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BUCKLING ANALYSIS OF COLD FORMED STEEL CHANNEL SECTIONS WITH AND WITHOUT STIFFENERS

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ABSTRACT- The Light gauge cold-formed steel sections being used extensively in residential, industrial and commercial building as secondary load bearing members since last three decadez. In this context a study is being made to analyses C Sections with and without stiffeners to arrive at design strength criterion in compression. The direct strength method of design for cold formed steel sections has been validated over the years through research and the same has been incorporated in the standard codes of practice in the countries like USA and Australia.

ABAQUS and CUFSM has been extensively used to perform Finite Element analysis and Finite Strip method of thin walled cold formed steel sections and the results are compared to each other. The analysis is being done on CUFSM and ABAQUS. The design strength curves will be arrived at using direct strength method. This is because cold-formed steel sections have a very high strength to weight ratio compared with thicker hot-rolled steel sections, and their manufacturing process is simple and cost-effective. In this context, a study is being made to analyze C sections with and without stiffeners to arrive at design strength criterion in compression members.

In this study, the behavior of C sections with and without stiffeners under the action of axial loads has been carried out with various thickness and depths. In ABAQUS, the loads are applied on both ends.
The clamped end conditions are considered.

KEYWORDs—C sections, Cold formed steel, parametric study, buckling modes, Axial capacity.

I. INTRODUCTION

In recent years, the usage of cold-formed steel structural members is more than the traditional heavier hot-rolled steel structural members due to higher strength materials and a wider range of structural applications. The cold formed structural steel concept is originated in the western world. In cold-formed steel structural elements steel sections are formed in a cold state from steel sheets of uniform thickness. The most using sectional profiles of the cold-formed steel members are angles, end stiffeners or web stiffeners in primary structural applications. Generally the thickness of steel members used in the cold formed steel is in between 0.4mm to 6.4mm. The yield point and the ultimate strength of the steel sections are increased due to this cold formed process. Now days cold formed steel structures are widely suggested by the architects, engineers, builders and manufacturers of building due to its large strength to weight ratio, versatility, non-combustibility with appropriate measures and ease of production, economical. The cold-formed steel products are used in primary beams, floor units, roof trusses, wall panels and building frames.

Buckling is the major structural aspect that governs the behaviour of cold formed steel sections due to thickness of sections. Buckling occurs as local and distortional buckling before it can get into torsional and axial-torsional modes. To resist the local and overall buckling problems, stiffeners are used in the members having a larger cross-sectional effective area.

In this context C-section is chosen which are commonly manufactured in Cold Formed Steel Industry and a parametric study has been conducted on the C sections. By the results of the parametric study, the parameters are the parameters that are considered for the study are the web depth, thickness, and spans So as to arrive at the optimum cross-section profiles. Following are the sizes of the sections that are considered for this study.

- Web depth = 200mm, 250mm
- Flange Width = 100mm
- Thickness = 1.75mm, 2mm, 2.5mm.
- Span = 2m, 3m, 4m.

II. METHODOLOGY

The most commonly used numerical methods which for conducting buckling analysis are the finite strip method (FSM) and the finite element method (FEM).So both FSM and FEM are used in this study, Using FEM could solve the nonlinear buckling/ultimate failure loads easily, because large number of equations and extremely big matrix impossible to work on solutions. It is easy to get the different buckling loads/modes by using FSM. In order to understand both the elastic buckling and post-buckling failure performance the following analytical methods are used:

A. *ABAQUS*

ABAQUS is designed primarily, to analysis the behavior of solids and structures under externally applied loading. It is a finite element program which is having high degree of complexity, Capable of solving both static and dynamic problems. It can able to analyze the nonlinearities viz. material non-linearity and geometric non-linearity and also to model a number of phenomena of interest, including vibrations, coupled fluid/structure interactions, acoustics, buckling problems, and so on.

The most efficient tool to analyse the behaviour of steel structures is finite element analysis program (FEM). It is a new technique. It can analyse Light gauge cold-formed steel compression members under different types of boundary conditions and temperature levels.. It was first introduced in 1950 and there are many new techniques added to it.

