5.309**	**6.201**	3.71700852 (+/- 6.8e-009)	**7.243**	1.136	**1.168**	*2.336*	*2.273*	**5.309**	**6.201**	2.414	**7.243**
68	1.103	**1.128**	**5.478**	**6.179**	4.29679328 (+/- 1e-008)	**6.970**	1.214	**1.128**	*2.256*	*2.428*	**5.478**	**6.179**	2.323	**6.970**
69	1.166	**1.293**	**6.765**	**8.747**	5.70458845 (+/- 5.5e-009)	**11.310**	1.308	**1.293**	*2.586*	*2.616*	**6.765**	**8.747**	3.770	**11.310**
70	1.161	**1.480**	**7.720**	**11.426**	8.67477217 (+/- 2.4e-007)	**16.910**	1.304	**1.480**	*2.960*	*2.608*	**7.720**	**11.426**	5.637	**16.910**
71	1.155	**1.536**	**7.918**	**12.162**	8.41901068 (+/- 6.7e-009)	**18.681**	1.289	**1.536**	*3.072*	*2.577*	**7.918**	**12.162**	6.227	**18.681**
72	1.098	**1.468**	**7.217**	**10.595**	7.04583436 (+/- 2.4e-008)	**15.553**	1.229	**1.468**	*2.936*	*2.458*	**7.217**	**10.595**	5.184	**15.553**
73	0.953	**1.196**	**5.101**	**6.101**	3.9487569 (+/- 1e-008)	**7.297**	1.066	**1.196**	*2.392*	*2.133*	**5.101**	**6.101**	2.432	**7.297**

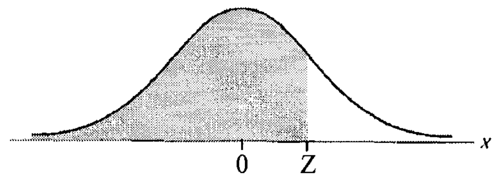
	Original cross section							**Modified cross section (Rectangular cross section)**							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}	mm.	mm.	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}
74	1.124	**1.326**	**6.691**	**8.872**	5.96560853 (+/- 3.1e-008)	**11.765**	1.262	**1.326**	*2.652*	*2.523*	**6.691**	**8.872**	3.922	**11.765**
75	1.101	**1.436**	**7.080**	**10.167**	6.70063523 (+/- 1.3e-008)	**14.600**	1.233	**1.436**	*2.872*	*2.465*	**7.080**	**10.167**	4.867	**14.600**
76	1.096	**1.406**	**6.887**	**9.683**	7.49512328 (+/- 9.7e-009)	**13.614**	1.225	**1.406**	*2.812*	*2.449*	**6.887**	**9.683**	4.538	**13.614**
77	1.127	**1.189**	**6.021**	**7.159**	4.21655391 (+/- 1.6e-007)	**8.512**	1.266	**1.189**	*2.378*	*2.532*	**6.021**	**7.159**	2.837	**8.512**
78	1.285	**1.402**	**8.088**	**11.339**	7.80718748 (+/- 1.5e-008)	**15.898**	1.442	**1.402**	*2.804*	*2.884*	**8.088**	**11.339**	5.299	**15.898**
79	1.089	**1.761**	**8.443**	**14.868**	10.6014203 (+/- 2.1e-007)	**26.183**	1.199	**1.761**	*3.522*	*2.397*	**8.443**	**14.868**	8.728	**26.183**
80	1.528	**1.449**	**9.957**	**14.428**	10.752079 (+/- 1.3e-007)	**20.906**	1.718	**1.449**	*2.898*	*3.436*	**9.957**	**14.428**	6.969	**20.906**
81	1.302	**1.273**	**7.413**	**9.437**	6.5272318 (+/- 1.9e-008)	**12.013**	1.456	**1.273**	*2.546*	*2.912*	**7.413**	**9.437**	4.004	**12.013**
82	1.399	**1.450**	**9.099**	**13.194**	10.2957182 (+/- 3.3e-008)	**19.131**	1.569	**1.450**	*2.900*	*3.138*	**9.099**	**13.194**	6.377	**19.131**
83	1.535	**1.272**	**8.726**	**11.099**	7.91073489 (+/- 7.6e-009)	**14.119**	1.715	**1.272**	*2.544*	*3.430*	**8.726**	**11.099**	4.706	**14.119**
84	1.358	**1.168**	**7.122**	**8.318**	5.07099791 (+/- 4.6e-009)	**9.716**	1.524	**1.168**	*2.336*	*3.049*	**7.122**	**8.318**	3.239	**9.716**
85	1.192	**1.159**	**6.175**	**7.157**	4.6876123 (+/- 4.4e-008)	**8.295**	1.332	**1.159**	*2.318*	*2.664*	**6.175**	**7.157**	2.765	**8.295**
86	1.759	**1.466**	**11.574**	**16.967**	13.0633471 (+/- 1.3e-007)	**24.874**	1.974	**1.466**	*2.932*	*3.947*	**11.574**	**16.967**	8.291	**24.874**
87	1.528	**1.143**	**7.786**	**8.899**	5.84721611 (+/- 1.9e-008)	**10.172**	1.703	**1.143**	*2.286*	*3.406*	**7.786**	**8.899**	3.391	**10.172**
88	1.617	**1.268**	**9.119**	**11.563**	8.63965563 (+/- 4.8e-009)	**14.662**	1.798	**1.268**	*2.536*	*3.596*	**9.119**	**11.563**	4.887	**14.662**
89	1.316	**1.232**	**7.250**	**8.932**	6.18113934 (+/- 8.2e-009)	**11.004**	1.471	**1.232**	*2.464*	*2.942*	**7.250**	**8.932**	3.668	**11.004**
90	1.283	**1.106**	**6.365**	**7.040**	4.53271 (+/- 2.2e-005)	**7.786**	1.439	**1.106**	*2.212*	*2.877*	**6.365**	**7.040**	2.595	**7.786**
91	1.279	**1.151**	**6.570**	**7.562**	4.94583713 (+/- 4.3e-009)	**8.704**	1.427	**1.151**	*2.302*	*2.854*	**6.570**	**7.562**	2.901	**8.704**
92	1.154	**1.042**	**5.396**	**5.623**	3.05737891 (+/- 5.4e-009)	**5.859**	1.295	**1.042**	*2.084*	*2.589*	**5.396**	**5.623**	1.953	**5.859**
93	1.264	**1.062**	**5.973**	**6.343**	3.99275798 (+/- 3.5e-009)	**6.737**	1.406	**1.062**	*2.124*	*2.812*	**5.973**	**6.343**	2.246	**6.737**
94	1.619	**1.440**	**10.448**	**15.045**	11.8037232 (+/- 2.5e-008)	**21.665**	1.814	**1.440**	*2.880*	*3.628*	**10.448**	**15.045**	7.222	**21.665**
95	1.445	**1.169**	**7.511**	**8.780**	6.08322883 (+/- 1.5e-008)	**10.264**	1.606	**1.169**	*2.338*	*3.213*	**7.511**	**8.780**	3.421	**10.264**
96	1.322	**1.099**	**6.459**	**7.098**	4.63743561 (+/- 4.3e-009)	**7.801**	1.469	**1.099**	*2.198*	*2.939*	**6.459**	**7.098**	2.600	**7.801**
97	1.232	**1.257**	**6.889**	**8.659**	6.37451578 (+/- 1.1e-008)	**10.885**	1.370	**1.257**	*2.514*	*2.740*	**6.889**	**8.659**	3.628	**10.885**
98	1.178	**1.381**	**7.293**	**10.072**	7.61296588 (+/- 4.2e-009)	**13.909**	1.320	**1.381**	*2.762*	*2.640*	**7.293**	**10.072**	4.636	**13.909**

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}	mm.	mm.	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}
99	1.303	**1.145**	**6.569**	**7.522**	5.4287374 (+/- 4.5e-009)	**8.612**	1.434	**1.145**	*2.290*	*2.869*	**6.569**	**7.522**	2.871	**8.612**
100	1.020	**1.174**	**5.372**	**6.307**	3.91049196 (+/- 3.1e-009)	**7.404**	1.144	**1.174**	*2.348*	*2.288*	**5.372**	**6.307**	2.468	**7.404**
101	1.428	**1.310**	**8.266**	**10.828**	8.3690648 (+/- 1.8e-007)	**14.185**	1.577	**1.310**	*2.620*	*3.155*	**8.266**	**10.828**	4.728	**14.185**
102	1.272	**0.916**	**5.184**	**4.749**	2.1836638 (+/- 2.8e-008)	**4.350**	1.415	**0.916**	*1.832*	*2.830*	**5.184**	**4.749**	1.450	**4.350**
103	1.100	**1.124**	**5.498**	**6.180**	3.77340044 (+/- 1.2e-008)	**6.946**	1.223	**1.124**	*2.248*	*2.446*	**5.498**	**6.180**	2.315	**6.946**
104	1.098	**1.517**	**7.460**	**11.317**	8.87307956 (+/- 7.3e-009)	**17.168**	1.229	**1.517**	*3.034*	*2.459*	**7.460**	**11.317**	5.723	**17.168**
105	0.956	**1.216**	**5.098**	**6.199**	4.50002304 (+/- 1.5e-008)	**7.538**	1.048	**1.216**	*2.432*	*2.096*	**5.098**	**6.199**	2.513	**7.538**
106	1.503	**1.413**	**9.484**	**13.401**	10.569524 (+/- 1e-008)	**18.935**	1.678	**1.413**	*2.826*	*3.356*	**9.484**	**13.401**	6.312	**18.935**
107	1.531	**1.659**	**11.374**	**18.869**	17.2172464 (+/- 1e-008)	**31.304**	1.714	**1.659**	*3.318*	*3.428*	**11.374**	**18.869**	10.435	**31.304**
108	1.343	**1.681**	**10.119**	**17.010**	16.15797 (+/- 2.8e-005)	**28.594**	1.505	**1.681**	*3.362*	*3.010*	**10.119**	**17.010**	9.531	**28.594**
109	1.414	**1.595**	**10.140**	**16.173**	12.8907655 (+/- 1.5e-007)	**25.796**	1.589	**1.595**	*3.190*	*3.179*	**10.140**	**16.173**	8.599	**25.796**
110	1.130	**1.628**	**8.265**	**13.455**	10.3767165 (+/- 3.4e-008)	**21.905**	1.269	**1.628**	*3.256*	*2.538*	**8.265**	**13.455**	7.302	**21.905**
111	1.279	**1.741**	**9.978**	**17.372**	13.9279948 (+/- 1.8e-007)	**30.244**	1.433	**1.741**	*3.482*	*2.866*	**9.978**	**17.372**	10.081	**30.244**
112	1.141	**1.471**	**7.524**	**11.068**	7.88385139 (+/- 1.5e-008)	**16.281**	1.279	**1.471**	*2.942*	*2.557*	**7.524**	**11.068**	5.427	**16.281**
113	1.418	**1.719**	**10.931**	**18.790**	14.9395875 (+/- 5.4e-008)	**32.301**	1.590	**1.719**	*3.438*	*3.179*	**10.931**	**18.790**	10.767	**32.301**
114	1.150	**1.375**	**7.098**	**9.760**	6.55586388 (+/- 1.2e-008)	**13.420**	1.291	**1.375**	*2.750*	*2.581*	**7.098**	**9.760**	4.473	**13.420**
115	2.547	**2.350**	**26.897**	**63.208**	71.3946213 (+/- 2.5e-008)	**148.539**	2.861	**2.350**	*4.700*	*5.723*	**26.897**	**63.208**	49.513	**148.539**
116	1.683	**1.653**	**12.515**	**20.687**	16.6286819 (+/- 3e-008)	**34.196**	1.893	**1.653**	*3.306*	*3.786*	**12.515**	**20.687**	11.399	**34.196**
117	1.577	**1.684**	**11.827**	**19.917**	19.5870073 (+/- 1.9e-008)	**33.540**	1.756	**1.684**	*3.368*	*3.512*	**11.827**	**19.917**	11.180	**33.540**
118	1.582	**1.860**	**13.214**	**24.578**	24.156659 (+/- 1.1e-008)	**45.715**	1.776	**1.860**	*3.720*	*3.552*	**13.214**	**24.578**	15.238	**45.715**
119	1.634	**1.702**	**12.497**	**21.270**	18.3417866 (+/- 1e-008)	**36.201**	1.836	**1.702**	*3.404*	*3.671*	**12.497**	**21.270**	12.067	**36.201**
120	1.747	**1.596**	**12.508**	**19.963**	15.964107 (+/- 2.3e-008)	**31.861**	1.959	**1.596**	*3.192*	*3.919*	**12.508**	**19.963**	10.620	**31.861**
121	1.653	**1.528**	**11.344**	**17.334**	12.6387632 (+/- 1.3e-008)	**26.486**	1.856	**1.528**	*3.056*	*3.712*	**11.344**	**17.334**	8.829	**26.486**
122	1.651	**1.367**	**10.112**	**13.823**	8.72132591 (+/- 5.1e-008)	**18.896**	1.849	**1.367**	*2.734*	*3.699*	**10.112**	**13.823**	6.299	**18.896**
123	1.467	**1.361**	**8.931**	**12.155**	9.22422632 (+/- 5.1e-008)	**16.543**	1.641	**1.361**	*2.722*	*3.281*	**8.931**	**12.155**	5.514	**16.543**

