PREDICTION OF BUCKLING OF RHS COLUMNS USING FINITE ELEMENT ANALYSIS METHOD

by

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Dissertation submitted in partial fulfillment of
the requirements for the
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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
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In partial fulfilment of the requirement for the Bachelor of Engineering (Hons)
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Approved by,

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TRONOH, PERAK

January 2021

CERTIFICATION OF ORIGINALITY

This is to certify that I am liable for the work submitted in this project that, except were stated in the references and acknowledgments, the original work is my own, and that the original work found herein has not been taken out or shared out by unspecified sources or individuals.

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SAILENDRA A/L SIVAN, 24487

Date : 23-03-21

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ABSTRACT

In a structural system, column is a vertical structural member whose longitudinal dimension exceeds the lateral dimension of the section. The column failure modes include short column compression failure and long column buckling failure. In the overall design process mechanics, column buckling is a special and inquisitive emphasis with which the loss is not attributed to the material strength. As in the factory plants and process facilities, it is a common practice to use RHS Columns as structural elements, however the behavioral changes on buckling of RHS Columns as consequence of combination of variations parameters such the boundary conditions, wall thickness, columns lengths and especially on structural openings in the cut-out configuration, shape, size, location and numbers are not well understood. Thus, in this project, parametric study was conducted to predict the buckling of RHS Columns with varying parameters using Finite Elements Analysis and the finding are compared results obtained using the proposed approach in Eurocode 3. In this paper finite element analysis is done by using general purpose ABAQUS software to investigate the behavior of rectangular hollow steel column with openings. In the numerical studies, steel grade S275, S355and S460 of rectangular hollow steel columns with sharp corners were used in the constriction of the specimens which have dimensions of cross section (100×60)mm, (120×80)mm, (300×200)mm and (450×250)mm with different type of column length 4,6 and 8m height were modelled for all four different boundary conditions. To analyze the influence of the slenderness ratio, size and position of openings on the buckling potential and ultimate strength of the RHS columns, numerical analysis considering three different orientations of the opening dimension were studied, representing 50×50mm, 60×60mm and 70×70mm. A very strong association was found between numerical simulations and theoretical studies based on Eurocode 3.

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CHAPTER 1
INTRODUCTION

1.1 CHAPTER OVERVIEW

In this chapter, the overview study of the buckling phenomena and a series of previous experimental studies have been carried out into the behavior under axial compression of structural steel RHS members were discussed. Furthermore, this chapter is also discussing the problem statement , objective , scope of studies and research significance.

1.2 BACKGROUND

The square and rectangular hollow section of structural steel (SHS and RHS) elements are widely used as structural components in the construction sector due to their aesthetic appearance and exquisite structural qualities, particularly under predominantly compressive loading. Product from SHS and RHS are usually produced by hot-rolling processes , cold-forming or welded four plates into a box shape. With the increasing use in the construction of high-strength steel SHS and RHS, the development of satisfactory rules to ensure their safe and efficient specification is eessential. **Figure 1.1** shows the steel column failure under compression which lead to column buckling. In this article, the prediction of the buckling of RHS columns using Finite Element Analysis is studied. A series of previous experimental studies have been carried out into the behavior under axial compression of structural steel RHS members. Meng, X., and Gardner, L. (2020) performed laboratory experiments on hot-rolled SHS and RHS columns, and buckling experiments on cold formed SHS and RHS compression members were performed and recorded by Gardner, L., Fieber, A., & Macorini, L. (2019),Ellobody, E. (2007) and Ahmed, S., & Ashraf,M. (2017).Several studies have also been conducted by the Committee for International Development and Education on the Construction of Tubular Structures (CIDECT) to investigate the column buckling behaviour of members of SHS and RHS, including those by

Gardner, L., & Nethercot, D. A. (2004),Gonçalves, R., & Camotim, D. (2004),Hradil, P., & Talja, A. (2014), and Huang, Z., Li, D., Uy, B., Thai, H.-T., & Hou, C. (2019), in which a significant number of hot-rolled and cold-foot buckling experiments are conducted. Extensive laboratory testing has also been carried out, for example, by Gardner, L., & Young, B. (2019),Ranawaka, T., & Mahendran, M. (2010) and Wang, Y., Wang, Z., Yin, F., Yang, L., Shi, Y., & Yin, J. (2016) on welded box section columns, although these sections are outside the range of the current study. This parametric study uses computer simulations to confirm the validity of Finite Elements Analysis Methods of Buckling RHS Columns using the theoretical approach specified in Eurocode 3 by modifying the column cross sections, wall thickness, opening size, numbers, and opening positions of RHS Columns and then validating the results of Finite Elements Analysis Methods of Buckling RHS Columns. Finite-element (FE) designs are then developed, validated, and used to generate additional numerical data. Subsequently, the column structure rules in EC3 are evaluated using the FE data and reveal some limitations. Finally, the existing EC3 design method and the stimulus outcome will be examined for reliability.

Figure 1.1 : Steel Column Failure under compression

1.3 PROBLEM STATEMENT

In the Factory plants and process facilities, it is a common practice to use RHS Columns as structural elements, however the behavioral changes on Buckling of RHS Columns because of variations parameters such the boundary conditions, wall thickness, columns lengths and structural openings in the cut-out configuration, shape, size, location and number, are not well understood. Thus, in this study, parametric study will be conducted to predict the Buckling of RHS Columns with vary parameters (especially different size of opening in the column) using Finite Elements Analysis and compared the result with the proposed approach in Eurocode 3.

In addition, physical studies are relatively time-consuming and the results of geometric imperfections and residual column pressures are difficult to test experimentally most of the time. Finite Element Analysis (FEA) therefore plays an important role in engineering practise, as it is relatively inexpensive and time-efficient especially when cross-sectional geometric parametric research is involved. The aim of this analysis is to examine the RHS steel column's buckling behaviour and failure modes under axial loading analytically.

1.4 OBJECTIVE

The main objectives of this project and study are listed below:

i. To carry out parametric study using computer simulations by varying the column cross sections, wall thickness, opening size, numbers, and opening locations and determine their effects on buckling of RHS Columns.

ii. To validate the results of Finite Elements Analysis Method of buckling of RHS Columns using theoretical approach recommended in Eurocode 3.

1.5 SCOPE OF STUDY

In this study, the scope was mainly focused on the hot rolled steel with variations parameters such as the boundary conditions, wall thickness, columns lengths and structural openings in the cut-out configuration, shape, size, location and number. Thus, to evaluate the parameters a parametric study will be conducted to predict the Buckling of RHS Columns using Finite Elements Analysis by ABAQUS software. Then, the obtained result will be compared with the recommended approach in Eurocode 3.

1.6 REASERCH SIGNIFICANCE

The findings of this study will relate the percentage error between theoretical and simulation studies in the failure of hot-rolled RHS column under compression with variations parameters such the boundary conditions, wall thickness, columns lengths and structural openings in the cut-out configuration, shape, size, location and number. By conducting this analysis, the design engineer can predict the strength and the failure of the column in according to avoid column failure majorly in industrial area. To obtain the result a parametric study was conducted using Finite Element Analysis (FEA) by using ABAQUS software. This method effective by doing computer simulation to predict the failure of column. Where physical studies are relatively time-consuming and the results of geometric imperfections and residual column pressures are difficult to test experimentally most of the time. Finite Element Analysis (FEA) therefore plays an important role in engineering practise, as it is relatively inexpensive and time-efficient especially when cross-sectional geometric parametric research. Thus, through this study in further this simulation result has to be take into account to calculate the buckling of the RHS column with studied parameters especially structural opening in the column.

1.7 CHAPTER SUMMARY

In this Chapter 1, the overview study of the buckling phenomena and a series of previous experimental studies have been carried out into the behavior under axial compression of structural steel RHS members were discussed. Furthermore, this chapter were also discussing the problem statement , objective , scope of studies and research significance. The next Chapter is discussed about the literature review of the study.

CHAPTER 2
LITERATURE REVIEW

2.1 CHAPTER OVERVIEW

In this chapter, literature review of the studies is carried out under general overview in steel column buckling. Then, this chapter also discussed the type of column failure under two different category failure which is local and overall buckling. Moreover, the fundamental of finite element model and its element type also explained in this chapter.

2.2 GENERAL OVERVIEW

The limited state design approach based on the probabilistic principle has now been increasingly developed and implemented by structure design requirements. It is well understood that limit states can describe the structural performance of a structure or structural members. There are two kinds of limit states, which are the ultimate limit states and the serviceability limit states, that should be included in architecture. For the former, adequate ultimate load carrying ability (strength and stability) should be designed for the structure. Therefore, the measurement of its ultimate load carrying capacity is an important step in the structural construction of the limit sate design process. Unfortunately, this form of final load is not easy to get.

In general, the ultimate load bearing capability of the column or frameworks of hot-formed compression steel depends on the stiffness situation involved in elastic plasticity and broad deformation. There is no closed-form solution and there is a need for numerical methods. The buckling of real hot-formed column steel is found to consist of three buckling modes, which are local buckling, specific column buckling, and dynamic local-overall buckling.

On the behaviour of column buckling and ultimate strength of the complete buckled column, a significant number of theoretical research and construction approaches have been published (Kwon, Y. B., & Seo, E. G. 2013 and Batista, E. d. M. 2009). In the previous hot-rolled column design, the average buckling of the column was typically separately evaluated. The relationship between local buckling and overall column buckling is overlooked in all these treatments, and some problems are therefore developed, such as in the construction of practical hot-rolled steel column, when the design load of the column is much less than the permissible load of the overall column buckling, the hot-rolled column portion is always determined by the allowable column ratio; it is not rational and certain resources are lost.

2.3 TYPE OF RHS COLUMN FAILURE

Kinds of buckling are available: local buckling and overall buckling. As the small steel elements are strained in their planes, local buckling occurs (Zhang, L., & Tong, G.-S. 2011). The failure mode can be avoided with this in mind, and to properly use the steel strength until the steel hits its yield stress. **Figure 2.1** shows the effect of buckling is important to its strength in the case of slender column.

In the case of long or slender columns, general buckling usually occurs. The weakness is expressed by sideways bending where the global equilibrium is more fragile for the individual columns, when the columns appear to collapse due to flexural buckling (Toneff, J. D., Stiemer, S. F., & Osterreder, P. 1987). This deficiency happens when the state of a stable balance is no longer possible in the system between the internal and external forces (Vieira, L., Gonçalves, R., & Camotim, D. 2018).The slenderness ratio affects the behavior of these columns, with the slenderness sometimes leading to the so-called second order effects.

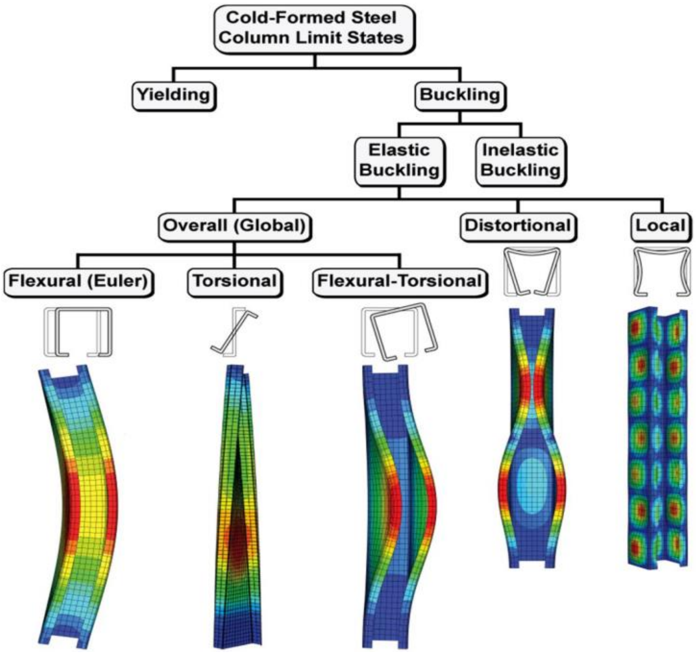


Figure 2.1: Type of steel column failure

(Zhang, L., & Tong, G.-S. 2011)

2.4 FINITE ELEMENT MODEL

FEM is a very effective method that solves a wide variety of problems in numerical terms. The basic idea is that a body or structure may be separated into "finite elements" called smaller elements with finite dimensions. The original body or form is then known as an assemblage of these elements, called "Nodes" or "Nodal Points," attached to a finite number of joints. To obtain the properties of the wopening body, the properties of the elements are formulated and mixed. The equilibrium equation for the entire structure or body is then derived by integrating each element's equilibrium equation, so that continuity is maintained at each node. The requisite boundary conditions are then applied, and the equilibrium equation is solved to achieve the required component, depending on the application, such as stress, strain, temperature distribution or velocity flow. Thus, instead of solving the problem in one operation for the entire structure or entity, attention is primarily dedicated to formulating the properties of the constituent elements in the process. In all fields, a standard technique is followed to integrate the components, solve the equations and test the necessary variables. In multiple instances, the modular structure of the procedure is therefore well used. **Table 1** shows the comparison between Finite Element and Finite Strip Methods according to (Mohammed, A., & Afshan, S. ,2019).

The oldest paper on the non-liner finite elements seems to be one the aircraft sector draws substantially from (Zhao, X.-L., Hancock, G. J., & Trahair, N. S. 1995). Most of the other early work on geometric non-linearity was mainly related to the problem of linear buckling and was carried out by others. Finite element analysis (FEA) was conducted in conjunction with the experimental work using a commercial finite element bundle, ABAQUS, to further study the behavior of the composite RHS column structures. Due to costly experimental projects, the use of numerical models is widely recognized as a substitute. To predict the structural reaction and simulations using the ABAQUS software kit, some researchers have followed the finite element analysis method to model the RHS columns, since it was found to be the most favored structural modelling method.

Table 1 : Comparison between Finite Element and Finite Strip Method

(Mohammed, A., & Afshan, S. ,2019)

Category	**Finite Element**	**Finite Strip**
Applicability	Applicable to any geometry, state of boundaries and variety of substance. Extremely polyvalent.	In static analysis, it is most used for strictures of two simply supported ends opposite and with or without intermediate elastic supports. It is used for systems with both boundary conditions and distinct supports in dynamic analysis.
Number of equations	Typically, huge numbers of relatively large bandwidth equation and matrix. Due to constraints of computational resources, it can be very costly and often difficult to figure out solution.	Currently massive numbers with a relatively large bandwidth and matrix equation. It can be very expensive and often impossible to work out a solution due to computing resource limitations.
Input data	Huge numbers of input data and errors are easier to produce. Automatic mesh and load generation schemes are required.	Due to the minimal number of mesh lines involved due to the decrease in dimensional processing, there is a very small volume of input data.

Table 1 (Continued)

Output data	Huge output volumes. Both nodal displacement and element stresses are printed as a norm. Even certain lower order elements will not generate right stresses at the nodes and averaging stress or consequence interpolation.	Just those positions where displacement and stresses are required, and the performance accordingly can be easily defined.

2.4.1 ELEMENT TYPE

When trying to collect accurate data, the correct choice of element form and mesh is critical. When modelling the steel tube, most researchers choose various types of element, although few choose the use of only one type of element to model both steel tube. To model the hollow section, non-linear analysis of numerical models carried out by Ellobody and Young (2006) on SHS and RHS columns was performed by selecting element forms of 4-noded double shell components with reduced integration, S4R to model the steel tube element. Another research undertaken by Ellobody et al. (2006), however, witnessed a stable element form of S5R chosen to reflect both the steel tube . In the analysis of the axially loaded RHS columns, the element form was found to be more effective, according to this report. Notably, this was determined after several different kinds of elements were attempted to mimic the behavior of the RHS columns. In studies by Hu et al. (2003) and Johansson and Gylltoft (2002), a three-dimensional FE model based on a solid element form was developed by the implementation of the same methodology.

2.5 SUMMARY OF LITERATURE REVIEW

Table 2 shows the summary of literature review, which discuss the overview of the research.

Table 2: Summary of Research Gap

No	Type of Column	Effect On	Parameters	Research Gap	Reference
1	SHS (Square hollow section)	Grade	S460,S770	Opening of columns do not consider Did not use computer simulation	Xin Ming and Leroy Gardner,2020
		Dimension	100×100×4 & 120×120×6.3		
		Boundary Condition	P-P		
		Method	Experiment + EC3		
2	SHS (Square hollow section)	Grade	S460,S690	Did not consider the other 3 type of boundary conditions Opening of columns do not consider	Jie Wang,PhD. and Leroy Gardner,2017
		Dimension	50×50×5 ,70×70×6.3 ,100×100×5 & 50×50×5, 100×100×5.6		
		Boundary Condition	P-P		
		Method	Experiment + FEA +EC3		

Table (Continuous)

3	RHS (rectangular hollow section)	Grade	S350,S410	Did not consider the other 3 type of boundary conditions Opening of columns do not consider Did not use computer simulation	L. Gardner , D.A. Nethercot,2003
		Dimension	60×40×4 ,100×50×(2,3,4,6) & 120×80×(3,6) & 150×100×4		
		Boundary Condition	P-P		
		Method	Experiment +EC3		
4	SHS , RHS (Square hollow section and rectangular hollow section)	Grade	S460,S410	Did not consider the other 2 type of boundary conditions Opening of columns do not consider	American Journal of Civil Engineering.Vol. 2, No. 3, 2014, pp. 102-108.
		Dimension	60×60×3.6 & 90×40×3.6		
		Boundary Condition	P-P, F-Free		
		Method	FEA + EC3		
5	SHS , RHS (Square hollow section and rectangular hollow section)	Grade	S350	Focus on shorter column less than 2m Opening of columns do not consider	Shameem Ahmed, Mahmud Ashraf,2017
		Dimension	100×60×3.6 & 120×80×4		
		Boundary Condition	P-P,F-F and F-P		
		Method	Experiment + FEA		

2.5.1 CRITICAL LITERATURE REVIEW

In this part, the summary of research gap is presented in **Table 2**. Firstly, the first research gap found in this study was opening of columns do not considered and the computer simulation does not consider by Xin Ming,(2020). Secondly, the limited boundary conditions are tested especially pinned-pinned support by Wang, Leroy,(2017).Thirdly, shorter span column was tested by Ahmed and Ashraf,(2017).According to American Journal of Civil Engineering Vol. 2, only two type of boundary conditions is tested and opening of columns do not considered.

2.6 CHAPTER SUMMARY

In this Chapter 2, literature review of the studies is carried out under general overview in steel column buckling. Then, this chapter also discussed the type of column failure under two different category failure which is local and overall buckling. Moreover, the fundamental of finite element model and its element type also explained in this chapter. Furthermore, in next chapter methodology of the study is discussed.

CHAPTER 3

METHODOLOGY

3.1 CHAPTER OVERVIEW

In this chapter, the results of critical load and failure modes obtained by finite element for rectangular hollow cross-section were obtained in this analysis. The channel sections are compared with the underlying theory that Eurocode 3 recommends. In the other hand, **Figure 3.1 (a) (b)** shows the overall FYP flow and the Finite Element Analysis flow that must be passed on by the project to meet the project's targets.

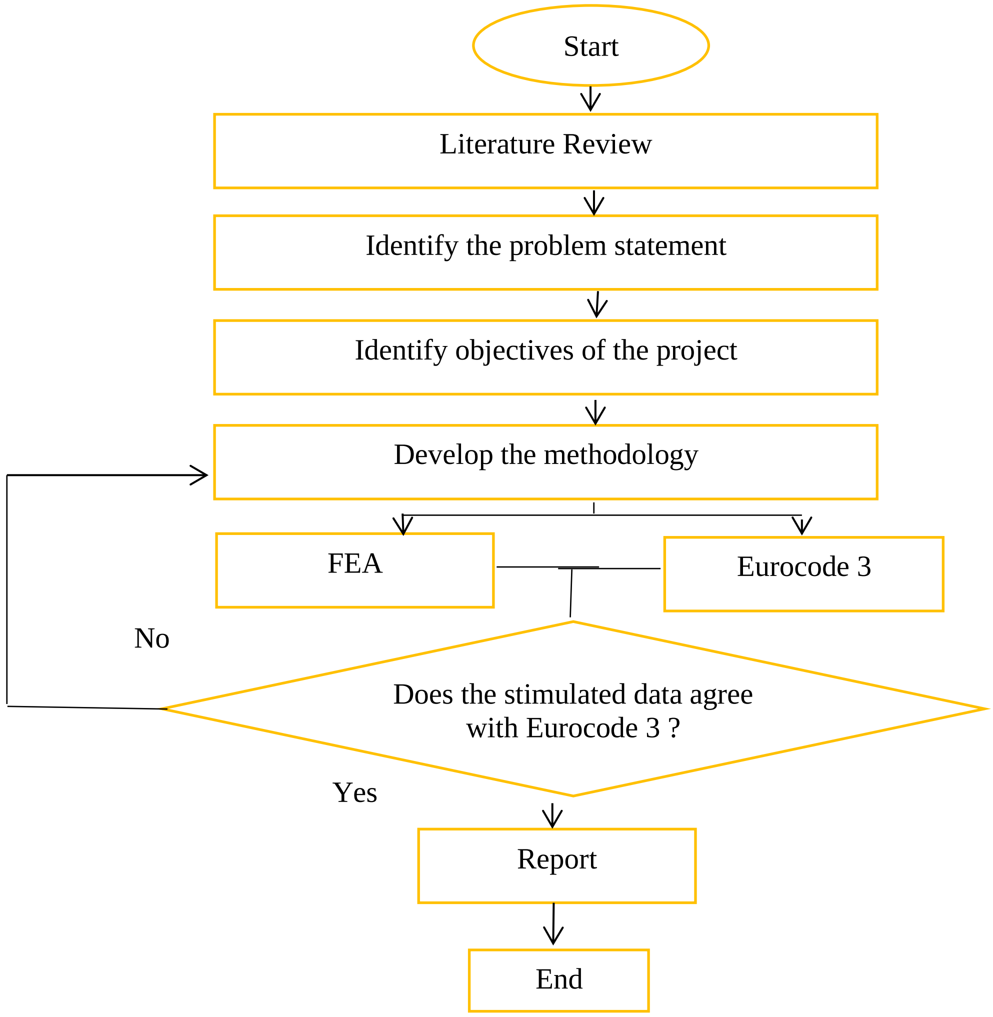


Figure 3.1 (a) : Overall FYP flow

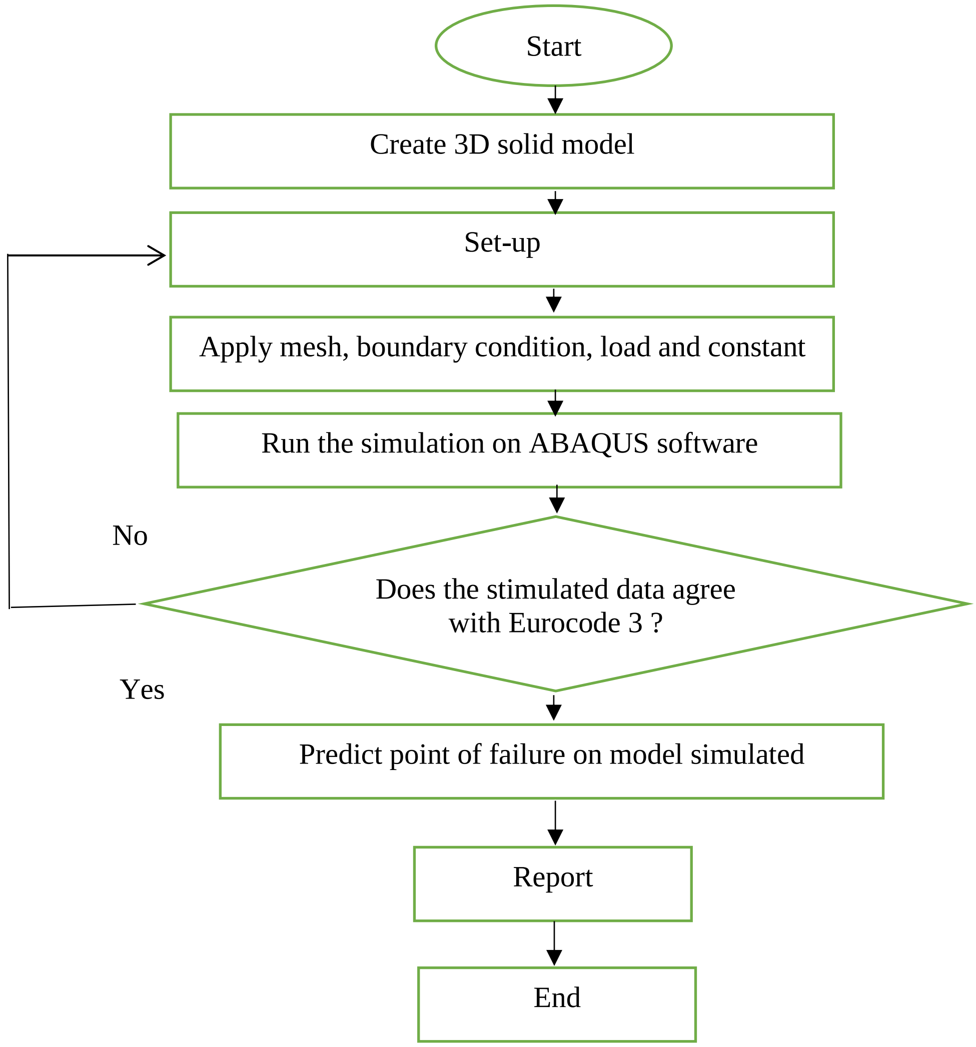


Figure 3.1 (b) : Finite Element Analysis (FEA) flow

3.2 EUROCODE 3 : BUCKLING

The construction of steel members in the buckling of the cross section is one of the most crucial characteristics. In deciding the design strength and stiffness of the members, the impact of local buckling is taken into account. Using definition of effective width and effective thickness of individual elements vulnerable to local buckling, the effect of cross-sectional properties is measured. The method of calculation depends, for instance, on stress levels and the distribution of various components. The code ENV 1993-1-3 specifies that yield stress is used in ultimate resistance measurements and only serviceability verification is used, actual stress values are used due to serviceability limit loading. Therefore, the basic formulas for the successful measurement of the width of the flat plane element without compression stiffeners are presented in general form, in compliance with the specific alternative ENV code rules:

$$\rho = 1, when\ \lambda_p \leq 0.673 \quad (3.1)$$

$$\rho = \frac{\lambda_p - 0.22}{\lambda_p{}^2}\ , when\ \lambda_p > 0.673 \quad (3.2)$$

$$\lambda_p = \sqrt{\sigma_c/\sigma_{el}} = 1.052\left(\frac{b\rho}{t}\right)\sqrt{\sigma_c/E/k_\sigma} \quad (3.3)$$

$$\sigma_{el} = k_\sigma \pi^2 E/12(1-v^2)/{}^{b\rho}/_{t}{}^{2} \quad (3.4)$$

Where is the element's width reduction factor, λp relative slenderness, b_p width, σ_c maximal compressive tension, and k buckling factor. The model stress (xfy) for a compressed member is generally based on total buckling (flexural or flexural-torsional). In some circumstances, σc will have the value fy in compression or bending. Obviously, the secure simplification σ_c = fy can be used at any time, and it is also advised to prevent iteration. For internal and external compression components, the reduction factor ρ is calculated according to the table.

3.3 LOCAL RESISTANCE OF CROSS-SECTION

The compression resistance N_{sd} must not be greater than the equivalent resistance of the cross-section N_{cRd}:

$$N_{sd} \leq N_{tRd} = f_y \frac{A_g}{\gamma_m}\ , when\ A_{eff} = A_g \quad (3.5)$$

$$N_{sd} \leq N_{cRd} = f_y \frac{A_g}{\gamma_{m1}}\ , when\ A_{eff} < A_g \quad (3.6)$$

By assuming a uniform compression stress of f_y / γ_{m1} in the equation, A_{eff} is the effective region of the cross-section. In simultaneous compression and bending, the additional moment due to change e_n of the centroidal axis is called if the centroid of the effective cross-section does not coincide with the centroid of the gross section. However, according to a variety of sources, this effect is generally considered as negligible.

3.4 GLOBAL BUCKLING RESISTANCE OF MEMBERS

If the point of loading coincides with the centroid of the effective cross-section dependent on uniform compression, the member is subject to concentric compression. N_{sd} is the compression design value.

$$N_{sd} \leq N_{bRd} = xA_{eff}\ f_y/\gamma_{m1} \tag{3.7}$$

Where the effective areas of the cross-section A_{eff} is conservatively based on uniform compressive stress equal to f_y / γ_{m1} according to ENV 1993-1-3. The x factor is the required buckling resistance reduction factor value:

$$X = \min(xy, xz, xt, xtf) \tag{3.8}$$

Where the subscripts y, z, T, and TF denote varying buckling forms, such as flexural buckling of the member about the related y and z axes, and torsional-flexural buckling. Factor x is calculated as follows according to ENV 1993-1-3:

$$X = 1, \text{when } \lambda \leq 0.2 \tag{3.9}$$

$$X = \frac{1}{\left(\varphi + \sqrt{(\varphi^2 - \lambda^2)}\right)}, when\ \lambda > 0.2 \tag{3.10}$$

$$\lambda = \sqrt{f_y/\sigma_{cr}} \tag{3.11}$$

$$\varphi = 0.5(1 + \alpha(\lambda - 0.2) + \lambda^2) \tag{3.12}$$

Depending on the required buckling curve and λ in the relative slenderness for the relevant buckling mode, is an imperfection factor. The relationship between various buckling curves and the corresponding values of α is shown in **Figure 3.2**. Using ENV 1993-1-3, the buckling curve is obtained. The cross-section diagnostic models in Table 3.2 are very limited. The correct buckling curve, however, is obtained from the **Table 3** for any cross-section. In any mode, the critical buckling stress is determined in a traditional way using equations, e.g., from the ENV 1993-

1-3 code. Especially because the cross-sectional properties are calculated for cross-section, these equations for critical buckling stresses are more suitable for every day design.

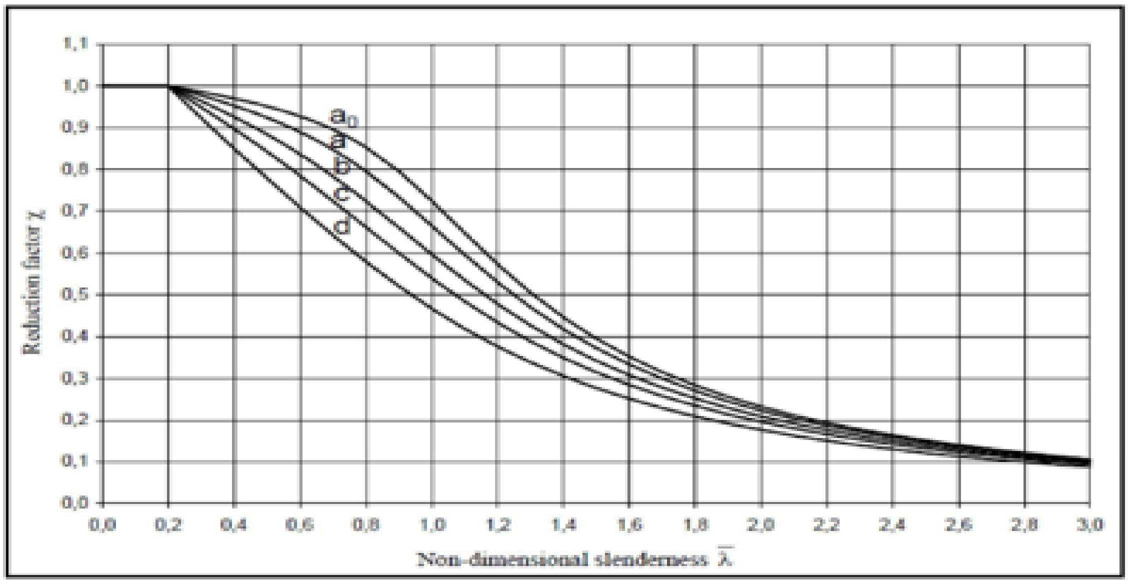


Figure 3.2: Different buckling curve corresponding imperfection factors

Table 3: Selection of buckling curve for a cross-section

Cross section		Limits		Buckling about axis	Buckling curve S 235 S 275 S 355 S 420	Buckling curve S 460
Rolled sections		$h/b > 1,2$	$t_f \leq 40$ mm	y – y z – z	a b	a_0 a_0
			$40 \text{ mm} < t_f \leq 100$	y – y z – z	b c	a a
		$h/b \leq 1,2$	$t_f \leq 100$ mm	y – y z – z	b c	a a
			$t_f > 100$ mm	y – y z – z	d d	c c
Welded I-sections		$t_f \leq 40$ mm		y – y z – z	b c	b c
		$t_f > 40$ mm		y – y z – z	c d	c d
Hollow sections		hot finished		any	a	a_0
		cold formed		any	c	c
Welded box sections		generally (except as below)		any	b	b
		thick welds: $a > 0,5t_f$ $b/t_f < 30$ $h/t_w < 30$		any	c	c
U-, T- and solid sections				any	c	c
L-sections				any	b	b

3.5 DEVELOPMENT OF FINITE ELEMENT METHOD

The ABAQUS finite element non-linear analysis software is used to model the rectangular hollow section column with different parameters for critical loads, axial shortenings and failure modes. To achieve the ultimate load and failure modes of the column models, a non-linear analysis was conducted by integrating both geometric and material non-linearities. The calculated cross-section lengths, material properties, and original geometric imperfections from the test are modeled in the finite element model (FEM). Along with base metal thickness, the model was based on the contour's measurements of the cross-sections. However, the model did not include the residual stresses and the rounded corners of the channel segment. This is due to the limited values of the estimated membrane and residual stresses that were less than 3 percent and 7 percent of the evidence stress. The method of finite elements is a computational method for solving complex systems that can be difficult to solve with closed solutions. As a finite number of elements, assembled in a structural system (discretee a continuous system), every solid or arrangement can be idealzed. As the initial spectrum is separated into an analogous patchwork with the use of two and three-dimensional structural components, the analysis itself is an approximation.

As part of the research methodology, the material properties of the spectrum are preserved by the elements. This technique is a versatile instrument that can be used to examine any of the two three-dimensional structural elements. The industrial multipurpose software kit ABAQUS is being used in current studies. It is possible to sum up the finite element process protocol in three stages. Structural idealzaction, or discretezaction, is the first step. The subdivision of the initial member into a member into a set of similar finite elements was idealzed. This phase is taken special consideration, for the finite elements constructed must simulate the conduct of the original continuum. Using a finer discretization scheme that leads to a denser mesh covering the problem geometry, stronger results are usually obtained.

In theory, the solution of the problem will converge to the exact solution (exactly within the expectations of the underlying classical theory) as the mesh size of properly formulated elements is successively decreased. It is also necessary to choose elements that are consistent in deformation with adjacent elements. If consistency was not reached, the components would distort each other individually, thus causing openings or overlaps within the model i.e., allowing a spectrum to break the compatibility condition). This would lead to a much more fluid idealzaction than the actual spectrum. In addition, large stress concentrations at the nodal points would evolve if compatibility were not reached. The accumulation of tension will make the problem's solution deviate much more from the positive resolution.

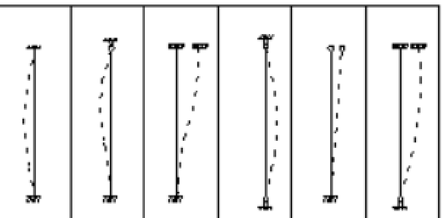
The second step in the finite element process is to determine the properties of the elements. This involves designing the stiffness matrix to form a force-displacement relationship for the original member for the given components. By comparing the forces applied to the nodes to the resultant deflection, the force-displacement relationship encapsulates the characteristics of the components. For obtaining correct findings from the study, this stage is essential. The following equation relates the force vector {F} to the displacement vector {d} using the stiffness matrix of the system {K} :[F] = [K] [d].

The actual structural analysis of the element assemblage is the third and final step of the finite element process. To evaluate the structure, three conditions must be met. Equilibrium, compatibility, and the relationship of force-displacement must all be satisfied. To satisfy the demands, two simple methods can be used. Those methods include the method of force and displacement method , which can be used to evaluate the components structurally. In any case, the ruling structure can be solved directly using any of a variety of effective solution algorithms, as long as the structural system or continuum is elastic. This is not the case in a nonlinear analysis and the equilibrium direction must also be traced in an iterative and gradual way.