Today any type of problems can be analysed by using this finite element program ABAQUS although it is complex. However, finite element analysis is playing an important role in engineering practice. In a structural simulation, FEM helps in producing stiffness and strength visualizations [2].Light gauge cold-formed steel compression members can be modelled and analysed under different types of boundary conditions.. It is relatively inexpensive and time efficient compared with physical experiments. In ABAQUS, simulation for the cold formed steel C section, 4-node shell element is used i.e S4R (4-node doubly curved general-purpose shell, reduced integration with hourglass control) [3].

There are two methods involved in the ABAQUS model. Those are elastic buckling analysis and non-linear static analysis. Firstly, for the analysis of elastic buckling, typical linear perturbation analysis is used. Several buckling modes can be obtained from the perturbation analysis. The particular buckling mode is to be identified and the eigen value is to be picked up. Essentially a critical elastic buckling load is provided by this step. For non linear static analysis, Modified Riks Method which is relatively based on Newton- Raphson Method is used. To get the axial capacity of the section, the elastic buckling load obtained from the first step is further used in the second step.

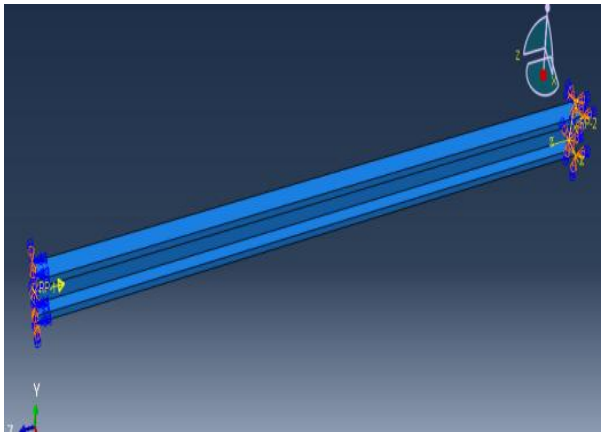


Fig. 1Setting up of Boundary condition (clamped-clamped) and Loading

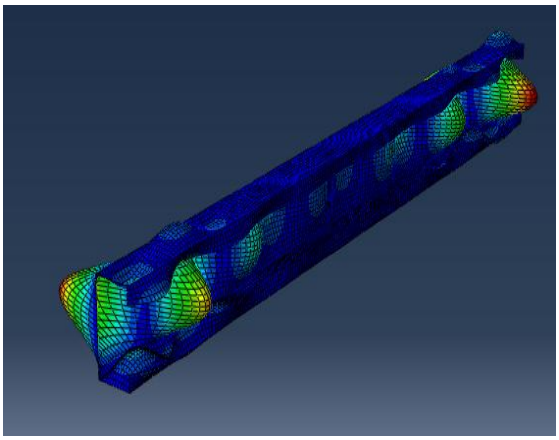


Fig. 2 Buckled Shape

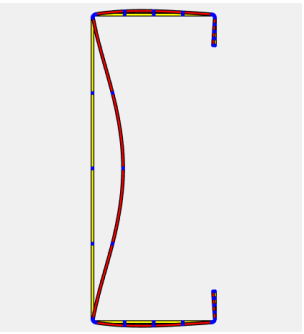
B. CUFSM

CUFSM stands for Constrained and Unconstrained Finite Strip Method. It is a computer programme which has been developed by W. Schafer at John Hopkins University, Baltimore to investigate different modes of buckling in thin-walled structures. The analysis is based on the finite strip method, which subdivides the thin-walled sections into longitudinal strips. Any steel section can be analysed using CUFSM program and the appropriate length of a member can be obtained to suit the desired buckling mode.