	Original cross section						Modified cross section (Rectangular cross section)							
	Centroid to		Area	First moment of area	Local moment of inertia	Second moment of area	Centroid to		Dimension		Area	First moment of area	Local moment of inertia	Second moment of area
	vertical axis	horizontal axis					vertical axis	horizontal axis	h	b				
	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}	mm.	mm.	mm.	mm.	mm.^{2}	mm.^{3}	mm.^{4}	mm.^{4}
124	1.736	**1.591**	**12.373**	**19.685**	14.5980551 (+/- 5.9e-008)	**31.320**	1.944	**1.591**	*3.182*	*3.888*	**12.373**	**19.685**	10.440	**31.320**
125	1.434	**1.664**	**10.748**	**17.885**	13.96255 (+/- 2.8e-005)	**29.760**	1.615	**1.664**	*3.328*	*3.230*	**10.748**	**17.885**	9.920	**29.760**
126	1.947	**1.379**	**12.033**	**16.594**	10.4212377 (+/- 1e-008)	**22.882**	2.181	**1.379**	*2.758*	*4.363*	**12.033**	**16.594**	7.627	**22.882**
127	1.934	**1.586**	**13.768**	**21.836**	16.0712623 (+/- 1e-008)	**34.632**	2.170	**1.586**	*3.172*	*4.340*	**13.768**	**21.836**	11.544	**34.632**
128	1.814	**1.425**	**11.587**	**16.511**	12.3609383 (+/- 1.4e-008)	**23.529**	2.033	**1.425**	*2.850*	*4.066*	**11.587**	**16.511**	7.843	**23.529**
129	1.712	**1.464**	**11.274**	**16.505**	11.775839 (+/- 1e-008)	**24.164**	1.925	**1.464**	*2.928*	*3.850*	**11.274**	**16.505**	8.055	**24.164**
130	1.749	**1.907**	**14.986**	**28.578**	27.4453301 (+/- 1.3e-008)	**54.499**	1.965	**1.907**	*3.814*	*3.929*	**14.986**	**28.578**	18.166	**54.499**
131	1.624	**1.593**	**11.637**	**18.538**	14.8062536 (+/- 3.5e-008)	**29.531**	1.826	**1.593**	*3.186*	*3.653*	**11.637**	**18.538**	9.844	**29.531**
132	1.709	**1.396**	**10.656**	**14.876**	11.7356022 (+/- 1.8e-008)	**20.767**	1.908	**1.396**	*2.792*	*3.817*	**10.656**	**14.876**	6.922	**20.767**
133	1.723	**1.572**	**12.139**	**19.083**	16.2829883 (+/- 1.4e-008)	**29.998**	1.931	**1.572**	*3.144*	*3.861*	**12.139**	**19.083**	9.999	**29.998**
134	1.823	**1.607**	**13.162**	**21.151**	17.2610654 (+/- 2.1e-008)	**33.990**	2.048	**1.607**	*3.214*	*4.095*	**13.162**	**21.151**	11.330	**33.990**
							Sum		366.80	437.94				
							Mean		2.737	3.268				

APPENDIX C

Table of standard normal probability

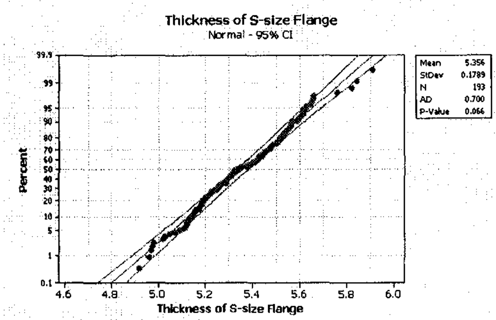


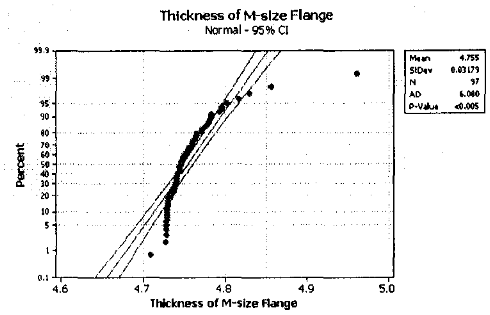
Z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.5000	0.5040	0.5080	0.5120	0.5160	0.5199	0.5239	0.5279	0.5319	0.5359
0.1	0.5398	0.5438	0.5478	0.5517	0.5557	0.5596	0.5636	0.5675	0.5714	0.5753
0.2	0.5793	0.5832	0.5871	0.5910	0.5948	0.5987	0.6026	0.6064	0.6103	0.6141
0.3	0.6179	0.6217	0.6255	0.6293	0.6331	0.6368	0.6406	0.6443	0.6480	0.6517
0.4	0.6554	0.6591	0.6628	0.6664	0.6700	0.6736	0.6772	0.6808	0.6844	0.6879
0.5	0.6915	0.6950	0.6985	0.7019	0.7054	0.7088	0.7123	0.7157	0.7190	0.7224
0.6	0.7257	0.7291	0.7324	0.7357	0.7389	0.7422	0.7454	0.7486	0.7517	0.7549
0.7	0.7580	0.7611	0.7642	0.7673	0.7704	0.7734	0.7764	0.7794	0.7823	0.7852
0.8	0.7881	0.7910	0.7939	0.7967	0.7995	0.8023	0.8051	0.8078	0.8106	0.8133
0.9	0.8159	0.8186	0.8212	0.8238	0.8264	0.8289	0.8315	0.8340	0.8365	0.8389
1.0	0.8413	0.8438	0.8461	0.8485	0.8508	0.8531	0.8554	0.8577	0.8599	0.8621
1.1	0.8643	0.8665	0.8686	0.8708	0.8729	0.8749	0.8770	0.8790	0.8810	0.8830
1.2	0.8849	0.8869	0.8888	0.8907	0.8925	0.8944	0.8962	0.8980	0.8997	0.9015
1.3	0.9032	0.9049	0.9066	0.9082	0.9099	0.9115	0.9131	0.9147	0.9162	0.9177
1.4	0.9192	0.9207	0.9222	0.9236	0.9251	0.9265	0.9279	0.9292	0.9306	0.9319
1.5	0.9332	0.9345	0.9357	0.9370	0.9382	0.9394	0.9406	0.9418	0.9429	0.9441
1.6	0.9452	0.9463	0.9474	0.9484	0.9495	0.9505	0.9515	0.9525	0.9535	0.9545
1.7	0.9554	0.9564	0.9573	0.9582	0.9591	0.9599	0.9608	0.9616	0.9625	0.9633
1.8	0.9641	0.9649	0.9656	0.9664	0.9671	0.9678	0.9686	0.9693	0.9699	0.9706
1.9	0.9713	0.9719	0.9726	0.9732	0.9738	0.9744	0.9750	0.9756	0.9761	0.9767
2.0	0.9772	0.9778	0.9783	0.9788	0.9793	0.9798	0.9803	0.9808	0.9812	0.9817
2.1	0.9821	0.9826	0.9830	0.9834	0.9838	0.9842	0.9846	0.9850	0.9854	0.9857
2.2	0.9861	0.9864	0.9868	0.9871	0.9875	0.9878	0.9881	0.9884	0.9887	0.9890
2.3	0.9893	0.9896	0.9898	0.9901	0.9904	0.9906	0.9909	0.9911	0.9913	0.9916
2.4	0.9918	0.9920	0.9922	0.9925	0.9927	0.9929	0.9931	0.9932	0.9934	0.9936
2.5	0.9938	0.9940	0.9941	0.9943	0.9945	0.9946	0.9948	0.9949	0.9951	0.9952
2.6	0.9953	0.9955	0.9956	0.9957	0.9959	0.9960	0.9961	0.9962	0.9963	0.9964
2.7	0.9965	0.9966	0.9967	0.9968	0.9969	0.9970	0.9971	0.9972	0.9973	0.9974
2.8	0.9974	0.9975	0.9976	0.9977	0.9977	0.9978	0.9979	0.9979	0.9980	0.9981
2.9	0.9981	0.9982	0.9982	0.9983	0.9984	0.9984	0.9985	0.9985	0.9986	0.9986
3.0	0.9987	0.9987	0.9987	0.9988	0.9988	0.9989	0.9989	0.9989	0.9990	0.9990
3.1	0.9990	0.9991	0.9991	0.9991	0.9992	0.9992	0.9992	0.9992	0.9993	0.9993
3.2	0.9993	0.9993	0.9994	0.9994	0.9994	0.9994	0.9994	0.9995	0.9995	0.9995
3.3	0.9995	0.9995	0.9995	0.9996	0.9996	0.9996	0.9996	0.9996	0.9996	0.9997
3.4	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9998