3.6 BOUNDARY CONDITION

The FEM simulated the channel with columns of hollow box cross-sections compressed between ends. With the exception of the transitional degree of freedom in the axial direction at the top end of the column, the two fixed-ended, pinned-ended, pinned-free ended and fixed-free ended boundary conditions are modelled by limiting all the degrees of freedom of the nodes at both ends. **Table 4** shows the 'K' value for each type of boundary conditions. This is due to the load added at the column's top end. In either direction, the nodes other than the two ends are able to translate and rotate.

Table 4 : K value for each type of boundary condition

BUCKLING MODE						
THEORETICAL Ke	0.5	0.7	1.0	1.0	2.0	2.0
RECOMMENDED DESIGN Ke	0.65	0.8	1.2	1.0	2.1	2.4
END CONDITION	ROTATION FIXED, TRANSLATION FIXED ROTATION FREE, TRANSLATION FIXED ROTATION FIXED, TRANSLATION FREE ROTATION FREE, TRANSLATION FIXED					

3.7 METHOD OF LOADING

The method of loading used in the study of finite elements (FEA) is similar to that used in the calculation. For the study of the columns, the displacement control technique is used. By defining a displacement for the nodes at the top end of the grid, the ultimate axial load is applied to the column. The displacement is morally equivalent to the column bucking.

3.8 PROCESS OF MODELLING USING ABAQUS

- **Geometry**

The **Figure 3.3 and 3.4** define a cross-section to be analysed. Then, the material properties in which for the case of steel column the value was taken as E=210000MPa and for the steel poison ratio chosen 0.3.

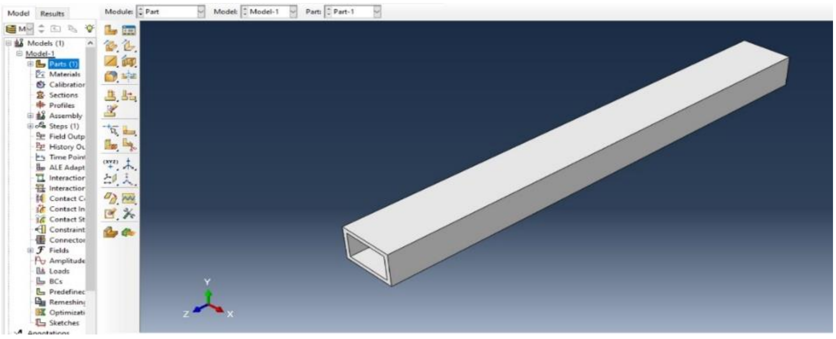


Figure 3.3: Geometry of column

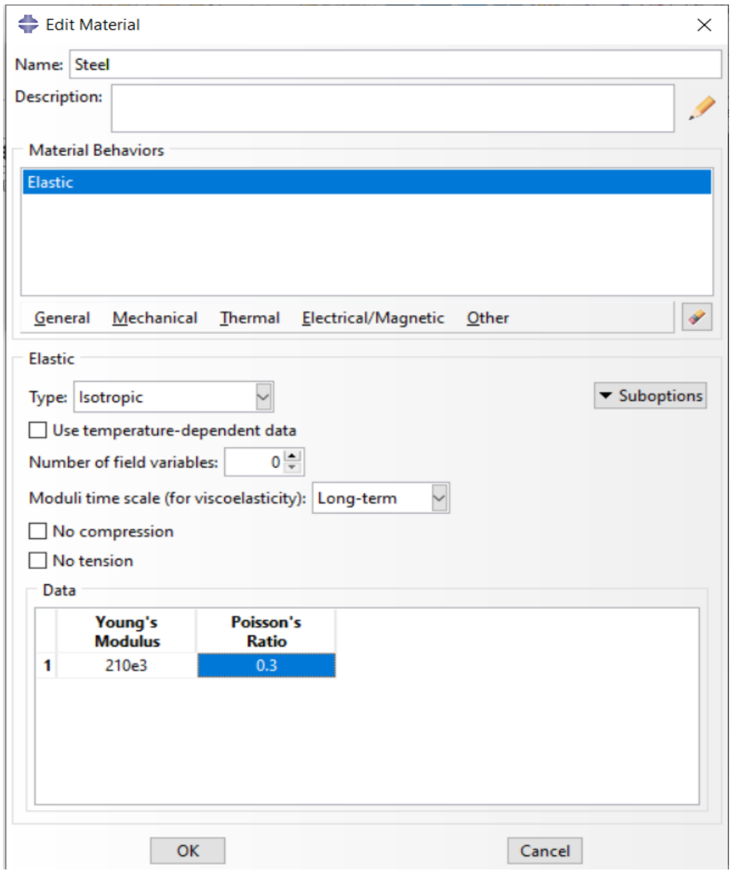


Figure 3.4: Material Properties

- **Meshing Apply Constraint and Loading**

After importing the column geometry into the ABAQUS Software, the column was meshed to the required fineness, with a preference for high speed for convenience. In addition, face meshing on the column was used to fine-tune the mesh for the simulation, resulting in a smoother mesh. In terms of the set parameters, the green surface in **Figure 3.5** above highlights the boxed column area. Furthermore, the light-green shade at both ends of the column is set to pre-set loading. This boundary conditions are set such that a column with both ends fixed is created and simulated.

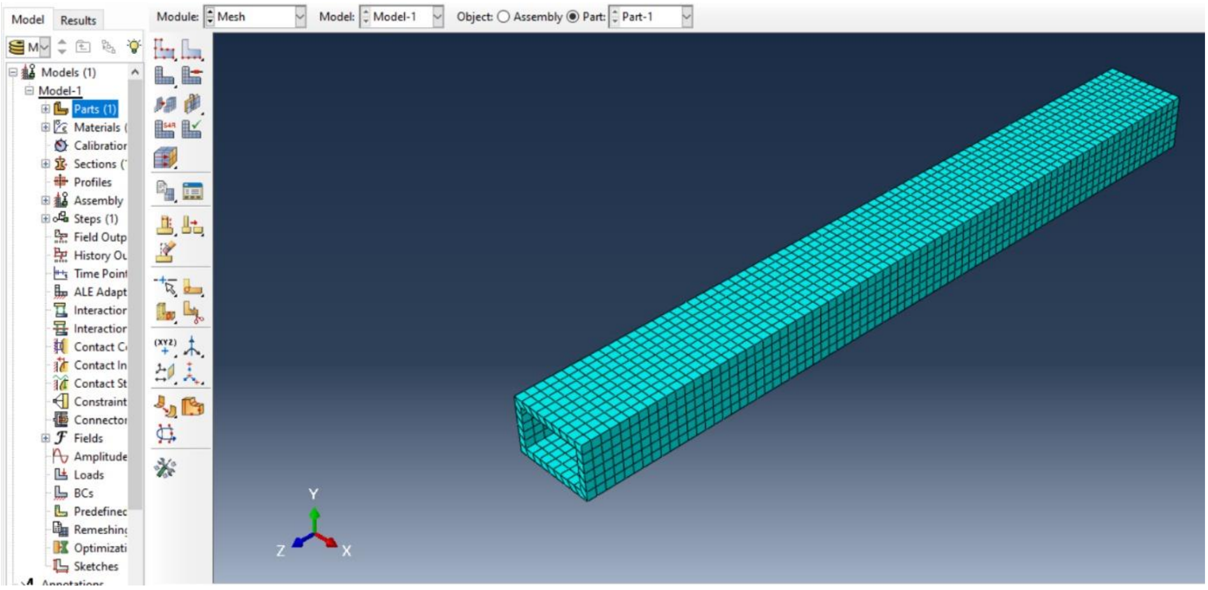


Figure 3.5:Meshing on column surface area

- **Processing and Solving**

Since this simulation includes linear buckling, the structural and buckling equations will be assembled and solved separately using the ABAQUS Software. The discrete mechanics are then combined at the same time until they achieve equilibrium. The simulation is programmed to search for and solve for six distinct mode forms. The method is replicated by following the steps below. **Figure 3.6** shows the result of simulation output.

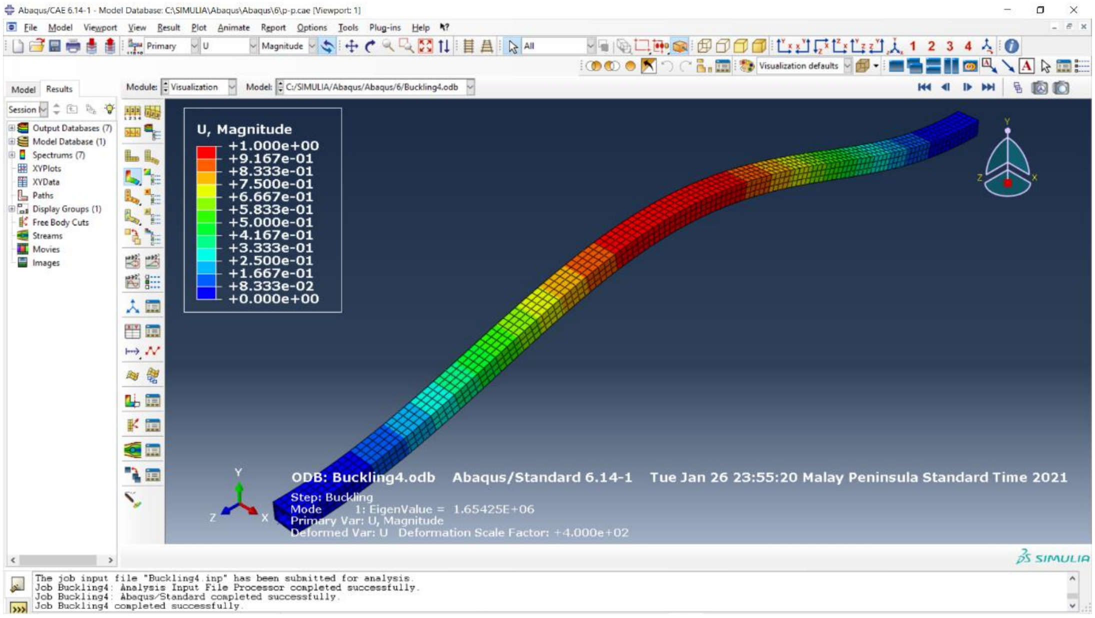


Figure 3.6: Result of FEA buckling column

3.9 GANTT CHART

The results of critical load and failure modes obtained by finite element for rectangular hollow cross-section were obtained in this analysis. The channel sections are compared with the underlying theory that Eurocode 3 recommends. The progress of this project and the weekly tasks already completed within 25 weeks of the first and second final year projects as seen in **Table 5**. The Gantt Chart shows the mission schedule and the stations that must be passed on by the project to meet the project's targets.

Table 5 :Gantt Chart (FYP I & II)

Description of Activities & Key Milestones	Week																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1. Completion of Problem Analysis																								
Preliminary research work																								
Collect and study of research papers																								
2. Completion of preliminary analysis.																								
Study the buckling behavior on RHS Column																								
Research on the structural failures and properties of RHS Column																								
Identify the possibly simulation, theoretical.																								
3. Completion of FEA Model																								
Study Modelling Techniques of FEA																								
Model Actual Prototype																								
4. Completion of Data Analysis																								
Validate FEA results with theoretical																								
Discussion of the data obtained																								
5. Completion of Report Documentation and Dissertation Submission																								
Report Documentation																								
Final presentation and dissertation submission																								

3.10 CHAPTER SUMMARY

In this chapter, the results of critical load and failure modes obtained by finite element for rectangular hollow cross-section were obtained in this analysis. The channel sections are compared with the underlying theory that Eurocode 3 recommends. In the other hand, the overall FYP flow and the Finite Element Analysis flow that must be passed on by the project to meet the project's targets. In the next chapter the results and discussion part were presented.

CHAPTER 4
RESULTS & DISCUSSION

4.1 CHAPTER OVERVIEW

The critical load that affects local and global buckling of columns has been measured using the finite element method for various models. The findings were validated using feature codes Euro-codes 3. The values were compared, and the results were displayed in the form of tables and charts, demonstrating how the critical load varied as some parameters were modified.

The author has divided this chapter into two parts, the first of which focuses on the results obtained in calculating critical buckling loads and comparing them to the simulation results obtained from finite element analysis. As a result, this analysis involves four different cross sections with three different column lengths, as well as four different boundary conditions: fixed-fixed, pinned-pinned, fixed-pinned, and fixed-free. In comparison, the analysis is put through its paces with three separate steel grades: S275, S355, and S460. ABAQUS software is used to develop the models. The simulation findings are compared to the theoretical results using the Euro-code 3 methodology. The second section applies finite element analysis to analyze the buckling behavior of RHS steel columns in the increasing number of openings in the column surface with three different opening sizes.

4.2 ULTIMATE BUCKLING LOAD OF RHS COLUMN

The RHS cross-section properties is calculated manually according to Euro-code 3 are presented in **Table 6**,where the table below shows the moment of inertia, area, modulus of elasticity, aspect ratio and the radius of gyration for all three different column length and column grade S275, S355 and S460.

Table 6: Cross-Section Properties of RHS Column

Profile	Depth	Width	Wall thickness	Second moment of area	Radius of gyration	Second moment of area	Radius of gyration	Area	Length								
	h	b	t	Ix	rx	Iy	ry	A	Leff	Fy	E	Ncr	λ	Ø	χ	Nb,rd	Aspect Ratio,t/B
	[mm]	[mm]	[mm]	[$\times10^6$ mm^4]	[mm]	[$\times10^6$ mm^4]	[mm]	[mm^2]	[mm]	[N/mm2]	[N/mm2]	kN				kN	
RHS 100 x 60/3.2	100	60	3.2	1.337	36.7	0.5989	24.6	983.04	4000	275	210000	77.6	1.87	2.42	0.253	68.39	0.05
RHS 100 x 60/6.3	100	60	6.3	2.3629	35.2	1.0244	23.3	1857.24	4000	275	210000	132.7	1.96	2.61	0.231	117.96	0.11
RHS 100 x 60/8	100	60	8	2.8268	34.4	1.2037	22.5	2304	4000	275	210000	155.9	2.02	2.72	0.220	139.19	0.13
RHS 120 x 80/4	120	80	4	3.0904	44.6	1.6364	32.5	1536	4000	275	210000	212.0	1.41	1.62	0.412	174.14	0.05
RHS 120 x 80/8	120	80	8	5.5207	42.7	2.8481	30.8	2944	4000	275	210000	368.9	1.48	1.73	0.380	307.98	0.10
RHS 120 x 80/10	120	80	10	6.52	41.8	3.32	29.9	3600	4000	275	210000	430.1	1.52	1.79	0.365	361.61	0.13
RHS 300 x 200/8	300	200	8	98.77	112.5	52.568	82.2	7744	4000	275	210000	6809.6	0.56	0.69	0.905	1926.88	0.04
RHS 300 x 200/10	300	200	10	120.72	111.6	63.92	81.3	9600	4000	275	210000	8280.1	0.56	0.70	0.903	2383.67	0.05
RHS 300 x 200/16	300	200	16	180.52	108.8	94.104	78.7	14976	4000	275	210000	12190.1	0.58	0.71	0.897	3694.05	0.08
RHS 450 x 250/8	450	250	8	304.38	166.3	122.54	105.7	10944	4000	275	210000	15873.7	0.44	0.62	0.943	2838.69	0.03
RHS 450 x 250/10	450	250	10	374.55	165.4	149.95	104.8	13600	4000	275	210000	19424.3	0.44	0.62	0.942	3524.11	0.04
RHS 450 x 250/16	450	250	16	571.64	162.5	225.06	102.2	21376	4000	275	210000	29153.9	0.45	0.63	0.939	5522.12	0.06

4.2.1 COMPARISON BETWEEN THEORETICAL AND NUMERICAL APPROACH ON ULTIMATE BUCKLING LOAD

In this part, RHS cross-section column with heights of 4,6 and 8m with three different thickness are simulated for each cross-section. Under four different conditions, the buckling load and its associated critical buckling values of the long column under consideration are measured. In this kind of long column, four different cross-section types are numerically measured using ABAQUS software for RHS structural steel section, and the analysis approach is Eigenvalue. The ultimate loads corresponding to aspect ratio of column and percentage differences between theoretical method and numerical method are presented in Figures below.

The **Figure 4.1** until **Figure 4.9** represents the theoretical (Pcr) versus simulation (Pcr) for RHS column corresponding to 4,6,8m column for all three type of steel grade such as S275,S355 and S460. The results show when the column length is constant, an increase in thickness of column, the average percentage different between theoretical and simulation for each type of boundary conditions is presented in **Table 6** to **Table 14**.

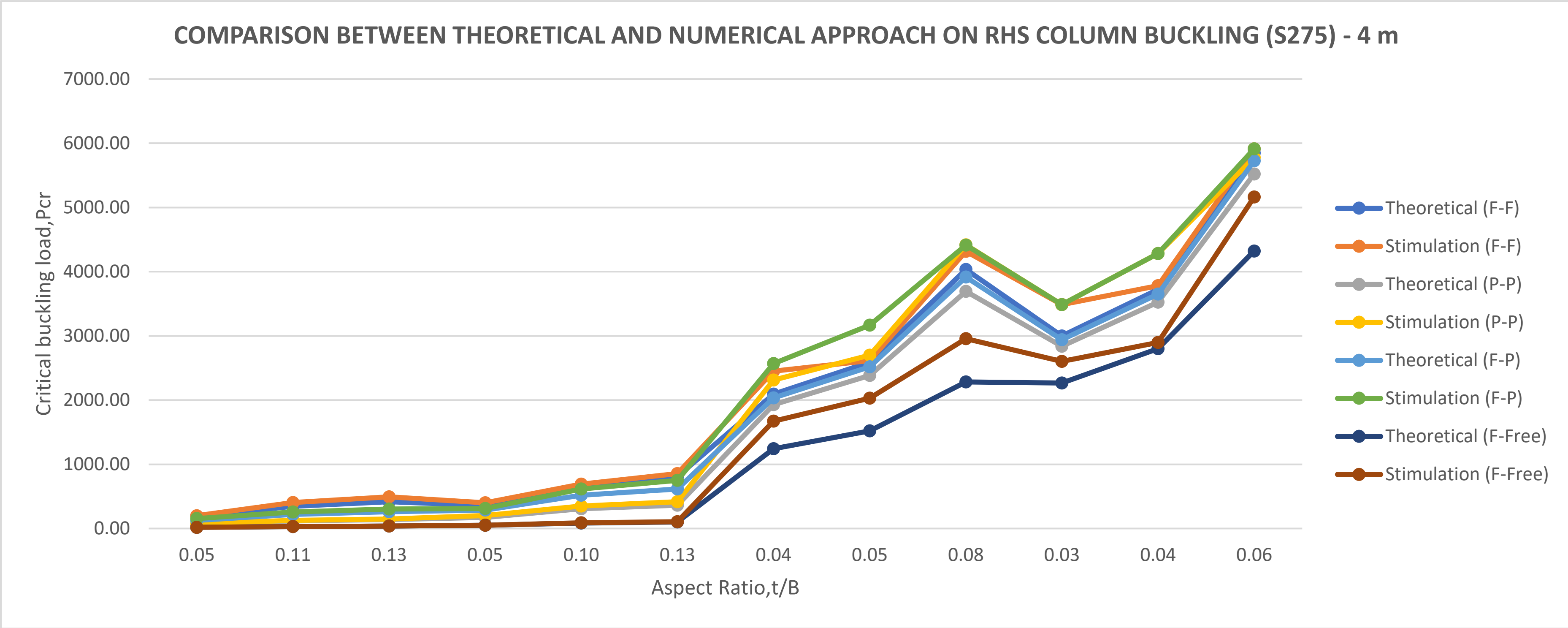


Figure 4.1: Theoretical (Pcr) VS Simulation (Pcr) for steel column grade S275 – 4m

Table 7: Percentage Different Between Theoretical VS Simulation for RHS Column Corresponding to steel grade S275 – 4m

Boundary Condition	Average Percentage Difference,%
F-F	3.99
P-P	6.60
F-P	7.96
F-Free	5.55

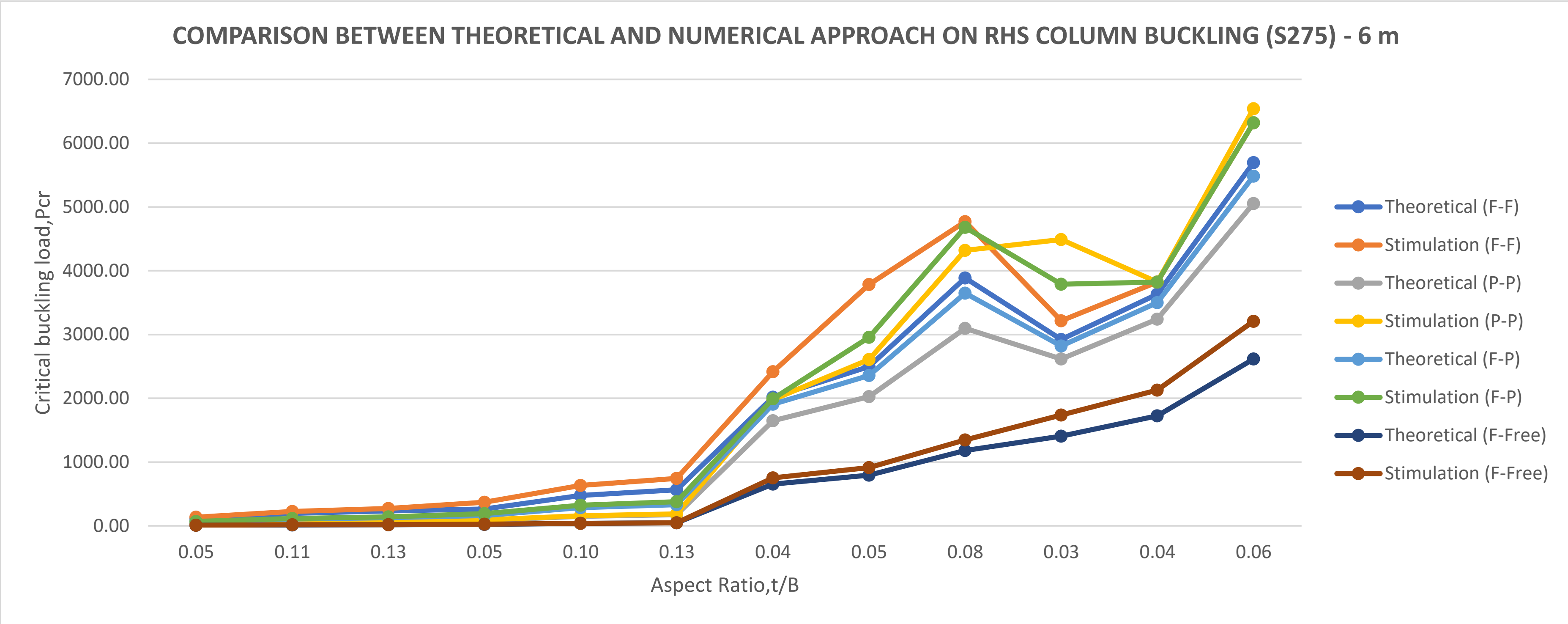


Figure 4.2: Theoretical (Pcr) VS Simulation (Pcr) for steel column grade S275 – 6m

Table 8: Percentage Different Between Theoretical VS Simulation for RHS Column Corresponding to steel grade S275 – 6m

Boundary Condition	Average Percentage Difference,%
F-F	9.93
P-P	8.60
F-P	7.16
F-Free	5.01

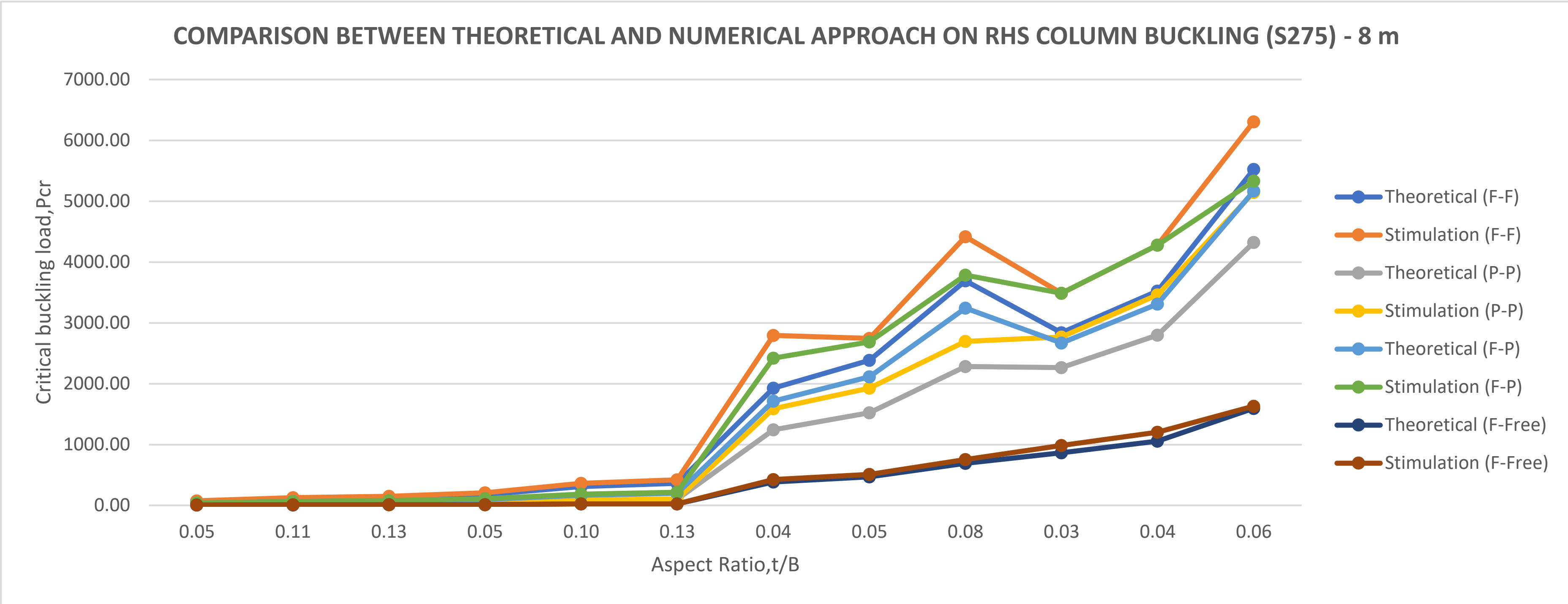


Figure 4.3: Theoretical (Pcr) VS Simulation (Pcr) for steel column grade S275 – 8m

Table 9: Percentage Different Between Theoretical VS Simulation for RHS Column Corresponding to steel grade S275 – 8m

Boundary Condition	Average Percentage Difference,%
F-F	8.02
P-P	5.90
F-P	6.98
F-Free	4.02

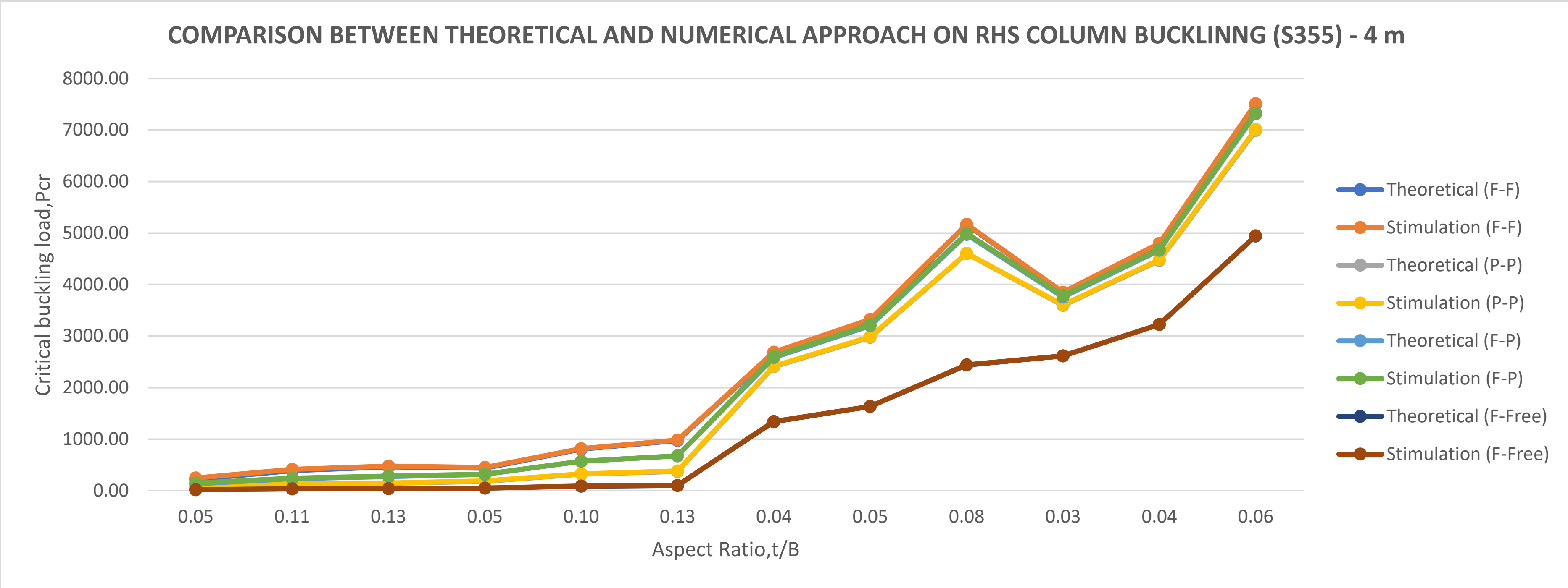


Figure 4.4: Theoretical (Pcr) VS Simulation (Pcr) for steel column grade S355 – 4m

Table 10: Percentage Different Between Theoretical VS Simulation for RHS Column Corresponding to steel grade S355 – 4m

Boundary Condition	Average Percentage Difference,%
F-F	1.29
P-P	1.43
F-P	1.13
F-Free	0.77

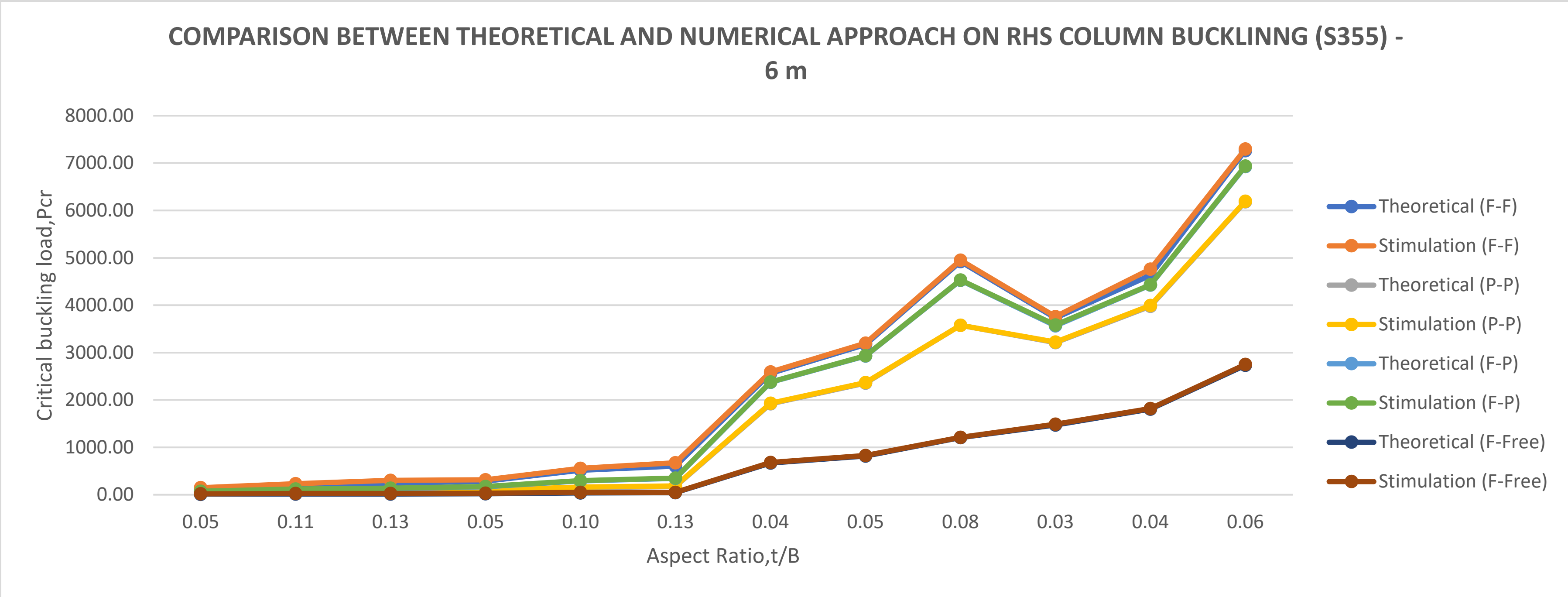


Figure 4.5: Theoretical (Pcr) VS Simulation (Pcr) for steel column grade S355 – 6m

Table 11: Percentage Different Between Theoretical VS Simulation for RHS Column Corresponding to steel grade S355 – 6m

Boundary Condition	Average Percentage Difference,%
F-F	3.97
P-P	5.06
F-P	1.78
F-Free	10.41

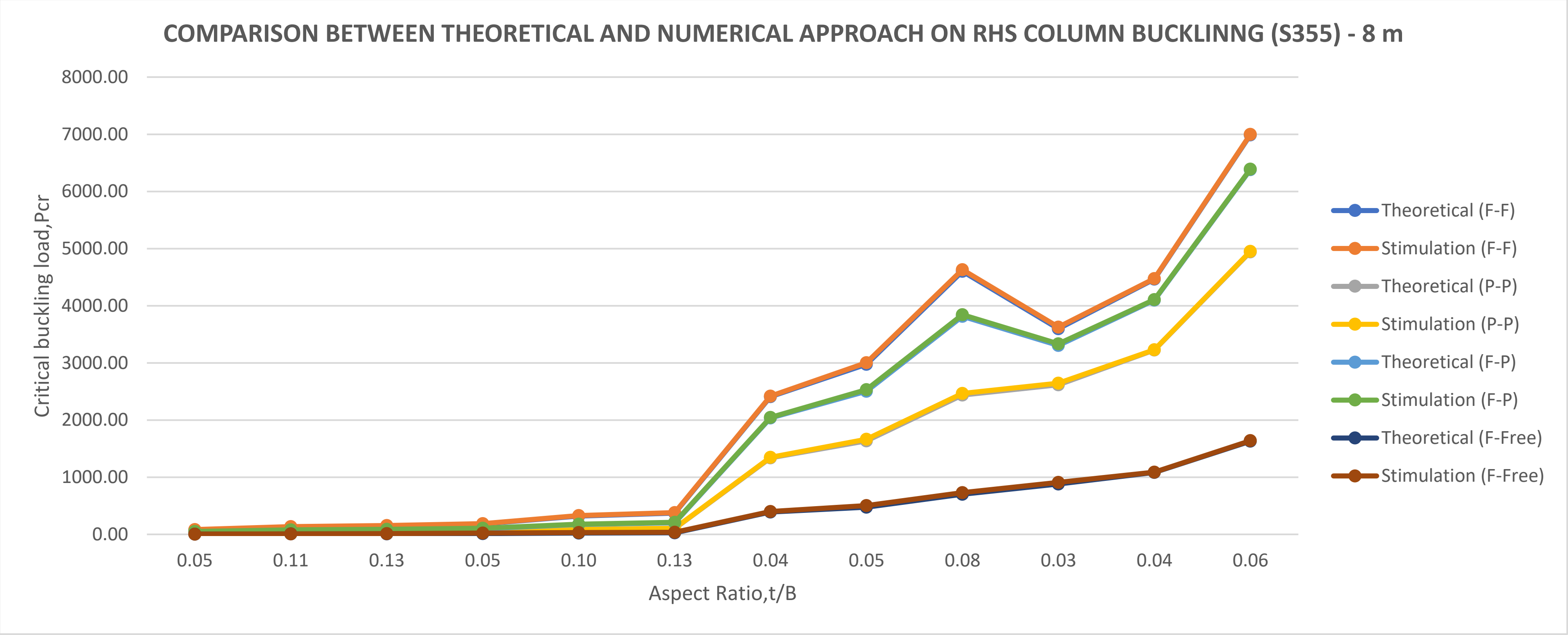


Figure 4.6: Theoretical (Pcr) VS Simulation (Pcr) for steel column grade S355 – 8m

Table 12: Percentage Different Between Theoretical VS Simulation for RHS Column Corresponding to steel grade S355 – 8m

Boundary Condition	Average Percentage Difference,%
F-F	2.19
P-P	6.50
F-P	3.84
F-Free	6.74