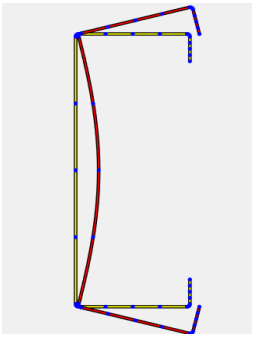
Following are the steps involved in modelling:

- Give the coordinates of each node on the cross-section as input
- Material properties have to be set.
- Boundary conditions have to be specify
- Define loads on the cross-section
- calculation and the post processing of results

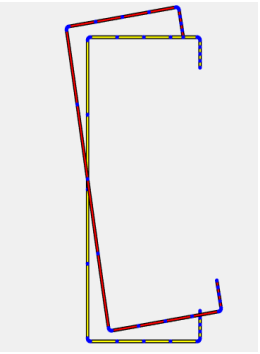
The critical load values for different buckling modes are arrived at from the above analysis. They are further substituted into the Direct Strength Method equations to obtain the design strength. Fig. 3 shows the buckle shapes and the buckling curve obtained from CUFSM for C section.



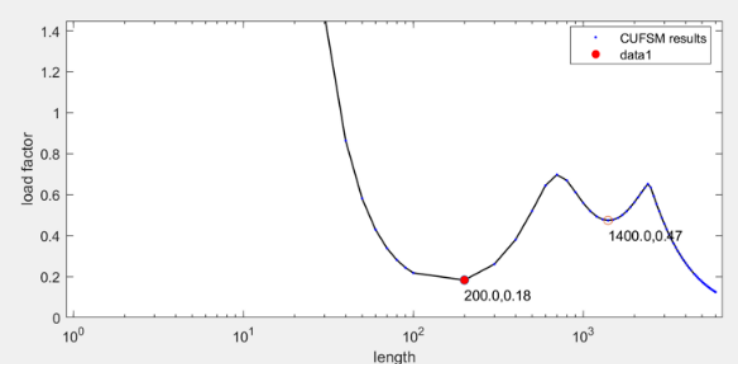
a. Local Buckling shape



b. Distortional Buckling shape



c. Global Buckling shape



d. Buckling Curve

Fig. 3 Buckle shapes and the buckling curve of C section obtained from CUFSM

c. Direct Strength Method

The Direct Strength Method is relatively new design method for CFS. This method is used to determine the design load after obtaining load factors in elastic buckling in local, distortional, and global modes from CUFSM. After the determination of the load that causes first yield for entire cross-section, is then to be applied into equations in order to define strength prediction. Once the determination of elastic local, distortional, and global buckling loads is made then application of the method is straightforward [4].

The **DSM** does not depend on effective width, nor require iteration for the determination of member design strength. Instead, the analyses have to determine the load after elastic buckling in local, distortional, and global buckling. From the determination dealing with the load that causes first yield are then to be applied into equations in order to define strength prediction (directly).

Direct Strength Method is used to evaluate the elastic buckling capacities of local, distortional and global buckling modes for both compression and flexural CFS members. If elastic buckling value is high enough then full capacity will be developed. Then, the buckling failure modes will not occur before the yielding of the materials. However, the section flexural strength will not reduce due to local, distortional and global buckling effects. Therefore, yield moment (M_y) can be specified as the section flexural strength when the following conditions are satisfied:

Local buckling: $M_{crl} > 1.66M_y$
Distortional buckling: $M_{crd} > 2.21M_y$
Global buckling: $M_{cre} > 2.78M_y$

The buckling capacity can be sufficiently the smallest capacity for the design section:

$$\mathbf{M_n = Min\ (M_{nl}, M_{nd}, M_{ne}, M_y).}$$

For a C section due to its anti-symmetry, with This is because the Center of Gravity (C.G) and Shear center coincides. So first local buckling occurs, then global buckling is followed after the local buckling. However Distortional mode is not a distint mode and never be a governing mode for C section.

Comparison between the Finite Element Method and the Finite Strip Method[5]

Finite strip is a specialized version of the finite element method. In the finite strip method, element shape functions use polynomials in the transverse direction, but trigonometric functions in the longitudinal direction. Judicious choice of the longitudinal shape function allows a single element, a "strip" to be used. In finite element method, usually large number of equations and extremely big matrix. In Finite strip method, much shorter computing time for solution with nearly the same accuracy. Classical finite strip, as implemented in CUFSM, uses a single half sine wave (sin(px/a)) for the longitudinal direction.