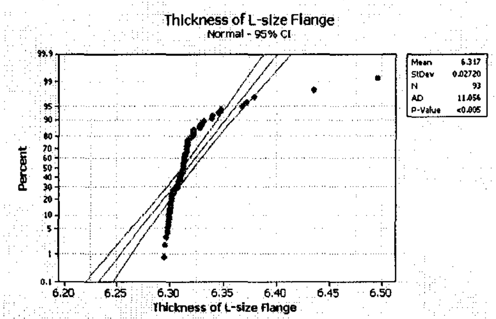
APPENDIX D

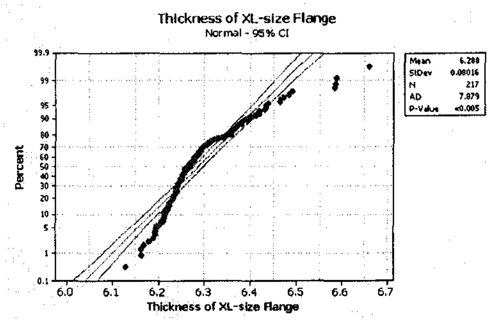
Plots of all data sets that are tested for normality of distribution

Model I: Thickness of flanges

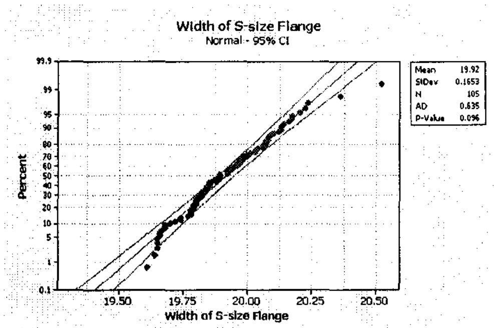


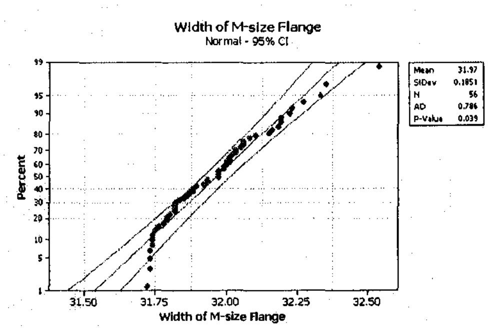


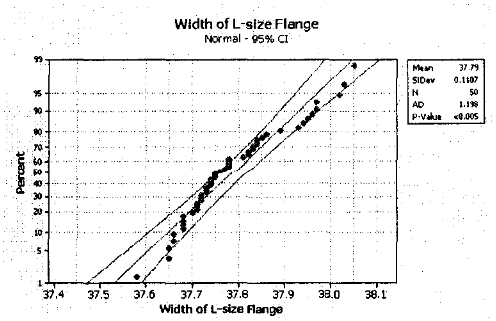


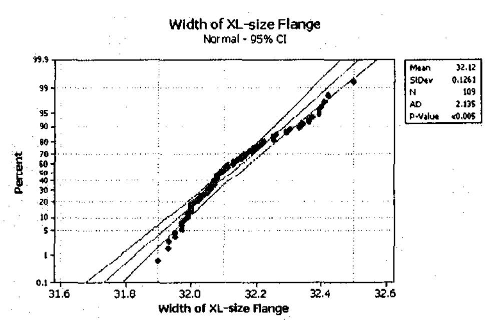


Model I: Width of flanges

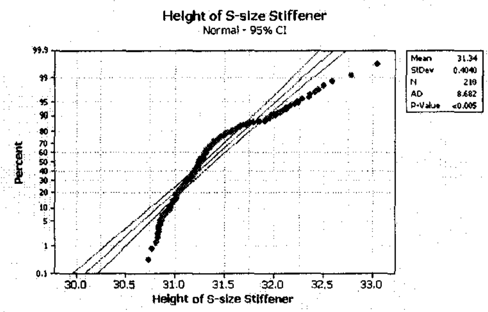


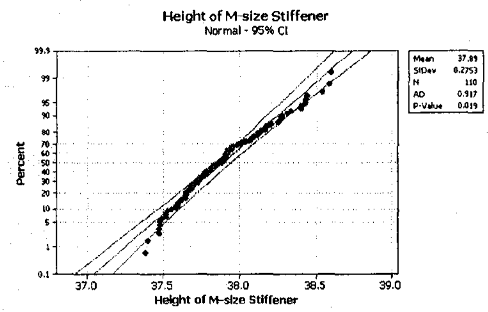


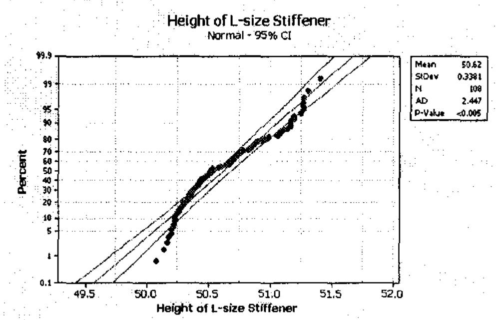


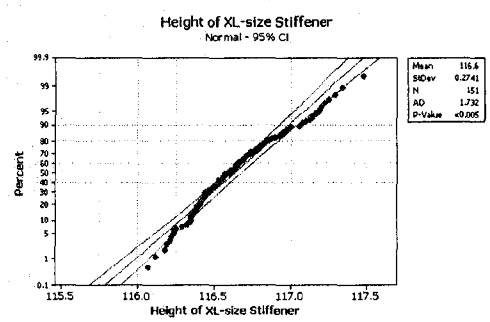


Model I: Height of stiffeners

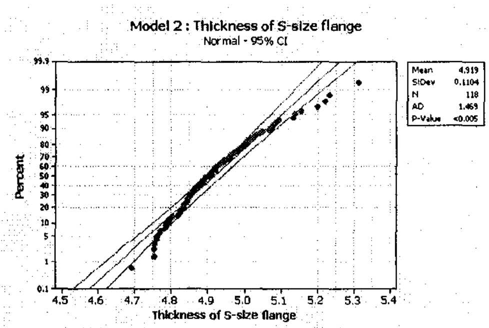


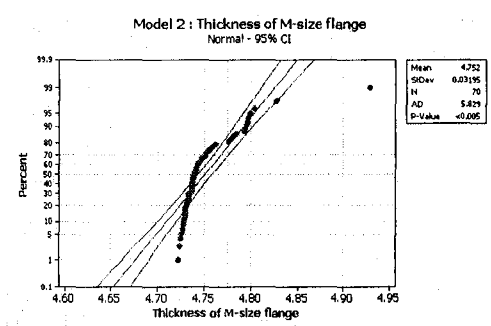


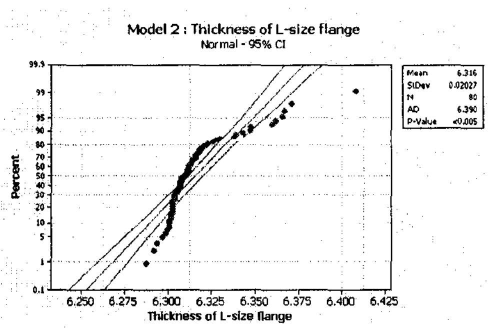


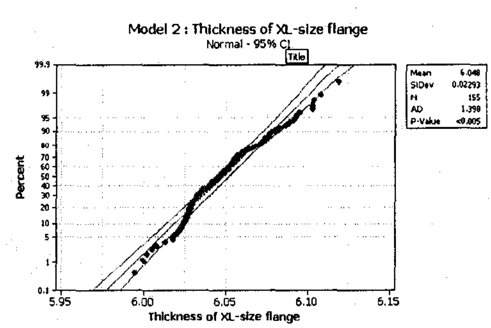


Model II: Thickness of flanges

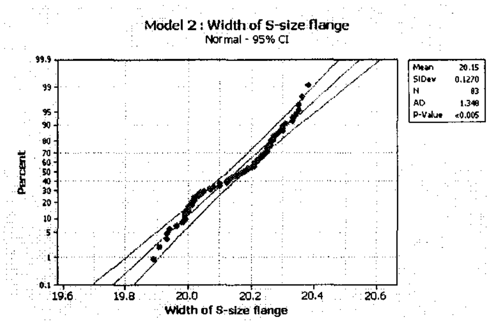


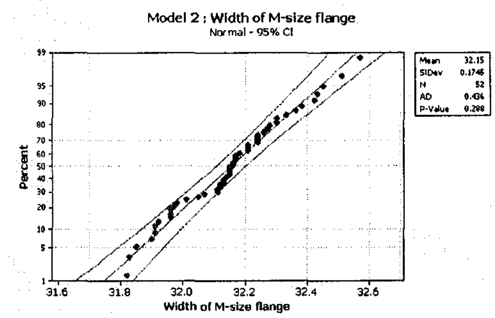


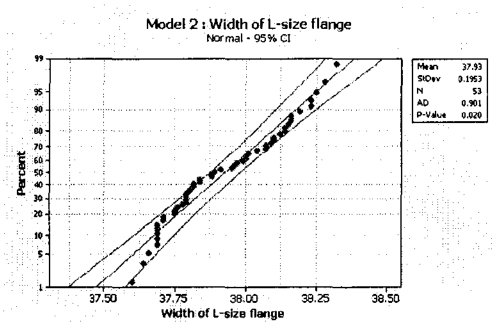


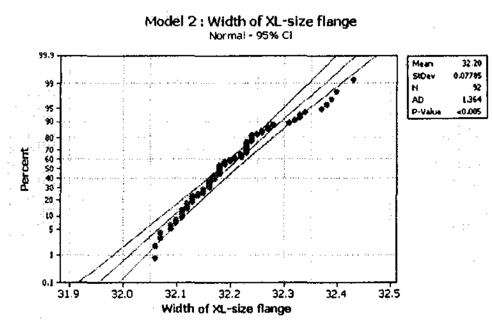


Model II: Width of flanges

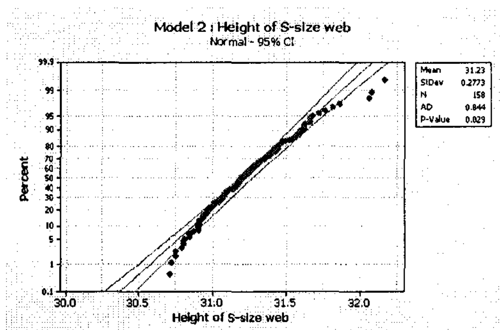


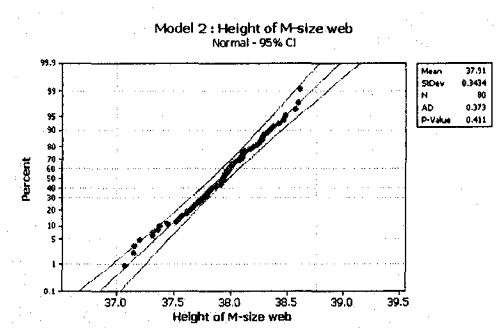


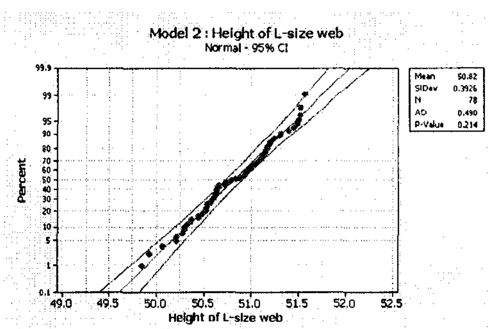


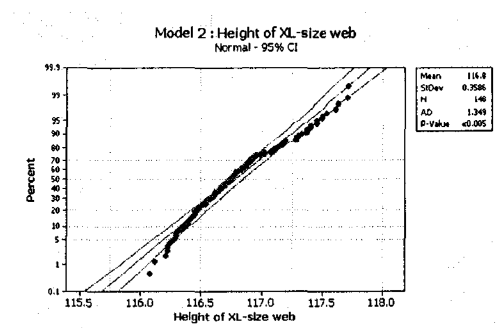


Model II: Height of stiffeners

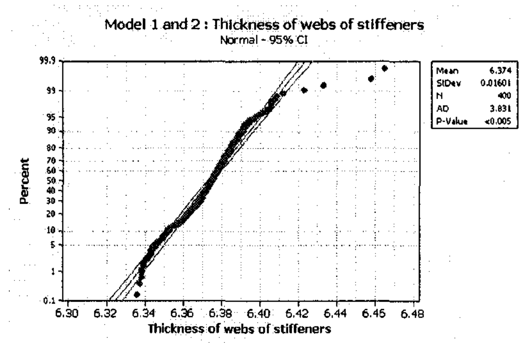




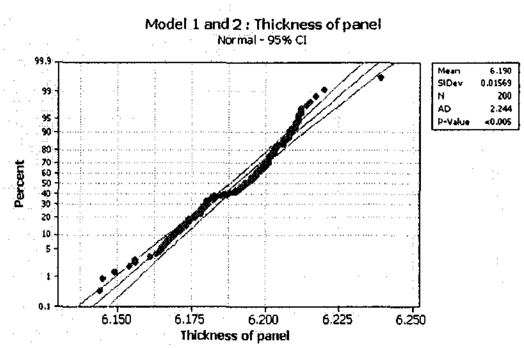




Model I and II: Thickness of webs of stiffeners