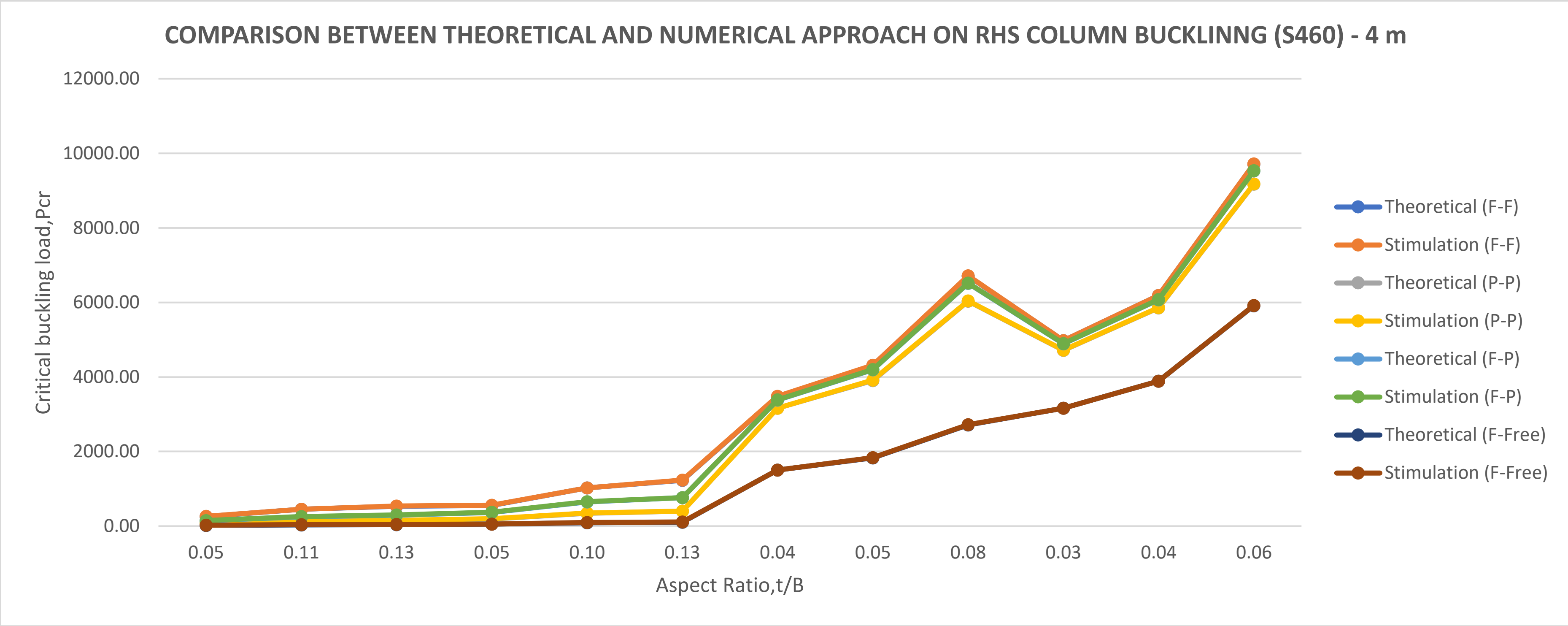


Figure 4.7: Theoretical (Pcr) VS Simulation (Pcr) for steel column grade S460 – 4m

Table 13: Percentage Different Between Theoretical VS Simulation for RHS Column Corresponding to steel grade S460 – 4m

Boundary Condition	Average Percentage Difference,%
F-F	0.29
P-P	0.94
F-P	0.50
F-Free	3.33

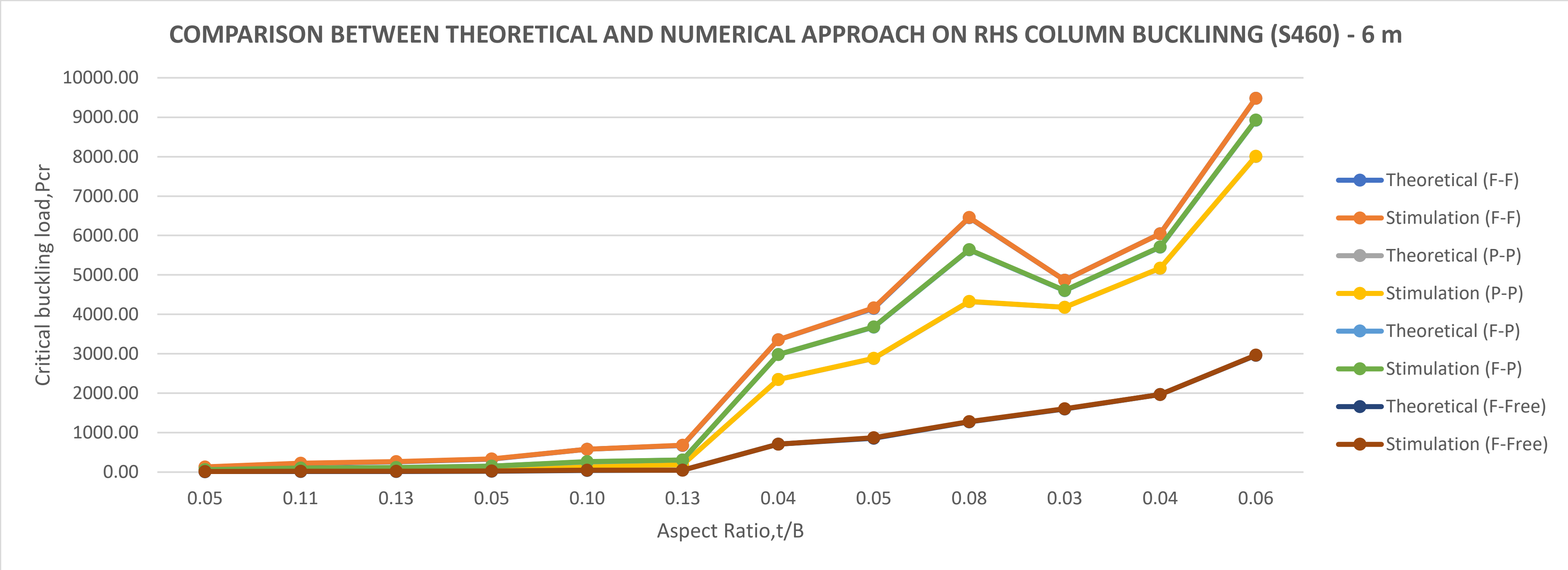


Figure 4.8: Theoretical (Pcr) VS Simulation (Pcr) for steel column grade S460 – 6m

Table 14: Percentage Different Between Theoretical VS Simulation for RHS Column Corresponding to steel grade S460 – 6m

Boundary Condition	Average Percentage Difference,%
F-F	0.55
P-P	1.99
F-P	1.21
F-Free	6.70

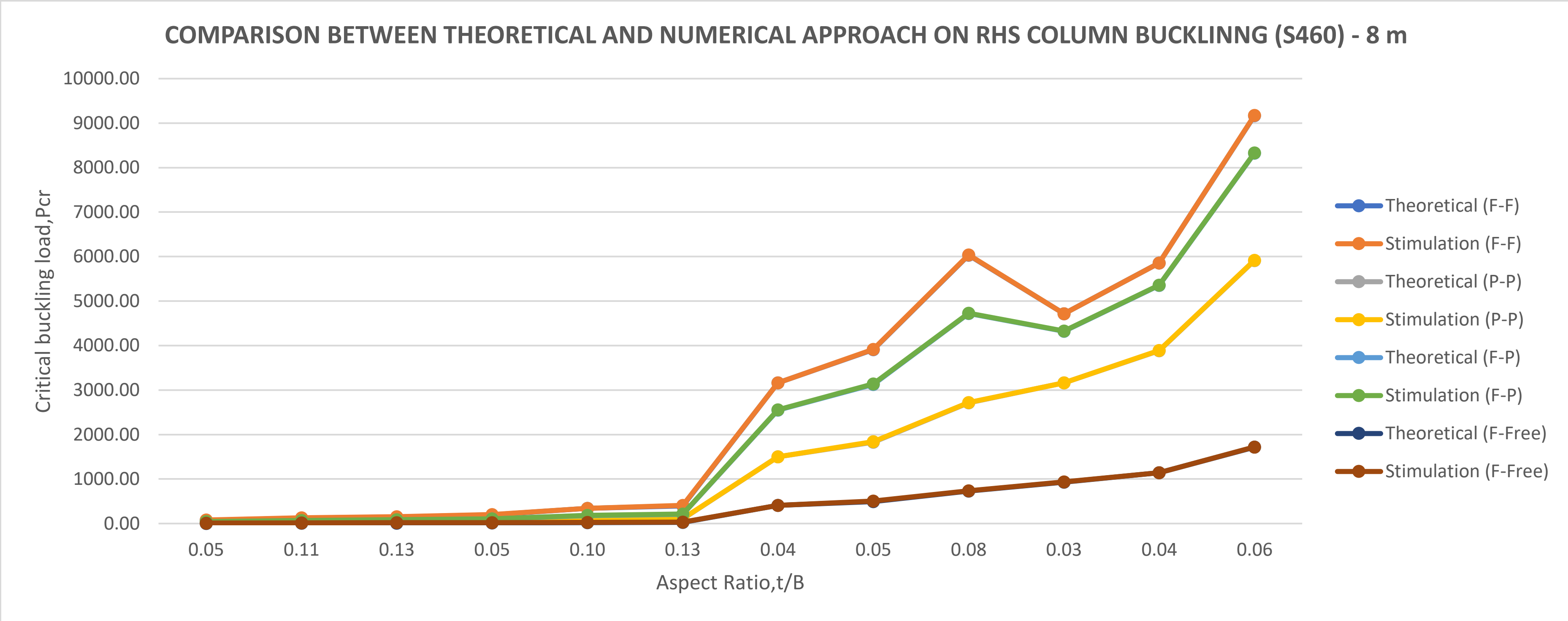


Figure 4.9: Theoretical (Pcr) VS Simulation (Pcr) for steel column grade S460 – 8m

Table 15: Percentage Different Between Theoretical VS Simulation for RHS Column Corresponding to steel grade S460 – 8m

Boundary Condition	Average Percentage Difference,%
F-F	0.93
P-P	3.37
F-P	1.74
F-Free	10.51