III) Results and Discussion:

The study conducted on lipped C section to see the variation of strength with depths, thickness, spans and ratios has been summarised and presented in the following tables and in the form of graphs. The section profiles considered for analysis are LC, SCC and DSC. The analysis has been carried out for different spans (2m, 3m and 4m) and by varying thickness (1.75mm, 2mm and 2.5mm). Two different sizes of sections were considered i.e, 200x100x35 and 250x100x35. The analysis results show the effect of cross section profile on the axial strength. Numerical simulation of different channel sections by using stiffeners has been carried out and also by varying different parameters such as thickness of sections, span of sections, and by varying web depths.

TABLE I
RESULTS OF CUFSM FOR LIPPED C SECTION

Lipped C-Section (Clamped-clamped)					
Span (mm)	**Thickness (mm)**	**Load (KN)**			
		200 X 100 X 35 mm		**250 x 100 x 35 mm**	
		CUFSM	**ABAQUS**	**CUFSM**	**ABAQUS**
2000	**1.75**	153.47	136.58	164.42	146.34
3000		114.51	99.62	127.21	111.64
4000		105.9	95.31	124.32	110.67
2000	**2**	193.59	164.55	206.85	175.83
3000		163.8	150.69	167.59	154.1
4000		150.79	129.68	160.29	137.85
2000	**2.5**	284.21	250.1	302.68	266.36
3000		227.06	206.62	254.94	231.99
4000		212.46	184.84	234.77	204.23

From table 1. Comparison between CUFSM and ABAQUS for Lipped channel section

TABLE II
RESULTS OF CUFSM FOR SINGLE STIFFNER SECTION

Lipped Single stiffener C-Section (Clamped-clamped)					
Span (mm)	**Thickness (mm)**	**Load (KN)**			
		200 X 100 X 35 mm		**250 x 100 x 35 mm**	
		CUFSM	**ABAQUS**	**CUFSM**	**ABAQUS**
2000	**1.75**	227.18	202.19	253.06	225.22
3000		187.51	163.33	193.68	168.51
4000		171.47	154.32	183.59	165.23
2000	**2**	281.61	239.37	304.37	258.71
3000		239.83	210.48	241.29	221.99
4000		228.78	206.25	237.21	204
2000	**2.5**	315.37	277.53	355.97	313.25
3000		307.44	279.23	342.98	312.12
4000		306.85	267.47	310.45	270.09

Table 2. Comparison between CUFSM and ABAQUS for single stiffener channel section.

TABLE III
RESULTS OF CUFSM FOR DOUBLE STIFFNER SECTION

Lipped Double stiffener C-Section (Clamped-clamped)					
Span (mm)	**Thickness (mm)**	**Load (KN)**			
		200 X 100 X 35 mm		**250 x 100 x 35 mm**	
		CUFSM	**ABAQUS**	**CUFSM**	**ABAQUS**
2000	**1.75**	239.27	212.95	261.42	232.66
3000		199.69	179.72	204.29	186.86
4000		185.13	161.06	191.56	166.66
2000	**2**	290.1	246.58	320.96	272.82
3000		257.58	236.97	261.08	240.19
4000		237.42	204.18	255	219.31
2000	**2.5**	357.46	314.56	362.59	319.08
3000		348.63	296.34	357.46	325.29
4000		321.52	270.08	345.83	300.87

Table 3. Comparison between CUFSM and ABAQUS for Double stiffener channel section.