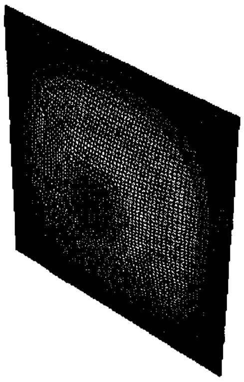
Model I and II: Thickness of panel



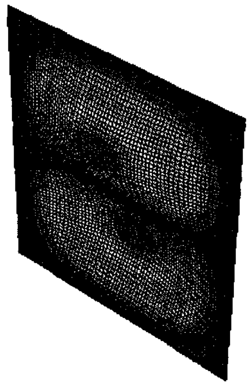
APPENDIX E

Mode shapes of models analyzes using ABAQUS and ANSYS

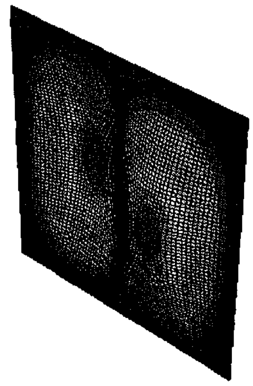
Stage 1 of the stiffened plate model analyzed using S4R and S8R in ABAQUS



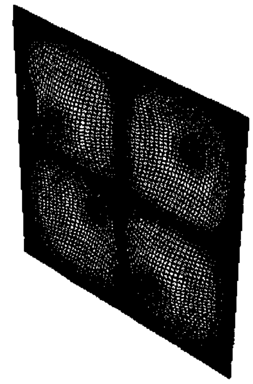
Mode 1



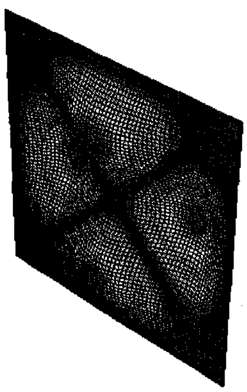
Mode 2



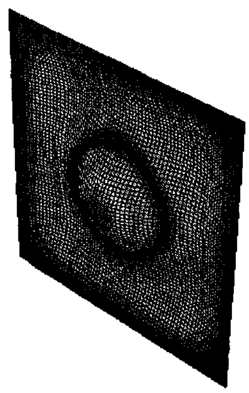
Mode 3



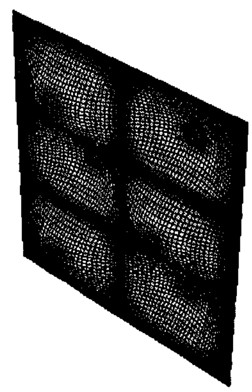
Mode 4



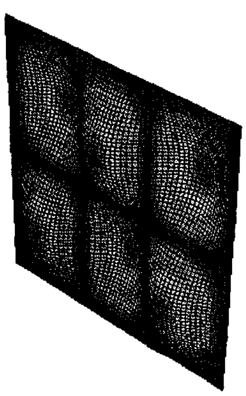
Mode 5



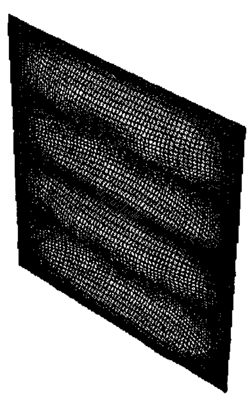
Mode 6



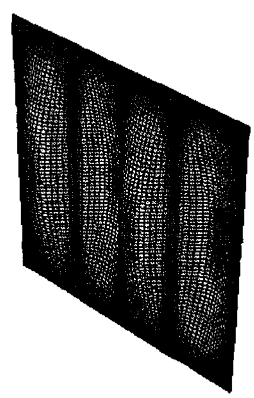
Mode 7



Mode 8

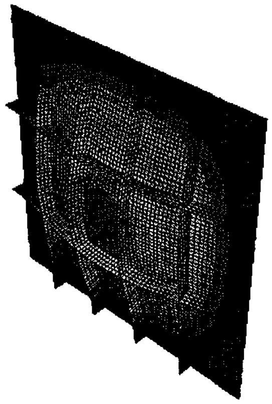


Mode 9

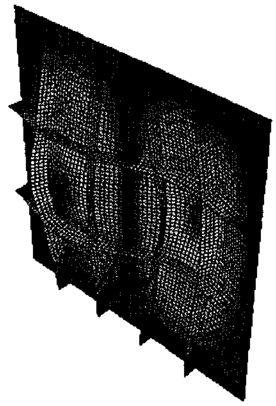


Mode 10

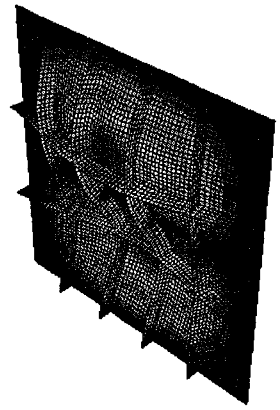
Stage 2 of the stiffened plate model analyzed using S4R and S8R in ABAQUS



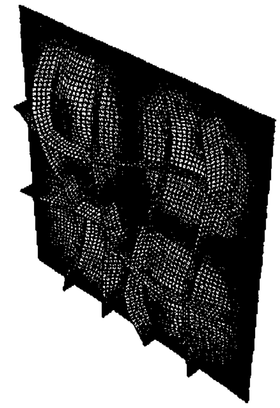
Mode 1



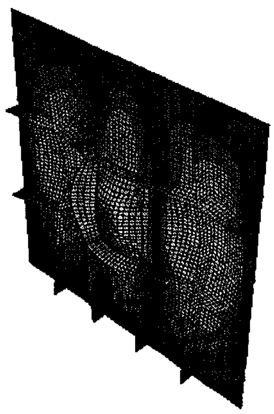
Mode 2



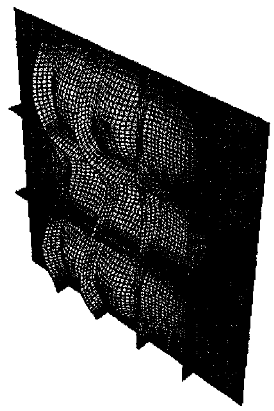
Mode 3



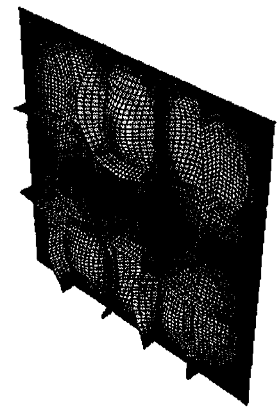
Mode 4



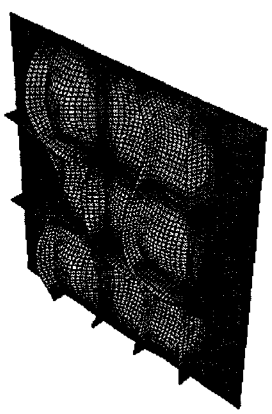
Mode 5



Mode 6



Mode 7



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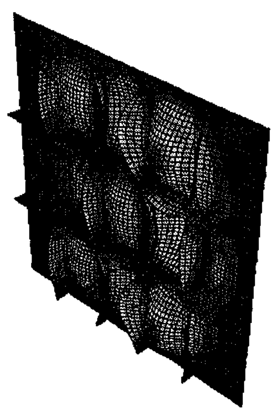
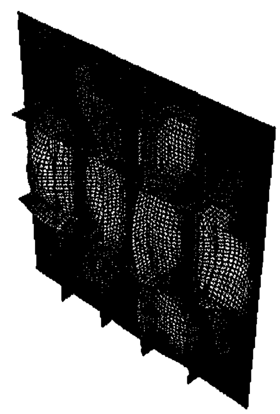
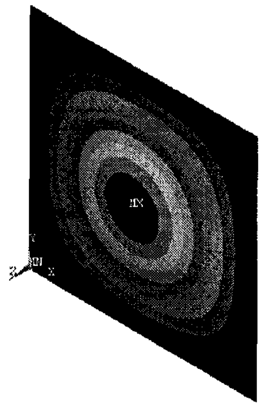