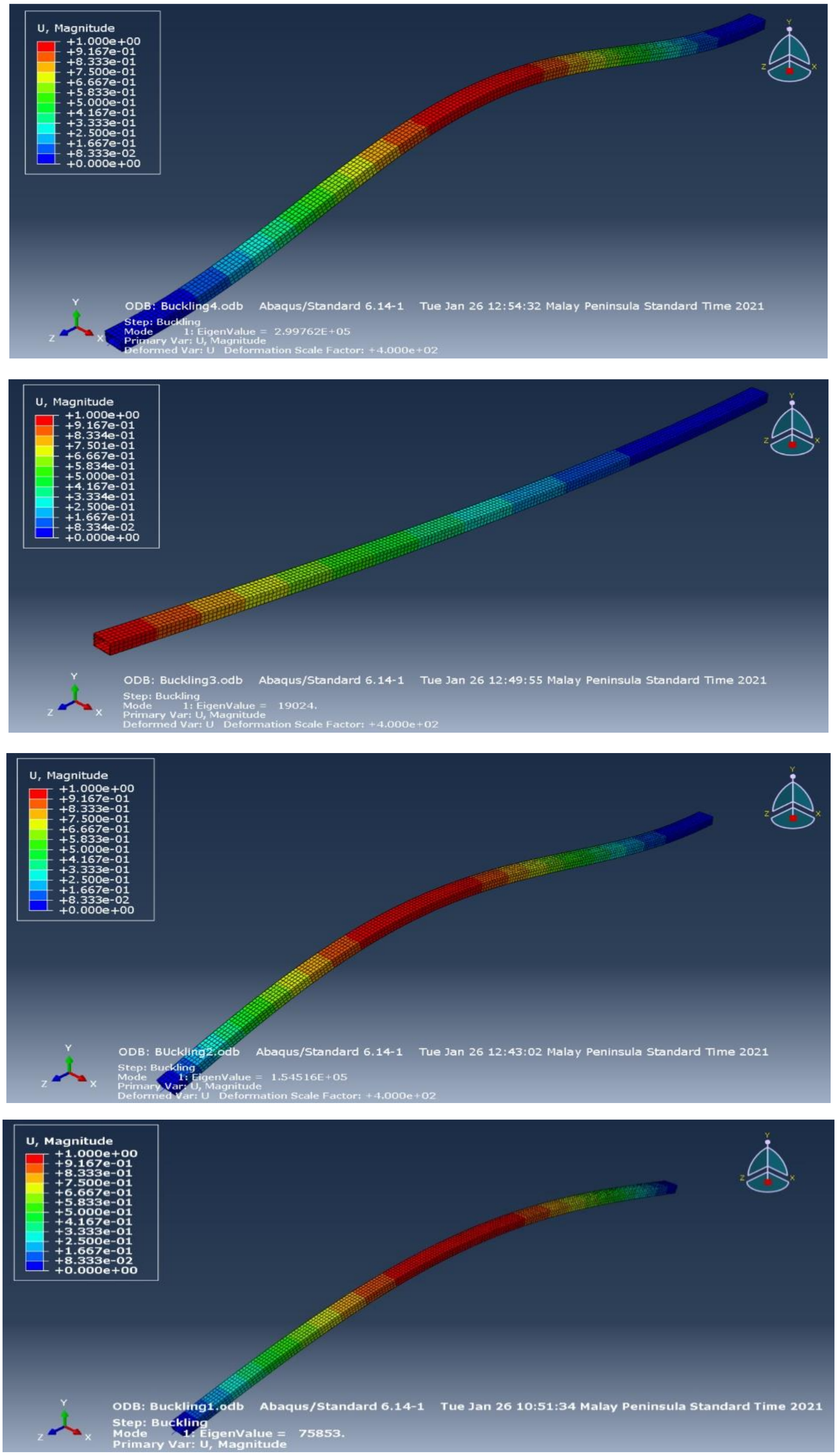


Figure 4.10: Simulation results of RHS column for 4m – S275

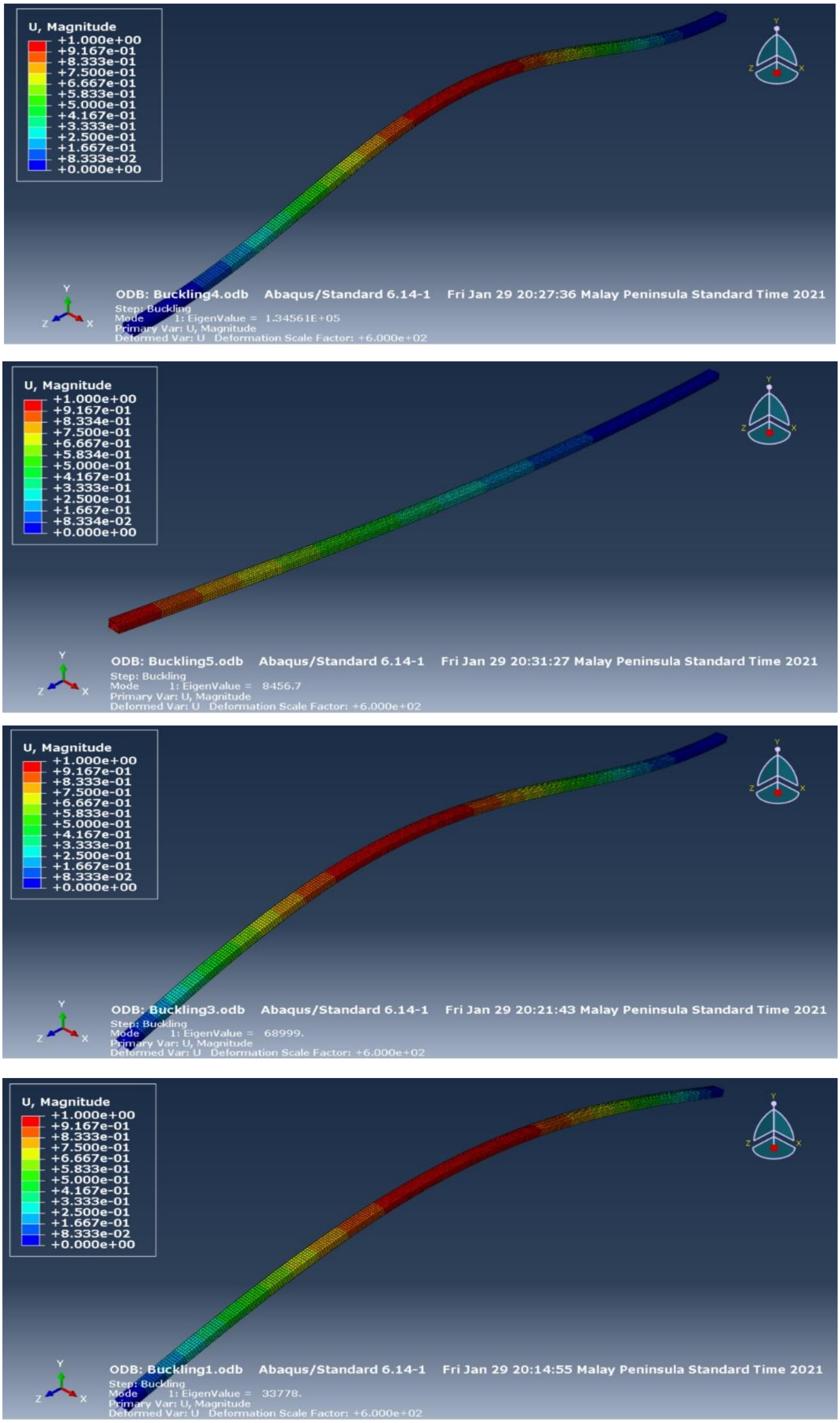


Figure 4.11: Simulation results of RHS column for 6m – S275

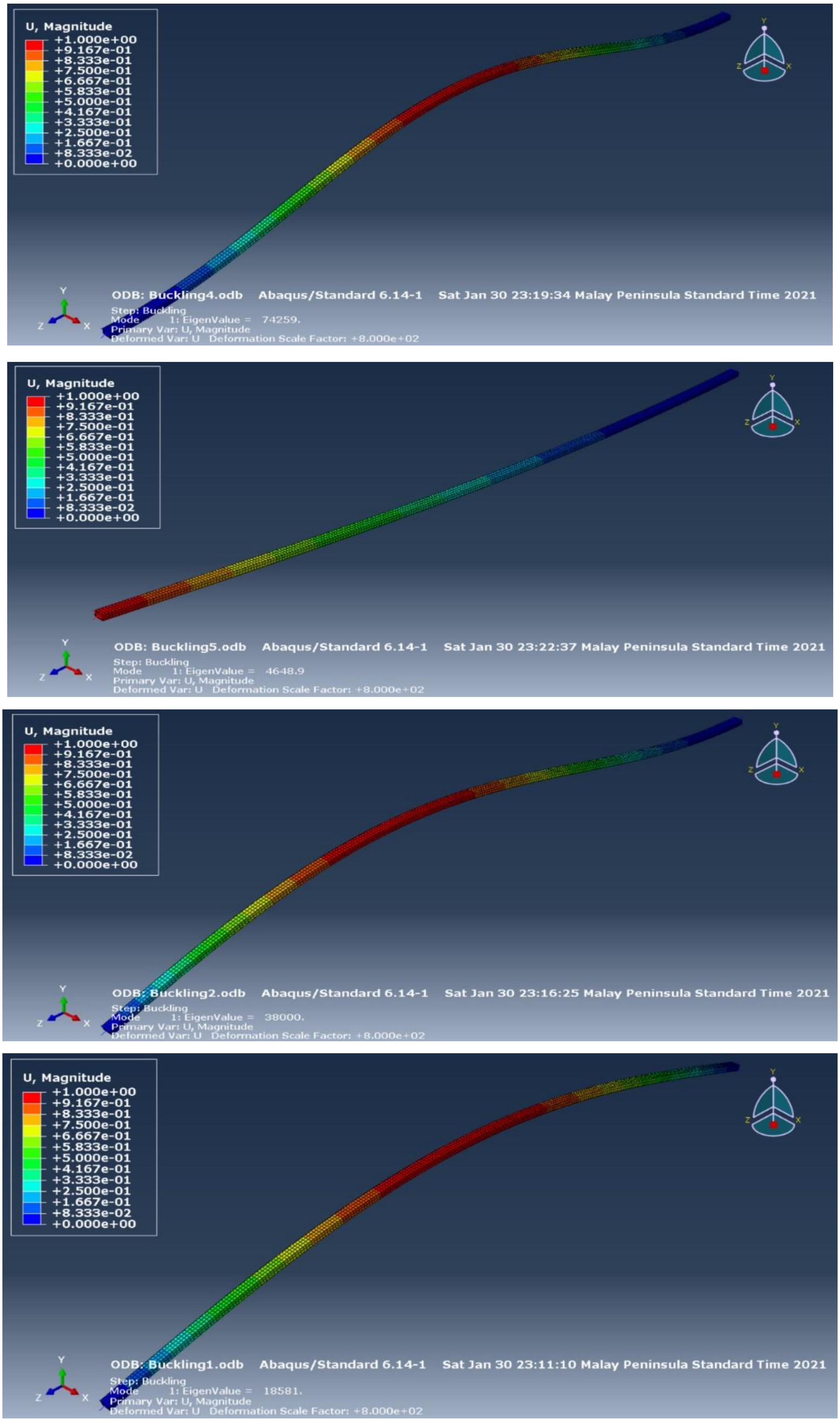


Figure 4.12: Simulation results of RHS column for 8m – S275

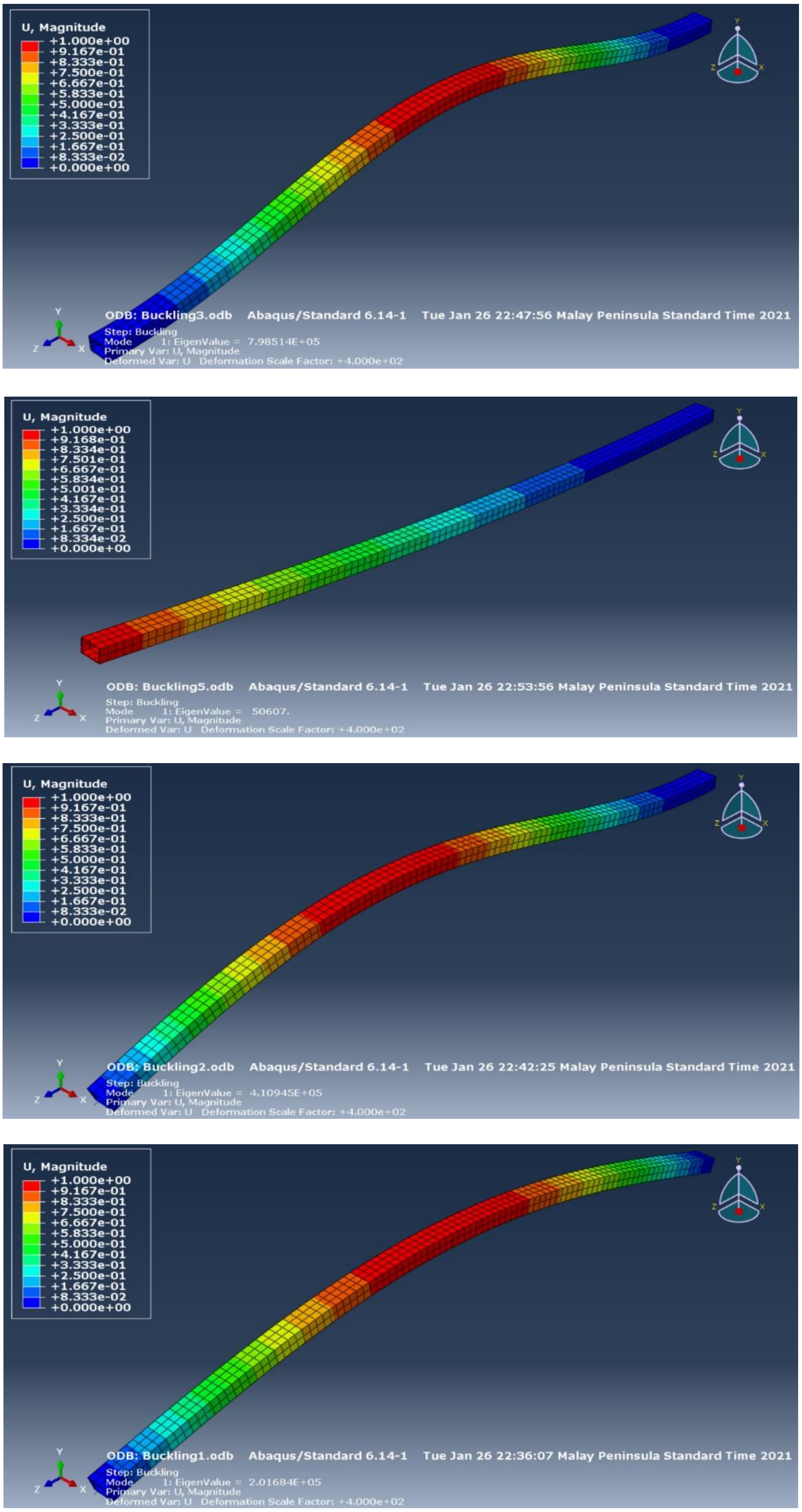


Figure 4.13: Simulation results of RHS column for 4m – S355

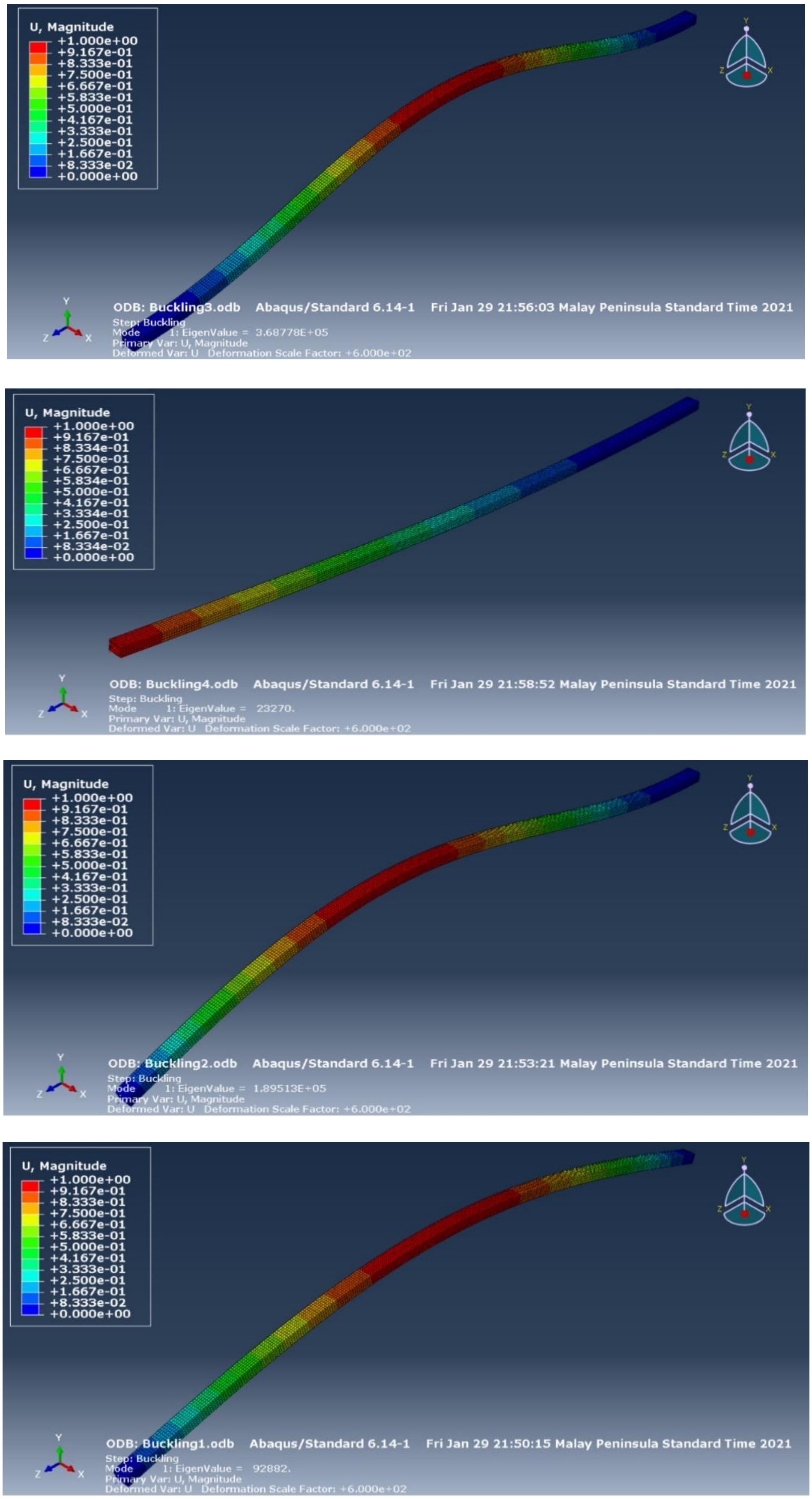


Figure 4.14: Simulation results of RHS column for 6m – S355

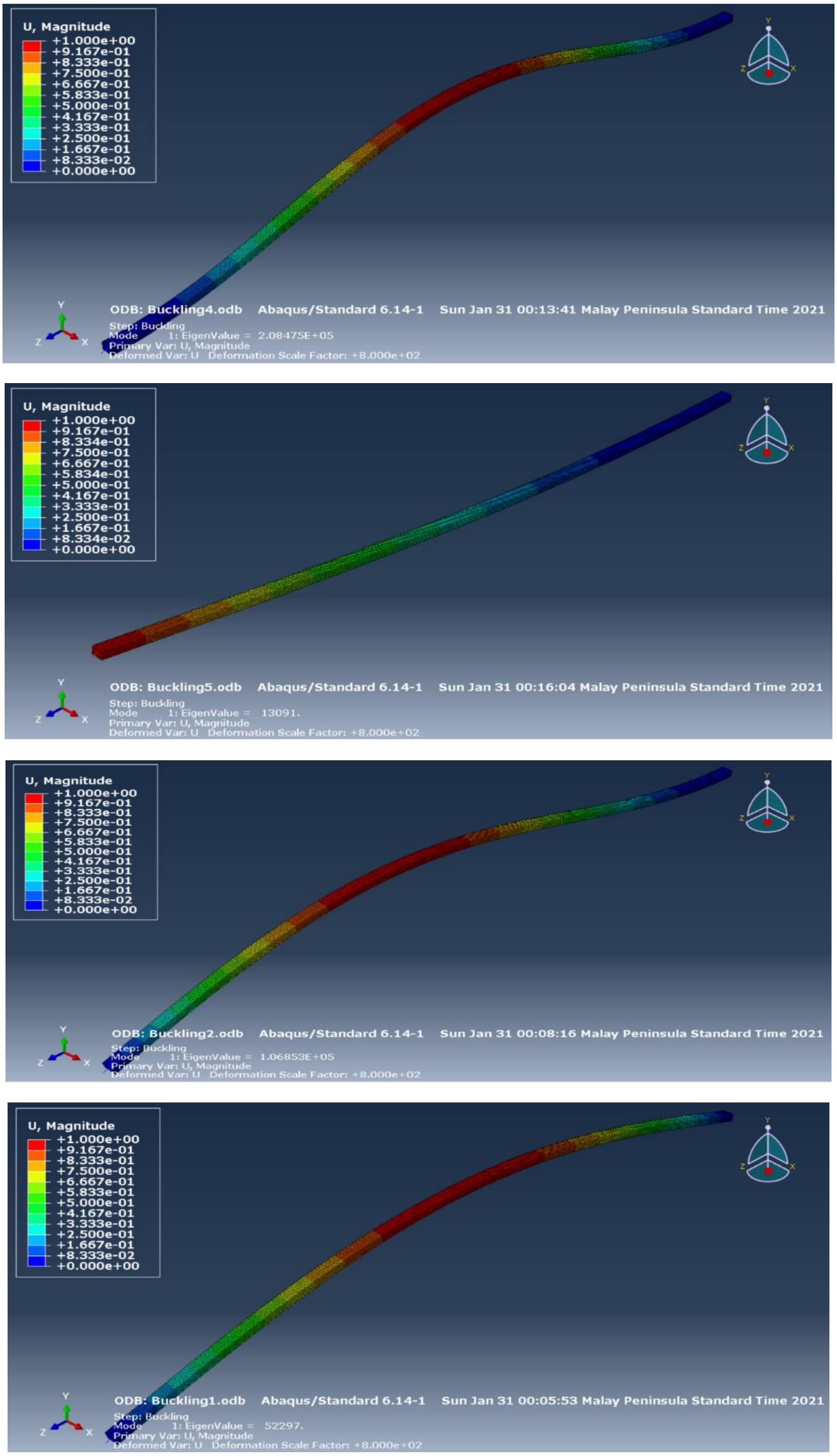


Figure 4.15: Simulation results of RHS column for 8m – S355

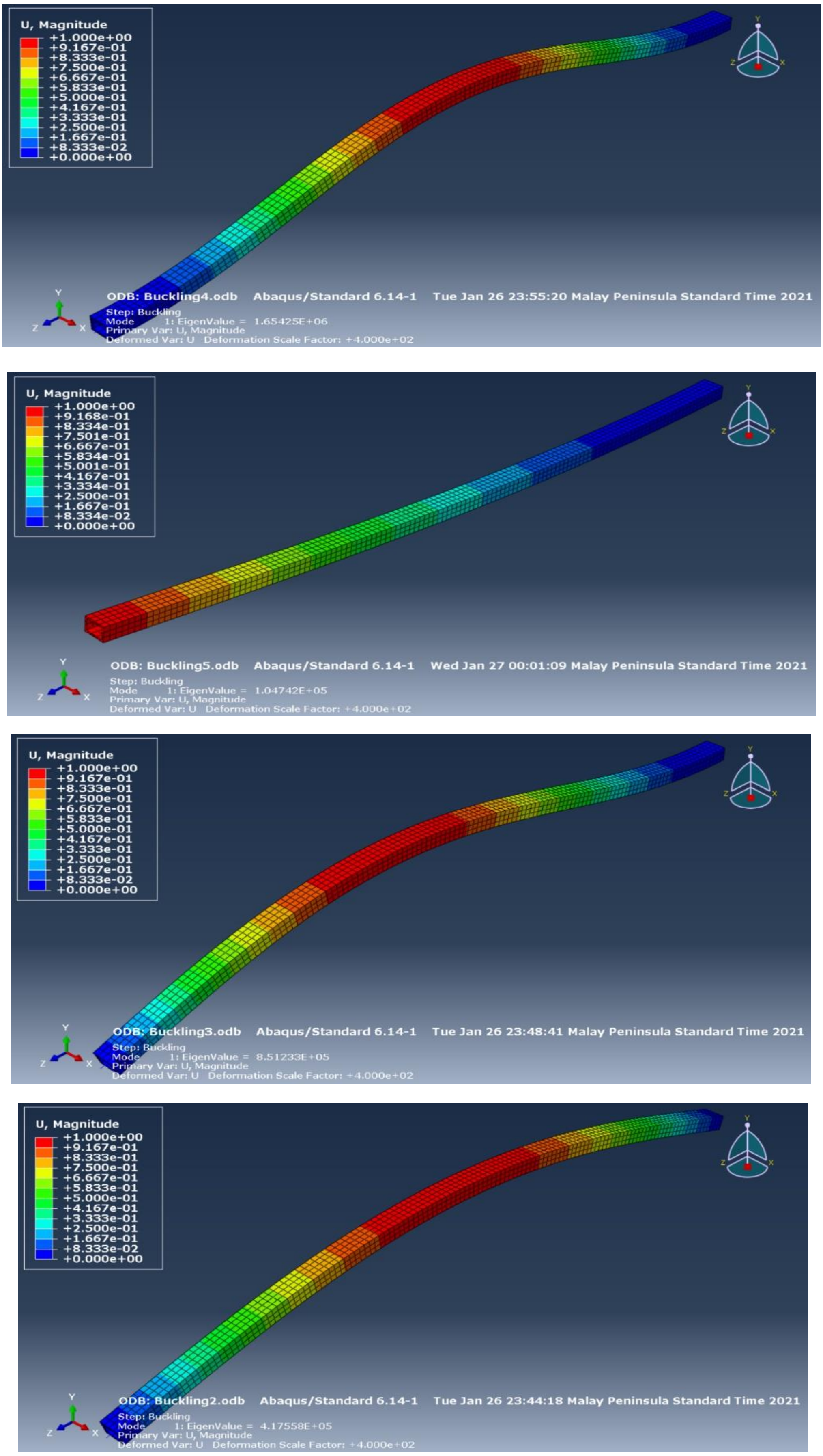


Figure 4.16: Simulation results of RHS column for 4m – S460

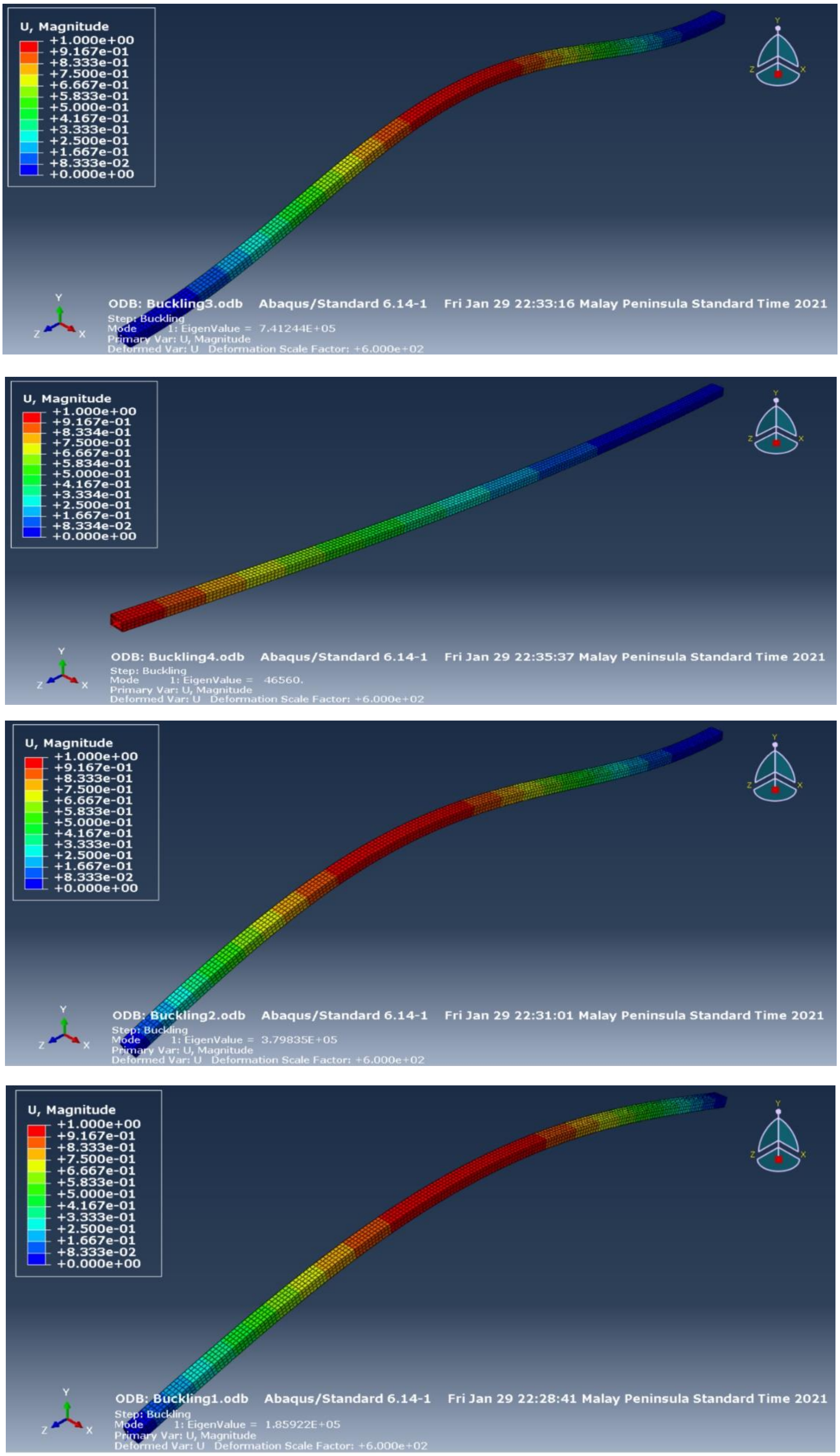


Figure 4.17: Simulation results of RHS column for 6m – S460

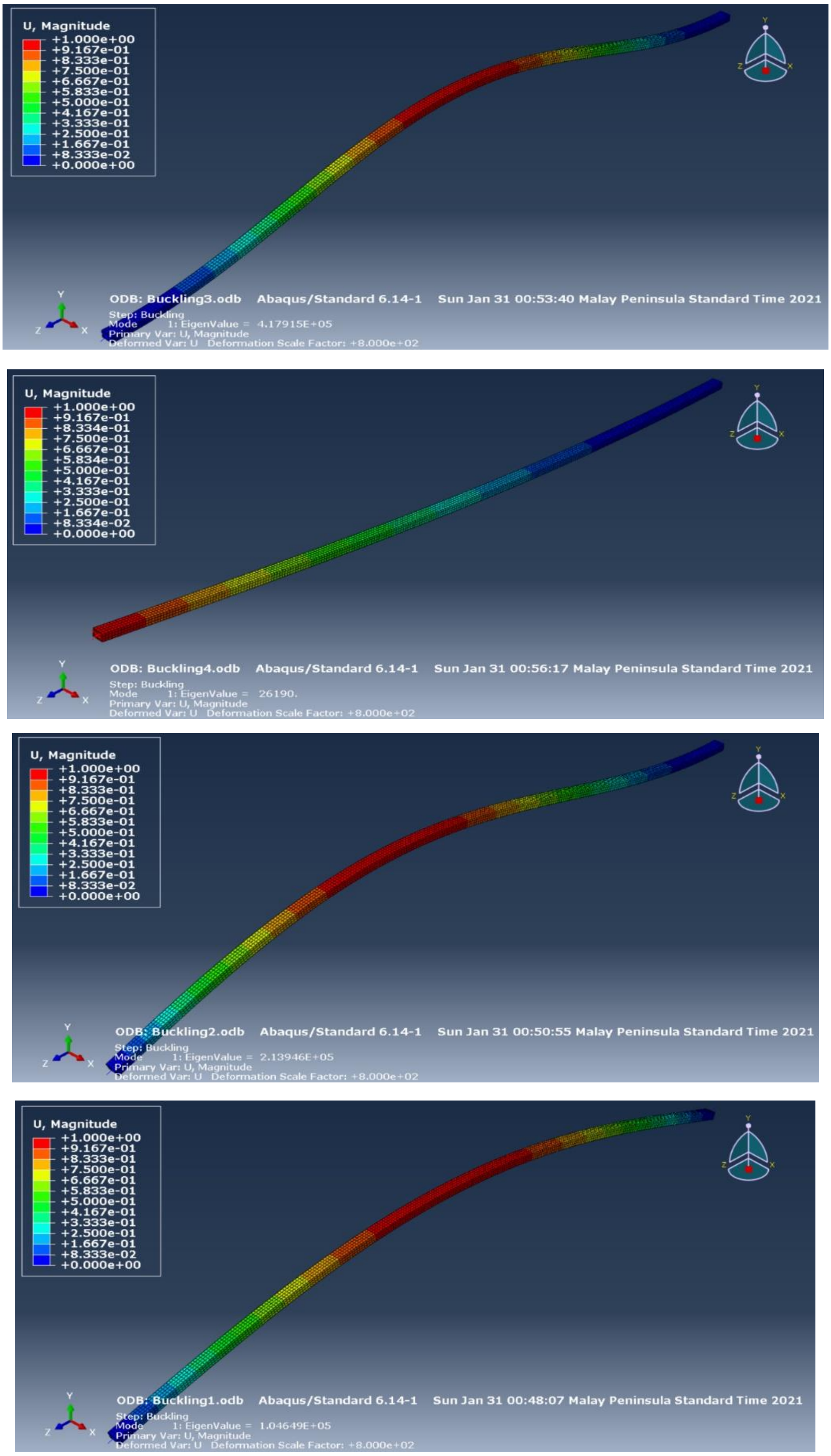


Figure 4.18: Simulation results of RHS column for 8m – S460

In this part **Table 16** presents summary of the average percentage difference of buckling capacity of RHS column versus different steel grade, which is S275,S355 and S460,the length is constant for all three length: 4m,6m and 8m. The properties and thickness of column are constant .The results show the percentage difference between theoretical and simulation buckling capacity of RHS column accordance to different steel grade.

Table 16: Summary of Average Percentage Different Corresponding to Steel Grade and Boundary Conditions

	Boundary Condition	Average Percentage Difference,%		
		4m	6m	8m
S275	F-F	3.99	9.93	8.02
	P-P	6.60	8.60	5.90
	F-P	7.96	7.16	6.98
	F-Free	5.55	5.01	4.02

	Boundary Condition	Average Percentage Difference,%		
		4m	6m	8m
S355	F-F	1.29	3.97	2.19
	P-P	1.43	5.06	6.50
	F-P	1.13	1.78	3.84
	F-Free	0.77	10.41	6.74

	Boundary Condition	Average Percentage Difference,%		
		4m	6m	8m
S460	F-F	0.29	0.55	0.93
	P-P	0.94	1.99	3.37
	F-P	0.50	1.21	1.74
	F-Free	3.33	6.70	10.51

Thus, from the results obtain from the **Table 16**. The critical boundary condition with higher percentage difference for steel grade S275 was fixed-fixed support for column length 6m with 9.93% difference between theoretical and numerical approach. For steel grade S355 the critical boundary condition with higher percentage difference was fixed-free support for column length 6m with 10.41% different. For steel grade S460 the critical boundary condition with higher percentage difference was fixed-free support for column length 8m with 10.51% different. Therefore, from here we can conclude that the critical boundary condition with higher percentage difference found for fixed-free support. The other boundary conditions were obtained less percentage difference compared to fixed-free support.

4.3 ANALYSIS OF BUCKLING BEHAVIOR OF RHS STEEL COLUMNS IN THE INCREASING NUMBER OF OPENINGS

The RHS cross-section properties is shown according to Euro-code 3 are presented in **Table 17** ,where the table below shows the opening dimensions, number of openings and cross-section details for all three different column length and this analysis is conducted for steel grade S275.

Table 17: Cross-section properties, openings dimensions and number of openings of the column

Profile	Depth h [mm]	Width b [mm]	Wall thickness t [mm]	Area A [mm2]	Dimension of Openings, mm	No. of Openings
RHS 100 x 60/3.2	100	60	3.2	983.04	50×50,60×60 and 70×70	Without Opening, 1 Opening,2 Opening and 3 Opening
RHS 100 x 60/6.3	100	60	6.3	1857.24		
RHS 100 x 60/8	100	60	8	2304		
RHS 120 x 80/4	120	80	4	1536		
RHS 120 x 80/8	120	80	8	2944		
RHS 120 x 80/10	120	80	10	3600		
RHS 300 x 200/8	300	200	8	7744		
RHS 300 x 200/10	300	200	10	9600		
RHS 300 x 200/16	300	200	16	14976		
RHS 450 x 250/8	450	250	8	10944		
RHS 450 x 250/10	450	250	10	13600		
RHS 450 x 250/16	450	250	16	21376		

Figure 4.19 represent the geometry of the RHS column and the location of the column openings. In this part the column is tested with three different size of openings such as 50×50,60×60 and 70×70mm openings. This test was conducted for steel grade S275 and for column length which were 4m. The aim of this numerical simulation was to determine the reduction difference for the increasing in opening numbers and opening sizes.

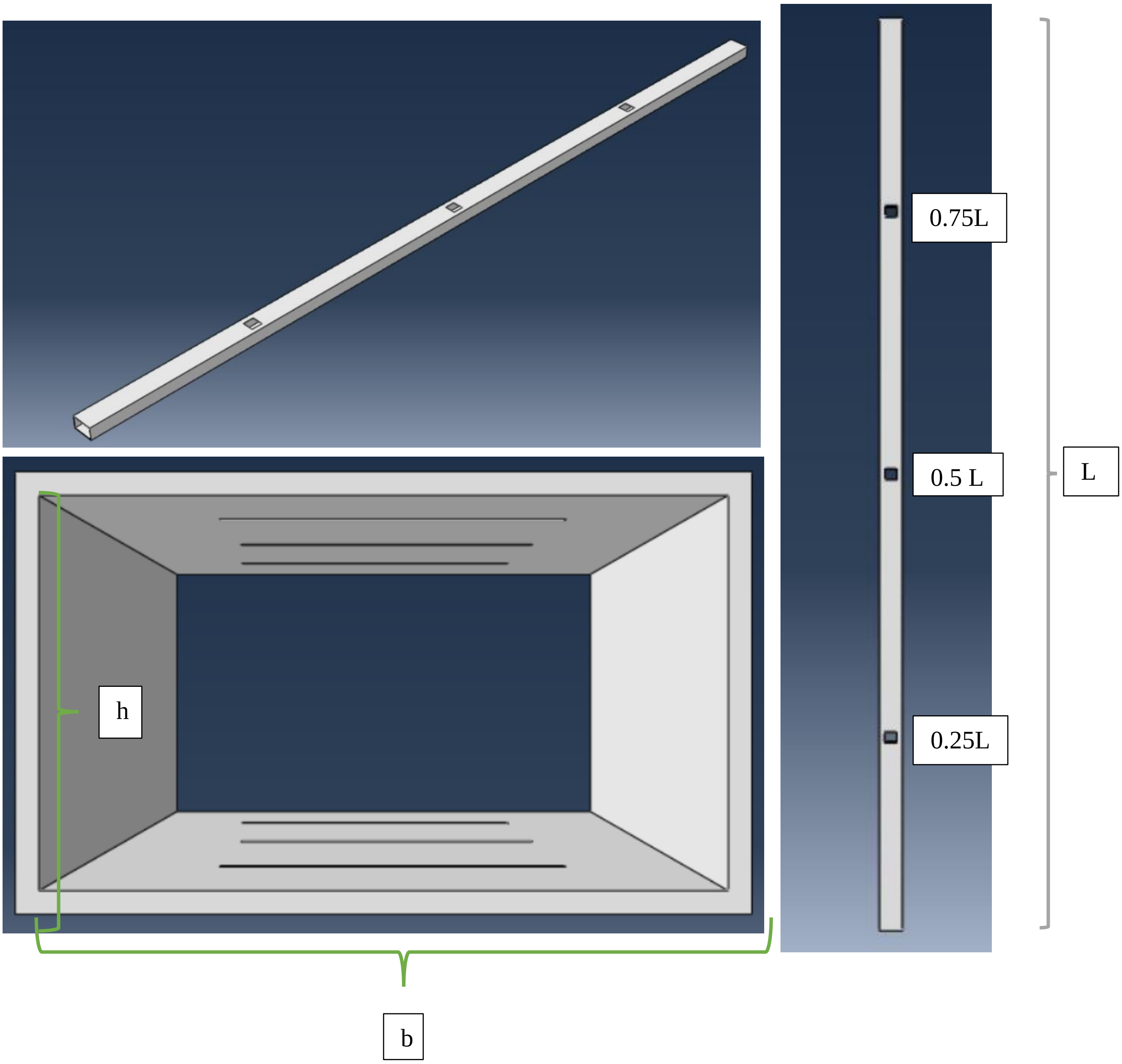


Figure 4.19: Geometry of RHS column and opening location

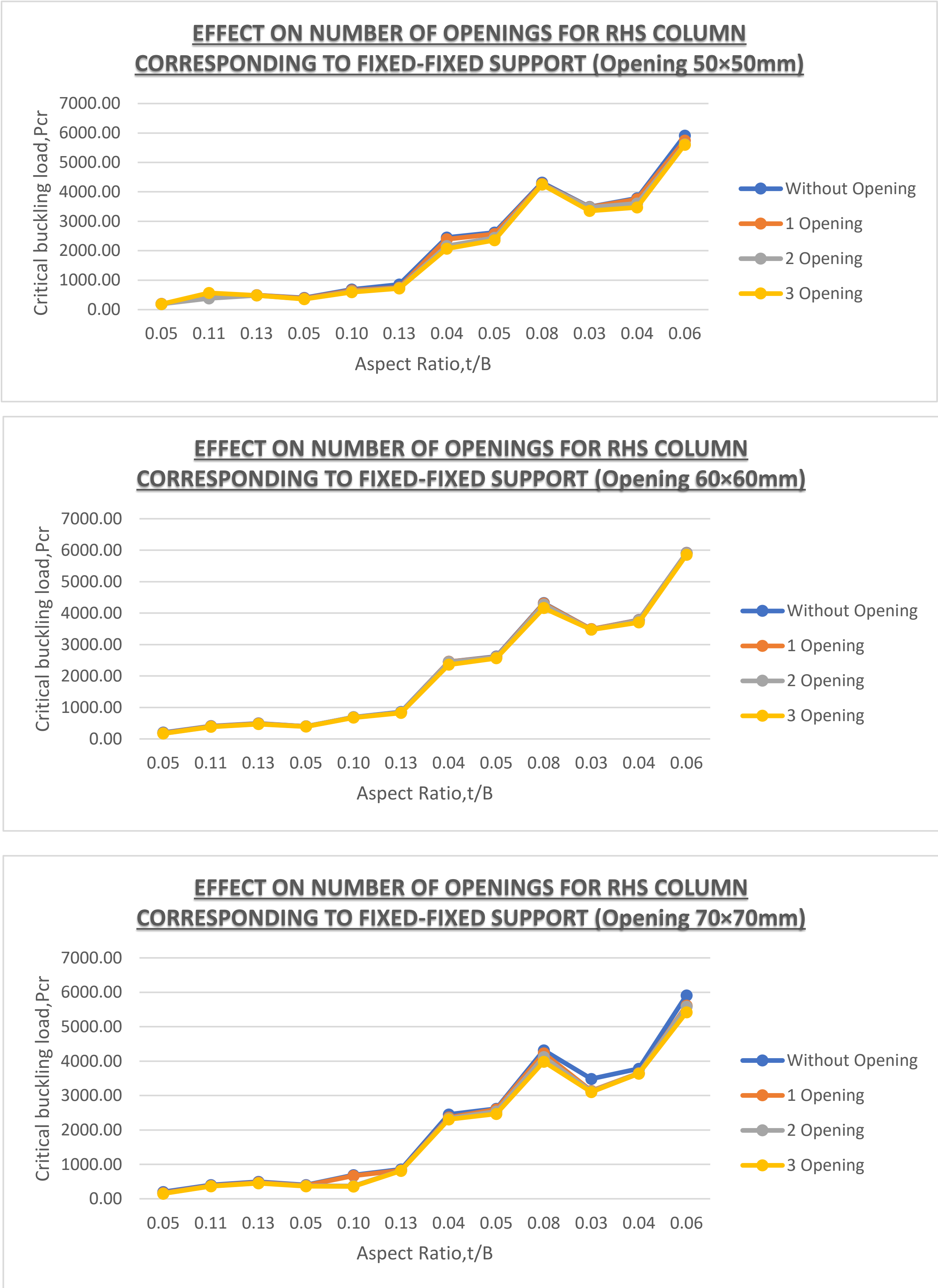
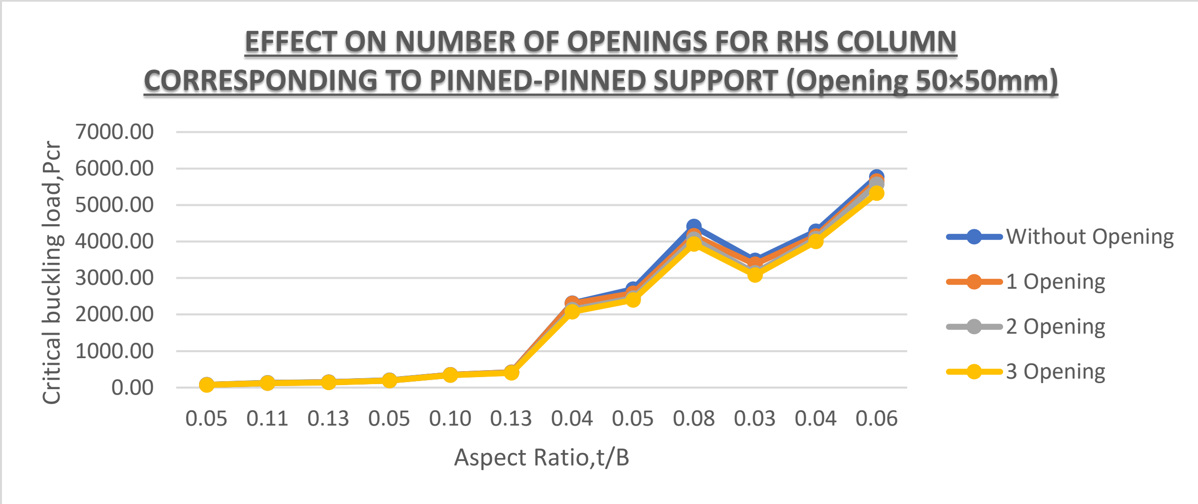
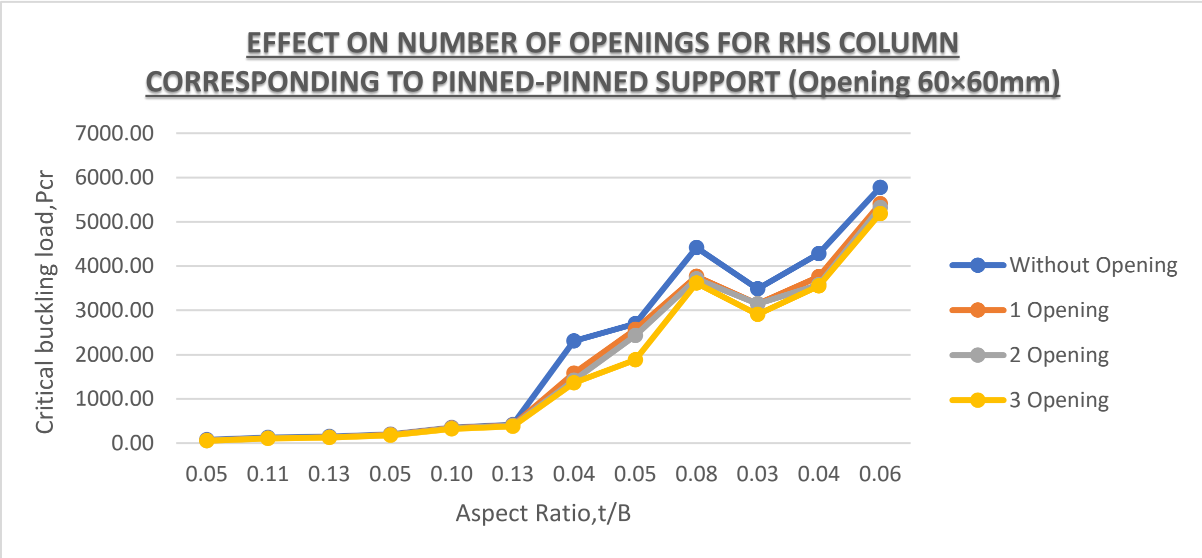


Figure 4.20: Summary of the buckling capacity of RHS column with variable numbers of openings corresponding to Fixed-Fixed boundary condition





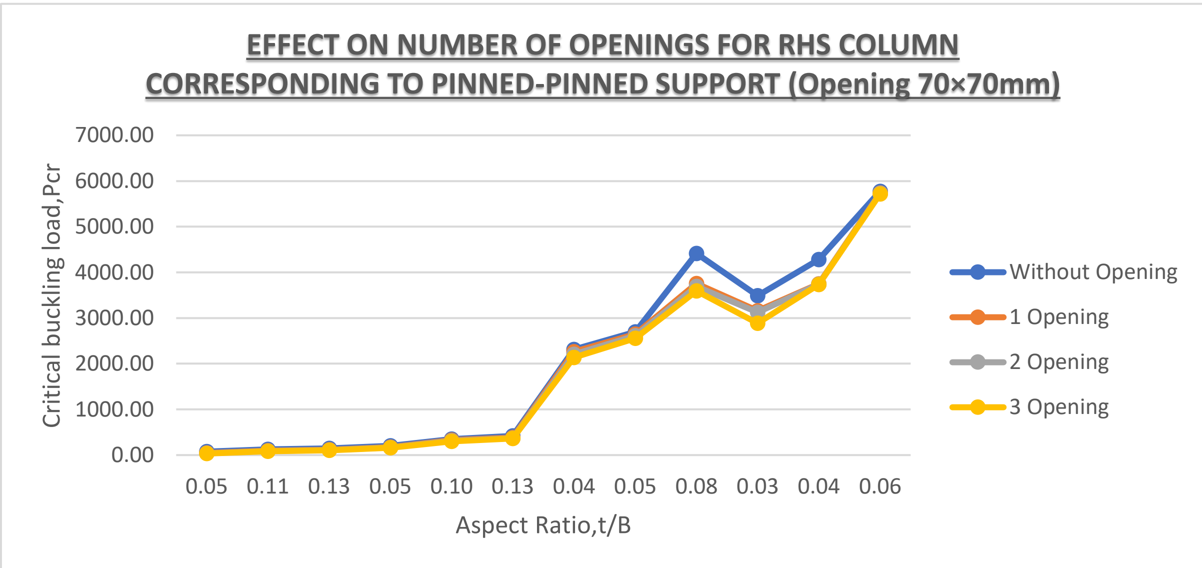
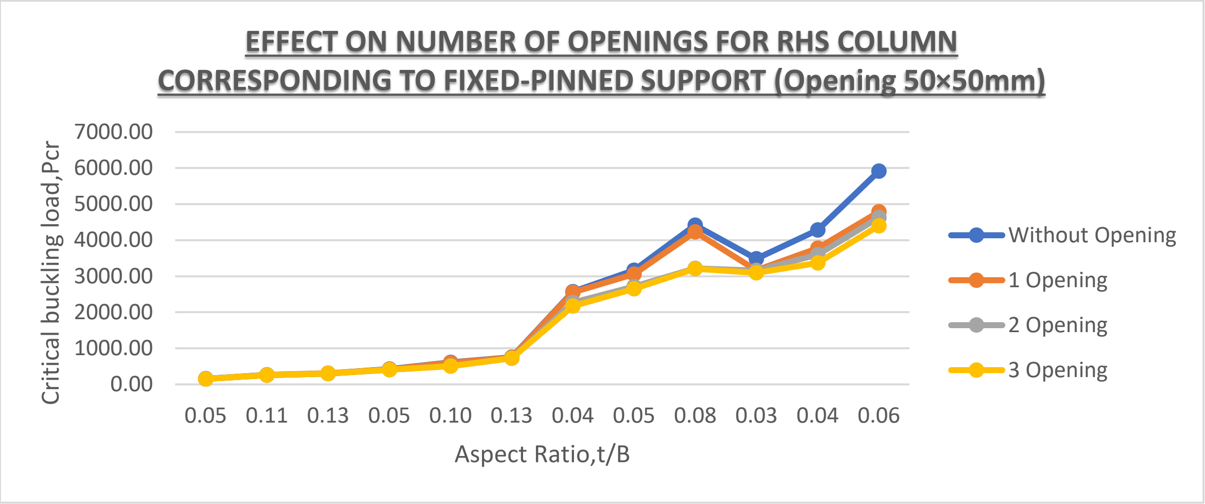
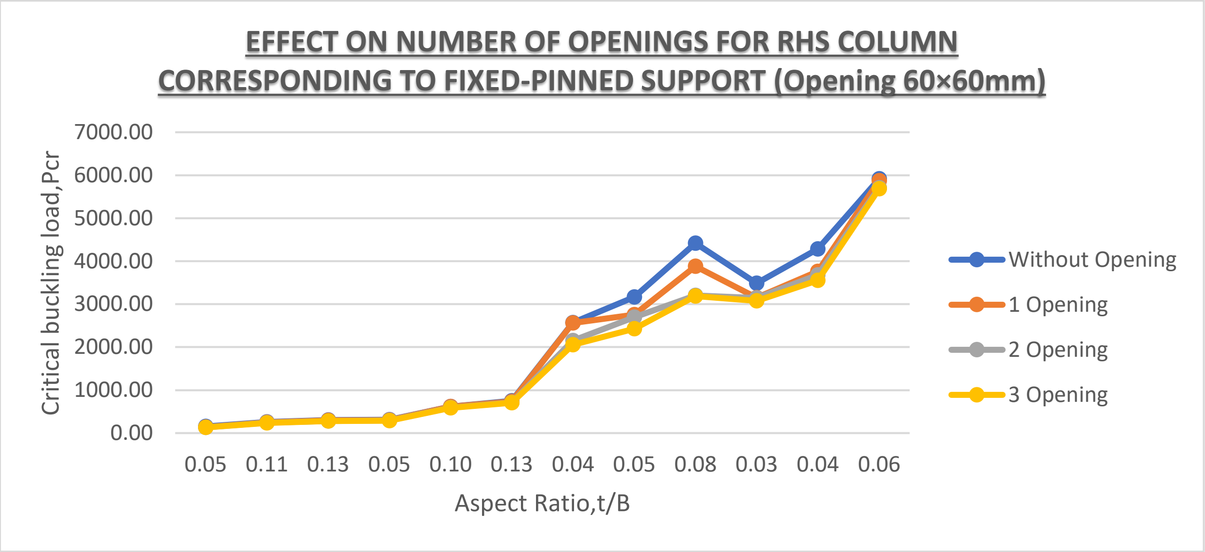


Figure 4.21: Summary of the buckling capacity of RHS column with variable numbers of openings corresponding to Pinned-Pinned boundary condition





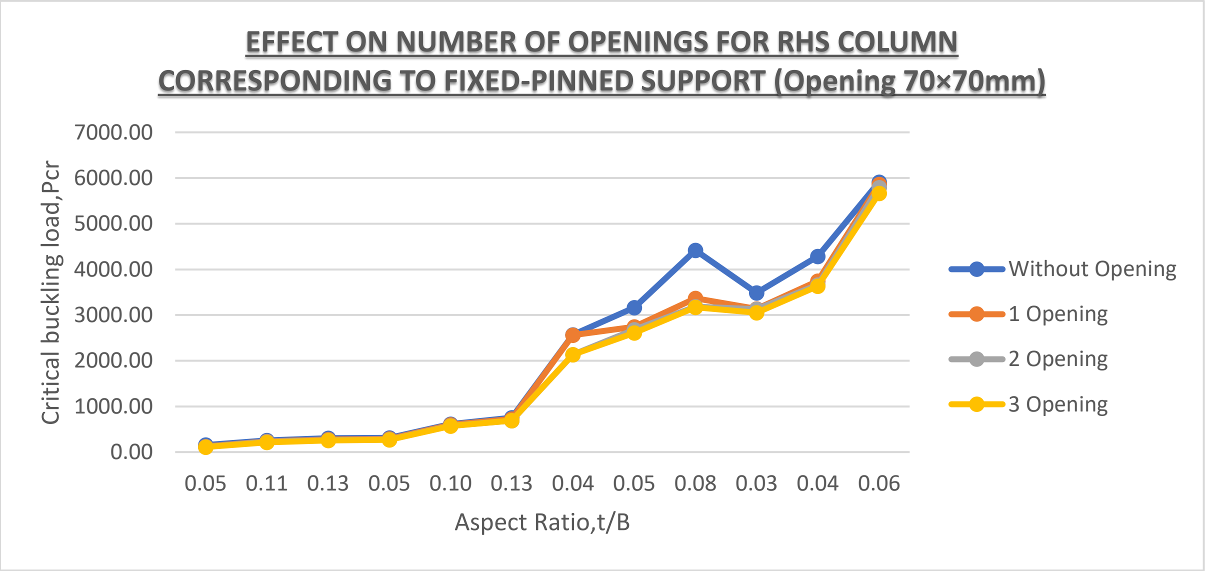
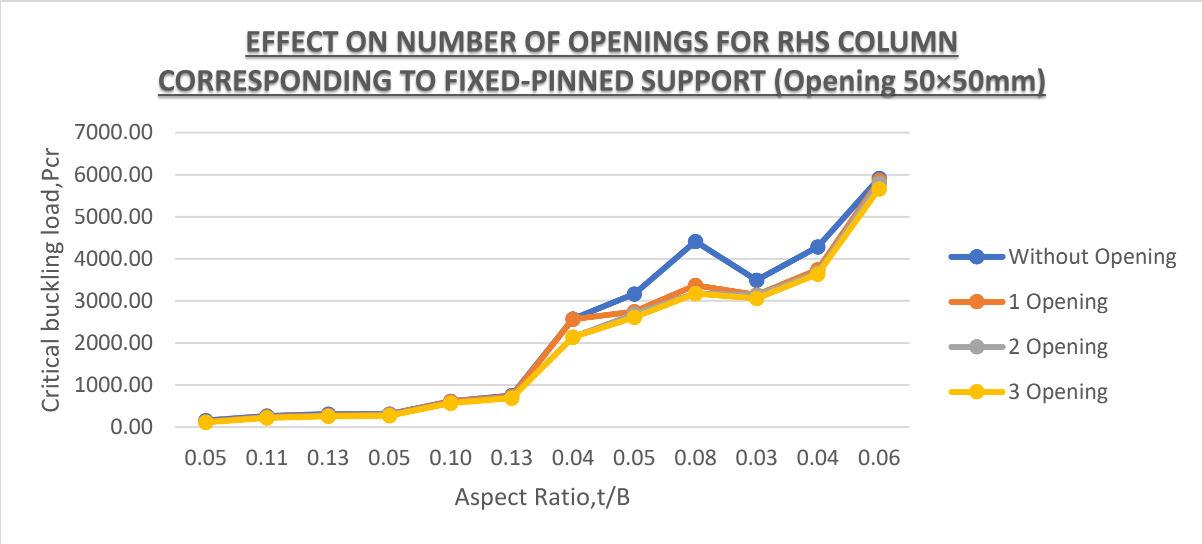
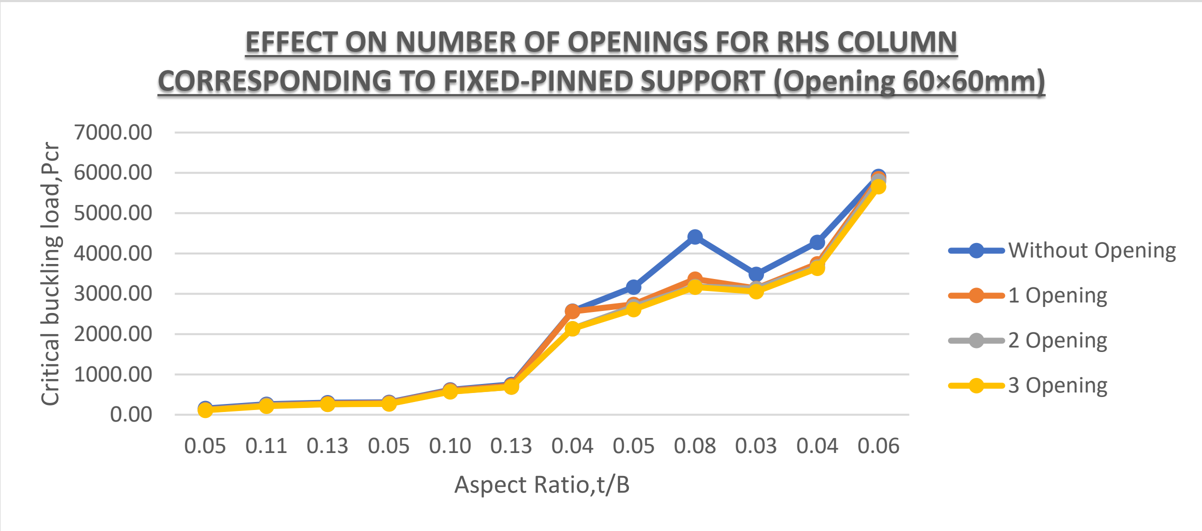


Figure 4.22: Summary of the buckling capacity of RHS column with variable numbers of openings corresponding to Fixed-Pinned boundary condition