Graphs:

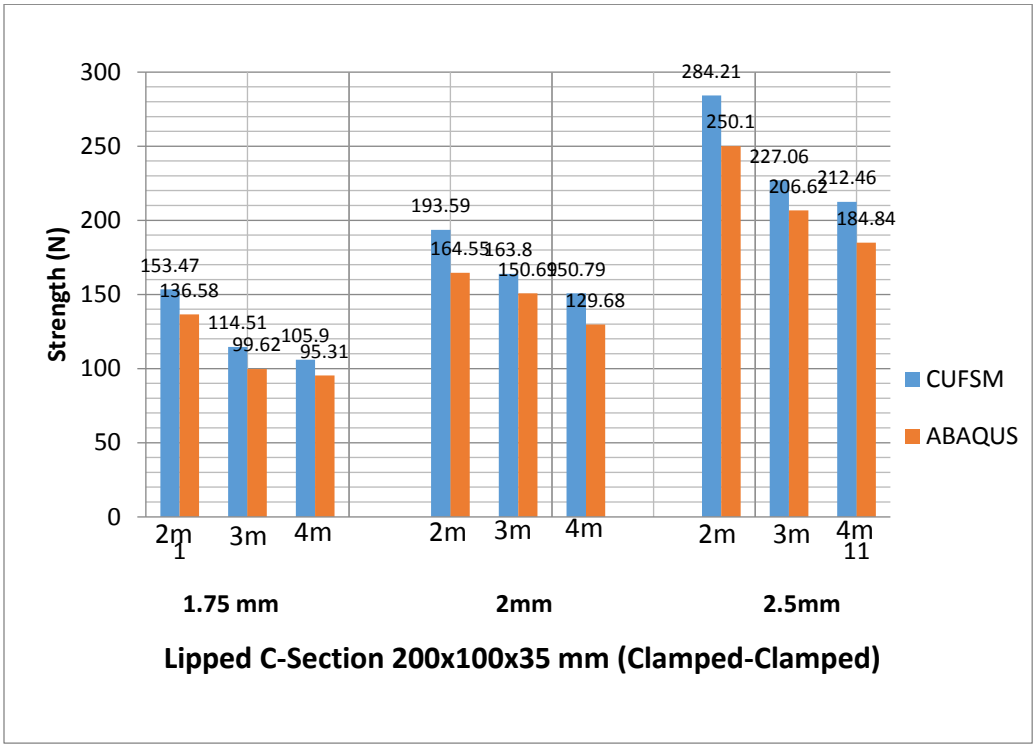


Fig.4 A graph of strength versus span/web depth for 200mm depth for Lipped C section