Mode 9

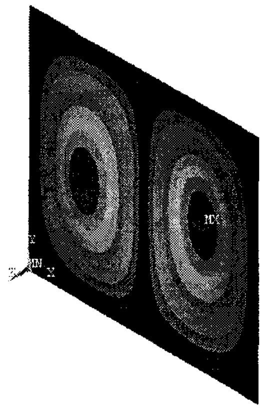


Mode 10

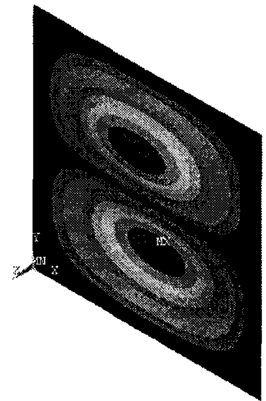
Stage 1 of the stiffened plate model analyzed using shell 63 and 93 in ANSYS



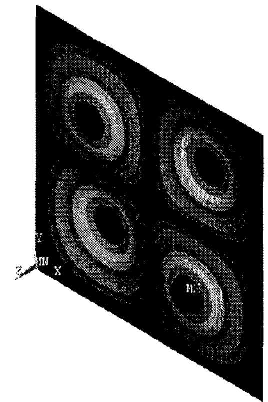
Mode 1



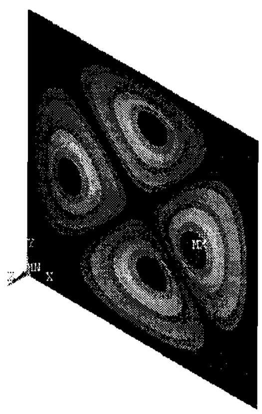
Mode 2



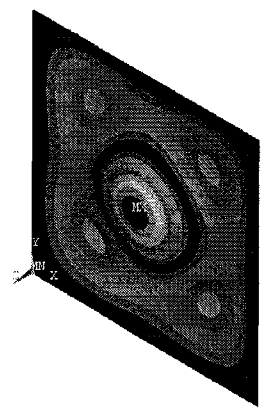
Mode 3



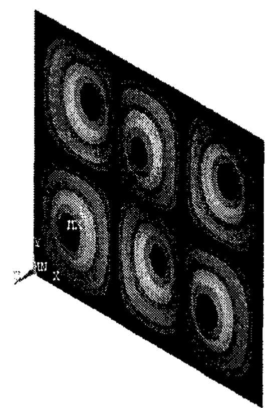
Mode 4



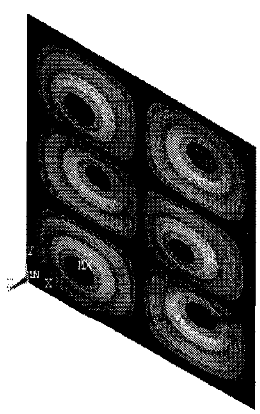
Mode 5



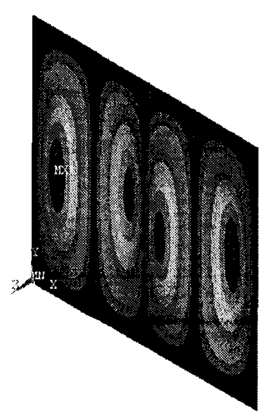
Mode 6



Mode 7



Mode 8



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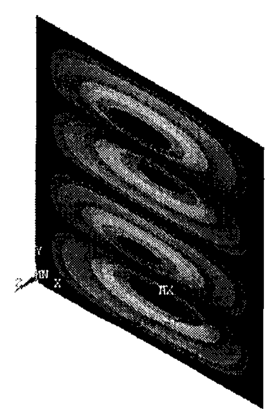
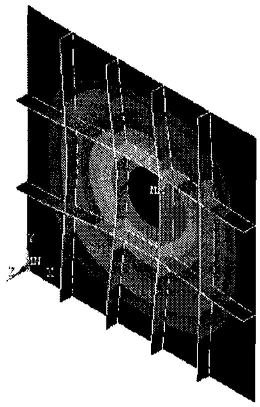
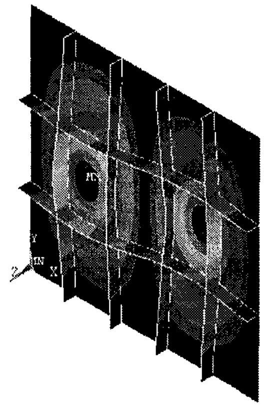


Mode 10

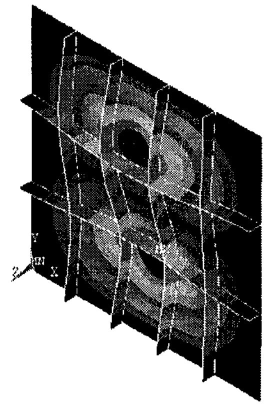
Stage 2 of the stiffened plate model analyzed using shell 63 and 93 in ANSYS



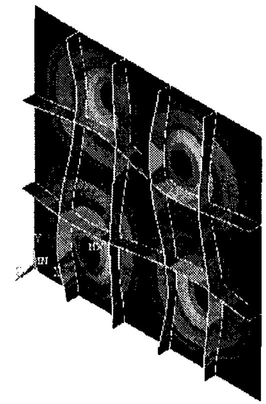
Mode 1



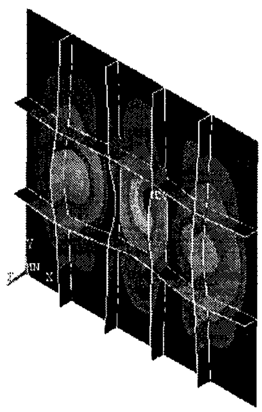
Mode 2



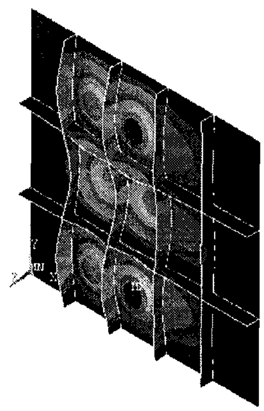
Mode 3



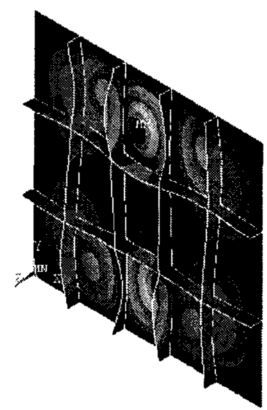
Mode 4



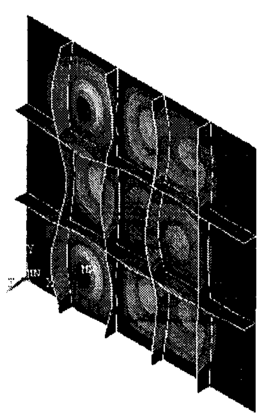
Mode 5



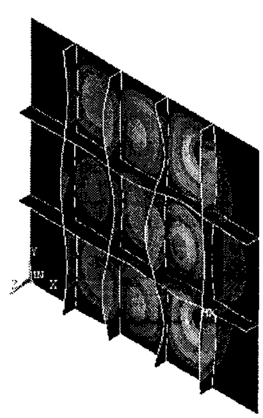
Mode 6



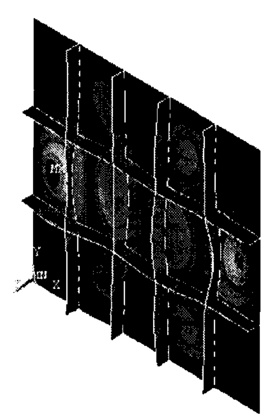
Mode 7



Mode 8



Mode 9

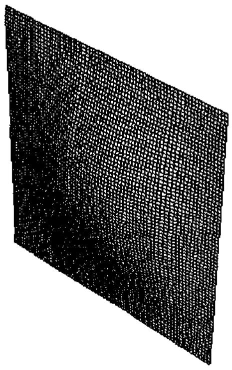
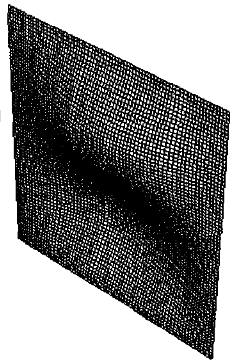
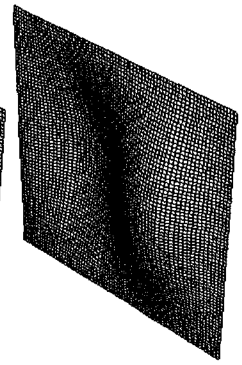
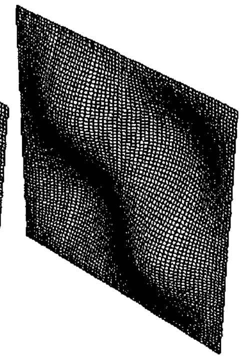


Mode 10

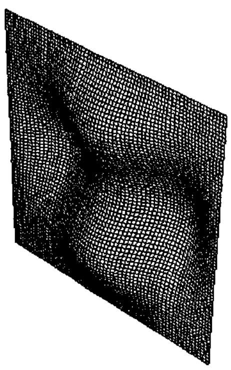
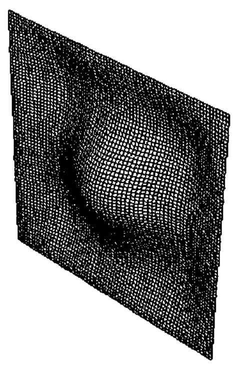
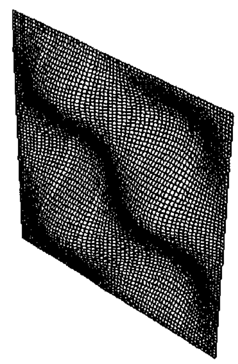
APPENDIX F

Mode shapes in stage 1, 2, 3 and 4 of Model I and II

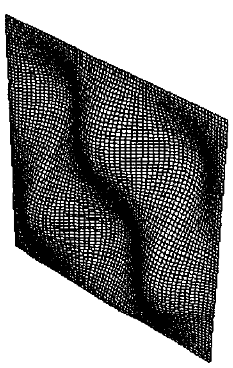
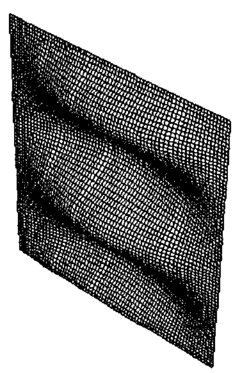
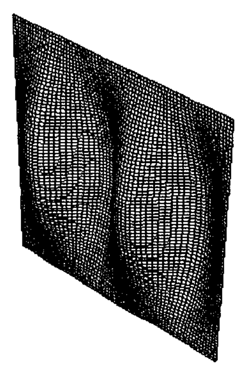
Stage 1