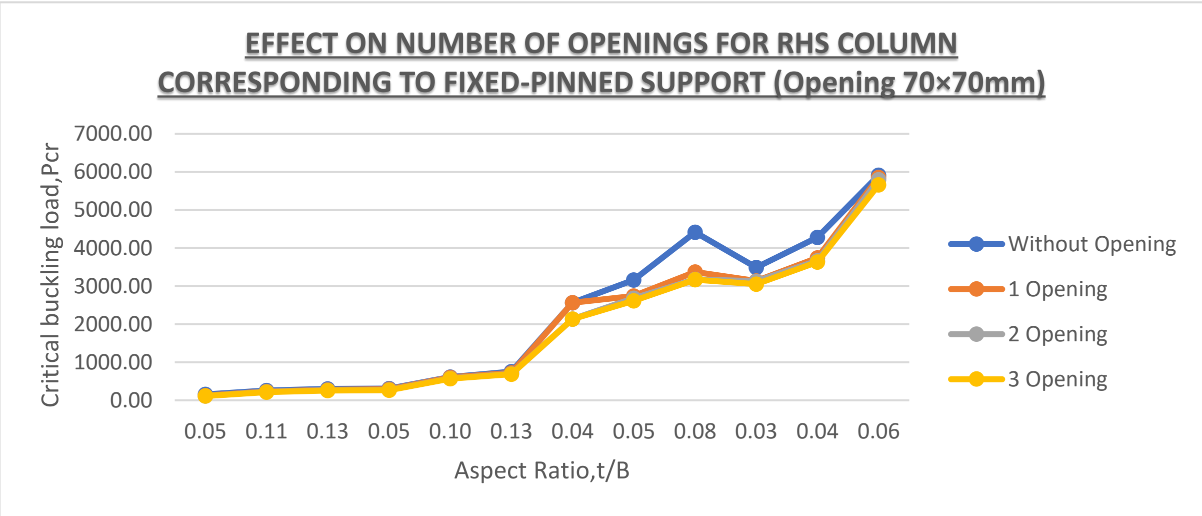


Figure 4.23: Summary of the buckling capacity of RHS column with variable numbers of openings corresponding to Fixed-Free boundary condition

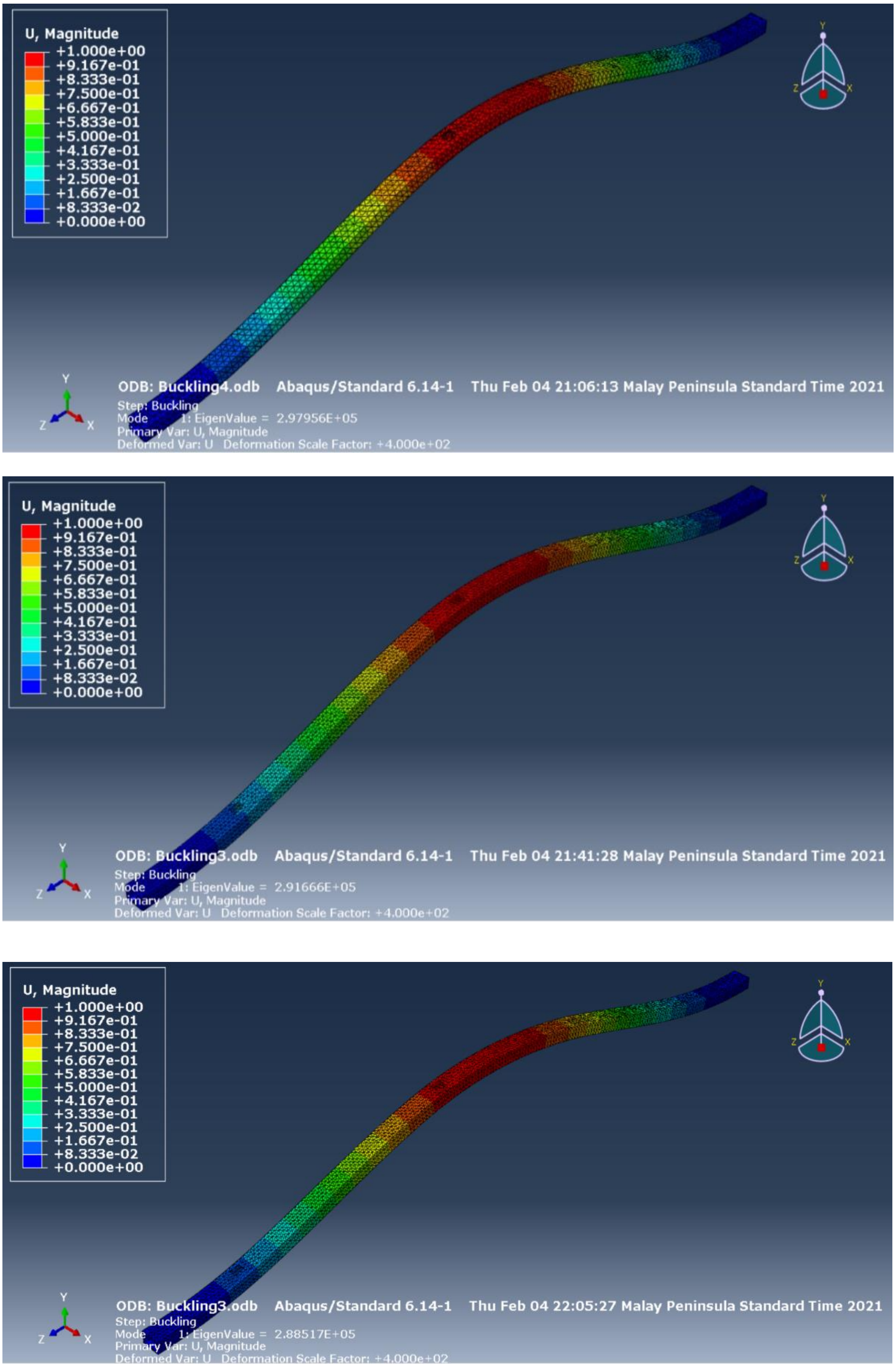


Figure 4.24: Simulation results of RHS column with versus number of opening sizes 50mm×50mm

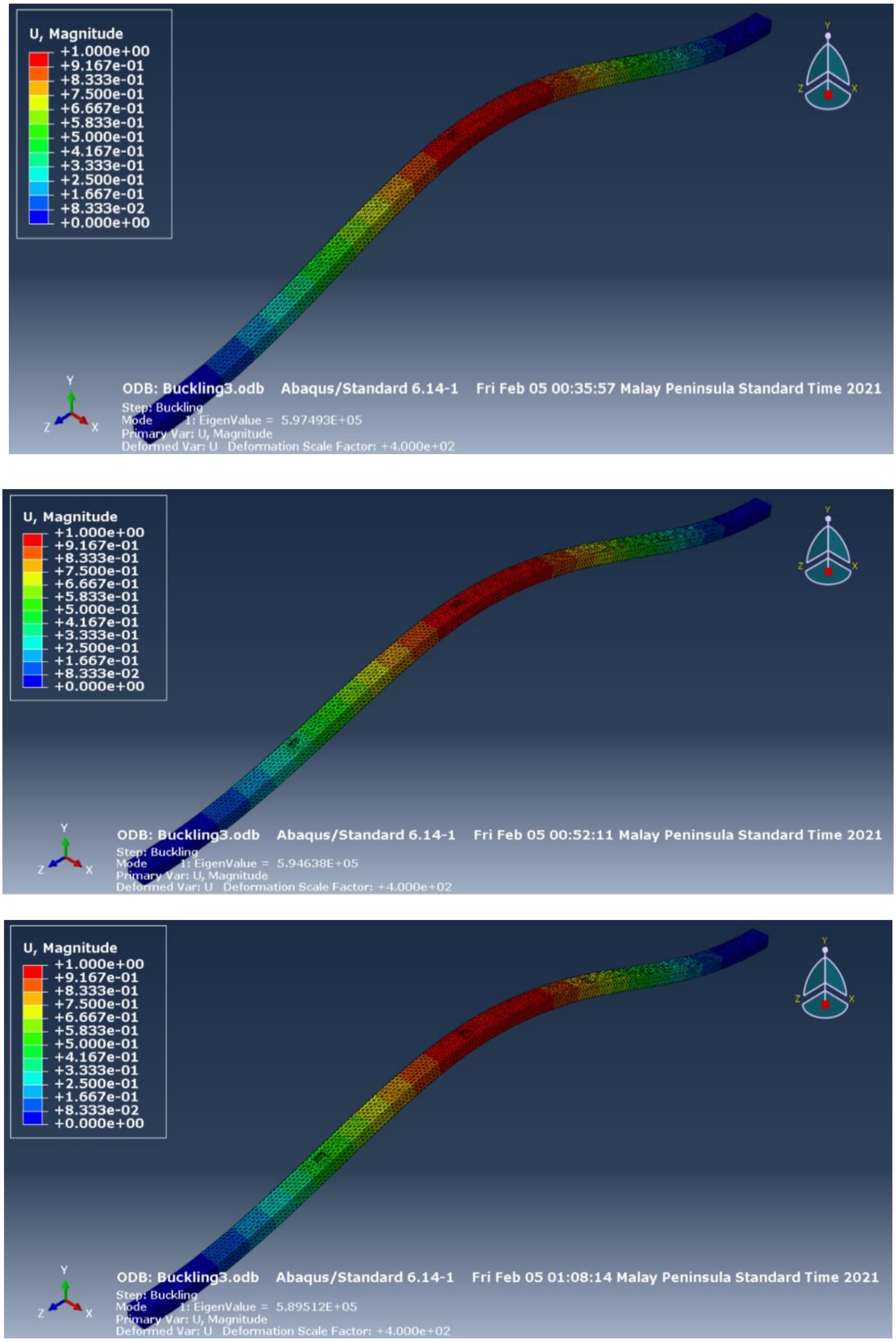
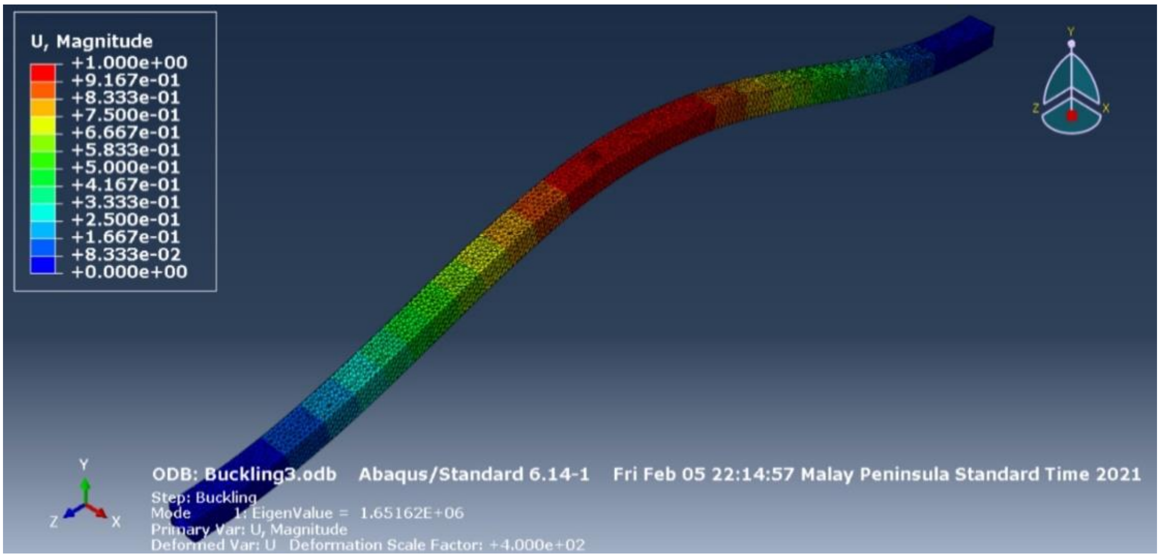
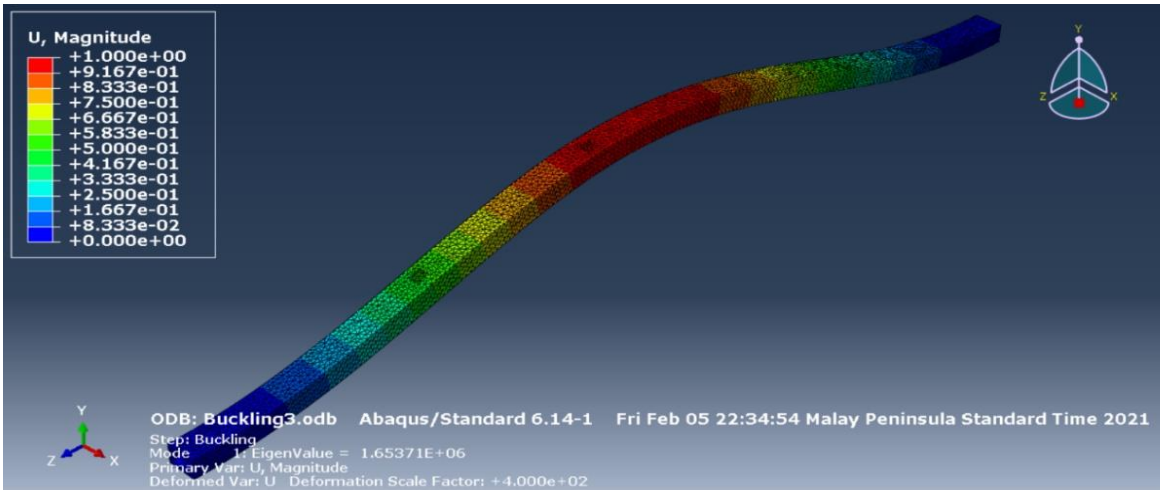


Figure 4.25: Simulation results of RHS column with versus number of openings size 60mm×60mm





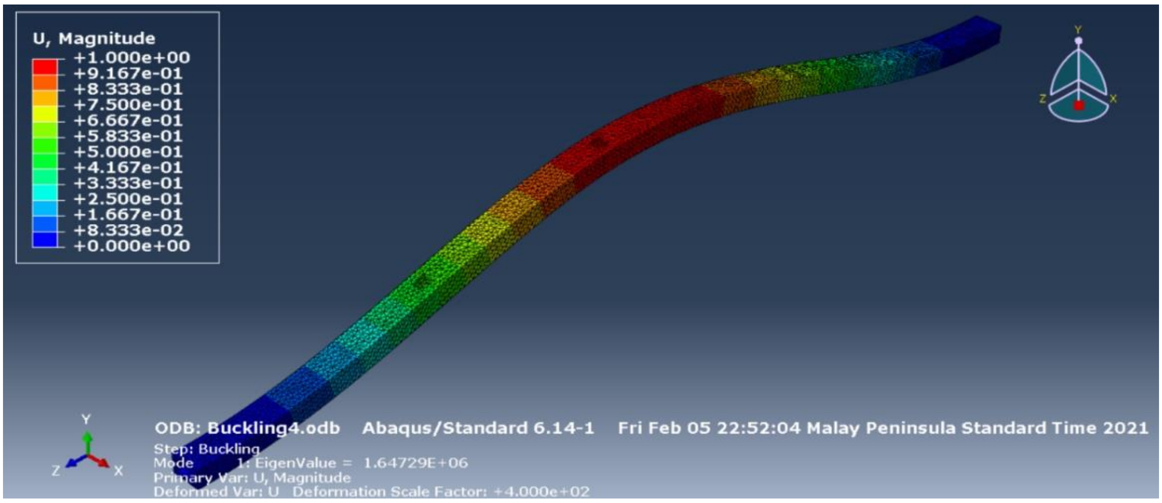


Figure 4.26: Simulation results of RHS column with versus number of opening sizes 70mm×70mm

4.3.1 THE EFFECT OF OPENING SIZE

The buckling load versus the aspect ratio, t/B with a constant size is seen in **Figure 4.20-4.23**, with the length of opening equivalent to 50mm×50mm, 60mm×60mm, and 70mm×70mm. The outcomes can be seen in **Figure 4.20-4.23**, where the buckling load decreases by 15% as the number of openings is increased when the opening size is varied.

From the precedes results, the following remarks are records:

- The typical failure mode for all the stimulated hollow specimens was global buckling, as can be observed.
- The stimulated analysis indicates that increasing the opening dimension reduces the ultimate loads of the stimulated column by 15%.
- The findings show a 94.7% reduction in load due to a decrease in column thickness while the opening sizes remain stable at 50mm50mm, 60mm60mm, and 70mm70mm.
- In addition, a good linear graph with decreasing column thickness can be observed.

4.3.2 EFFECT OF OPENING NUMBERS

The buckling load versus the number of openings with a constant size is seen in **Figure 4.20-4.23**, with the length of opening equivalent to 50mm×50mm, 60mm×60mm, and 70mm×70mm. The buckling load decreases by 18.74 % as the opening number is increased while the opening size remains unchanged, as seen in **Figure 4.20-4.23**.

- It can be found that increasing the number of openings has a major impact on the ultimate loads and deformation of stimulated columns, reducing load capacity by 18.74 %, but column length has a slight impact on ultimate loads and deformation of measured columns.

- Openings with dimensions of 50mm×50mm result in a 16.95 percent reduction in ultimate load, while openings with dimensions of 60mm×60mm result in an 15.25

% reduction, a difference of 1.7 % as applied to the 4m column. Meanwhile, an opening with dimensions of 70mm×70mm ,reduces ultimate load by 17.45%, which is greater than the 0.5 % and 2.2 % reductions in 4m and 6m column lengths.

-

4.3.3 EFFECT OF BOUNDARY CONDITIONS IN PRESENTS OF OPENING

The buckling load versus the boundary conditions with a constant size is seen in **Figure 4.20-4.23**, with the length of opening equivalent to 50mm×50mm, 60mm×60mm, and 70mm×70mm. The outcomes can be seen in **Table 18**, where the buckling load decreases rapidly for boundary condition fixed-pinned and fixed-free by 8.12 % and 11.26% as the number of openings is increased when the opening size is varied.

Table 18: Summary of average percentage difference according to difference boundary conditions

	Boundary Condition	Average Percentage Difference,%		
		50 × 50	**60 × 60**	**70 × 70**
S275	F-F	1.37	2.82	3.92
	P-P	1.64	3.78	4.16
	F-P	2.56	5.11	8.12
	F-Free	4.69	7.88	11.26

4.4 CHAPTER SUMMARY

The critical load that affects local and global buckling of columns has been measured using the finite element method for various models. The findings were validated using feature codes Euro-codes 3. The values were compared, and the results were displayed in the form of tables and charts, demonstrating how the critical load varied as some parameters were modified. The first of which focuses on the results obtained in calculating critical buckling loads and comparing them to the simulation results obtained from finite element analysis. As a result, this analysis involves four different cross sections with three different column lengths, as well as four different boundary conditions: fixed-fixed, pinned-pinned, fixed-pinned, and fixed-free. In comparison, the analysis is put through its paces with three separate steel grades: S275, S355, and S460. ABAQUS software is used to develop the models. The simulation findings are compared to the theoretical results using the Euro-code 3 methodology. The second section applies finite element analysis to analyze the buckling behavior of RHS steel columns in the increasing number of openings in the column surface. Thus, the critical boundary will be fixed-free support and the critical length will be 6m.In next chapter the conclusion and recommendation part are discussed.

CHAPTER 5
CONCLUSION

5.1 CHAPTER OVERVIEW

This chapter, conclude the entire studies which were on the prediction of buckling of the RHS Column using Finite Element Analysis and compared with the recommended approach Eurocode 3. Where, in this chapter the result and recommendation are discussed.

5.2 THEORETICAL AND NUMERICAL SIMULATION RESULTS

The objective of the study which are to carry out parametric study using computer simulations by varying the column cross sections, wall thickness, opening size, numbers, and opening locations and determine their effects on buckling of RHS Columns and to validate the results of Finite Elements Analysis Method of buckling of RHS Columns using theoretical approach recommended in Eurocode 3 were achieved. In conclusion, buckling loads are heavily influenced by the material properties and column geometry. Except for the column length, buckling loads are proportional to modulus of elasticity, weight, and all other column geometry parameters. The critical load values of various cross-sections of column are determined using Eigenvalue analysis, and they are almost identical, with the only difference being in percentages that are not surpassed by more than 0.8 percent. Since it is used for the total cross sections of the column it had regular shapes, the numerical solution of the columns is ideal for calculating the critical load. The buckling analysis of a column with one end set and the other ends open shows minimal difference in critical buckling load. In this paper, an ABAQUS modelling analysis of a RHS steel column has been presented. Furthermore, it covers research gap which investigates the relationship of simulation result with the recommended approach Eurocode 3.

From the results of RHS columns analysis, the following conclusions obtained:

- ✓ The typical failure mode for all the tested hollow specimen was the global buckling.
- ✓ The tested results indicated that the increasing of openings dimension leads to reduction in ultimate loads of tested column.
- ✓ The increasing of openings number has significant effect on the ultimate loads and deformation of stimulated steel columns, decreasing of load capacity, but length of column has limited effect on the ultimate loads and deformation of columns.
- ✓ When the opening position is constant an increase in thickness of column, the local buckling and global buckling occur in the smaller thickness. when he increased the size of the openings, the ultimate load is reduced .

5.3 RECOMMENDATION

Given that results obtain from the simulation-based project are extremely subjective due to the input data which comes from the user themselves, it must be verified through actual lab experiment before it can be applied in the real-world. Thus, for those who will continue this work, it is recommended to conduct a lab experiment and compare the obtained results with this research. From there, a further refinement can then be done on the simulation parameter itself and increase its relative reliability for future applications in industry.

APPENDIX

Steel Grade :275		
Length(m) :	4	
E=	210000	N/mm2
Support System:	F-F	
K value:	0.5	

Profile	Depth h [mm]	Width b [mm]	Wall thickness t [mm]	Second moment of area Ix [×10^6 mm^4]	Radius of gyration rx [mm]	Second moment of area Iy [×10^6 mm^4]	Radius of gyration ry [mm]	Area A [mm^2]	Length Leff [mm]	Fy [N/mm2]	E [N/mm2]	Ncr kN	λ	ϕ	χ	Nb,rd kN	Aspect Ratio	Stimulation	Percentage difference,%
RHS 100 x 60/3.2	100	60	3.2	1.337	36.7	0.5989	24.6	983.04	2000	275	210000	310.3	0.93	1.01	0.712	192.38	0.05	199.76	1.88
RHS 100 x 60/6.3	100	60	6.3	2.3629	35.2	1.0244	23.3	1857.24	2000	275	210000	530.8	0.98	1.06	0.679	346.75	0.11	403.93	7.62
RHS 100 x 60/8	100	60	8	2.8268	34.4	1.2037	22.5	2304	2000	275	210000	623.7	1.01	1.09	0.660	418.22	0.13	493.07	8.21
RHS 120 x 80/4	120	80	4	3.0904	44.6	1.6364	32.5	1536	2000	275	210000	847.9	0.71	0.80	0.845	356.93	0.05	398.51	5.51
RHS 120 x 80/8	120	80	8	5.5207	42.7	2.8481	30.8	2944	2000	275	210000	1475.8	0.74	0.83	0.828	670.20	0.10	689.09	1.39
RHS 120 x 80/10	120	80	10	6.52	41.8	3.32	29.9	3600	2000	275	210000	1720.3	0.76	0.85	0.818	810.30	0.13	854.25	2.64
RHS 300 x 200/8	300	200	8	98.77	112.5	52.568	82.2	7744	2000	275	210000	27238.3	0.28	0.55	0.982	2091.72	0.04	2452.40	7.94
RHS 300 x 200/10	300	200	10	120.72	111.6	63.92	81.3	9600	2000	275	210000	33120.4	0.28	0.55	0.982	2591.39	0.05	2616.90	0.49
RHS 300 x 200/16	300	200	16	180.52	108.8	94.104	78.7	14976	2000	275	210000	48760.4	0.29	0.55	0.980	4034.69	0.08	4316.40	3.37
RHS 450 x 250/8	450	250	8	304.38	166.3	122.54	105.7	10944	2000	275	210000	63494.6	0.22	0.53	0.996	2997.90	0.03	3488.23	7.56
RHS 450 x 250/10	450	250	10	374.55	165.4	149.95	104.8	13600	2000	275	210000	77697.2	0.22	0.53	0.996	3724.07	0.04	3780.56	0.75
RHS 450 x 250/16	450	250	16	571.64	162.5	225.06	102.2	21376	2000	275	210000	116615.8	0.22	0.53	0.995	5846.71	0.06	5912.40	0.56

Steel Grade :275		
Length(m) :	4	
E=	210000	N/mm2
Support System:	P-P	
K value:	1	

Profile	Depth h [mm]	Width b [mm]	Wall thickness t [mm]	Second moment of area Ix [×10^6 mm^4]	Radius of gyration rx [mm]	Second moment of area Iy [×10^6 mm^4]	Radius of gyration ry [mm]	Area A [mm^2]	Length Leff [mm]	Fy [N/mm2]	E [N/mm2]	Ncr kN	λ	ϕ	χ	Nb,rd kN	Aspect Ratio	Stimulation	Percentage difference,%
RHS 100 x 60/3.2	100	60	3.2	1.337	36.7	0.5989	24.6	983.04	4000	275	210000	77.6	1.87	2.42	0.253	68.39	0.05	75.85	5.18
RHS 100 x 60/6.3	100	60	6.3	2.3629	35.2	1.0244	23.3	1857.24	4000	275	210000	132.7	1.96	2.61	0.231	117.96	0.11	126.62	3.54
RHS 100 x 60/8	100	60	8	2.8268	34.4	1.2037	22.5	2304	4000	275	210000	155.9	2.02	2.72	0.220	139.19	0.13	148.44	3.22
RHS 120 x 80/4	120	80	4	3.0904	44.6	1.6364	32.5	1536	4000	275	210000	212.0	1.41	1.62	0.412	174.14	0.05	201.68	7.33
RHS 120 x 80/8	120	80	8	5.5207	42.7	2.8481	30.8	2944	4000	275	210000	368.9	1.48	1.73	0.380	307.98	0.10	350.36	6.44
RHS 120 x 80/10	120	80	10	6.52	41.8	3.32	29.9	3600	4000	275	210000	430.1	1.52	1.79	0.365	361.61	0.13	417.56	7.18
RHS 300 x 200/8	300	200	8	98.77	112.5	52.568	82.2	7744	4000	275	210000	6809.6	0.56	0.69	0.905	1926.88	0.04	2311.38	9.07
RHS 300 x 200/10	300	200	10	120.72	111.6	63.92	81.3	9600	4000	275	210000	8280.1	0.56	0.70	0.903	2383.67	0.05	2698.05	6.19
RHS 300 x 200/16	300	200	16	180.52	108.8	94.104	78.7	14976	4000	275	210000	12190.1	0.58	0.71	0.897	3694.05	0.08	4416.40	8.91
RHS 450 x 250/8	450	250	8	304.38	166.3	122.54	105.7	10944	4000	275	210000	15873.7	0.44	0.62	0.943	2838.69	0.03	3488.20	10.27
RHS 450 x 250/10	450	250	10	374.55	165.4	149.95	104.8	13600	4000	275	210000	19424.3	0.44	0.62	0.942	3524.11	0.04	4280.56	9.69
RHS 450 x 250/16	450	250	16	571.64	162.5	225.06	102.2	21376	4000	275	210000	29153.9	0.45	0.63	0.939	5522.12	0.06	5775.10	2.24

Theoretical and Numerical results of critical buckling load for steel grade S275

Steel Grade :275	
Length(m) :	4
E=	210000 N/mm2
Support System:	F-P
K value:	0.7

Profile	Depth h [mm]	Width b [mm]	Wall thickness t [mm]	Second moment of area Ix $[\times 10^6\ mm^4]$	Radius of gyration rx [mm]	Second moment of area Iy $[\times 10^6\ mm^4]$	Radius of gyration ry [mm]	Area A $[mm^2]$	Length Leff [mm]	Fy [N/mm2]	E [N/mm2]	Ncr kN	λ	ϕ	χ	Nb,rd kN	Aspect Ratio	Stimulation	Percentage difference,%
RHS 100 x 60/3.2	100	60	3.2	1.337	36.7	0.5989	24.6	983.04	2800	275	210000	158.3	1.31	1.47	0.467	126.14	0.05	154.52	10.11
RHS 100 x 60/6.3	100	60	6.3	2.3629	35.2	1.0244	23.3	1857.24	2800	275	210000	270.8	1.37	1.57	0.431	220.23	0.11	258.52	8.00
RHS 100 x 60/8	100	60	8	2.8268	34.4	1.2037	22.5	2304	2800	275	210000	318.2	1.41	1.62	0.413	261.38	0.13	303.91	7.52
RHS 120 x 80/4	120	80	4	3.0904	44.6	1.6364	32.5	1536	2800	275	210000	432.6	0.99	1.07	0.674	284.65	0.05	310.95	4.41
RHS 120 x 80/8	120	80	8	5.5207	42.7	2.8481	30.8	2944	2800	275	210000	752.9	1.04	1.13	0.640	517.94	0.10	614.32	8.51
RHS 120 x 80/10	120	80	10	6.52	41.8	3.32	29.9	3600	2800	275	210000	877.7	1.06	1.15	0.622	615.99	0.13	751.23	9.89
RHS 300 x 200/8	300	200	8	98.77	112.5	52.568	82.2	7744	2800	275	210000	13897.1	0.39	0.60	0.955	2033.81	0.04	2567.90	11.61
RHS 300 x 200/10	300	200	10	120.72	111.6	63.92	81.3	9600	2800	275	210000	16898.2	0.40	0.60	0.954	2518.64	0.05	3164.60	11.37
RHS 300 x 200/16	300	200	16	180.52	108.8	94.104	78.7	14976	2800	275	210000	24877.7	0.41	0.60	0.951	3916.47	0.08	4415.00	5.98
RHS 450 x 250/8	450	250	8	304.38	166.3	122.54	105.7	10944	2800	275	210000	32395.2	0.30	0.56	0.976	2938.48	0.03	3488.20	8.55
RHS 450 x 250/10	450	250	10	374.55	165.4	149.95	104.8	13600	2800	275	210000	39641.4	0.31	0.56	0.976	3649.55	0.04	4280.56	7.96
RHS 450 x 250/16	450	250	16	571.64	162.5	225.06	102.2	21376	2800	275	210000	59497.9	0.31	0.56	0.974	5726.28	0.06	5912.40	1.60

Steel Grade :275	
Length(m) :	4
E=	210000 N/mm2
Support System:	F-Free
K value:	2

Profile	Depth h [mm]	Width b [mm]	Wall thickness t [mm]	Second moment of area Ix $[\times 10^6\ mm^4]$	Radius of gyration rx [mm]	Second moment of area Iy $[\times 10^6\ mm^4]$	Radius of gyration ry [mm]	Area A $[mm^2]$	Length Leff [mm]	Fy [N/mm2]	E [N/mm2]	Ncr kN	λ	ϕ	χ	Nb,rd kN	Aspect Ratio	Stimulation	Percentage difference,%
RHS 100 x 60/3.2	100	60	3.2	1.337	36.7	0.5989	24.6	983.04	8000	275	210000	19.4	3.73	7.84	0.068	18.35	0.05	19.02	1.81
RHS 100 x 60/6.3	100	60	6.3	2.3629	35.2	1.0244	23.3	1857.24	8000	275	210000	33.2	3.92	8.59	0.062	31.47	0.11	31.72	0.39
RHS 100 x 60/8	100	60	8	2.8268	34.4	1.2037	22.5	2304	8000	275	210000	39.0	4.03	9.03	0.058	37.03	0.13	37.26	0.30
RHS 120 x 80/4	120	80	4	3.0904	44.6	1.6364	32.5	1536	8000	275	210000	53.0	2.82	4.76	0.116	49.15	0.05	50.61	1.46
RHS 120 x 80/8	120	80	8	5.5207	42.7	2.8481	30.8	2944	8000	275	210000	92.2	2.96	5.18	0.106	85.88	0.10	87.86	1.14
RHS 120 x 80/10	120	80	10	6.52	41.8	3.32	29.9	3600	8000	275	210000	107.5	3.03	5.40	0.101	100.30	0.13	104.74	2.17
RHS 300 x 200/8	300	200	8	98.77	112.5	52.568	82.2	7744	8000	275	210000	1702.4	1.12	1.22	0.583	1242.50	0.04	1670.56	14.69
RHS 300 x 200/10	300	200	10	120.72	111.6	63.92	81.3	9600	8000	275	210000	2070.0	1.13	1.24	0.576	1520.96	0.05	2031.13	14.36
RHS 300 x 200/16	300	200	16	180.52	108.8	94.104	78.7	14976	8000	275	210000	3047.5	1.16	1.28	0.554	2282.05	0.08	2955.62	12.86
RHS 450 x 250/8	450	250	8	304.38	166.3	122.54	105.7	10944	8000	275	210000	3968.4	0.87	0.95	0.753	2265.69	0.03	2600.54	6.88
RHS 450 x 250/10	450	250	10	374.55	165.4	149.95	104.8	13600	8000	275	210000	4856.1	0.88	0.96	0.749	2799.44	0.04	2897.79	1.73
RHS 450 x 250/16	450	250	16	571.64	162.5	225.06	102.2	21376	8000	275	210000	7288.5	0.90	0.98	0.735	4321.85	0.06	5162.51	8.86

Theoretical and Numerical results of critical buckling load for steel grade S275

Steel Grade :275		
Length(m) :	6	
E=	210000	N/mm2
Support System:	F-F	
K value:	0.5	

Profile	Depth h (mm)	Width b (mm)	Wall thickness t (mm)	Second moment of area Ix [$\times 10^6$ mm^4]	Radius of gyration rx (mm)	Second moment of area Iy [$\times 10^6$ mm^4]	Radius of gyration ry (mm)	Area A (mm^2)	Length Leff (mm)	Fy [N/mm2]	E [N/mm2]	Ncr kN	$\bar{\lambda}$	ϕ	χ	Nb,rd kN	Aspect Ratio	Stimulation	Percentage difference,%
RHS 100 x 60/3.2	100	60	3.2	1.337	36.7	0.5989	24.6	983.04	3000	275	210000	137.9	1.40	1.61	0.418	112.97	0.05	134.56	8.72
RHS 100 x 60/6.3	100	60	6.3	2.3629	35.2	1.0244	23.3	1857.24	3000	275	210000	235.9	1.47	1.72	0.385	196.52	0.11	224.95	6.75
RHS 100 x 60/8	100	60	8	2.8268	34.4	1.2037	22.5	2304	3000	275	210000	277.2	1.51	1.78	0.367	232.83	0.13	269.83	7.36
RHS 120 x 80/4	120	80	4	3.0904	44.6	1.6364	32.5	1536	3000	275	210000	376.8	1.06	1.15	0.625	263.81	0.05	368.78	16.59
RHS 120 x 80/8	120	80	8	5.5207	42.7	2.8481	30.8	2944	3000	275	210000	655.9	1.11	1.21	0.588	476.44	0.10	631.63	14.01
RHS 120 x 80/10	120	80	10	6.52	41.8	3.32	29.9	3600	3000	275	210000	764.6	1.14	1.25	0.570	564.65	0.13	741.24	13.52
RHS 300 x 200/8	300	200	8	98.77	112.5	52.568	82.2	7744	3000	275	210000	12105.9	0.42	0.61	0.948	2018.01	0.04	2416.80	8.99
RHS 300 x 200/10	300	200	10	120.72	111.6	63.92	81.3	9600	3000	275	210000	14720.2	0.42	0.61	0.946	2498.75	0.05	3785.30	20.47
RHS 300 x 200/16	300	200	16	180.52	108.8	94.104	78.7	14976	3000	275	210000	21671.3	0.44	0.62	0.943	3883.95	0.08	4770.70	10.25
RHS 450 x 250/8	450	250	8	304.38	166.3	122.54	105.7	10944	3000	275	210000	28219.8	0.33	0.57	0.971	2922.93	0.03	3215.70	4.77
RHS 450 x 250/10	450	250	10	374.55	165.4	149.95	104.8	13600	3000	275	210000	34532.1	0.33	0.57	0.971	3630.03	0.04	3822.780	2.59
RHS 450 x 250/16	450	250	16	571.64	162.5	225.06	102.2	21376	3000	275	210000	51829.2	0.34	0.57	0.969	5694.64	0.06	6318.400	5.19

Steel Grade :275		
Length(m) :	6	
E=	210000	N/mm2
Support System:	P-P	
K value:	1	