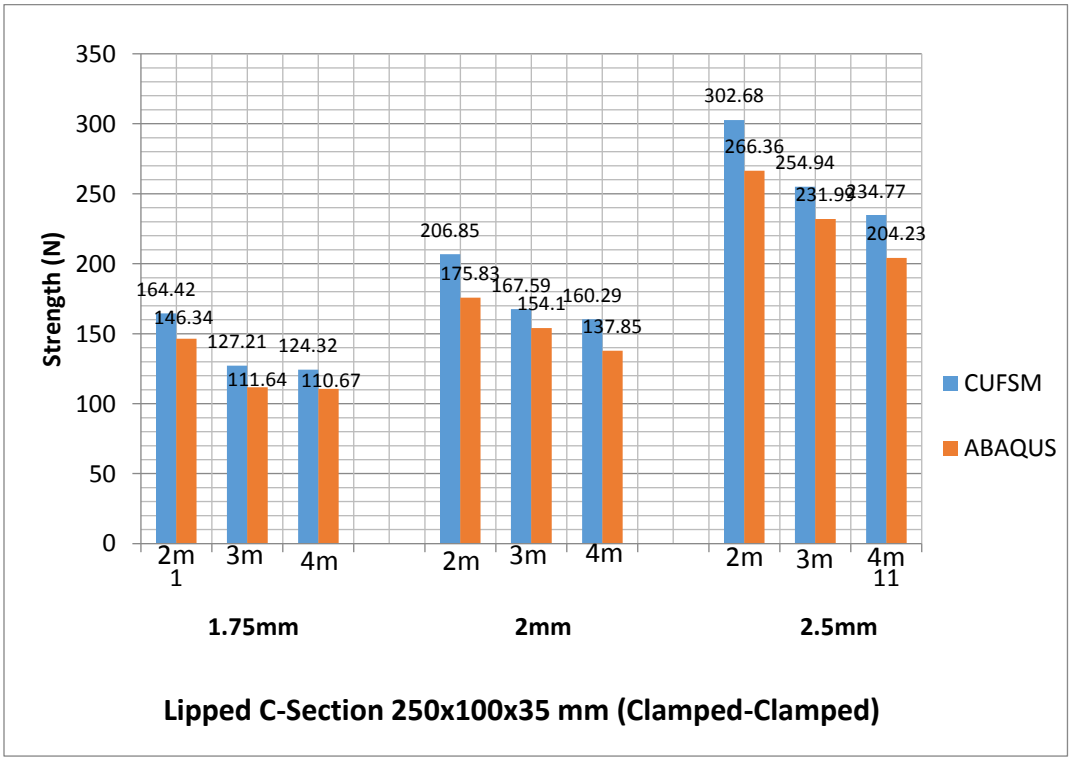


Fig.5 A graph of strength versus span/web depth for 250mm depth for Lipped C section

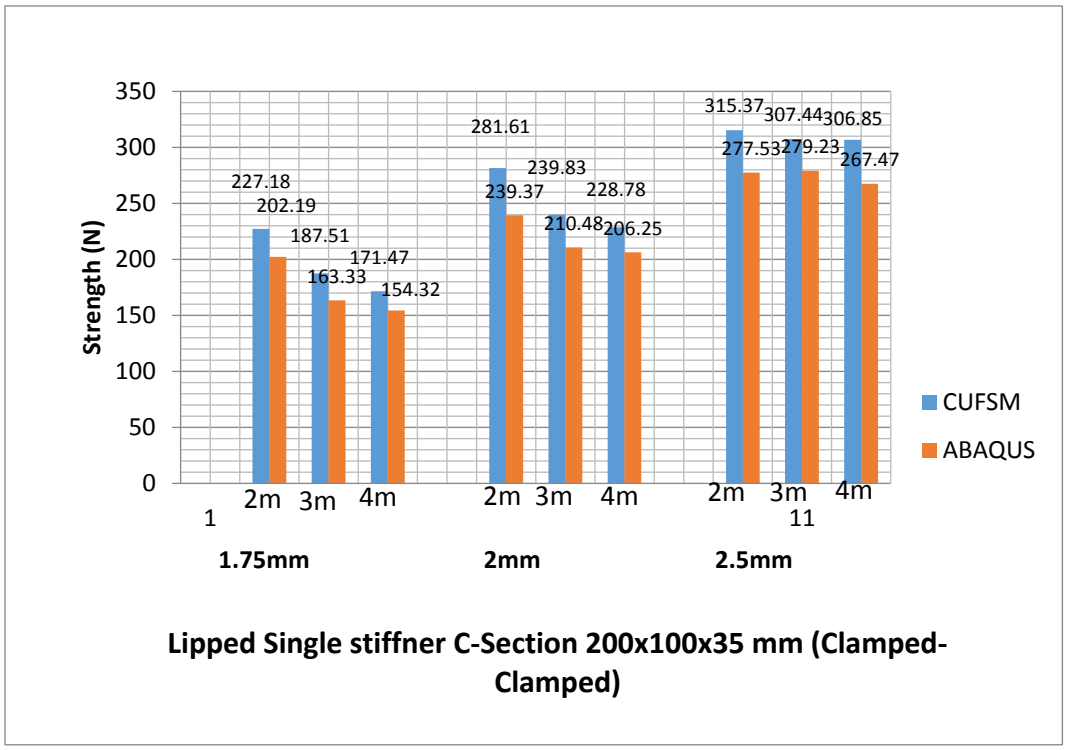


Fig. 6 A graph of strength versus span/web depth for 200mm depth for single stiffener section.