Mode 1 Mode 2 Mode 3 Mode 4

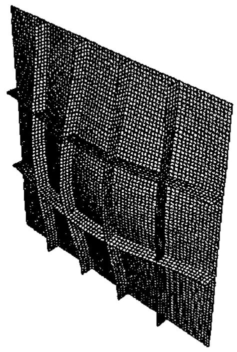




Mode 5 Mode 6 Mode 7

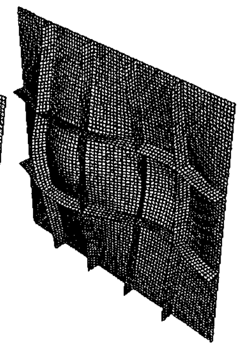




Mode 8 Mode 9 Mode 10

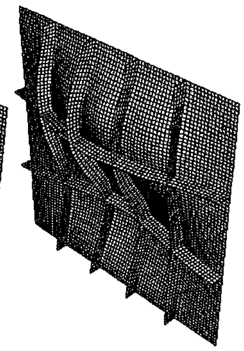
Stage 2



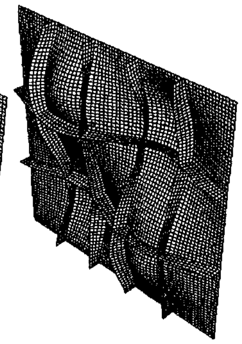
Mode 1



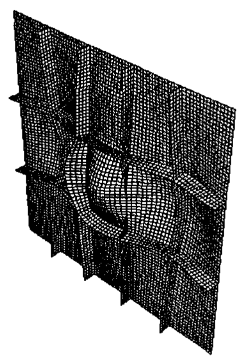
Mode 2



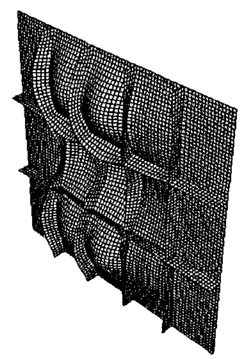
Mode 3



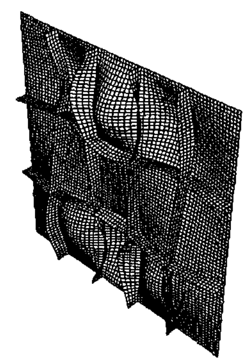
Mode 4



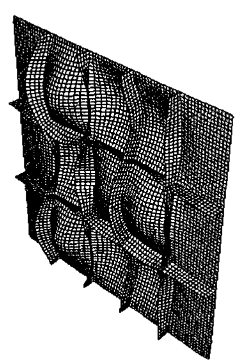
Mode 5



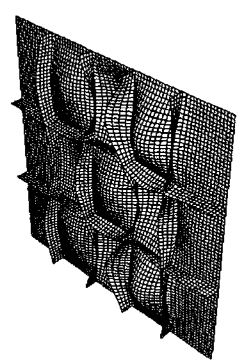
Mode 6



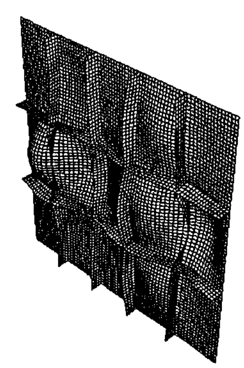
Mode 7



Mode 8

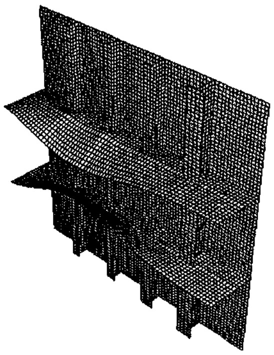


Mode 9

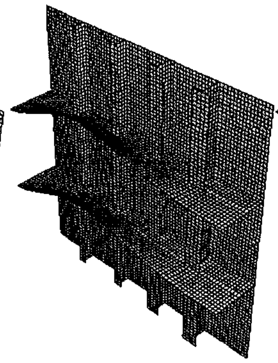


Mode 10

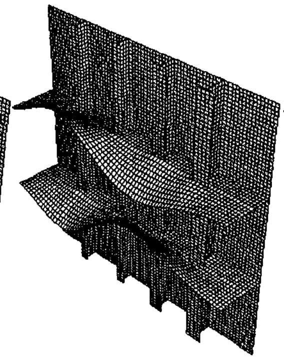
Stage 3



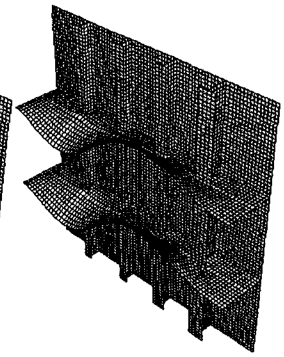
Mode 1



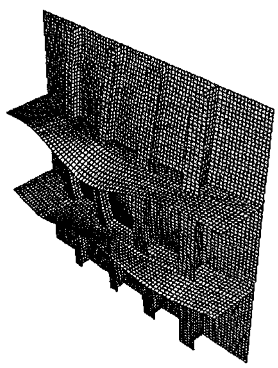
Mode 2



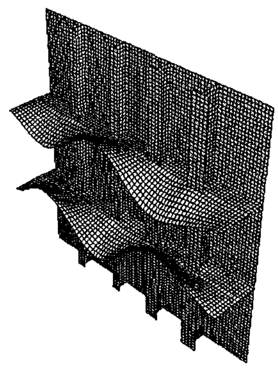
Mode 3



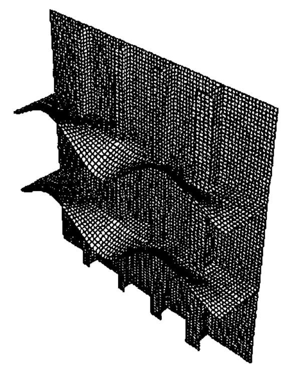
Mode 4



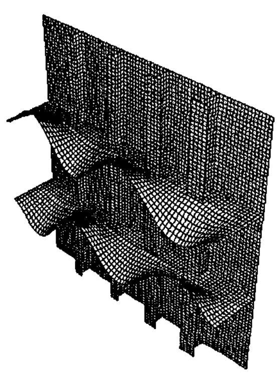
Mode 5



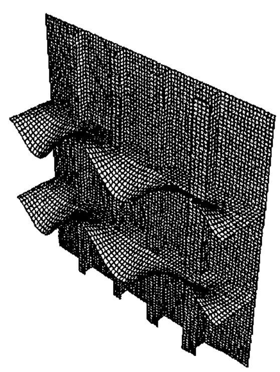
Mode 6



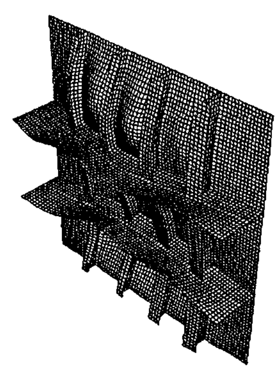
Mode 7



Mode 8

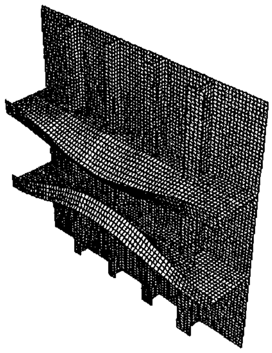
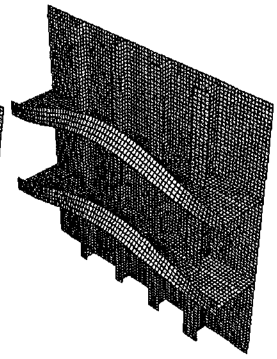
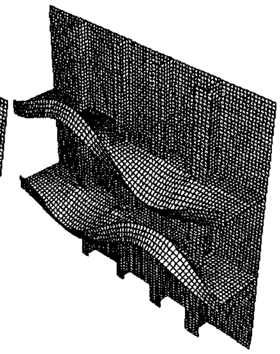
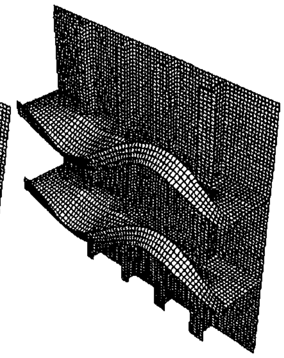


Mode 9

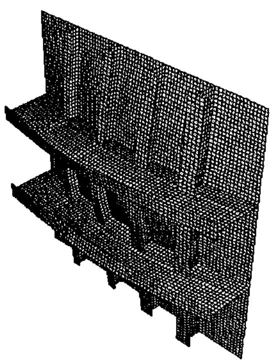
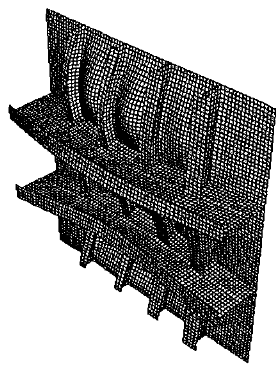
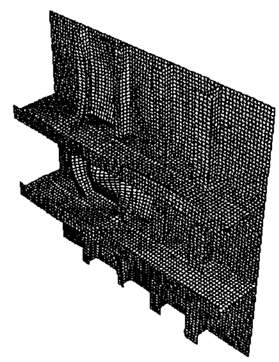


Mode 10

Stage 4

Mode 1 Mode 2 Mode 3 Mode 4

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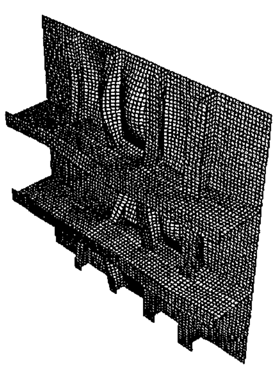
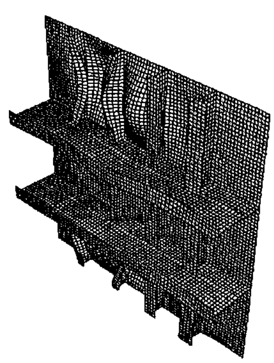
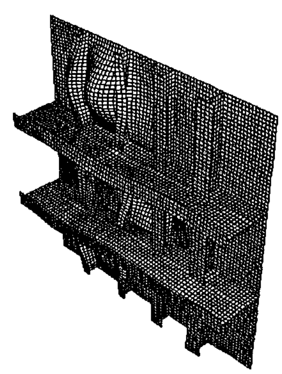

Mode 8 Mode 9 Mode 10

APPENDIX G

Table of details of rigidity calculations

<u>Rigidities in x and y direction of each zone</u>

Note: There is no need to modify the rigidities of certain areas which are A-1 in x and y directions, A-2 in x direction, A-3 in x direction, A-4 in x direction and A-5 in y direction; therefore, no rigidity calculation is given for these areas.