Profile	Depth h (mm)	Width b (mm)	Wall thickness t (mm)	Second moment of area Ix [$\times 10^6$ mm^4]	Radius of gyration rx (mm)	Second moment of area Iy [$\times 10^6$ mm^4]	Radius of gyration ry (mm)	Area A (mm^2)	Length Leff (mm)	Fy [N/mm2]	E [N/mm2]	Ncr kN	$\bar{\lambda}$	ϕ	λ	Nb,rd kN	Aspect Ratio	Stimulation	Percentage difference,%
RHS 100 x 60/3.2	100	60	3.2	1.337	36.7	0.5989	24.6	983.04	6000	275	210000	34.5	2.80	4.69	0.118	31.96	0.05	33.78	2.77
RHS 100 x 60/6.3	100	60	6.3	2.3629	35.2	1.0244	23.3	1857.24	6000	275	210000	59.0	2.94	5.12	0.107	54.89	0.11	56.33	1.30
RHS 100 x 60/8	100	60	8	2.8268	34.4	1.2037	22.5	2304	6000	275	210000	69.3	3.02	5.37	0.102	64.63	0.13	67.60	2.24
RHS 120 x 80/4	120	80	4	3.0904	44.6	1.6364	32.5	1536	6000	275	210000	94.2	2.12	2.94	0.201	84.70	0.05	92.88	4.61
RHS 120 x 80/8	120	80	8	5.5207	42.7	2.8481	30.8	2944	6000	275	210000	164.0	2.22	3.18	0.183	148.35	0.10	158.45	3.29
RHS 120 x 80/10	120	80	10	6.52	41.8	3.32	29.9	3600	6000	275	210000	191.1	2.28	3.31	0.175	173.44	0.13	185.92	3.47
RHS 300 x 200/8	300	200	8	98.77	112.5	52.568	82.2	7744	6000	275	210000	3026.5	0.84	0.92	0.773	1645.69	0.04	1977.15	9.15
RHS 300 x 200/10	300	200	10	120.72	111.6	63.92	81.3	9600	6000	275	210000	3680.0	0.85	0.93	0.768	2026.94	0.05	2607.16	12.52
RHS 300 x 200/16	300	200	16	180.52	108.8	94.104	78.7	14976	6000	275	210000	5417.8	0.87	0.95	0.752	3097.75	0.08	4318.18	16.46
RHS 450 x 250/8	450	250	8	304.38	166.3	122.54	105.7	10944	6000	275	210000	7055.0	0.65	0.76	0.869	2614.35	0.03	4488.20	26.38
RHS 450 x 250/10	450	250	10	374.55	165.4	149.95	104.8	13600	6000	275	210000	8633.0	0.66	0.76	0.867	3240.76	0.04	3822.77	8.24
RHS 450 x 250/16	450	250	16	571.64	162.5	225.06	102.2	21376	6000	275	210000	12957.3	0.67	0.78	0.860	5054.31	0.06	6541.30	12.82

Theoretical and Numerical results of critical buckling load for steel grade S275

Steel Grade :275		
Length(m) :	6	
E=	210000	N/mm2
Support System:	F-P	
K value:	0.7	

Profile	Depth h [mm]	Width b [mm]	Wall thickness t [mm]	Second moment of area Ix $[\times 10^6\ mm^4]$	Radius of gyration rx [mm]	Second moment of area Iy $[\times 10^6\ mm^4]$	Radius of gyration ry [mm]	Area A [mm2]	Length Leff [mm]	Fy [N/mm2]	E [N/mm2]	Ncr kN	λ	ϕ	λ	Nb,rd kN	Aspect Ratio	Stimulation	Percentage difference,%
RHS 100 x 60/3.2	100	60	3.2	1.337	36.7	0.5989	24.6	983.04	4200	275	210000	70.4	1.96	2.61	0.231	62.54	0.05	68.99	4.90
RHS 100 x 60/6.3	100	60	6.3	2.3629	35.2	1.0244	23.3	1857.24	4200	275	210000	120.4	2.06	2.82	0.211	107.79	0.11	115.17	3.31
RHS 100 x 60/8	100	60	8	2.8268	34.4	1.2037	22.5	2304	4200	275	210000	141.4	2.12	2.94	0.201	127.14	0.13	138.17	4.16
RHS 120 x 80/4	120	80	4	3.0904	44.6	1.6364	32.5	1536	4200	275	210000	192.3	1.48	1.73	0.380	160.53	0.05	189.51	8.28
RHS 120 x 80/8	120	80	8	5.5207	42.7	2.8481	30.8	2944	4200	275	210000	334.6	1.56	1.85	0.350	283.35	0.10	323.70	6.65
RHS 120 x 80/10	120	80	10	6.52	41.8	3.32	29.9	3600	4200	275	210000	390.1	1.59	1.92	0.336	332.40	0.13	379.84	6.66
RHS 300 x 200/8	300	200	8	98.77	112.5	52.568	82.2	7744	4200	275	210000	6176.5	0.59	0.71	0.895	1905.53	0.04	1992.21	2.22
RHS 300 x 200/10	300	200	10	120.72	111.6	63.92	81.3	9600	4200	275	210000	7510.3	0.59	0.72	0.893	2356.65	0.05	2957.75	11.31
RHS 300 x 200/16	300	200	16	180.52	108.8	94.104	78.7	14976	4200	275	210000	11056.8	0.61	0.73	0.886	3649.09	0.08	4679.00	12.37
RHS 450 x 250/8	450	250	8	304.38	166.3	122.54	105.7	10944	4200	275	210000	14397.9	0.46	0.63	0.937	2820.17	0.03	3788.20	14.65
RHS 450 x 250/10	450	250	10	374.55	165.4	149.95	104.8	13600	4200	275	210000	17618.4	0.46	0.63	0.936	3500.78	0.04	3822.77	4.40
RHS 450 x 250/16	450	250	16	571.64	162.5	225.06	102.2	21376	4200	275	210000	26443.5	0.47	0.64	0.933	5483.94	0.06	6318.40	7.07

Steel Grade :275		
Length(m) :	6	
E=	210000	N/mm2
Support System:	F-Free	
K value:	2	

Profile	Depth h [mm]	Width b [mm]	Wall thickness t [mm]	Second moment of area Ix $[\times 10^6\ mm^4]$	Radius of gyration rx [mm]	Second moment of area Iy $[\times 10^6\ mm^4]$	Radius of gyration ry [mm]	Area A [mm2]	Length Leff [mm]	Fy [N/mm2]	E [N/mm2]	Ncr kN	λ	ϕ	λ	Nb,rd kN	Aspect Ratio	Stimulation	Percentage difference,%
RHS 100 x 60/3.2	100	60	3.2	1.337	36.7	0.5989	24.6	983.04	12000	275	210000	8.6	5.60	16.75	0.031	8.31	0.05	8.46	0.88
RHS 100 x 60/6.3	100	60	6.3	2.3629	35.2	1.0244	23.3	1857.24	12000	275	210000	14.7	5.89	18.42	0.028	14.24	0.11	15.26	3.46
RHS 100 x 60/8	100	60	8	2.8268	34.4	1.2037	22.5	2304	12000	275	210000	17.3	6.05	19.40	0.026	16.75	0.13	16.92	0.51
RHS 120 x 80/4	120	80	4	3.0904	44.6	1.6364	32.5	1536	12000	275	210000	23.6	4.23	9.89	0.053	22.43	0.05	23.27	1.83
RHS 120 x 80/8	120	80	8	5.5207	42.7	2.8481	30.8	2944	12000	275	210000	41.0	4.44	10.82	0.048	39.14	0.10	39.68	0.69
RHS 120 x 80/10	120	80	10	6.52	41.8	3.32	29.9	3600	12000	275	210000	47.8	4.55	11.32	0.046	45.67	0.13	46.56	0.96
RHS 300 x 200/8	300	200	8	98.77	112.5	52.568	82.2	7744	12000	275	210000	756.6	1.68	2.06	0.307	652.83	0.04	752.33	7.08
RHS 300 x 200/10	300	200	10	120.72	111.6	63.92	81.3	9600	12000	275	210000	920.0	1.69	2.09	0.301	795.52	0.05	911.75	6.81
RHS 300 x 200/16	300	200	16	180.52	108.8	94.104	78.7	14976	12000	275	210000	1354.5	1.74	2.18	0.286	1178.45	0.08	1344.47	6.58
RHS 450 x 250/8	450	250	8	304.38	166.3	122.54	105.7	10944	12000	275	210000	1763.7	1.31	1.47	0.467	1404.97	0.03	1738.34	10.61
RHS 450 x 250/10	450	250	10	374.55	165.4	149.95	104.8	13600	12000	275	210000	2158.3	1.32	1.48	0.461	1725.06	0.04	2127.92	10.46
RHS 450 x 250/16	450	250	16	571.64	162.5	225.06	102.2	21376	12000	275	210000	3239.3	1.35	1.53	0.445	2614.33	0.06	3208.06	10.20

Theoretical and Numerical results of critical buckling load for steel grade S275

Steel Grade :275		
Length(m) :	8	
E=	210000	N/mm2
Support System:	F-F	
K value:	0.5	

Profile	Depth	Width	Wall thickness	Second moment of area	Radius of gyration	Second moment of area	Radius of gyration	Area	Length										
	h	b	t	Ix	rx	Iy	ry	A	Leff	Fy	E	Ncr	λ	ϕ	χ	Nb,rd	Aspect Ratio	Stimulation	Percentage difference, %
	[mm]	[mm]	[mm]	$[\times 10^6\ mm^4]$	[mm]	$[\times 10^6\ mm^4]$	[mm]	$[mm^2]$	[mm]	[N/mm2]	[N/mm2]	kN				kN			
RHS 100 x 60/3.2	100	60	3.2	1.337	36.7	0.5989	24.6	983.04	4000	275	210000	77.6	1.87	2.42	0.253	68.39	0.05	74.26	4.12
RHS 100 x 60/6.3	100	60	6.3	2.3629	35.2	1.0244	23.3	1857.24	4000	275	210000	132.7	1.96	2.61	0.231	117.96	0.11	126.70	3.57
RHS 100 x 60/8	100	60	8	2.8268	34.4	1.2037	22.5	2304	4000	275	210000	155.9	2.02	2.72	0.220	139.19	0.13	148.57	3.26
RHS 120 x 80/4	120	80	4	3.0904	44.6	1.6364	32.5	1536	4000	275	210000	212.0	1.41	1.62	0.412	174.14	0.05	208.48	8.97
RHS 120 x 80/8	120	80	8	5.5207	42.7	2.8481	30.8	2944	4000	275	210000	368.9	1.48	1.73	0.380	307.98	0.10	362.96	8.19
RHS 120 x 80/10	120	80	10	6.52	41.8	3.32	29.9	3600	4000	275	210000	430.1	1.52	1.79	0.365	361.61	0.13	417.92	7.22
RHS 300 x 200/8	300	200	8	98.77	112.5	52.568	82.2	7744	4000	275	210000	6809.6	0.56	0.69	0.905	1926.88	0.04	2791.97	18.33
RHS 300 x 200/10	300	200	10	120.72	111.6	63.92	81.3	9600	4000	275	210000	8280.1	0.56	0.70	0.903	2383.67	0.05	2744.46	7.04
RHS 300 x 200/16	300	200	16	180.52	108.8	94.104	78.7	14976	4000	275	210000	12190.1	0.58	0.71	0.897	3694.05	0.08	4415.19	8.89
RHS 450 x 250/8	450	250	8	304.38	166.3	122.54	105.7	10944	4000	275	210000	15873.7	0.44	0.62	0.943	2838.69	0.03	3488.20	10.27
RHS 450 x 250/10	450	250	10	374.55	165.4	149.95	104.8	13600	4000	275	210000	19424.3	0.44	0.62	0.942	3524.11	0.04	4280.54	9.69
RHS 450 x 250/16	450	250	16	571.64	162.5	225.06	102.2	21376	4000	275	210000	29153.9	0.45	0.63	0.939	5522.12	0.06	6306.90	6.63

Steel Grade :275		
Length(m) :	8	
E=	210000	N/mm2
Support System:	P-P	
K value:	1	

Profile	Depth	Width	Wall thickness	Second moment of area	Radius of gyration	Second moment of area	Radius of gyration	Area	Length										
	h	b	t	Ix	rx	Iy	ry	A	Leff	Fy	E	Ncr	λ	ϕ	χ	Nb,rd	Aspect Ratio	Stimulation	Percentage difference, %
	[mm]	[mm]	[mm]	$[\times 10^6\ mm^4]$	[mm]	$[\times 10^6\ mm^4]$	[mm]	$[mm^2]$	[mm]	[N/mm2]	[N/mm2]	kN				kN			
RHS 100 x 60/3.2	100	60	3.2	1.337	36.7	0.5989	24.6	983.04	8000	275	210000	19.4	3.73	7.84	0.068	18.35	0.05	18.58	0.63
RHS 100 x 60/6.3	100	60	6.3	2.3629	35.2	1.0244	23.3	1857.24	8000	275	210000	33.2	3.92	8.59	0.062	31.47	0.11	31.70	0.36
RHS 100 x 60/8	100	60	8	2.8268	34.4	1.2037	22.5	2304	8000	275	210000	39.0	4.03	9.03	0.058	37.03	0.13	37.15	0.16
RHS 120 x 80/4	120	80	4	3.0904	44.6	1.6364	32.5	1536	8000	275	210000	53.0	2.82	4.76	0.116	49.15	0.05	52.30	3.10
RHS 120 x 80/8	120	80	8	5.5207	42.7	2.8481	30.8	2944	8000	275	210000	92.2	2.96	5.18	0.106	85.88	0.10	90.93	2.85
RHS 120 x 80/10	120	80	10	6.52	41.8	3.32	29.9	3600	8000	275	210000	107.5	3.03	5.40	0.101	100.30	0.13	104.65	2.12
RHS 300 x 200/8	300	200	8	98.77	112.5	52.568	82.2	7744	8000	275	210000	1702.4	1.12	1.22	0.583	1242.50	0.04	1587.54	12.19
RHS 300 x 200/10	300	200	10	120.72	111.6	63.92	81.3	9600	8000	275	210000	2070.0	1.13	1.24	0.576	1520.96	0.05	1926.60	11.77
RHS 300 x 200/16	300	200	16	180.52	108.8	94.104	78.7	14976	8000	275	210000	3047.5	1.16	1.28	0.554	2282.05	0.08	2698.31	8.36
RHS 450 x 250/8	450	250	8	304.38	166.3	122.54	105.7	10944	8000	275	210000	3968.4	0.87	0.95	0.753	2265.69	0.03	2767.66	9.97
RHS 450 x 250/10	450	250	10	374.55	165.4	149.95	104.8	13600	8000	275	210000	4856.1	0.88	0.96	0.749	2799.44	0.04	3462.53	10.59
RHS 450 x 250/16	450	250	16	571.64	162.5	225.06	102.2	21376	8000	275	210000	7288.5	0.90	0.98	0.735	4321.85	0.06	5145.88	8.70

Theoretical and Numerical results of critical buckling load for steel grade S275

Steel Grade :275		
Length(m) :	8	
E=	210000	N/mm2
Support System:	F-P	
K value:	0.7	

Profile	Depth h [mm]	Width b [mm]	Wall thickness t [mm]	Second moment of area Ix $[\times 10^6\ mm^4]$	Radius of gyration rx [mm]	Second moment of area Iy $[\times 10^6\ mm^4]$	Radius of gyration ry [mm]	Area A $[mm^2]$	Length Leff [mm]	Fy [N/mm2]	E [N/mm2]	Ncr kN	$\boxed{\bar{\lambda}}$	$\boxed{\phi}$	$\boxed{\chi}$	Nb,rd kN	Aspect Ratio	Stimulation	Percentage difference, %
RHS 100 x 60/3.2	100	60	3.2	1.337	36.7	0.5989	24.6	983.04	5600	275	210000	39.6	2.61	4.17	0.135	36.46	0.05	38.00	2.07
RHS 100 x 60/6.3	100	60	6.3	2.3629	35.2	1.0244	23.3	1857.24	5600	275	210000	67.7	2.75	4.54	0.123	62.64	0.11	64.83	1.72
RHS 100 x 60/8	100	60	8	2.8268	34.4	1.2037	22.5	2304	5600	275	210000	79.6	2.82	4.76	0.116	73.78	0.13	75.99	1.48
RHS 120 x 80/4	120	80	4	3.0904	44.6	1.6364	32.5	1536	5600	275	210000	108.2	1.98	2.64	0.228	96.25	0.05	106.85	5.22
RHS 120 x 80/8	120	80	8	5.5207	42.7	2.8481	30.8	2944	5600	275	210000	188.2	2.07	2.85	0.208	168.73	0.10	185.96	4.86
RHS 120 x 80/10	120	80	10	6.52	41.8	3.32	29.9	3600	5600	275	210000	219.4	2.12	2.96	0.199	197.35	0.13	213.95	4.04
RHS 300 x 200/8	300	200	8	98.77	112.5	52.568	82.2	7744	5600	275	210000	3474.3	0.78	0.87	0.805	1715.00	0.04	2421.34	17.08
RHS 300 x 200/10	300	200	10	120.72	111.6	63.92	81.3	9600	5600	275	210000	4224.5	0.79	0.87	0.801	2114.84	0.05	2687.21	11.92
RHS 300 x 200/16	300	200	16	180.52	108.8	94.104	78.7	14976	5600	275	210000	6219.4	0.81	0.90	0.788	3244.28	0.08	3785.22	7.70
RHS 450 x 250/8	450	250	8	304.38	166.3	122.54	105.7	10944	5600	275	210000	8098.8	0.61	0.73	0.886	2667.47	0.03	3488.20	13.33
RHS 450 x 250/10	450	250	10	374.55	165.4	149.95	104.8	13600	5600	275	210000	9910.4	0.61	0.73	0.884	3307.98	0.04	4280.54	12.82
RHS 450 x 250/16	450	250	16	571.64	162.5	225.06	102.2	21376	5600	275	210000	14874.5	0.63	0.74	0.879	5165.94	0.06	5331.50	1.58

Steel Grade :275		
Length(m) :	8	
E=	210000	N/mm2
Support System:	F-Free	
K value:	2	

Profile	Depth h [mm]	Width b [mm]	Wall thickness t [mm]	Second moment of area Ix $[\times 10^6\ mm^4]$	Radius of gyration rx [mm]	Second moment of area Iy $[\times 10^6\ mm^4]$	Radius of gyration ry [mm]	Area A $[mm^2]$	Length Leff [mm]	Fy [N/mm2]	E [N/mm2]	Ncr kN	$\boxed{\bar{\lambda}}$	$\boxed{\phi}$	$\boxed{\chi}$	Nb,rd kN	Aspect Ratio	Stimulation	Percentage difference, %
RHS 100 x 60/3.2	100	60	3.2	1.337	36.7	0.5989	24.6	983.04	16000	275	210000	4.8	7.47	29.14	0.017	4.72	0.05	5.65	8.99
RHS 100 x 60/6.3	100	60	6.3	2.3629	35.2	1.0244	23.3	1857.24	16000	275	210000	8.3	7.85	32.09	0.016	8.08	0.11	9.93	10.27
RHS 100 x 60/8	100	60	8	2.8268	34.4	1.2037	22.5	2304	16000	275	210000	9.7	8.06	33.83	0.015	9.50	0.13	9.30	-1.07
RHS 120 x 80/4	120	80	4	3.0904	44.6	1.6364	32.5	1536	16000	275	210000	13.2	5.65	17.01	0.030	12.78	0.05	13.09	1.22
RHS 120 x 80/8	120	80	8	5.5207	42.7	2.8481	30.8	2944	16000	275	210000	23.1	5.93	18.66	0.028	22.27	0.10	22.76	1.08
RHS 120 x 80/10	120	80	10	6.52	41.8	3.32	29.9	3600	16000	275	210000	26.9	6.07	19.53	0.026	25.99	0.13	26.19	0.39
RHS 300 x 200/8	300	200	8	98.77	112.5	52.568	82.2	7744	16000	275	210000	425.6	2.24	3.22	0.181	385.38	0.04	424.55	4.84
RHS 300 x 200/10	300	200	10	120.72	111.6	63.92	81.3	9600	16000	275	210000	517.5	2.26	3.27	0.178	469.16	0.05	510.82	4.25
RHS 300 x 200/16	300	200	16	180.52	108.8	94.104	78.7	14976	16000	275	210000	761.9	2.32	3.43	0.168	693.09	0.08	753.94	4.21
RHS 450 x 250/8	450	250	8	304.38	166.3	122.54	105.7	10944	16000	275	210000	992.1	1.74	2.18	0.287	862.98	0.03	983.60	6.53
RHS 450 x 250/10	450	250	10	374.55	165.4	149.95	104.8	13600	16000	275	210000	1214.0	1.76	2.20	0.283	1057.68	0.04	1202.06	6.39
RHS 450 x 250/16	450	250	16	571.64	162.5	225.06	102.2	21376	16000	275	210000	1822.1	1.80	2.28	0.271	1594.75	0.06	1630.90	1.12

Theoretical and Numerical results of critical buckling load for steel grade S275

Eurocode 3

Steel Grade :355		
Length(m) :	4	
E=	210000	N/mm2
Support System:	F-F	
K value:	0.5	

Profile	Depth h [mm]	Width b [mm]	Wall thickness t [mm]	Second moment of area Ix $[\times 10^6\ mm^4]$	Radius of gyration rx [mm]	Second moment of area Iy $[\times 10^6\ mm^4]$	Radius of gyration ry [mm]	Area A $[mm^2]$	Length Leff [mm]	Fy [N/mm2]	E [N/mm2]	Ncr kN	λ	ϕ	λ	Nb,rd kN	Stimulation kN	Aspect Ratio,t/B	Percentage Difference,%
RHS 100 x 60/3.2	100	60	3.2	1.337	36.7	0.5989	24.6	983.04	2000	355	210000	310.3	1.06	1.15	0.623	217.53	245.14	0.05	5.97
RHS 100 x 60/6.3	100	60	6.3	2.3629	35.2	1.0244	23.3	1857.24	2000	355	210000	530.8	1.11	1.22	0.586	386.44	415.14	0.11	3.58
RHS 100 x 60/8	100	60	8	2.8268	34.4	1.2037	22.5	2304	2000	355	210000	623.7	1.15	1.25	0.566	462.56	478.26	0.13	1.67
RHS 120 x 80/4	120	80	4	3.0904	44.6	1.6364	32.5	1536	2000	355	210000	847.9	0.80	0.88	0.795	433.28	450.55	0.05	1.95
RHS 120 x 80/8	120	80	8	5.5207	42.7	2.8481	30.8	2944	2000	355	210000	1475.8	0.84	0.92	0.771	805.91	817.61	0.10	0.72
RHS 120 x 80/10	120	80	10	6.52	41.8	3.32	29.9	3600	2000	355	210000	1720.3	0.86	0.94	0.758	969.33	981.03	0.13	0.60
RHS 300 x 200/8	300	200	8	98.77	112.5	52.568	82.2	7744	2000	355	210000	27238.3	0.32	0.56	0.973	2675.78	2687.48	0.04	0.22
RHS 300 x 200/10	300	200	10	120.72	111.6	63.92	81.3	9600	2000	355	210000	33120.4	0.32	0.56	0.973	3314.58	3326.28	0.05	0.18
RHS 300 x 200/16	300	200	16	180.52	108.8	94.104	78.7	14976	2000	355	210000	48760.4	0.33	0.57	0.970	5158.74	5170.44	0.08	0.11
RHS 450 x 250/8	450	250	8	304.38	166.3	122.54	105.7	10944	2000	355	210000	63494.6	0.25	0.54	0.990	3844.42	3850.12	0.03	0.07
RHS 450 x 250/10	450	250	10	374.55	165.4	149.95	104.8	13600	2000	355	210000	77697.2	0.25	0.54	0.989	4775.35	4801.05	0.04	0.27
RHS 450 x 250/16	450	250	16	571.64	162.5	225.06	102.2	21376	2000	355	210000	116615.8	0.26	0.54	0.988	7495.80	7511.50	0.06	0.10

Steel Grade :355		
Length(m) :	4	
E=	210000	N/mm2
Support System:	P-P	
K value:	1	

Profile	Depth h [mm]	Width b [mm]	Wall thickness t [mm]	Second moment of area Ix $[\times 10^6\ mm^4]$	Radius of gyration rx [mm]	Second moment of area Iy $[\times 10^6\ mm^4]$	Radius of gyration ry [mm]	Area A $[mm^2]$	Length Leff [mm]	Fy [N/mm2]	E [N/mm2]	Ncr kN	λ	ϕ	λ	Nb,rd kN	Stimulation kN	Aspect Ratio,t/B	Percentage Difference,%
RHS 100 x 60/3.2	100	60	3.2	1.337	36.7	0.5989	24.6	983.04	4000	355	210000	77.6	2.12	2.95	0.200	69.76	77.99	0.05	5.57
RHS 100 x 60/6.3	100	60	6.3	2.3629	35.2	1.0244	23.3	1857.24	4000	355	210000	132.7	2.23	3.20	0.182	120.11	128.34	0.11	3.31
RHS 100 x 60/8	100	60	8	2.8268	34.4	1.2037	22.5	2304	4000	355	210000	155.9	2.29	3.34	0.173	141.60	149.83	0.13	2.82
RHS 120 x 80/4	120	80	4	3.0904	44.6	1.6364	32.5	1536	4000	355	210000	212.0	1.60	1.93	0.332	180.94	189.17	0.05	2.22
RHS 120 x 80/8	120	80	8	5.5207	42.7	2.8481	30.8	2944	4000	355	210000	368.9	1.68	2.07	0.305	318.56	326.79	0.10	1.28
RHS 120 x 80/10	120	80	10	6.52	41.8	3.32	29.9	3600	4000	355	210000	430.1	1.72	2.15	0.292	373.28	381.51	0.13	1.09
RHS 300 x 200/8	300	200	8	98.77	112.5	52.568	82.2	7744	4000	355	210000	6809.6	0.64	0.75	0.876	2408.42	2416.65	0.04	0.17
RHS 300 x 200/10	300	200	10	120.72	111.6	63.92	81.3	9600	4000	355	210000	8280.1	0.64	0.75	0.874	2976.99	2985.22	0.05	0.14
RHS 300 x 200/16	300	200	16	180.52	108.8	94.104	78.7	14976	4000	355	210000	12190.1	0.66	0.77	0.866	4601.75	4609.98	0.08	0.09
RHS 450 x 250/8	450	250	8	304.38	166.3	122.54	105.7	10944	4000	355	210000	15873.7	0.49	0.65	0.926	3597.24	3605.47	0.03	0.11
RHS 450 x 250/10	450	250	10	374.55	165.4	149.95	104.8	13600	4000	355	210000	19424.3	0.50	0.66	0.925	4464.55	4482.78	0.04	0.20
RHS 450 x 250/16	450	250	16	571.64	162.5	225.06	102.2	21376	4000	355	210000	29153.9	0.51	0.66	0.921	6989.60	7012.83	0.06	0.17

Theoretical and Numerical results of critical buckling load for steel grade S355

Steel Grade :355		
Length(m) :	4	
E=	210000	N/mm2
Support System:	F-P	
K value:	0.7	

Profile	Depth h [mm]	Width b [mm]	Wall thickness t [mm]	Second moment of area Ix [×10⁶ mm⁴]	Radius of gyration rx [mm]	Second moment of area Iy [×10⁶ mm⁴]	Radius of gyration ry [mm]	Area A [mm²]	Length Leff [mm]	Fy [N/mm2]	E [N/mm2]	Ncr kN	λ	ϕ	χ	Nb,rd kN	Stimulation kN	Aspect Ratio,t/B	Percentage Difference,%
RHS 100 x 60/3.2	100	60	3.2	1.337	36.7	0.5989	24.6	983.04	2800	355	210000	158.3	1.48	1.74	0.379	132.26	146.49	0.05	5.10
RHS 100 x 60/6.3	100	60	6.3	2.3629	35.2	1.0244	23.3	1857.24	2800	355	210000	270.8	1.56	1.86	0.348	229.51	243.73	0.11	3.01
RHS 100 x 60/8	100	60	8	2.8268	34.4	1.2037	22.5	2304	2800	355	210000	318.2	1.60	1.93	0.332	271.60	285.82	0.13	2.55
RHS 120 x 80/4	120	80	4	3.0904	44.6	1.6364	32.5	1536	2800	355	210000	432.6	1.12	1.23	0.581	316.58	320.80	0.05	0.66
RHS 120 x 80/8	120	80	8	5.5207	42.7	2.8481	30.8	2944	2800	355	210000	752.9	1.18	1.30	0.544	568.48	572.70	0.10	0.37
RHS 120 x 80/10	120	80	10	6.52	41.8	3.32	29.9	3600	2800	355	210000	877.7	1.21	1.33	0.526	671.96	676.18	0.13	0.31
RHS 300 x 200/8	300	200	8	98.77	112.5	52.568	82.2	7744	2800	355	210000	13897.1	0.44	0.62	0.941	2585.82	2604.04	0.04	0.35
RHS 300 x 200/10	300	200	10	120.72	111.6	63.92	81.3	9600	2800	355	210000	16898.2	0.45	0.63	0.939	3201.40	3219.62	0.05	0.28
RHS 300 x 200/16	300	200	16	180.52	108.8	94.104	78.7	14976	2800	355	210000	24877.7	0.46	0.63	0.936	4974.05	4992.27	0.08	0.18
RHS 450 x 250/8	450	250	8	304.38	166.3	122.54	105.7	10944	2800	355	210000	32395.2	0.35	0.58	0.966	3754.64	3782.86	0.03	0.37
RHS 450 x 250/10	450	250	10	374.55	165.4	149.95	104.8	13600	2800	355	210000	39641.4	0.35	0.58	0.966	4662.67	4680.90	0.04	0.20
RHS 450 x 250/16	450	250	16	571.64	162.5	225.06	102.2	21376	2800	355	210000	59497.9	0.36	0.58	0.964	7313.34	7331.56	0.06	0.12

Steel Grade :355		
Length(m) :	4	
E=	210000	N/mm2
Support System:	F-Free	
K value:	2	

Profile	Depth h [mm]	Width b [mm]	Wall thickness t [mm]	Second moment of area Ix [×10⁶ mm⁴]	Radius of gyration rx [mm]	Second moment of area Iy [×10⁶ mm⁴]	Radius of gyration ry [mm]	Area A [mm²]	Length Leff [mm]	Fy [N/mm2]	E [N/mm2]	Ncr kN	λ	ϕ	χ	Nb,rd kN	Stimulation kN	Aspect Ratio,t/B	Percentage Difference,%
RHS 100 x 60/3.2	100	60	3.2	1.337	36.7	0.5989	24.6	983.04	8000	355	210000	19.4	4.24	9.92	0.053	18.47	19.67	0.05	3.15
RHS 100 x 60/6.3	100	60	6.3	2.3629	35.2	1.0244	23.3	1857.24	8000	355	210000	33.2	4.46	10.88	0.048	31.68	32.88	0.11	1.86
RHS 100 x 60/8	100	60	8	2.8268	34.4	1.2037	22.5	2304	8000	355	210000	39.0	4.58	11.45	0.046	37.27	38.47	0.13	1.58
RHS 120 x 80/4	120	80	4	3.0904	44.6	1.6364	32.5	1536	8000	355	210000	53.0	3.21	5.96	0.091	49.64	50.84	0.05	1.19
RHS 120 x 80/8	120	80	8	5.5207	42.7	2.8481	30.8	2944	8000	355	210000	92.2	3.37	6.50	0.083	86.69	87.89	0.10	0.69
RHS 120 x 80/10	120	80	10	6.52	41.8	3.32	29.9	3600	8000	355	210000	107.5	3.45	6.78	0.079	101.21	102.41	0.13	0.59
RHS 300 x 200/8	300	200	8	98.77	112.5	52.568	82.2	7744	8000	355	210000	1702.4	1.27	1.42	0.487	1338.93	1340.13	0.04	0.04
RHS 300 x 200/10	300	200	10	120.72	111.6	63.92	81.3	9600	8000	355	210000	2070.0	1.28	1.44	0.480	1635.56	1636.76	0.05	0.04
RHS 300 x 200/16	300	200	16	180.52	108.8	94.104	78.7	14976	8000	355	210000	3047.5	1.32	1.49	0.459	2439.37	2440.57	0.08	0.02
RHS 450 x 250/8	450	250	8	304.38	166.3	122.54	105.7	10944	8000	355	210000	3968.4	0.99	1.07	0.673	2614.57	2615.77	0.03	0.02
RHS 450 x 250/10	450	250	10	374.55	165.4	149.95	104.8	13600	8000	355	210000	4856.1	1.00	1.08	0.668	3223.30	3224.50	0.04	0.02
RHS 450 x 250/16	450	250	16	571.64	162.5	225.06	102.2	21376	8000	355	210000	7288.5	1.02	1.11	0.651	4942.72	4943.92	0.06	0.01

Theoretical and Numerical results of critical buckling load for steel grade S355

Steel Grade :355		
Length(m) :	6	
E=	210000	N/mm2
Support System:	F-F	
K value:	0.5	

Profile	Depth	Width	Wall thickness	Second moment of area	Radius of gyration	Second moment of area	Radius of gyration	Area	Length										
	h	b	t	Ix	rx	Iy	ry	A	Leff	Fy	E	Ncr	λ	ϕ	χ	Nb,rd	Stimulation	Aspect Ratio,t/B	Percentage Difference,%
	[mm]	[mm]	[mm]	$[\times 10^6 mm^4]$	[mm]	$[\times 10^6 mm^4]$	[mm]	$[mm^2]$	[mm]	[N/mm2]	[N/mm2]	kN				kN	kN		
RHS 100 x 60/3.2	100	60	3.2	1.337	36.7	0.5989	24.6	983.04	3000	355	210000	137.9	1.59	1.91	0.337	117.48	147.70	0.05	11.40
RHS 100 x 60/6.3	100	60	6.3	2.3629	35.2	1.0244	23.3	1857.24	3000	355	210000	235.9	1.67	2.05	0.308	203.38	233.60	0.11	6.92
RHS 100 x 60/8	100	60	8	2.8268	34.4	1.2037	22.5	2304	3000	355	210000	277.2	1.72	2.13	0.294	240.42	302.64	0.13	11.46
RHS 120 x 80/4	120	80	4	3.0904	44.6	1.6364	32.5	1536	3000	355	210000	376.8	1.20	1.33	0.528	288.00	318.22	0.05	4.98
RHS 120 x 80/8	120	80	8	5.5207	42.7	2.8481	30.8	2944	3000	355	210000	655.9	1.26	1.41	0.492	514.19	557.26	0.10	4.02
RHS 120 x 80/10	120	80	10	6.52	41.8	3.32	29.9	3600	3000	355	210000	764.6	1.29	1.45	0.474	606.22	676.44	0.13	5.47
RHS 300 x 200/8	300	200	8	98.77	112.5	52.568	82.2	7744	3000	355	210000	12105.9	0.48	0.64	0.931	2560.53	2590.75	0.04	0.59
RHS 300 x 200/10	300	200	10	120.72	111.6	63.92	81.3	9600	3000	355	210000	14720.2	0.48	0.65	0.930	3169.51	3199.73	0.05	0.47
RHS 300 x 200/16	300	200	16	180.52	108.8	94.104	78.7	14976	3000	355	210000	21671.3	0.50	0.65	0.926	4921.60	4951.82	0.08	0.31
RHS 450 x 250/8	450	250	8	304.38	166.3	122.54	105.7	10944	3000	355	210000	28219.8	0.37	0.59	0.960	3730.70	3760.92	0.03	0.40
RHS 450 x 250/10	450	250	10	374.55	165.4	149.95	104.8	13600	3000	355	210000	34532.1	0.37	0.59	0.960	4632.59	4762.88	0.04	1.39
RHS 450 x 250/16	450	250	16	571.64	162.5	225.06	102.2	21376	3000	355	210000	51829.2	0.38	0.59	0.957	7264.44	7294.66	0.06	0.21

Steel Grade :355		
Length(m) :	6	
E=	210000	N/mm2
Support System:	P-P	
K value:	1	