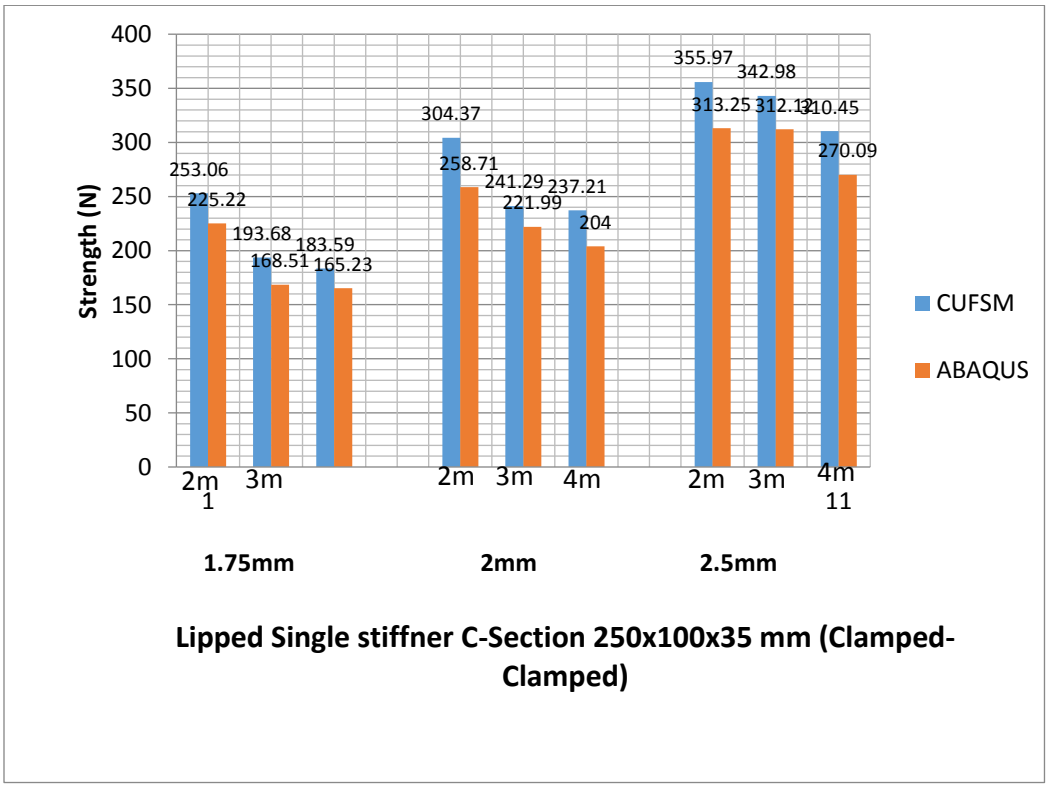


Fig. 7 A graph of strength versus span/web depth for 250mm depth for single stiffener section.