Area	Direction	No	Items	Width	Thickness	Total area	Height from baseline	First moment of area	Local moment of inertia	Second moment of area	Centroid to N.A.	Local rigidity	Additional rigidity with respect to N.A.	Total rigidity with respect to N.A.
				b	t	a	h	ah	I	ah^2	e	EI	Eae^2	D
				m.	m.	$m.^2$	m.	$m.^3$	$m.^4$	$m.^4$	m.	$N.m.^2$	$N.m.^2$	$N.m.^2$
A-2	Y	1	Plate	0.120000	0.006190	0.000743	0.003095	2.299E-06	2.372E-09	7.115E-09	0.005619	1.9758E+02	1.9535E+03	2.1511E+03
		2	Stiffener's web	0.026403	0.004755	0.000126	0.019392	2.435E-06	7.293E-09	4.721E-08	0.010678	5.3315E+02	1.0464E+03	1.5795E+03
		3	Stiffener's flange	0.019917	0.005356	0.000107	0.035271	3.763E-06	2.550E-10	1.327E-07	0.026557	1.8642E+01	5.4998E+03	5.5185E+03
			Summation			0.000975		8.496E-06	9.920E-09	1.870E-07				**9.2491E+03**
A-3	Y	1	Plate	0.120000	0.006190	0.000743	0.003095	2.299E-06	2.372E-09	7.115E-09	0.009309	1.9758E+02	5.3627E+03	5.5603E+03
		2	Stiffener's web	0.033854	0.004755	0.000161	0.023117	3.721E-06	1.537E-08	8.602E-08	0.010713	1.1239E+03	1.3504E+03	2.4743E+03
		3	Stiffener's flange	0.031965	0.005356	0.000171	0.042722	7.314E-06	4.093E-10	3.125E-07	0.030318	2.9918E+01	1.1503E+04	1.1533E+04
			Summation			0.001075		1.333E-05	1.816E-08	4.056E-07				**1.9568E+04**

Area	Direction	No	Items	Width	Thickness	Total area	Height from baseline	First moment of area	Local moment of inertia	Second moment of area	Centroid to N.A.	Local rigidity	Additional rigidity with respect to N.A.	Total rigidity with respect to N.A.
				b	t	a	h	ah	I	ah^2	e	EI	Eae^2	D
				m.	m.	$m.^2$	m.	$m.^3$	$m.^4$	$m.^4$	m.	$N.m.^2$	$N.m.^2$	$N.m.^2$
A-4	Y	1	Plate	0.120000	0.006190	0.000743	0.003095	2.299E-06	2.372E-09	7.115E-09	0.011003	1.9758E+02	7.4911E+03	7.6887E+03
		2	Stiffener's web	0.044240	0.006380	0.000282	0.028310	7.991E-06	4.603E-08	2.262E-07	0.014212	3.3651E+03	4.1675E+03	7.5327E+03
		3	Stiffener's flange	0.019917	0.005356	0.000107	0.053108	5.665E-06	2.550E-10	3.009E-07	0.039010	1.8642E+01	1.1867E+04	1.1886E+04
			Summation			0.001132		1.595E-05	4.866E-08	5.342E-07				**2.7107E+04**
A-5	X	1	Plate	0.200000	0.006190	0.001238	0.003095	3.832E-06	3.953E-09	1.186E-08	0.030100	3.2930E+02	9.3435E+04	9.3765E+04
		2	Stiffener's web	0.110296	0.006380	0.000704	0.061338	4.316E-05	7.134E-07	2.648E-06	0.028143	5.2148E+04	4.0743E+04	9.2891E+04
		3	Stiffener's flange	0.032123	0.006288	0.000202	0.119630	2.416E-05	6.655E-10	2.891E-06	0.086435	4.8651E+01	1.1031E+05	1.1036E+05
			Summation			0.002144		7.116E-05	7.180E-07	5.550E-06				**2.9702E+05**
A-6	X	1	Plate	0.200000	0.006190	0.001238	0.003095	3.832E-06	3.953E-09	1.186E-08	0.030100	3.2930E+02	9.3435E+04	9.3765E+04
		2	Stiffener's web	0.110296	0.006380	0.000704	0.061338	4.316E-05	7.134E-07	2.648E-06	0.028143	5.2148E+04	4.0743E+04	9.2891E+04
		3	Stiffener's flange	0.032123	0.006288	0.000202	0.119630	2.416E-05	6.655E-10	2.891E-06	0.086435	4.8651E+01	1.1031E+05	1.1036E+05
			Summation			0.002144		7.116E-05	7.180E-07	5.550E-06				**2.9702E+05**
	Y	1	Plate	0.120000	0.006190	0.000743	0.003095	2.299E-06	2.372E-09	7.115E-09	0.005619	1.9758E+02	1.9535E+03	2.1511E+03
		2	Stiffener's web	0.026403	0.004755	0.000126	0.019392	2.435E-06	7.293E-09	4.721E-08	0.010678	5.3315E+02	1.0464E+03	1.5795E+03
		3	Stiffener's flange	0.019917	0.005356	0.000107	0.035271	3.763E-06	2.550E-10	1.327E-07	0.026557	1.8642E+01	5.4998E+03	5.5185E+03
			Summation			0.000975		8.496E-06	9.920E-09	1.870E-07				**9.2491E+03**

Area	Direction	No	Items	Width	Thickness	Total area	Height from baseline	First moment of area	Local moment of inertia	Second moment of area	Centroid to N.A.	Local rigidity	Additional rigidity with respect to N.A.	Total rigidity with respect to N.A.
				b	t	a	h	ah	I	ah^2	e	EI	Eae^2	D
				m.	m.	$m.^2$	m.	$m.^3$	$m.^4$	$m.^4$	m.	$N.m.^2$	$N.m.^2$	$N.m.^2$
A-7	X	1	Plate	0.200000	0.006190	0.001238	0.003095	3.832E-06	3.953E-09	1.186E-08	0.030100	3.2930E+02	9.3435E+04	9.3765E+04
		2	Stiffener's web	0.110296	0.006380	0.000704	0.061338	4.316E-05	7.134E-07	2.648E-06	0.028143	5.2148E+04	4.0743E+04	9.2891E+04
		3	Stiffener's flange	0.032123	0.006288	0.000202	0.119630	2.416E-05	6.655E-10	2.891E-06	0.086435	4.8651E+01	1.1031E+05	1.1036E+05
			Summation			0.002144		7.116E-05	7.180E-07	5.550E-06				**2.9702E+05**
	Y	1	Plate	0.120000	0.006190	0.000743	0.003095	2.299E-06	2.372E-09	7.115E-09	0.009309	1.9758E+02	5.3627E+03	5.5603E+03
		2	Stiffener's web	0.033854	0.004755	0.000161	0.023117	3.721E-06	1.537E-08	8.602E-08	0.010713	1.1239E+03	1.3504E+03	2.4743E+03
		3	Stiffener's flange	0.031965	0.005356	0.000171	0.042722	7.314E-06	4.093E-10	3.125E-07	0.030318	2.9918E+01	1.1503E+04	1.1533E+04
			Summation			0.001075		1.333E-05	1.816E-08	4.056E-07				**1.9568E+04**
A-8	X	1	Plate	0.200000	0.006190	0.001238	0.003095	3.832E-06	3.953E-09	1.186E-08	0.030100	3.2930E+02	9.3435E+04	9.3765E+04
		2	Stiffener's web	0.110296	0.006380	0.000704	0.061338	4.316E-05	7.134E-07	2.648E-06	0.028143	5.2148E+04	4.0743E+04	9.2891E+04
		3	Stiffener's flange	0.032123	0.006288	0.000202	0.119630	2.416E-05	6.655E-10	2.891E-06	0.086435	4.8651E+01	1.1031E+05	1.1036E+05
			Summation			0.002144		7.116E-05	7.180E-07	5.550E-06				**2.9702E+05**
	Y	1	Plate	0.120000	0.006190	0.000743	0.003095	2.299E-06	2.372E-09	7.115E-09	0.011003	1.9758E+02	7.4911E+03	7.6887E+03
		2	Stiffener's web	0.044240	0.006380	0.000282	0.028310	7.991E-06	4.603E-08	2.262E-07	0.014212	3.3651E+03	4.1675E+03	7.5327E+03
		3	Stiffener's flange	0.019917	0.005356	0.000107	0.053108	5.665E-06	2.550E-10	3.009E-07	0.039010	1.8642E+01	1.1867E+04	1.1886E+04
			Summation			0.001132		1.595E-05	4.866E-08	5.342E-07				**2.7107E+04**

Rigidities of the original sections (sections of stiffened plate), area moment of inertia of the modified equivalent orthotropic section, elastic moduli of the modified equivalent orthotropic sections and the modified Poison's ratios orthotropic

Area	Variables												
	D_x	D_y	I_x	I_y	E_1	E_2	E_3	ν_{12}	ν_{21}	ν_{13}	ν_{31}	ν_{23}	ν_{32}
A-1	9.8790E+01	1.6465E+02	1.1859E-09	1.9765E-09	7.3100E+10	7.3100E+10	7.3100E+10	0.350000	0.350000	0.350000	0.350000	0.350000	0.350000
A-2	9.2491E+03	1.6465E+02	2.3718E-09	1.9765E-09	3.4219E+12	7.3100E+10	7.3100E+10	0.350000	0.007477	0.350000	0.007477	0.350000	0.350000
A-3	1.9568E+04	1.6465E+02	2.3718E-09	1.9765E-09	7.2395E+12	7.3100E+10	7.3100E+10	0.350000	0.003534	0.350000	0.003534	0.350000	0.350000
A-4	2.7107E+04	1.6465E+02	2.3718E-09	1.9765E-09	1.0029E+13	7.3100E+10	7.3100E+10	0.350000	0.002551	0.350000	0.002551	0.350000	0.350000
A-5	9.8790E+01	2.9702E+05	1.1859E-09	3.9529E-09	7.3100E+10	6.5934E+13	7.3100E+10	0.000388	0.350000	0.350000	0.350000	0.350000	0.000388
A-6	9.2491E+03	2.9702E+05	2.3718E-09	3.9529E-09	3.4219E+12	6.5934E+13	7.3100E+10	0.018165	0.350000	0.350000	0.007477	0.350000	0.000388
A-7	1.9568E+04	2.9702E+05	2.3718E-09	3.9529E-09	7.2395E+12	6.5934E+13	7.3100E+10	0.038430	0.350000	0.350000	0.003534	0.350000	0.000388
A-8	2.7107E+04	2.9702E+05	2.3718E-09	3.9529E-09	1.0029E+13	6.5934E+13	7.3100E+10	0.053237	0.350000	0.350000	0.002551	0.350000	0.000388