Profile	Depth	Width	Wall thickness	Second moment of area	Radius of gyration	Second moment of area	Radius of gyration	Area	Length										
	h	b	t	Ix	rx	Iy	ry	A	Leff	Fy	E	Ncr	λ	ϕ	χ	Nb,rd	Stimulation	Aspect Ratio,t/B	Percentage Difference,%
	[mm]	[mm]	[mm]	$[\times 10^6 mm^4]$	[mm]	$[\times 10^6 mm^4]$	[mm]	$[mm^2]$	[mm]	[N/mm2]	[N/mm2]	kN				kN	kN		
RHS 100 x 60/3.2	100	60	3.2	1.337	36.7	0.5989	24.6	983.04	6000	355	210000	34.5	3.18	5.87	0.092	32.28	62.50	0.05	31.88
RHS 100 x 60/6.3	100	60	6.3	2.3629	35.2	1.0244	23.3	1857.24	6000	355	210000	59.0	3.34	6.42	0.084	55.41	65.62	0.11	8.44
RHS 100 x 60/8	100	60	8	2.8268	34.4	1.2037	22.5	2304	6000	355	210000	69.3	3.44	6.74	0.080	65.22	77.26	0.13	8.45
RHS 120 x 80/4	120	80	4	3.0904	44.6	1.6364	32.5	1536	6000	355	210000	94.2	2.41	3.63	0.158	86.04	95.05	0.05	4.98
RHS 120 x 80/8	120	80	8	5.5207	42.7	2.8481	30.8	2944	6000	355	210000	164.0	2.52	3.93	0.144	150.51	160.73	0.10	3.28
RHS 120 x 80/10	120	80	10	6.52	41.8	3.32	29.9	3600	6000	355	210000	191.1	2.59	4.09	0.138	175.86	186.08	0.13	2.82
RHS 300 x 200/8	300	200	8	98.77	112.5	52.568	82.2	7744	6000	355	210000	3026.5	0.95	1.03	0.698	1919.36	1929.58	0.04	0.27
RHS 300 x 200/10	300	200	10	120.72	111.6	63.92	81.3	9600	6000	355	210000	3680.0	0.96	1.04	0.692	2357.65	2367.87	0.05	0.22
RHS 300 x 200/16	300	200	16	180.52	108.8	94.104	78.7	14976	6000	355	210000	5417.8	0.99	1.07	0.672	3573.55	3575.23	0.08	0.02
RHS 450 x 250/8	450	250	8	304.38	166.3	122.54	105.7	10944	6000	355	210000	7055.0	0.74	0.83	0.827	3213.34	3223.56	0.03	0.16
RHS 450 x 250/10	450	250	10	374.55	165.4	149.95	104.8	13600	6000	355	210000	8633.0	0.75	0.84	0.824	3978.91	3992.55	0.04	0.17
RHS 450 x 250/16	450	250	16	571.64	162.5	225.06	102.2	21376	6000	355	210000	12957.3	0.77	0.85	0.815	6184.11	6194.33	0.06	0.08

Theoretical and Numerical results of critical buckling load for steel grade S355

Steel Grade :355		
Length(m) :	6	
E=	210000	N/mm2
Support System :	F-P	
K value:	0.7	

Profile	Depth h [mm]	Width b [mm]	Wall thickness t [mm]	Second moment of area Ix [$\times 10^6$ mm^4]	Radius of gyration rx [mm]	Second moment of area Iy [$\times 10^6$ mm^4]	Radius of gyration ry [mm]	Area A [mm^2]	Length Leff [mm]	Fy [N/mm2]	E [N/mm2]	Ncr kN	λ	ϕ	λ	Nb,rd kN	Stimulation kN	Aspect Ratio,t/B	Percentage Difference, %
RHS 100 x 60/3.2	100	60	3.2	1.337	36.7	0.5989	24.6	983.04	4200	355	210000	70.4	2.23	3.19	0.182	63.68	73.90	0.05	7.43
RHS 100 x 60/6.3	100	60	6.3	2.3629	35.2	1.0244	23.3	1857.24	4200	355	210000	120.4	2.34	3.46	0.166	109.58	119.80	0.11	4.46
RHS 100 x 60/8	100	60	8	2.8268	34.4	1.2037	22.5	2304	4200	355	210000	141.4	2.40	3.62	0.158	129.15	139.37	0.13	3.81
RHS 120 x 80/4	120	80	4	3.0904	44.6	1.6364	32.5	1536	4200	355	210000	192.3	1.68	2.07	0.304	166.04	176.26	0.05	2.99
RHS 120 x 80/8	120	80	8	5.5207	42.7	2.8481	30.8	2944	4200	355	210000	334.6	1.77	2.23	0.279	291.95	295.17	0.10	0.55
RHS 120 x 80/10	120	80	10	6.52	41.8	3.32	29.9	3600	4200	355	210000	390.1	1.81	2.31	0.268	341.91	352.13	0.13	1.47
RHS 300 x 200/8	300	200	8	98.77	112.5	52.568	82.2	7744	4200	355	210000	6176.5	0.67	0.77	0.863	2371.48	2377.88	0.04	0.13
RHS 300 x 200/10	300	200	10	120.72	111.6	63.92	81.3	9600	4200	355	210000	7510.3	0.67	0.78	0.860	2930.12	2934.16	0.05	0.07
RHS 300 x 200/16	300	200	16	180.52	108.8	94.104	78.7	14976	4200	355	210000	11056.8	0.69	0.79	0.851	4523.29	4533.51	0.08	0.11
RHS 450 x 250/8	450	250	8	304.38	166.3	122.54	105.7	10944	4200	355	210000	14397.9	0.52	0.67	0.918	3567.01	3582.23	0.03	0.21
RHS 450 x 250/10	450	250	10	374.55	165.4	149.95	104.8	13600	4200	355	210000	17618.4	0.52	0.67	0.917	4426.42	4432.64	0.04	0.07
RHS 450 x 250/16	450	250	16	571.64	162.5	225.06	102.2	21376	4200	355	210000	26443.5	0.54	0.68	0.913	6926.85	6937.07	0.06	0.07

Steel Grade :355		
Length(m) :	6	
E=	210000	N/mm2
Support System :	F-Free	
K value:	2	

Profile	Depth h [mm]	Width b [mm]	Wall thickness t [mm]	Second moment of area Ix [$\times 10^6$ mm^4]	Radius of gyration rx [mm]	Second moment of area Iy [$\times 10^6$ mm^4]	Radius of gyration ry [mm]	Area A [mm^2]	Length Leff [mm]	Fy [N/mm2]	E [N/mm2]	Ncr kN	λ	ϕ	λ	Nb,rd kN	Stimulation kN	Aspect Ratio,t/B	Percentage Difference, %
RHS 100 x 60/3.2	100	60	3.2	1.337	36.7	0.5989	24.6	983.04	12000	355	210000	8.6	6.36	21.39	0.024	8.35	18.57	0.05	37.97
RHS 100 x 60/6.3	100	60	6.3	2.3629	35.2	1.0244	23.3	1857.24	12000	355	210000	14.7	6.69	23.54	0.022	14.30	24.52	0.11	26.33
RHS 100 x 60/8	100	60	8	2.8268	34.4	1.2037	22.5	2304	12000	355	210000	17.3	6.87	24.81	0.021	16.82	27.04	0.13	23.31
RHS 120 x 80/4	120	80	4	3.0904	44.6	1.6364	32.5	1536	12000	355	210000	23.6	4.81	12.56	0.041	22.57	32.79	0.05	18.46
RHS 120 x 80/8	120	80	8	5.5207	42.7	2.8481	30.8	2944	12000	355	210000	41.0	5.05	13.76	0.038	39.36	49.58	0.10	11.49
RHS 120 x 80/10	120	80	10	6.52	41.8	3.32	29.9	3600	12000	355	210000	47.8	5.17	14.39	0.036	45.93	50.15	0.13	4.39
RHS 300 x 200/8	300	200	8	98.77	112.5	52.568	82.2	7744	12000	355	210000	756.6	1.91	2.50	0.243	669.37	679.59	0.04	0.76
RHS 300 x 200/10	300	200	10	120.72	111.6	63.92	81.3	9600	12000	355	210000	920.0	1.92	2.53	0.239	815.24	825.46	0.05	0.62
RHS 300 x 200/16	300	200	16	180.52	108.8	94.104	78.7	14976	12000	355	210000	1354.5	1.98	2.65	0.227	1205.84	1213.06	0.08	0.30
RHS 450 x 250/8	450	250	8	304.38	166.3	122.54	105.7	10944	12000	355	210000	1763.7	1.48	1.74	0.379	1473.21	1491.43	0.03	0.61
RHS 450 x 250/10	450	250	10	374.55	165.4	149.95	104.8	13600	12000	355	210000	2158.3	1.50	1.75	0.374	1807.00	1819.22	0.04	0.34
RHS 450 x 250/16	450	250	16	571.64	162.5	225.06	102.2	21376	12000	355	210000	3239.3	1.53	1.81	0.360	2730.57	2748.79	0.06	0.33

Theoretical and Numerical results of critical buckling load for steel grade S355

Steel Grade :355		
Length(m) :	8	
E=	210000	N/mm2
Support System:	F-F	
K value:	0.5	

Profile	Depth h [mm]	Width b [mm]	Wall thickness t [mm]	Second moment of area Ix $[\times 10^6\ mm^4]$	Radius of gyration rx [mm]	Second moment of area Iy $[\times 10^6\ mm^4]$	Radius of gyration ry [mm]	Area A $[mm^2]$	Length Leff [mm]	Fy [N/mm2]	E [N/mm2]	Ncr kN	λ	ϕ	χ	Nb,rd kN	Stimulation kN	Aspect Ratio,t/B	Percentage Difference,%
RHS 100 x 60/3.2	100	60	3.2	1.337	36.7	0.5989	24.6	983.04	4000	355	210000	77.6	2.12	2.95	0.200	69.76	84.30	0.05	9.44
RHS 100 x 60/6.3	100	60	6.3	2.3629	35.2	1.0244	23.3	1857.24	4000	355	210000	132.7	2.23	3.20	0.182	120.11	134.65	0.11	5.71
RHS 100 x 60/8	100	60	8	2.8268	34.4	1.2037	22.5	2304	4000	355	210000	155.9	2.29	3.34	0.173	141.60	156.14	0.13	4.88
RHS 120 x 80/4	120	80	4	3.0904	44.6	1.6364	32.5	1536	4000	355	210000	212.0	1.60	1.93	0.332	180.94	189.48	0.05	2.31
RHS 120 x 80/8	120	80	8	5.5207	42.7	2.8481	30.8	2944	4000	355	210000	368.9	1.68	2.07	0.305	318.56	327.10	0.10	1.32
RHS 120 x 80/10	120	80	10	6.52	41.8	3.32	29.9	3600	4000	355	210000	430.1	1.72	2.15	0.292	373.28	381.82	0.13	1.13
RHS 300 x 200/8	300	200	8	98.77	112.5	52.568	82.2	7744	4000	355	210000	6809.6	0.64	0.75	0.876	2408.42	2416.96	0.04	0.18
RHS 300 x 200/10	300	200	10	120.72	111.6	63.92	81.3	9600	4000	355	210000	8280.1	0.64	0.75	0.874	2976.99	3005.53	0.05	0.48
RHS 300 x 200/16	300	200	16	180.52	108.8	94.104	78.7	14976	4000	355	210000	12190.1	0.66	0.77	0.866	4601.75	4630.29	0.08	0.31
RHS 450 x 250/8	450	250	8	304.38	166.3	122.54	105.7	10944	4000	355	210000	15873.7	0.49	0.65	0.926	3597.24	3625.78	0.03	0.40
RHS 450 x 250/10	450	250	10	374.55	165.4	149.95	104.8	13600	4000	355	210000	19424.3	0.50	0.66	0.925	4464.55	4473.09	0.04	0.10
RHS 450 x 250/16	450	250	16	571.64	162.5	225.06	102.2	21376	4000	355	210000	29153.9	0.51	0.66	0.921	6989.60	6998.14	0.06	0.06

Steel Grade :355		
Length(m) :	8	
E=	210000	N/mm2
Support System:	P-P	
K value:	1	

Profile	Depth h [mm]	Width b [mm]	Wall thickness t [mm]	Second moment of area Ix $[\times 10^6\ mm^4]$	Radius of gyration rx [mm]	Second moment of area Iy $[\times 10^6\ mm^4]$	Radius of gyration ry [mm]	Area A $[mm^2]$	Length Leff [mm]	Fy [N/mm2]	E [N/mm2]	Ncr kN	λ	ϕ	χ	Nb,rd kN	Stimulation kN	Aspect Ratio,t/B	Percentage Difference,%
RHS 100 x 60/3.2	100	60	3.2	1.337	36.7	0.5989	24.6	983.04	8000	355	210000	19.4	4.24	9.92	0.053	18.47	33.01	0.05	28.24
RHS 100 x 60/6.3	100	60	6.3	2.3629	35.2	1.0244	23.3	1857.24	8000	355	210000	33.2	4.46	10.88	0.048	31.68	46.22	0.11	18.67
RHS 100 x 60/8	100	60	8	2.8268	34.4	1.2037	22.5	2304	8000	355	210000	39.0	4.58	11.45	0.046	37.27	51.81	0.13	16.32
RHS 120 x 80/4	120	80	4	3.0904	44.6	1.6364	32.5	1536	8000	355	210000	53.0	3.21	5.96	0.091	49.64	58.18	0.05	7.92
RHS 120 x 80/8	120	80	8	5.5207	42.7	2.8481	30.8	2944	8000	355	210000	92.2	3.37	6.50	0.083	86.69	87.14	0.10	0.26
RHS 120 x 80/10	120	80	10	6.52	41.8	3.32	29.9	3600	8000	355	210000	107.5	3.45	6.78	0.079	101.21	109.75	0.13	4.05
RHS 300 x 200/8	300	200	8	98.77	112.5	52.568	82.2	7744	8000	355	210000	1702.4	1.27	1.42	0.487	1338.93	1347.47	0.04	0.32
RHS 300 x 200/10	300	200	10	120.72	111.6	63.92	81.3	9600	8000	355	210000	2070.0	1.28	1.44	0.480	1635.56	1664.10	0.05	0.86
RHS 300 x 200/16	300	200	16	180.52	108.8	94.104	78.7	14976	8000	355	210000	3047.5	1.32	1.49	0.459	2439.37	2467.91	0.08	0.58
RHS 450 x 250/8	450	250	8	304.38	166.3	122.54	105.7	10944	8000	355	210000	3968.4	0.99	1.07	0.673	2614.57	2643.11	0.03	0.54
RHS 450 x 250/10	450	250	10	374.55	165.4	149.95	104.8	13600	8000	355	210000	4856.1	1.00	1.08	0.668	3223.30	3231.84	0.04	0.13
RHS 450 x 250/16	450	250	16	571.64	162.5	225.06	102.2	21376	8000	355	210000	7288.5	1.02	1.11	0.651	4942.72	4951.26	0.06	0.09

Theoretical and Numerical results of critical buckling load for steel grade S355

Steel Grade :355		
Length(m) :	8	
E=	210000	N/mm2
Support System :	F-P	
K value :	0.7	

Profile	Depth	Width	Wall thickness	Second moment of area	Radius of gyration	Second moment of area	Radius of gyration	Area	Length										
	h	b	t	Ix	rx	Iy	ry	A	Leff	Fy	E	Ncr	λ	ϕ	χ	Nb,rd	Stimulation	Aspect Ratio,t/B	Percentage Difference,%
	[mm]	[mm]	[mm]	[×10^6 mm^4]	[mm]	[×10^6 mm^4]	[mm]	[mm^2]	[mm]	[N/mm2]	[N/mm2]	kN				kN	kN		
RHS 100 x 60/3.2	100	60	3.2	1.337	36.7	0.5989	24.6	983.04	5600	355	210000	39.6	2.97	5.20	0.106	36.86	51.40	0.05	16.47
RHS 100 x 60/6.3	100	60	6.3	2.3629	35.2	1.0244	23.3	1857.24	5600	355	210000	67.7	3.12	5.68	0.096	63.29	77.83	0.11	10.30
RHS 100 x 60/8	100	60	8	2.8268	34.4	1.2037	22.5	2304	5600	355	210000	79.6	3.21	5.96	0.091	74.52	89.06	0.13	8.89
RHS 120 x 80/4	120	80	4	3.0904	44.6	1.6364	32.5	1536	5600	355	210000	108.2	2.25	3.24	0.180	97.98	106.52	0.05	4.18
RHS 120 x 80/8	120	80	8	5.5207	42.7	2.8481	30.8	2944	5600	355	210000	188.2	2.36	3.50	0.164	171.50	180.04	0.10	2.43
RHS 120 x 80/10	120	80	10	6.52	41.8	3.32	29.9	3600	5600	355	210000	219.4	2.41	3.64	0.157	200.45	208.99	0.13	2.09
RHS 300 x 200/8	300	200	8	98.77	112.5	52.568	82.2	7744	5600	355	210000	3474.3	0.89	0.97	0.741	2036.52	2045.06	0.04	0.21
RHS 300 x 200/10	300	200	10	120.72	111.6	63.92	81.3	9600	5600	355	210000	4224.5	0.90	0.98	0.735	2505.37	2533.91	0.05	0.57
RHS 300 x 200/16	300	200	16	180.52	108.8	94.104	78.7	14976	5600	355	210000	6219.4	0.92	1.00	0.718	3814.99	3843.53	0.08	0.37
RHS 450 x 250/8	450	250	8	304.38	166.3	122.54	105.7	10944	5600	355	210000	8098.8	0.69	0.79	0.851	3306.93	3335.47	0.03	0.43
RHS 450 x 250/10	450	250	10	374.55	165.4	149.95	104.8	13600	5600	355	210000	9910.4	0.70	0.80	0.849	4097.47	4106.01	0.04	0.10
RHS 450 x 250/16	450	250	16	571.64	162.5	225.06	102.2	21376	5600	355	210000	14874.5	0.71	0.81	0.841	6381.48	6390.02	0.06	0.07

Steel Grade :355		
Length(m) :	8	
E=	210000	N/mm2
Support System :	F-Free	
K value :	2	

Profile	Depth	Width	Wall thickness	Second moment of area	Radius of gyration	Second moment of area	Radius of gyration	Area	Length										
	h	b	t	Ix	rx	Iy	ry	A	Leff	Fy	E	Ncr	λ	ϕ	χ	Nb,rd	Stimulation	Aspect Ratio,t/B	Percentage Difference,%
	[mm]	[mm]	[mm]	[×10^6 mm^4]	[mm]	[×10^6 mm^4]	[mm]	[mm^2]	[mm]	[N/mm2]	[N/mm2]	kN				kN	kN		
RHS 100 x 60/3.2	100	60	3.2	1.337	36.7	0.5989	24.6	983.04	16000	355	210000	4.8	8.48	37.36	0.014	4.73	5.43	0.05	6.89
RHS 100 x 60/6.3	100	60	6.3	2.3629	35.2	1.0244	23.3	1857.24	16000	355	210000	8.3	8.92	41.16	0.012	8.10	8.64	0.11	3.22
RHS 100 x 60/8	100	60	8	2.8268	34.4	1.2037	22.5	2304	16000	355	210000	9.7	9.16	43.41	0.012	9.53	11.07	0.13	7.48
RHS 120 x 80/4	120	80	4	3.0904	44.6	1.6364	32.5	1536	16000	355	210000	13.2	6.42	21.73	0.024	12.83	21.37	0.05	24.97
RHS 120 x 80/8	120	80	8	5.5207	42.7	2.8481	30.8	2944	16000	355	210000	23.1	6.73	23.85	0.021	22.37	30.91	0.10	16.03
RHS 120 x 80/10	120	80	10	6.52	41.8	3.32	29.9	3600	16000	355	210000	26.9	6.90	24.98	0.020	26.09	34.63	0.13	14.06
RHS 300 x 200/8	300	200	8	98.77	112.5	52.568	82.2	7744	16000	355	210000	425.6	2.54	3.98	0.142	390.91	399.45	0.04	1.08
RHS 300 x 200/10	300	200	10	120.72	111.6	63.92	81.3	9600	16000	355	210000	517.5	2.57	4.04	0.140	475.78	504.32	0.05	2.91
RHS 300 x 200/16	300	200	16	180.52	108.8	94.104	78.7	14976	16000	355	210000	761.9	2.64	4.25	0.132	702.41	730.95	0.08	1.99
RHS 450 x 250/8	450	250	8	304.38	166.3	122.54	105.7	10944	16000	355	210000	992.1	1.98	2.64	0.227	883.08	911.62	0.03	1.59
RHS 450 x 250/10	450	250	10	374.55	165.4	149.95	104.8	13600	16000	355	210000	1214.0	1.99	2.68	0.224	1081.91	1090.45	0.04	0.39
RHS 450 x 250/16	450	250	16	571.64	162.5	225.06	102.2	21376	16000	355	210000	1822.1	2.04	2.78	0.215	1629.51	1638.05	0.06	0.26

Theoretical and Numerical results of critical buckling load for steel grade S355

Steel Grade :420		
Length(m) :	8	
E=	210000	N/mm2
Support System:	F-F	
K value:	0.5	

Profile	Depth h [mm]	Width b [mm]	Wall thickness t [mm]	Second moment of area Ix [$\times10^6$ mm^4]	Radius of gyration rx [mm]	Second moment of area Iy [$\times10^6$ mm^4]	Radius of gyration ry [mm]	Area A [mm^2]	Length Leff [mm]	Fy [N/mm2]	E [N/mm2]	Ncr kN	λ	ϕ	χ	Nb,rd kN	Stimulation kN	Aspect Ratio,t/B	Percentage Difference, %
RHS 100 x 60/3.2	100	60	3.2	1.337	36.7	0.5989	24.6	983.04	2000	460	210000	310.3	1.21	1.29	0.568	256.88	262.77	0.05	1.13
RHS 100 x 60/6.3	100	60	6.3	2.3629	35.2	1.0244	23.3	1857.24	2000	460	210000	530.8	1.27	1.37	0.526	449.08	453.97	0.11	0.54
RHS 100 x 60/8	100	60	8	2.8268	34.4	1.2037	22.5	2304	2000	460	210000	623.7	1.30	1.42	0.503	533.13	540.75	0.13	0.71
RHS 120 x 80/4	120	80	4	3.0904	44.6	1.6364	32.5	1536	2000	460	210000	847.9	0.91	0.96	0.788	556.50	561.27	0.05	0.43
RHS 120 x 80/8	120	80	8	5.5207	42.7	2.8481	30.8	2944	2000	460	210000	1475.8	0.96	1.01	0.756	1024.31	1027.52	0.10	0.16
RHS 120 x 80/10	120	80	10	6.52	41.8	3.32	29.9	3600	2000	460	210000	1720.3	0.98	1.03	0.739	1224.52	1231.63	0.13	0.29
RHS 300 x 200/8	300	200	8	98.77	112.5	52.568	82.2	7744	2000	460	210000	27238.3	0.36	0.58	0.976	3478.45	3479.95	0.04	0.02
RHS 300 x 200/10	300	200	10	120.72	111.6	63.92	81.3	9600	2000	460	210000	33120.4	0.37	0.58	0.976	4309.64	4318.74	0.05	0.11
RHS 300 x 200/16	300	200	16	180.52	108.8	94.104	78.7	14976	2000	460	210000	48760.4	0.38	0.58	0.974	6711.03	6717.90	0.08	0.05
RHS 450 x 250/8	450	250	8	304.38	166.3	122.54	105.7	10944	2000	460	210000	63494.6	0.28	0.54	0.989	4976.97	4978.27	0.03	0.01
RHS 450 x 250/10	450	250	10	374.55	165.4	149.95	104.8	13600	2000	460	210000	77697.2	0.28	0.55	0.988	6182.86	6186.39	0.04	0.03
RHS 450 x 250/16	450	250	16	571.64	162.5	225.06	102.2	21376	2000	460	210000	116615.8	0.29	0.55	0.987	9708.53	9714.42	0.06	0.03

Steel Grade :420		
Length(m) :	8	
E=	210000	N/mm2
Support System:	P-P	
K value:	1	

Profile	Depth h [mm]	Width b [mm]	Wall thickness t [mm]	Second moment of area Ix [$\times10^6$ mm^4]	Radius of gyration rx [mm]	Second moment of area Iy [$\times10^6$ mm^4]	Radius of gyration ry [mm]	Area A [mm^2]	Length Leff [mm]	Fy [N/mm2]	E [N/mm2]	Ncr kN	λ	ϕ	χ	Nb,rd kN	Stimulation kN	Aspect Ratio,t/B	Percentage Difference, %
RHS 100 x 60/3.2	100	60	3.2	1.337	36.7	0.5989	24.6	983.04	4000	460	210000	77.6	2.41	3.56	0.162	73.26	79.15	0.05	3.86
RHS 100 x 60/6.3	100	60	6.3	2.3629	35.2	1.0244	23.3	1857.24	4000	460	210000	132.7	2.54	3.87	0.147	125.74	130.63	0.11	1.91
RHS 100 x 60/8	100	60	8	2.8268	34.4	1.2037	22.5	2304	4000	460	210000	155.9	2.61	4.06	0.140	148.01	155.63	0.13	2.51
RHS 120 x 80/4	120	80	4	3.0904	44.6	1.6364	32.5	1536	4000	460	210000	212.0	1.83	2.27	0.276	194.91	199.68	0.05	1.21
RHS 120 x 80/8	120	80	8	5.5207	42.7	2.8481	30.8	2944	4000	460	210000	368.9	1.92	2.45	0.252	341.22	347.43	0.10	0.90
RHS 120 x 80/10	120	80	10	6.52	41.8	3.32	29.9	3600	4000	460	210000	430.1	1.96	2.54	0.241	398.81	403.92	0.13	0.64
RHS 300 x 200/8	300	200	8	98.77	112.5	52.568	82.2	7744	4000	460	210000	6809.6	0.72	0.80	0.887	3160.94	3162.44	0.04	0.02
RHS 300 x 200/10	300	200	10	120.72	111.6	63.92	81.3	9600	4000	460	210000	8280.1	0.73	0.80	0.885	3906.22	3915.32	0.05	0.12
RHS 300 x 200/16	300	200	16	180.52	108.8	94.104	78.7	14976	4000	460	210000	12190.1	0.75	0.82	0.876	6032.39	6039.26	0.08	0.06
RHS 450 x 250/8	450	250	8	304.38	166.3	122.54	105.7	10944	4000	460	210000	15873.7	0.56	0.68	0.937	4717.36	4718.66	0.03	0.01
RHS 450 x 250/10	450	250	10	374.55	165.4	149.95	104.8	13600	4000	460	210000	19424.3	0.57	0.68	0.936	5855.52	5861.05	0.04	0.05
RHS 450 x 250/16	450	250	16	571.64	162.5	225.06	102.2	21376	4000	460	210000	29153.9	0.58	0.69	0.933	9170.71	9176.60	0.06	0.03

Theoretical and Numerical results of critical buckling load for steel grade S460

Steel Grade :420		
Length(m) :	8	
E=	210000	N/mm2
Support System :	F-P	
K value :	0.7	

Profile	Depth h [mm]	Width b [mm]	Wall thickness t [mm]	Second moment of area Ix [$\times 10^6$ mm^4]	Radius of gyration rx [mm]	Second moment of area Iy [$\times 10^6$ mm^4]	Radius of gyration ry [mm]	Area A [mm^2]	Length Leff [mm]	Fy [N/mm2]	E [N/mm2]	Ncr kN	$\bar{\lambda}$	ϕ	χ	Nb,rd kN	Stimulation kN	Aspect Ratio,t/B	Percentage Difference,%
RHS 100 x 60/3.2	100	60	3.2	1.337	36.7	0.5989	24.6	983.04	2800	460	210000	158.3	1.69	2.02	0.318	144.00	149.89	0.05	2.00
RHS 100 x 60/6.3	100	60	6.3	2.3629	35.2	1.0244	23.3	1857.24	2800	460	210000	270.8	1.78	2.18	0.290	248.11	253.00	0.11	0.98
RHS 100 x 60/8	100	60	8	2.8268	34.4	1.2037	22.5	2304	2800	460	210000	318.2	1.82	2.27	0.276	292.58	300.20	0.13	1.29
RHS 120 x 80/4	120	80	4	3.0904	44.6	1.6364	32.5	1536	2800	460	210000	432.6	1.28	1.39	0.520	367.06	371.83	0.05	0.65
RHS 120 x 80/8	120	80	8	5.5207	42.7	2.8481	30.8	2944	2800	460	210000	752.9	1.34	1.47	0.480	649.88	656.09	0.10	0.48
RHS 120 x 80/10	120	80	10	6.52	41.8	3.32	29.9	3600	2800	460	210000	877.7	1.37	1.52	0.461	763.22	767.33	0.13	0.27
RHS 300 x 200/8	300	200	8	98.77	112.5	52.568	82.2	7744	2800	460	210000	13897.1	0.51	0.65	0.950	3384.12	3388.62	0.04	0.07
RHS 300 x 200/10	300	200	10	120.72	111.6	63.92	81.3	9600	2800	460	210000	16898.2	0.51	0.65	0.949	4190.56	4199.66	0.05	0.11
RHS 300 x 200/16	300	200	16	180.52	108.8	94.104	78.7	14976	2800	460	210000	24877.7	0.53	0.66	0.946	6514.66	6521.53	0.08	0.05
RHS 450 x 250/8	450	250	8	304.38	166.3	122.54	105.7	10944	2800	460	210000	32395.2	0.39	0.59	0.971	4888.87	4894.17	0.03	0.05
RHS 450 x 250/10	450	250	10	374.55	165.4	149.95	104.8	13600	2800	460	210000	39641.4	0.40	0.59	0.971	6072.12	6074.65	0.04	0.02
RHS 450 x 250/16	450	250	16	571.64	162.5	225.06	102.2	21376	2800	460	210000	59497.9	0.41	0.60	0.969	9528.35	9534.24	0.06	0.03

Steel Grade :420		
Length(m) :	8	
E=	210000	N/mm2
Support System :	F-Free	
K value :	2	

Profile	Depth h [mm]	Width b [mm]	Wall thickness t [mm]	Second moment of area Ix [$\times 10^6$ mm^4]	Radius of gyration rx [mm]	Second moment of area Iy [$\times 10^6$ mm^4]	Radius of gyration ry [mm]	Area A [mm^2]	Length Leff [mm]	Fy [N/mm2]	E [N/mm2]	Ncr kN	$\bar{\lambda}$	ϕ	χ	Nb,rd kN	Stimulation kN	Aspect Ratio,t/B	Percentage Difference,%
RHS 100 x 60/3.2	100	60	3.2	1.337	36.7	0.5989	24.6	983.04	8000	460	210000	19.4	4.83	12.46	0.042	18.89	24.78	0.05	13.49
RHS 100 x 60/6.3	100	60	6.3	2.3629	35.2	1.0244	23.3	1857.24	8000	460	210000	33.2	5.07	13.69	0.038	32.35	37.24	0.11	7.03
RHS 100 x 60/8	100	60	8	2.8268	34.4	1.2037	22.5	2304	8000	460	210000	39.0	5.21	14.42	0.036	38.04	45.66	0.13	9.10
RHS 120 x 80/4	120	80	4	3.0904	44.6	1.6364	32.5	1536	8000	460	210000	53.0	3.65	7.39	0.072	51.14	55.91	0.05	4.46
RHS 120 x 80/8	120	80	8	5.5207	42.7	2.8481	30.8	2944	8000	460	210000	92.2	3.83	8.08	0.066	89.17	95.38	0.10	3.37
RHS 120 x 80/10	120	80	10	6.52	41.8	3.32	29.9	3600	8000	460	210000	107.5	3.92	8.44	0.063	104.03	108.14	0.13	1.94
RHS 300 x 200/8	300	200	8	98.77	112.5	52.568	82.2	7744	8000	460	210000	1702.4	1.45	1.63	0.421	1501.41	1502.91	0.04	0.05
RHS 300 x 200/10	300	200	10	120.72	111.6	63.92	81.3	9600	8000	460	210000	2070.0	1.46	1.65	0.414	1829.98	1839.08	0.05	0.25
RHS 300 x 200/16	300	200	16	180.52	108.8	94.104	78.7	14976	8000	460	210000	3047.5	1.50	1.71	0.394	2712.19	2719.06	0.08	0.13
RHS 450 x 250/8	450	250	8	304.38	166.3	122.54	105.7	10944	8000	460	210000	3968.4	1.13	1.19	0.628	3161.60	3162.90	0.03	0.02
RHS 450 x 250/10	450	250	10	374.55	165.4	149.95	104.8	13600	8000	460	210000	4856.1	1.14	1.20	0.621	3887.34	3889.87	0.04	0.03
RHS 450 x 250/16	450	250	16	571.64	162.5	225.06	102.2	21376	8000	460	210000	7288.5	1.16	1.24	0.601	5913.79	5919.68	0.06	0.05

Theoretical and Numerical results of critical buckling load for steel grade S460

Steel Grade :420		
Length(m) :	4	
E=	210000	N/mm2
Support System :	F-F	
K value :	0.5	

Profile	Depth h [mm]	Width b [mm]	Wall thickness t [mm]	Second moment of area Ix [$\times 10^6$ mm^4]	Radius of gyration rx [mm]	Second moment of area Iy [$\times 10^6$ mm^4]	Radius of gyration ry [mm]	Area A [mm^2]	Length Leff [mm]	Fy [N/mm2]	E [N/mm2]	Ncr kN	$\bar{\lambda}$	ϕ	χ	Nb,rd kN	Stimulation kN	Aspect Ratio, t/B	Percentage Difference,%
RHS 100 x 60/3.2	100	60	3.2	1.337	36.7	0.5989	24.6	983.04	3000	460	210000	137.9	1.81	2.24	0.280	126.68	132.57	0.05	2.27
RHS 100 x 60/6.3	100	60	6.3	2.3629	35.2	1.0244	23.3	1857.24	3000	460	210000	235.9	1.90	2.42	0.255	218.02	222.91	0.11	1.11
RHS 100 x 60/8	100	60	8	2.8268	34.4	1.2037	22.5	2304	3000	460	210000	277.2	1.96	2.53	0.242	256.96	264.58	0.13	1.46
RHS 120 x 80/4	120	80	4	3.0904	44.6	1.6364	32.5	1536	3000	460	210000	376.8	1.37	1.51	0.463	327.39	332.16	0.05	0.72
RHS 120 x 80/8	120	80	8	5.5207	42.7	2.8481	30.8	2944	3000	460	210000	655.9	1.44	1.61	0.426	577.48	580.69	0.10	0.28
RHS 120 x 80/10	120	80	10	6.52	41.8	3.32	29.9	3600	3000	460	210000	764.6	1.47	1.67	0.409	677.13	684.24	0.13	0.52
RHS 300 x 200/8	300	200	8	98.77	112.5	52.568	82.2	7744	3000	460	210000	12105.9	0.54	0.67	0.942	3355.57	3357.07	0.04	0.02
RHS 300 x 200/10	300	200	10	120.72	111.6	63.92	81.3	9600	3000	460	210000	14720.2	0.55	0.67	0.941	4154.37	4163.47	0.05	0.11
RHS 300 x 200/16	300	200	16	180.52	108.8	94.104	78.7	14976	3000	460	210000	21671.3	0.56	0.68	0.937	6454.23	6461.10	0.08	0.05
RHS 450 x 250/8	450	250	8	304.38	166.3	122.54	105.7	10944	3000	460	210000	28219.8	0.42	0.60	0.966	4864.34	4865.64	0.03	0.01
RHS 450 x 250/10	450	250	10	374.55	165.4	149.95	104.8	13600	3000	460	210000	34532.1	0.43	0.61	0.966	6041.22	6044.75	0.04	0.03
RHS 450 x 250/16	450	250	16	571.64	162.5	225.06	102.2	21376	3000	460	210000	51829.2	0.44	0.61	0.964	9477.76	9483.65	0.06	0.03

Steel Grade :420		
Length(m) :	4	
E=	210000	N/mm2
Support System :	P-P	
K value :	1	

Profile	Depth h [mm]	Width b [mm]	Wall thickness t [mm]	Second moment of area Ix [$\times 10^6$ mm^4]	Radius of gyration rx [mm]	Second moment of area Iy [$\times 10^6$ mm^4]	Radius of gyration ry [mm]	Area A [mm^2]	Length Leff [mm]	Fy [N/mm2]	E [N/mm2]	Ncr kN	$\bar{\lambda}$	ϕ	χ	Nb,rd kN	Stimulation kN	Aspect Ratio, t/B	Percentage Difference,%
RHS 100 x 60/3.2	100	60	3.2	1.337	36.7	0.5989	24.6	983.04	6000	460	210000	34.5	3.62	7.28	0.074	33.26	39.15	0.05	8.13
RHS 100 x 60/6.3	100	60	6.3	2.3629	35.2	1.0244	23.3	1857.24	6000	460	210000	59.0	3.81	7.98	0.067	57.00	61.89	0.11	4.11
RHS 100 x 60/8	100	60	8	2.8268	34.4	1.2037	22.5	2304	6000	460	210000	69.3	3.91	8.39	0.063	67.04	74.66	0.13	5.38
RHS 120 x 80/4	120	80	4	3.0904	44.6	1.6364	32.5	1536	6000	460	210000	94.2	2.74	4.41	0.127	89.69	94.46	0.05	2.59
RHS 120 x 80/8	120	80	8	5.5207	42.7	2.8481	30.8	2944	6000	460	210000	164.0	2.87	4.80	0.116	156.52	162.73	0.10	1.95
RHS 120 x 80/10	120	80	10	6.52	41.8	3.32	29.9	3600	6000	460	210000	191.1	2.94	5.01	0.110	182.69	187.80	0.13	1.38
RHS 300 x 200/8	300	200	8	98.77	112.5	52.568	82.2	7744	6000	460	210000	3026.5	1.08	1.15	0.660	2350.84	2352.34	0.04	0.03
RHS 300 x 200/10	300	200	10	120.72	111.6	63.92	81.3	9600	6000	460	210000	3680.0	1.10	1.16	0.652	2878.24	2887.34	0.05	0.16
RHS 300 x 200/16	300	200	16	180.52	108.8	94.104	78.7	14976	6000	460	210000	5417.8	1.13	1.20	0.627	4319.50	4326.37	0.08	0.08
RHS 450 x 250/8	450	250	8	304.38	166.3	122.54	105.7	10944	6000	460	210000	7055.0	0.84	0.90	0.830	4176.35	4177.65	0.03	0.02
RHS 450 x 250/10	450	250	10	374.55	165.4	149.95	104.8	13600	6000	460	210000	8633.0	0.85	0.90	0.826	5166.60	5172.13	0.04	0.05
RHS 450 x 250/16	450	250	16	571.64	162.5	225.06	102.2	21376	6000	460	210000	12957.3	0.87	0.92	0.814	8005.38	8011.27	0.06	0.04