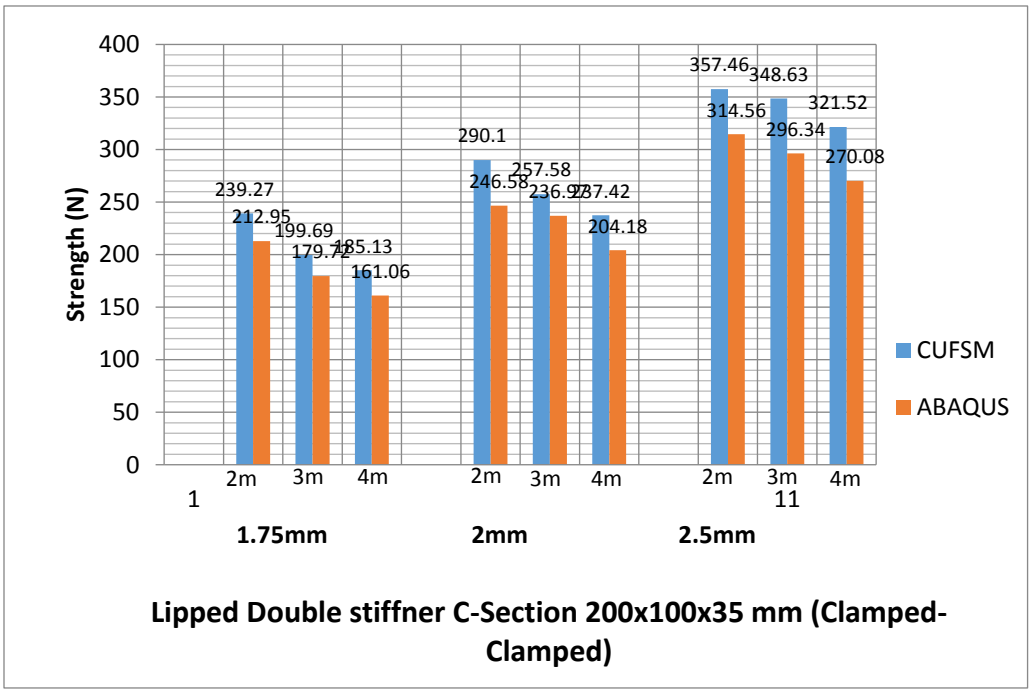


Fig. 8 A graph of strength versus span/web depth for 200mm depth for Double stiffener section.

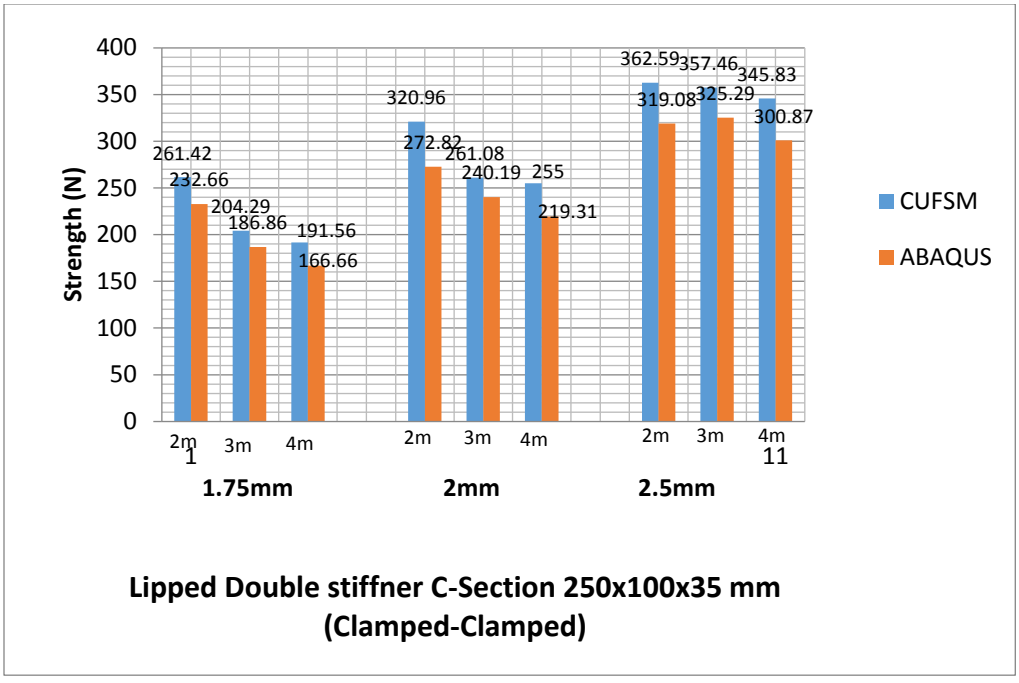


Fig. 9 A graph of strength versus span/web depth for 250mm depth for Double stiffener section.

IV. Conclusions

- Average of 23% of increase in axial capacity of lipped channel section with stiffener at center when compared to lipped channel section is observed.
- When two stiffeners are provided in the web, average of about 40% of increase in axial capacity isobserved.
- The axial capacity of double stiffener section is about 23% more than that of section with single stiffener at center of web.
- With the increase in web depth of 50mm, about an average of about 40% increase in strength is observed.

- An average of about 52% and 19% increase in axial capacity for 2.5mm and 2mm thickness respectively when compared to that of 1.75mmthickness.
- The depreciation of about an average of about 30% and 45% of axial strength is observed with the increase of spans 3.0m and 4.0mrespectively.

V. REFERENCES

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