All variables, described in section 5.2.4, those are required in the constitutive matrices in ABAQUS

Area	Value of all variable filled in the constitutive matrices								
	D1111	D1122	D2222	D1133	D2323	D3333	D1212	D1313	D2323
A-1	1.1732E+11	6.3173E+10	1.1732E+11	6.3173E+10	6.3173E+10	1.1732E+11	2.7074E+10	2.7074E+10	2.7074E+10
A-2	3.4497E+12	3.9681E+10	8.3761E+10	3.9681E+10	2.9613E+10	8.3761E+10	7.0538E+10	7.0538E+10	2.7074E+10
A-3	7.2671E+12	3.9512E+10	8.3520E+10	3.9512E+10	2.9372E+10	8.3520E+10	7.1866E+10	7.1866E+10	2.7074E+10
A-4	1.0057E+13	3.9470E+10	8.3460E+10	3.9470E+10	2.9312E+10	8.3460E+10	7.2205E+10	7.2205E+10	2.7074E+10
A-5	8.3328E+10	3.9378E+10	6.5961E+13	2.9180E+10	3.9378E+10	8.3328E+10	7.2962E+10	2.7074E+10	7.2962E+10
A-6	3.4533E+12	1.2178E+12	6.6372E+13	2.6292E+10	3.4861E+10	7.3310E+10	3.1445E+12	7.0538E+10	7.2962E+10
A-7	7.3481E+12	2.5813E+12	6.6850E+13	2.6971E+10	3.5063E+10	7.3209E+10	6.1007E+12	7.1866E+10	7.2962E+10
A-8	1.0230E+13	3.5900E+12	6.7203E+13	2.7490E+10	3.5236E+10	7.3184E+10	7.9685E+12	7.2205E+10	7.2962E+10

APPENDIX H

Derivation to obtain fixed-fixed beam stiffness under a couple load by moment-area method

Figure I shows a fixed-fixed beam under a couple load at one-fourth and three-fourth of the beam span, and also shows a free body diagram, elastic curve and $\frac{\text{M}}{\text{EI}}$ diagram.

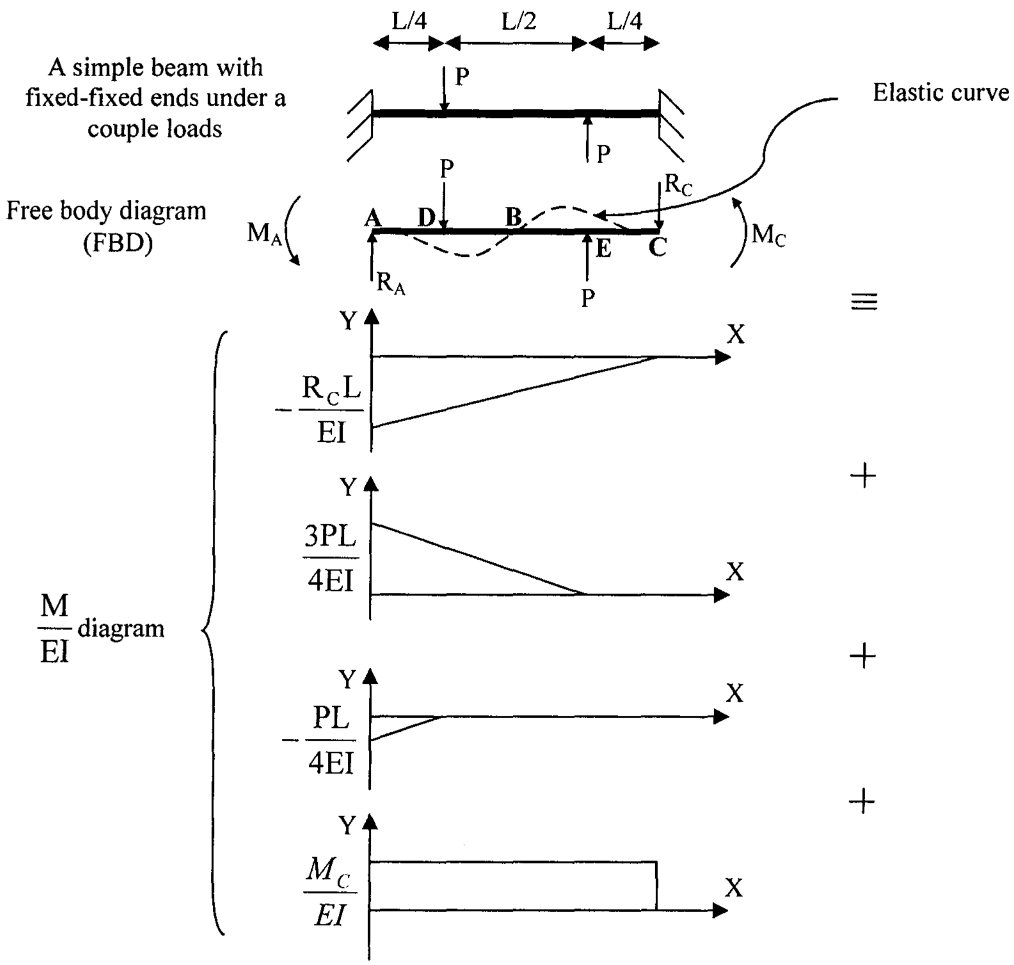

Figure I FBD, $\frac{\mathbf{M}}{\mathbf{EI}}$ diagram and elastic curve of a beam under a couple loads

Define variables:

L	= length of span	(m)
P	= applied force	(N)

R_A	= reaction force at point A	(N)
R_C	= reaction force at point C	(N)
M_A	= bending moment at point A	(N m)
M_C	= bending moment at point C	(N m)
E	= elastic modulus	(N / m^2)
I	= moment of inertia	(m^4)

According to static indeterminacy of the beam, the redundants were determined using moment-area method possessing two simple theorems which could be stated as [34]:

Theorem 1: The tangent between any two points on the elastic curve is equal to the area under $\frac{\mathrm{M}}{\mathrm{EI}}$ diagram of those two points.

$$\theta_{B/A} = \int_A^B \frac{M}{EI} dx \tag{H-1}$$

Theorem 2: On the elastic curve, the vertical deviation of a point A with respect to tangent extended from a point B is equal to the moment of area under $\frac{\mathrm{M}}{\mathrm{EI}}$ diagram where the moment is calculated at point A.

$$t_{A/B} = \int_A^B x \frac{M}{EI} dx \tag{H-2}$$

Since it was obvious that the displacement at point C with respect to the tangent extended from a point A was zero, theorem 2 was applied to obtain:

$$t_{C/A} = 0 = \left[\frac{1}{2} \times L \times \frac{-R_C L}{EI} \times \left(\frac{2L}{3}\right)\right] + \left[\frac{1}{2} \times \frac{3L}{4} \times \frac{3PL}{4EI} \times \left(\frac{L}{4} + \frac{2}{3} \times \frac{3L}{4}\right)\right]$$
$$+ \left[\frac{1}{2} \times \frac{L}{4} \times \frac{-PL}{4EI} \times \left(\frac{3L}{4} + \frac{2}{3} \times \frac{L}{4}\right)\right] + \left[\frac{M_C}{EI} \times L \times \left(\frac{L}{2}\right)\right] \tag{H-3}$$

Rearranging equation (H-3); consequently, equation (H-3) becomes:

$$0 = -128 R_C L + 70PL + 192 M_C \tag{H-4}$$

Theorem 2 was applied again once the displacement at point B with respect to the tangent extended from a point A was zero:

$$t_{B/A} = 0 = \left[\frac{-R_C L}{2EI} \times \frac{L}{2} \times \left(\frac{L}{4}\right)\right] + \left[\frac{1}{2} \times \frac{L}{2} \times \frac{-R_C L}{2EI} \times \left(\frac{2}{3} \times \frac{L}{2}\right)\right]$$
$$+ \left[\frac{PL}{4EI} \times \frac{L}{2} \times \left(\frac{L}{4}\right)\right] + \left[\frac{1}{2} \times \frac{L}{2} \times \frac{PL}{2EI} \times \left(\frac{2}{3} \times \frac{L}{2}\right)\right]$$
$$+ \left[\frac{1}{2} \times \frac{L}{4} \times \frac{-PL}{4EI} \times \left(\frac{L}{4} + \frac{2}{3} \times \frac{L}{4}\right)\right] \tag{H-5}$$
$$+ \left[\frac{M_C}{EI} \times \frac{L}{2} \times \left(\frac{L}{4}\right)\right]$$

Rearranging equation (H-5), equation (H-5) becomes:

$$0 = -160 R_C L + 92PL + 192 M_C \tag{H-6}$$

From equation (H-4) and (H-6), redundants could be determined and written as:

$$R_C = \frac{11P}{16} \downarrow \qquad \text{and} \qquad R_A = \frac{11P}{16} \uparrow$$

$$M_C = \frac{3PL}{32} \circlearrowleft \qquad \text{and} \qquad M_A = \frac{3PL}{32} \circlearrowright$$

Once redundants were known, theorem 2 was applied again to find the displacement of point D with respect to the tangent extended from a point A:

$$t_{D/A} = \left[\frac{-3R_C L}{4EI} \times \frac{L}{4} \times \left(\frac{L}{8}\right)\right] + \left[\frac{1}{2} \times \frac{L}{4} \times \frac{-R_C L}{4EI} \times \left(\frac{2}{3} \times \frac{L}{4}\right)\right]$$

$$+ \left[\frac{PL}{2EI} \times \frac{L}{4} \times \left(\frac{L}{8}\right)\right] + \left[\frac{1}{2} \times \frac{L}{4} \times \frac{PL}{4EI} \times \left(\frac{2}{3} \times \frac{L}{4}\right)\right] \tag{H-7}$$

$$+ \left[\frac{1}{2} \times \frac{L}{4} \times \frac{-PL}{4EI} \times \left(\frac{2}{3} \times \frac{L}{4}\right)\right] + \left[\frac{M_C}{EI} \times \frac{L}{4} \times \left(\frac{L}{8}\right)\right]$$

Substituting R_C and M_C into equation (H-7); consequently, equation (H-7) becomes:

$$t_{D/A} = \frac{-61PL^3}{15360EI} \tag{H-8}$$

Negative sign indicated that point D on the elastic curve was below the tangent extended from point A. Then, rearranging equation (H-8), the stiffness, obtained from the applied load and the deflection at the location of the applied load, can be written as:

$$k = \frac{P}{t_{D/A}} = \frac{15360EI}{61L^3} \tag{H-9}$$