Theoretical and Numerical results of critical buckling load for steel grade S460

Steel Grade : 420		
Length(m) :	4	
E =	210000	N/mm2
Support System :	F-P	
K value :	0.7	

Profile	Depth h [mm]	Width b [mm]	Wall thickness t [mm]	Second moment of area Ix [×10⁶ mm⁴]	Radius of gyration rx [mm]	Second moment of area Iy [×10⁶ mm⁴]	Radius of gyration ry [mm]	Area A [mm2]	Length Leff [mm]	Fy [N/mm2]	E [N/mm2]	Ncr kN	λ	ϕ	χ	Nb,rd kN	Stimulation kN	Aspect Ratio, t/B	Percentage Difference,%
RHS 100 x 60/3.2	100	60	3.2	1.337	36.7	0.5989	24.6	983.04	4600	460	210000	58.7	2.78	4.52	0.124	55.89	61.78	0.05	5.01
RHS 100 x 60/6.3	100	60	6.3	2.3629	35.2	1.0244	23.3	1857.24	4600	460	210000	100.3	2.92	4.93	0.112	95.86	100.75	0.11	2.49
RHS 100 x 60/8	100	60	8	2.8268	34.4	1.2037	22.5	2304	4600	460	210000	117.9	3.00	5.18	0.106	112.79	120.41	0.13	3.27
RHS 120 x 80/4	120	80	4	3.0904	44.6	1.6364	32.5	1536	4600	460	210000	160.3	2.10	2.83	0.212	149.65	154.42	0.05	1.57
RHS 120 x 80/8	120	80	8	5.5207	42.7	2.8481	30.8	2944	4600	460	210000	279.0	2.20	3.06	0.193	261.58	267.79	0.10	1.17
RHS 120 x 80/10	120	80	10	6.52	41.8	3.32	29.9	3600	4600	460	210000	325.2	2.26	3.18	0.184	305.52	309.63	0.13	0.67
RHS 300 x 200/8	300	200	8	98.77	112.5	52.568	82.2	7744	4600	460	210000	5149.0	0.83	0.89	0.837	2980.85	2985.35	0.04	0.08
RHS 300 x 200/10	300	200	10	120.72	111.6	63.92	81.3	9600	4600	460	210000	6260.9	0.84	0.89	0.832	3675.61	3684.71	0.05	0.12
RHS 300 x 200/16	300	200	16	180.52	108.8	94.104	78.7	14976	4600	460	210000	9217.5	0.86	0.92	0.818	5635.94	5642.81	0.08	0.06
RHS 450 x 250/8	450	250	8	304.38	166.3	122.54	105.7	10944	4600	460	210000	12002.8	0.65	0.74	0.914	4600.19	4605.49	0.03	0.06
RHS 450 x 250/10	450	250	10	374.55	165.4	149.95	104.8	13600	4600	460	210000	14687.6	0.65	0.74	0.912	5706.81	5709.34	0.04	0.02
RHS 450 x 250/16	450	250	16	571.64	162.5	225.06	102.2	21376	4600	460	210000	22044.6	0.67	0.75	0.907	8921.44	8927.33	0.06	0.03

Steel Grade : 420		
Length(m) :	4	
E =	210000	N/mm2
Support System :	F-Free	
K value :	2	

Profile	Depth h [mm]	Width b [mm]	Wall thickness t [mm]	Second moment of area Ix [×10⁶ mm⁴]	Radius of gyration rx [mm]	Second moment of area Iy [×10⁶ mm⁴]	Radius of gyration ry [mm]	Area A [mm2]	Length Leff [mm]	Fy [N/mm2]	E [N/mm2]	Ncr kN	λ	ϕ	χ	Nb,rd kN	Stimulation kN	Aspect Ratio, t/B	Percentage Difference,%
RHS 100 x 60/3.2	100	60	3.2	1.337	36.7	0.5989	24.6	983.04	12000	460	210000	8.6	7.24	27.19	0.019	8.47	14.36	0.05	25.80
RHS 100 x 60/6.3	100	60	6.3	2.3629	35.2	1.0244	23.3	1857.24	12000	460	210000	14.7	7.61	29.95	0.017	14.50	19.39	0.11	14.43
RHS 100 x 60/8	100	60	8	2.8268	34.4	1.2037	22.5	2304	12000	460	210000	17.3	7.82	31.58	0.016	17.04	24.66	0.13	18.27
RHS 120 x 80/4	120	80	4	3.0904	44.6	1.6364	32.5	1536	12000	460	210000	23.6	5.48	15.84	0.033	23.01	27.78	0.05	9.39
RHS 120 x 80/8	120	80	8	5.5207	42.7	2.8481	30.8	2944	12000	460	210000	41.0	5.75	17.38	0.030	40.09	46.30	0.10	7.19
RHS 120 x 80/10	120	80	10	6.52	41.8	3.32	29.9	3600	12000	460	210000	47.8	5.89	18.20	0.028	46.76	50.87	0.13	4.21
RHS 300 x 200/8	300	200	8	98.77	112.5	52.568	82.2	7744	12000	460	210000	756.6	2.17	2.98	0.199	708.52	710.02	0.04	0.11
RHS 300 x 200/10	300	200	10	120.72	111.6	63.92	81.3	9600	12000	460	210000	920.0	2.19	3.03	0.195	862.24	871.34	0.05	0.52
RHS 300 x 200/16	300	200	16	180.52	108.8	94.104	78.7	14976	12000	460	210000	1354.5	2.26	3.18	0.185	1272.47	1279.34	0.08	0.27
RHS 450 x 250/8	450	250	8	304.38	166.3	122.54	105.7	10944	12000	460	210000	1763.7	1.69	2.02	0.319	1604.04	1605.34	0.03	0.04
RHS 450 x 250/10	450	250	10	374.55	165.4	149.95	104.8	13600	12000	460	210000	2158.3	1.70	2.05	0.314	1965.18	1967.71	0.04	0.06
RHS 450 x 250/16	450	250	16	571.64	162.5	225.06	102.2	21376	12000	460	210000	3239.3	1.74	2.12	0.301	2959.66	2965.55	0.06	0.10

Theoretical and Numerical results of critical buckling load for steel grade S460

Steel Grade :420	
Length(m) :	6
E=	210000 N/mm2
Support System :	F-F
K value:	0.5

Profile	Depth h [mm]	Width b [mm]	Wall thickness t [mm]	Second moment of area Ix $[\times 10^6\ mm^4]$	Radius of gyration rx [mm]	Second moment of area Iy $[\times 10^6\ mm^4]$	Radius of gyration ry [mm]	Area A $[mm^2]$	Length Leff [mm]	Fy [N/mm2]	E [N/mm2]	Ncr kN	λ	ϕ	χ	Nb,rd kN	Stimulation kN	Aspect Ratio,t/B
RHS 100 x 60/3.2	100	60	3.2	1.337	36.7	0.5989	24.6	983.04	4000	460	210000	77.6	2.41	3.56	0.162	73.26	79.15	0.05
RHS 100 x 60/6.3	100	60	6.3	2.3629	35.2	1.0244	23.3	1857.24	4000	460	210000	132.7	2.54	3.87	0.147	125.74	130.63	0.11
RHS 100 x 60/8	100	60	8	2.8268	34.4	1.2037	22.5	2304	4000	460	210000	155.9	2.61	4.06	0.140	148.01	155.63	0.13
RHS 120 x 80/4	120	80	4	3.0904	44.6	1.6364	32.5	1536	4000	460	210000	212.0	1.83	2.27	0.276	194.91	199.68	0.05
RHS 120 x 80/8	120	80	8	5.5207	42.7	2.8481	30.8	2944	4000	460	210000	368.9	1.92	2.45	0.252	341.22	344.43	0.10
RHS 120 x 80/10	120	80	10	6.52	41.8	3.32	29.9	3600	4000	460	210000	430.1	1.96	2.54	0.241	398.81	405.92	0.13
RHS 300 x 200/8	300	200	8	98.77	112.5	52.568	82.2	7744	4000	460	210000	6809.6	0.72	0.80	0.887	3160.94	3162.44	0.04
RHS 300 x 200/10	300	200	10	120.72	111.6	63.92	81.3	9600	4000	460	210000	8280.1	0.73	0.80	0.885	3906.22	3915.32	0.05
RHS 300 x 200/16	300	200	16	180.52	108.8	94.104	78.7	14976	4000	460	210000	12190.1	0.75	0.82	0.876	6032.39	6039.26	0.08
RHS 450 x 250/8	450	250	8	304.38	166.3	122.54	105.7	10944	4000	460	210000	15873.7	0.56	0.68	0.937	4717.36	4718.66	0.03
RHS 450 x 250/10	450	250	10	374.55	165.4	149.95	104.8	13600	4000	460	210000	19424.3	0.57	0.68	0.936	5855.52	5859.05	0.04
RHS 450 x 250/16	450	250	16	571.64	162.5	225.06	102.2	21376	4000	460	210000	29153.9	0.58	0.69	0.933	9170.71	9176.60	0.06

Steel Grade :420	
Length(m) :	6
E=	210000 N/mm2
Support System :	P-P
K value:	1

Profile	Depth h [mm]	Width b [mm]	Wall thickness t [mm]	Second moment of area Ix $[\times 10^6\ mm^4]$	Radius of gyration rx [mm]	Second moment of area Iy $[\times 10^6\ mm^4]$	Radius of gyration ry [mm]	Area A $[mm^2]$	Length Leff [mm]	Fy [N/mm2]	E [N/mm2]	Ncr kN	λ	ϕ	χ	Nb,rd kN	Stimulation kN	Aspect Ratio,t/B
RHS 100 x 60/3.2	100	60	3.2	1.337	36.7	0.5989	24.6	983.04	8000	460	210000	19.4	4.83	12.46	0.042	18.89	24.78	0.05
RHS 100 x 60/6.3	100	60	6.3	2.3629	35.2	1.0244	23.3	1857.24	8000	460	210000	33.2	5.07	13.69	0.038	32.35	37.24	0.11
RHS 100 x 60/8	100	60	8	2.8268	34.4	1.2037	22.5	2304	8000	460	210000	39.0	5.21	14.42	0.036	38.04	45.66	0.13
RHS 120 x 80/4	120	80	4	3.0904	44.6	1.6364	32.5	1536	8000	460	210000	53.0	3.65	7.39	0.072	51.14	55.91	0.05
RHS 120 x 80/8	120	80	8	5.5207	42.7	2.8481	30.8	2944	8000	460	210000	92.2	3.83	8.08	0.066	89.17	95.38	0.10
RHS 120 x 80/10	120	80	10	6.52	41.8	3.32	29.9	3600	8000	460	210000	107.5	3.92	8.44	0.063	104.03	109.14	0.13
RHS 300 x 200/8	300	200	8	98.77	112.5	52.568	82.2	7744	8000	460	210000	1702.4	1.45	1.63	0.421	1501.41	1502.91	0.04
RHS 300 x 200/10	300	200	10	120.72	111.6	63.92	81.3	9600	8000	460	210000	2070.0	1.46	1.65	0.414	1829.98	1839.08	0.05
RHS 300 x 200/16	300	200	16	180.52	108.8	94.104	78.7	14976	8000	460	210000	3047.5	1.50	1.71	0.394	2712.19	2719.06	0.08
RHS 450 x 250/8	450	250	8	304.38	166.3	122.54	105.7	10944	8000	460	210000	3968.4	1.13	1.19	0.628	3161.60	3162.90	0.03
RHS 450 x 250/10	450	250	10	374.55	165.4	149.95	104.8	13600	8000	460	210000	4856.1	1.14	1.20	0.621	3887.34	3892.87	0.04
RHS 450 x 250/16	450	250	16	571.64	162.5	225.06	102.2	21376	8000	460	210000	7288.5	1.16	1.24	0.601	5913.79	5919.68	0.06

Theoretical and Numerical results of critical buckling load for steel grade S460

Steel Grade :420		
Length(m) :	6	
E=	210000	N/mm2
Support System :	F-P	
K value:	0.7	

Profile	Depth h [mm]	Width b [mm]	Wall thickness t [mm]	Second moment of area Ix $[\times 10^6\ mm^4]$	Radius of gyration rx [mm]	Second moment of area Iy $[\times 10^6\ mm^4]$	Radius of gyration ry [mm]	Area A $[mm^2]$	Length Leff [mm]	Fy [N/mm2]	E [N/mm2]	Ncr kN	λ	ϕ	χ	Nb,rd kN	Stimulation kN	Aspect Ratio,t/B
RHS 100 x 60/3.2	100	60	3.2	1.337	36.7	0.5989	24.6	983.04	5600	460	210000	39.6	3.38	6.42	0.084	38.08	43.97	0.05
RHS 100 x 60/6.3	100	60	6.3	2.3629	35.2	1.0244	23.3	1857.24	5600	460	210000	67.7	3.55	7.03	0.076	65.26	70.15	0.11
RHS 100 x 60/8	100	60	8	2.8268	34.4	1.2037	22.5	2304	5600	460	210000	79.6	3.65	7.39	0.072	76.77	84.39	0.13
RHS 120 x 80/4	120	80	4	3.0904	44.6	1.6364	32.5	1536	5600	460	210000	108.2	2.56	3.92	0.145	102.53	107.30	0.05
RHS 120 x 80/8	120	80	8	5.5207	42.7	2.8481	30.8	2944	5600	460	210000	188.2	2.68	4.26	0.132	178.98	185.19	0.10
RHS 120 x 80/10	120	80	10	6.52	41.8	3.32	29.9	3600	5600	460	210000	219.4	2.75	4.44	0.126	208.93	213.04	0.13
RHS 300 x 200/8	300	200	8	98.77	112.5	52.568	82.2	7744	5600	460	210000	3474.3	1.01	1.07	0.716	2549.88	2554.38	0.04
RHS 300 x 200/10	300	200	10	120.72	111.6	63.92	81.3	9600	5600	460	210000	4224.5	1.02	1.08	0.708	3127.84	3136.94	0.05
RHS 300 x 200/16	300	200	16	180.52	108.8	94.104	78.7	14976	5600	460	210000	6219.4	1.05	1.11	0.685	4719.78	4726.65	0.08
RHS 450 x 250/8	450	250	8	304.38	166.3	122.54	105.7	10944	5600	460	210000	8098.8	0.79	0.85	0.859	4324.44	4329.74	0.03
RHS 450 x 250/10	450	250	10	374.55	165.4	149.95	104.8	13600	5600	460	210000	9910.4	0.79	0.85	0.856	5355.44	5357.97	0.04
RHS 450 x 250/16	450	250	16	571.64	162.5	225.06	102.2	21376	5600	460	210000	14874.5	0.81	0.87	0.847	8325.80	8331.69	0.06

Steel Grade :420		
Length(m) :	6	
E=	210000	N/mm2
Support System :	F-Free	
K value:	2	

Profile	Depth h [mm]	Width b [mm]	Wall thickness t [mm]	Second moment of area Ix $[\times 10^6\ mm^4]$	Radius of gyration rx [mm]	Second moment of area Iy $[\times 10^6\ mm^4]$	Radius of gyration ry [mm]	Area A $[mm^2]$	Length Leff [mm]	Fy [N/mm2]	E [N/mm2]	Ncr kN	λ	ϕ	χ	Nb,rd kN	Stimulation kN	Aspect Ratio,t/B
RHS 100 x 60/3.2	100	60	3.2	1.337	36.7	0.5989	24.6	983.04	16000	460	210000	4.8	9.66	47.74	0.011	4.79	10.68	0.05
RHS 100 x 60/6.3	100	60	6.3	2.3629	35.2	1.0244	23.3	1857.24	16000	460	210000	8.3	10.15	52.65	0.010	8.19	13.08	0.11
RHS 100 x 60/8	100	60	8	2.8268	34.4	1.2037	22.5	2304	16000	460	210000	9.7	10.43	55.54	0.009	9.63	17.25	0.13
RHS 120 x 80/4	120	80	4	3.0904	44.6	1.6364	32.5	1536	16000	460	210000	13.2	7.30	27.63	0.018	13.02	17.79	0.05
RHS 120 x 80/8	120	80	8	5.5207	42.7	2.8481	30.8	2944	16000	460	210000	23.1	7.66	30.35	0.017	22.68	28.89	0.10
RHS 120 x 80/10	120	80	10	6.52	41.8	3.32	29.9	3600	16000	460	210000	26.9	7.85	31.80	0.016	26.45	30.56	0.13
RHS 300 x 200/8	300	200	8	98.77	112.5	52.568	82.2	7744	16000	460	210000	425.6	2.89	4.86	0.114	406.41	407.91	0.04
RHS 300 x 200/10	300	200	10	120.72	111.6	63.92	81.3	9600	16000	460	210000	517.5	2.92	4.94	0.112	494.43	503.53	0.05
RHS 300 x 200/16	300	200	16	180.52	108.8	94.104	78.7	14976	16000	460	210000	761.9	3.01	5.20	0.106	728.98	735.85	0.08
RHS 450 x 250/8	450	250	8	304.38	166.3	122.54	105.7	10944	16000	460	210000	992.1	2.25	3.17	0.185	931.96	933.26	0.03
RHS 450 x 250/10	450	250	10	374.55	165.4	149.95	104.8	13600	16000	460	210000	1214.0	2.27	3.21	0.182	1141.13	1143.66	0.04
RHS 450 x 250/16	450	250	16	571.64	162.5	225.06	102.2	21376	16000	460	210000	1822.1	2.32	3.34	0.174	1715.82	1721.71	0.06

Theoretical and Numerical results of critical buckling load for steel grade S460

Steel Grade :275		
Length(m) :	4	
E=	210000	N/mm2
Support System:	F-F	
K value:	0.5	

Profile	Depth h [mm]	Width b [mm]	Wall thickness t [mm]	Aspect Ratio	Stimulation	Opening 1	Opening 2	Opening 3
RHS 100 x 60/3.2	100	60	3.2	0.05	199.76	197.95	191.66	188.52
RHS 100 x 60/6.3	100	60	6.3	0.11	403.93	398.64	385.24	571.17
RHS 100 x 60/8	100	60	8	0.13	493.07	487.49	484.64	479.51
RHS 120 x 80/4	120	80	4	0.05	398.51	384.71	361.66	355.26
RHS 120 x 80/8	120	80	8	0.10	689.09	648.27	616.00	592.98
RHS 120 x 80/10	120	80	10	0.13	854.25	751.62	732.71	717.29
RHS 300 x 200/8	300	200	8	0.04	2452.40	2390.93	2166.43	2072.99
RHS 300 x 200/10	300	200	10	0.05	2616.90	2569.00	2441.60	2359.10
RHS 300 x 200/16	300	200	16	0.08	4316.40	4269.90	4253.30	4244.56
RHS 450 x 250/8	450	250	8	0.03	3488.23	3480.13	3472.94	3354.62
RHS 450 x 250/10	450	250	10	0.04	3780.56	3754.54	3610.35	3472.84
RHS 450 x 250/16	450	250	16	0.06	5912.40	5744.00	5614.58	5601.59

Steel Grade :275		
Length(m) :	4	
E=	210000	N/mm2
Support System:	P-P	
K value:	1	

Profile	Depth h [mm]	Width b [mm]	Wall thickness t [mm]	Aspect Ratio	Stimulation	Opening 1	Opening 2	Opening 3
RHS 100 x 60/3.2	100	60	3.2	0.05	75.85	74.54	73.89	71.87
RHS 100 x 60/6.3	100	60	6.3	0.11	126.62	125.28	123.31	121.68
RHS 100 x 60/8	100	60	8	0.13	148.44	145.34	144.87	141.81
RHS 120 x 80/4	120	80	4	0.05	201.68	194.81	192.77	190.28
RHS 120 x 80/8	120	80	8	0.10	350.36	345.48	341.72	338.61
RHS 120 x 80/10	120	80	10	0.13	417.56	415.22	408.78	400.54
RHS 300 x 200/8	300	200	8	0.04	2311.38	2297.94	2137.83	2078.24
RHS 300 x 200/10	300	200	10	0.05	2698.05	2578.32	2446.58	2398.21
RHS 300 x 200/16	300	200	16	0.08	4416.40	4158.88	4059.80	3926.95
RHS 450 x 250/8	450	250	8	0.03	3488.20	3375.56	3142.81	3078.22
RHS 450 x 250/10	450	250	10	0.04	4280.56	4151.28	4082.56	3998.15
RHS 450 x 250/16	450	250	16	0.06	5775.10	5655.28	5569.62	5322.47

FEA results of RHS column with increasing in opening numbers

Steel Grade :275		
Length(m) :	4	
E=	210000	N/mm2
Support System:	F-P	
K value:	0.7	

Profile	Depth h [mm]	Width b [mm]	Wall thickness t [mm]	Aspect Ratio	Stimulation	Opening 1	Opening 2	Opening 3
RHS 100 x 60/3.2	100	60	3.2	0.05	154.52	152.62	150.66	150.23
RHS 100 x 60/6.3	100	60	6.3	0.11	258.52	263.41	261.26	253.23
RHS 100 x 60/8	100	60	8	0.13	303.91	305.94	297.92	296.55
RHS 120 x 80/4	120	80	4	0.05	420.95	419.57	409.32	408.31
RHS 120 x 80/8	120	80	8	0.10	614.32	598.35	510.55	507.89
RHS 120 x 80/10	120	80	10	0.13	751.23	741.16	727.06	726.09
RHS 300 x 200/8	300	200	8	0.04	2567.90	2551.45	2266.42	2173.00
RHS 300 x 200/10	300	200	10	0.05	3164.60	3054.15	2714.70	2649.10
RHS 300 x 200/16	300	200	16	0.08	4415.00	4225.75	3216.30	3206.90
RHS 450 x 250/8	450	250	8	0.03	3488.20	3165.12	3159.83	3092.62
RHS 450 x 250/10	450	250	10	0.04	4280.56	3773.01	3598.15	3371.95
RHS 450 x 250/16	450	250	16	0.06	5912.40	4784.80	4626.30	4400.10

Steel Grade :275		
Length(m) :	4	
E=	210000	N/mm2
Support System:	F-Free	
K value:	2	

Profile	Depth h [mm]	Width b [mm]	Wall thickness t [mm]	Aspect Ratio	Stimulation	Opening 1	Opening 2	Opening 3
RHS 100 x 60/3.2	100	60	3.2	0.05	19.02	18.51	18.35	18.03
RHS 100 x 60/6.3	100	60	6.3	0.11	31.72	31.63	31.22	30.57
RHS 100 x 60/8	100	60	8	0.13	37.26	36.33	36.12	35.87
RHS 120 x 80/4	120	80	4	0.05	50.61	50.56	50.04	49.75
RHS 120 x 80/8	120	80	8	0.10	87.86	81.06	80.57	78.66
RHS 120 x 80/10	120	80	10	0.13	104.74	103.07	102.62	100.91
RHS 300 x 200/8	300	200	8	0.04	1670.56	1668.19	1667.67	1658.60
RHS 300 x 200/10	300	200	10	0.05	2031.13	2022.64	2020.27	2016.41
RHS 300 x 200/16	300	200	16	0.08	2955.62	2823.33	2756.04	2596.99
RHS 450 x 250/8	450	250	8	0.03	2600.54	2510.23	2505.95	1887.55
RHS 450 x 250/10	450	250	10	0.04	2897.79	2789.53	2761.99	4784.32
RHS 450 x 250/16	450	250	16	0.06	5162.51	5158.57	5091.78	4957.11

FEA results of RHS column with increasing in opening numbers

Steel Grade :275		
Length(m) :	6	
E=	210000	N/mm2
Support System:	F-F	
K value:	0.5	

Profile	Depth h [mm]	Width b [mm]	Wall thickness t [mm]	Aspect Ratio	Stimulation	Opening 1	Opening 2	Opening 3
RHS 100 x 60/3.2	100	60	3.2	0.05	199.76	185.01	175.44	170.39
RHS 100 x 60/6.3	100	60	6.3	0.11	403.93	395.69	389.01	383.04
RHS 100 x 60/8	100	60	8	0.13	493.07	484.54	478.41	471.38
RHS 120 x 80/4	120	80	4	0.05	398.51	397.76	395.43	387.13
RHS 120 x 80/8	120	80	8	0.10	689.09	685.12	679.43	674.13
RHS 120 x 80/10	120	80	10	0.13	854.25	838.67	837.48	824.16
RHS 300 x 200/8	300	200	8	0.04	2452.40	2448.98	2441.15	2354.86
RHS 300 x 200/10	300	200	10	0.05	2616.90	2604.05	2597.37	2561.97
RHS 300 x 200/16	300	200	16	0.08	4316.40	4302.95	4267.07	4160.57
RHS 450 x 250/8	450	250	8	0.03	3488.23	3484.14	3472.54	3469.15
RHS 450 x 250/10	450	250	10	0.04	3780.56	3774.69	3765.23	3698.52
RHS 450 x 250/16	450	250	16	0.06	5912.40	5904.52	5899.63	5852.74

Steel Grade :275		
Length(m) :	6	
E=	210000	N/mm2
Support System:	P-P	
K value:	1	

Profile	Depth h [mm]	Width b [mm]	Wall thickness t [mm]	Aspect Ratio	Stimulation	Opening 1	Opening 2	Opening 3
RHS 100 x 60/3.2	100	60	3.2	0.05	75.85	61.59	57.66	53.74
RHS 100 x 60/6.3	100	60	6.3	0.11	126.62	114.33	109.08	103.55
RHS 100 x 60/8	100	60	8	0.13	148.44	136.39	130.64	123.68
RHS 120 x 80/4	120	80	4	0.05	201.68	191.86	185.54	179.15
RHS 120 x 80/8	120	80	8	0.10	350.36	343.53	334.49	323.48
RHS 120 x 80/10	120	80	10	0.13	417.56	402.27	392.55	382.41
RHS 300 x 200/8	300	200	8	0.04	2311.38	1577.99	1421.60	1360.15
RHS 300 x 200/10	300	200	10	0.05	2698.05	2565.37	2430.35	1880.08
RHS 300 x 200/16	300	200	16	0.08	4416.40	3766.15	3706.57	3616.67
RHS 450 x 250/8	450	250	8	0.03	3488.20	3145.93	3143.57	2908.82
RHS 450 x 250/10	450	250	10	0.04	4280.56	3759.87	3579.87	3553.71
RHS 450 x 250/16	450	250	16	0.06	5775.10	5403.15	5318.17	5184.87

FEA results of RHS column with increasing in opening numbers

Steel Grade :275		
Length(m) :	6	
E=	210000	N/mm2
Support System:	F-P	
K value:	0.7	

Profile	Depth	Width	Wall thickness	Aspect Ratio	Stimulation	Opening 1	Opening 2	Opening 3
	h	b	t					
	[mm]	[mm]	[mm]					
RHS 100 x 60/3.2	100	60	3.2	0.05	154.52	139.67	134.43	132.10
RHS 100 x 60/6.3	100	60	6.3	0.11	258.52	250.46	245.03	235.10
RHS 100 x 60/8	100	60	8	0.13	303.91	292.99	281.69	278.42
RHS 120 x 80/4	120	80	4	0.05	310.95	306.62	293.09	290.18
RHS 120 x 80/8	120	80	8	0.10	614.32	613.40	594.32	589.76
RHS 120 x 80/10	120	80	10	0.13	751.23	737.21	710.83	707.96
RHS 300 x 200/8	300	200	8	0.04	2567.90	2557.99	2150.19	2054.87
RHS 300 x 200/10	300	200	10	0.05	3164.60	2756.05	2698.47	2430.97
RHS 300 x 200/16	300	200	16	0.08	4415.00	3882.25	3200.07	3188.77
RHS 450 x 250/8	450	250	8	0.03	3488.20	3152.17	3143.60	3074.49
RHS 450 x 250/10	450	250	10	0.04	4280.56	3760.06	3681.92	3553.82
RHS 450 x 250/16	450	250	16	0.06	5912.40	5871.85	5710.07	5681.97

Steel Grade :275		
Length(m) :	6	
E=	210000	N/mm2
Support System:	F-Free	
K value:	2	

Profile	Depth	Width	Wall thickness	Aspect Ratio	Stimulation	Opening 1	Opening 2	Opening 3
	h	b	t					
	[mm]	[mm]	[mm]					
RHS 100 x 60/3.2	100	60	3.2	0.05	19.02	6.15	2.80	0.40
RHS 100 x 60/6.3	100	60	6.3	0.11	31.72	19.68	14.99	13.44
RHS 100 x 60/8	100	60	8	0.13	37.26	25.38	21.89	18.74
RHS 120 x 80/4	120	80	4	0.05	50.61	39.33	35.81	32.81
RHS 120 x 80/8	120	80	8	0.10	87.86	78.11	74.34	70.53
RHS 120 x 80/10	120	80	10	0.13	104.74	93.12	89.39	84.78
RHS 300 x 200/8	300	200	8	0.04	1670.56	1663.24	1661.44	1651.47
RHS 300 x 200/10	300	200	10	0.05	2031.13	2024.69	2014.04	1994.28
RHS 300 x 200/16	300	200	16	0.08	2955.62	2845.12	2822.25	2766.98
RHS 450 x 250/8	450	250	8	0.03	2600.54	2597.34	2571.12	2345.85
RHS 450 x 250/10	450	250	10	0.04	2897.79	2856.42	2716.12	2664.84
RHS 450 x 250/16	450	250	16	0.06	5162.51	5142.74	5122.78	5029.56

FEA results of RHS column with increasing in opening numbers

Steel Grade :275		
Length(m) :	8	
E=	210000	N/mm2
Support System:	F-F	
K value:	0.5	

Profile	Depth h [mm]	Width b [mm]	Wall thickness t [mm]	Aspect Ratio	Stimulation	Opening 1	Opening 2	Opening 3
RHS 100 x 60/3.2	100	60	3.2	0.05	199.76	170.74	157.33	150.02
RHS 100 x 60/6.3	100	60	6.3	0.11	403.93	381.42	370.90	362.66
RHS 100 x 60/8	100	60	8	0.13	493.07	470.28	460.30	451.01
RHS 120 x 80/4	120	80	4	0.05	398.51	384.49	377.32	366.76
RHS 120 x 80/8	120	80	8	0.10	689.09	671.05	368.66	354.48
RHS 120 x 80/10	120	80	10	0.13	854.25	824.40	819.37	808.79
RHS 300 x 200/8	300	200	8	0.04	2452.40	2363.71	2334.49	2305.26
RHS 300 x 200/10	300	200	10	0.05	2616.90	2594.51	2541.04	2465.23
RHS 300 x 200/16	300	200	16	0.08	4316.40	4225.59	4117.33	3981.52
RHS 450 x 250/8	450	250	8	0.03	3488.23	3137.91	3125.50	3104.12
RHS 450 x 250/10	450	250	10	0.04	3780.56	3653.32	3646.01	3634.34
RHS 450 x 250/16	450	250	16	0.06	5912.40	5614.55	5587.48	5416.96

Steel Grade :275		
Length(m) :	8	
E=	210000	N/mm2
Support System:	P-P	
K value:	1	

Profile	Depth h [mm]	Width b [mm]	Wall thickness t [mm]	Aspect Ratio	Stimulation	Opening 1	Opening 2	Opening 3
RHS 100 x 60/3.2	100	60	3.2	0.05	75.85	47.32	39.55	33.37
RHS 100 x 60/6.3	100	60	6.3	0.11	126.62	100.06	90.97	83.18
RHS 100 x 60/8	100	60	8	0.13	148.44	122.12	112.53	103.31
RHS 120 x 80/4	120	80	4	0.05	201.68	177.59	167.43	158.77
RHS 120 x 80/8	120	80	8	0.10	350.36	329.26	316.38	303.11
RHS 120 x 80/10	120	80	10	0.13	417.56	387.99	374.44	362.04
RHS 300 x 200/8	300	200	8	0.04	2311.38	2263.72	2203.49	2139.78
RHS 300 x 200/10	300	200	10	0.05	2698.05	2651.10	2612.24	2559.71
RHS 300 x 200/16	300	200	16	0.08	4416.40	3751.88	3688.46	3596.30
RHS 450 x 250/8	450	250	8	0.03	3488.20	3161.66	3125.46	2888.45
RHS 450 x 250/10	450	250	10	0.04	4280.56	3745.29	3741.76	3733.34
RHS 450 x 250/16	450	250	16	0.06	5775.10	5738.88	5730.06	5716.50

FEA results of RHS column with increasing in opening numbers

Steel Grade :275		
Length(m) :	8	
E=	210000	N/mm2
Support System:	F-P	
K value:	0.7	

Profile	Depth h [mm]	Width b [mm]	Wall thickness t [mm]	Aspect Ratio	Stimulation	Opening 1	Opening 2	Opening 3
RHS 100 x 60/3.2	100	60	3.2	0.05	154.52	125.40	116.32	111.73
RHS 100 x 60/6.3	100	60	6.3	0.11	258.52	236.19	226.92	214.73
RHS 100 x 60/8	100	60	8	0.13	303.91	278.73	263.58	258.05
RHS 120 x 80/4	120	80	4	0.05	310.95	292.35	274.98	269.81
RHS 120 x 80/8	120	80	8	0.10	614.32	601.13	576.21	569.39
RHS 120 x 80/10	120	80	10	0.13	751.23	722.94	692.72	687.59
RHS 300 x 200/8	300	200	8	0.04	2567.90	2563.72	2132.08	2134.50
RHS 300 x 200/10	300	200	10	0.05	3164.60	2741.78	2680.36	2610.60
RHS 300 x 200/16	300	200	16	0.08	4415.00	3367.98	3181.96	3168.40
RHS 450 x 250/8	450	250	8	0.03	3488.20	3137.90	3125.49	3054.12
RHS 450 x 250/10	450	250	10	0.04	4280.56	3745.79	3663.81	3633.45
RHS 450 x 250/16	450	250	16	0.06	5912.40	5857.58	5791.96	5661.60

Steel Grade :275		
Length(m) :	8	
E=	210000	N/mm2
Support System:	F-Free	
K value:	2	

Profile	Depth h [mm]	Width b [mm]	Wall thickness t [mm]	Aspect Ratio	Stimulation	Opening 1	Opening 2	Opening 3
RHS 100 x 60/3.2	100	60	3.2	0.05	19.02	16.12	15.31	13.97
RHS 100 x 60/6.3	100	60	6.3	0.11	31.72	30.41	29.89	26.07
RHS 100 x 60/8	100	60	8	0.13	37.26	35.11	33.73	30.65
RHS 120 x 80/4	120	80	4	0.05	50.61	25.06	17.70	12.44
RHS 120 x 80/8	120	80	8	0.10	87.86	63.84	56.23	50.16
RHS 120 x 80/10	120	80	10	0.13	104.74	78.85	71.28	64.41
RHS 300 x 200/8	300	200	8	0.04	1670.56	1658.97	1643.33	1631.10
RHS 300 x 200/10	300	200	10	0.05	2031.13	2025.42	2015.93	1995.91
RHS 300 x 200/16	300	200	16	0.08	2955.62	2946.11	2934.70	2918.49
RHS 450 x 250/8	450	250	8	0.03	2600.54	2583.01	2551.12	2449.85
RHS 450 x 250/10	450	250	10	0.04	2897.79	2762.31	2727.65	2645.82
RHS 450 x 250/16	450	250	16	0.06	5162.51	5171.35	5157.44	5118.61

FEA results of RHS column with increasing in opening numbers

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