International Journal of Engineering Science Invention (IJESI)
ISSN (Online): 2319-6734, ISSN (Print): 2319-6726
www.ijesi.org ||Volume 10 Issue 7 Series I || July 2021 || PP 22-29

Structural optimization and cost effective light weight composite Cold-form steel structures

Abhijith B Nair[1], Rohini G Nair [2]
[1]*(Civil Engineering Department, NSS College Of Engineering Palakkad, India)*
[2]*(Asst. Prof., Civil Engineering Department, NSS College Of Engineering Palakkad, India)*

ABSTRACT*: This paper aims to develop the optimized innovative less weight composite Column to replace the conventional hot rolled steel columns in aspect of weight reduction and economic design for steel and composite building. to achieve this less weight concept, four types of columns are made and cold form channel section is used in the form of multi sectional alignment which is embed with high strength bolt and ultra-light weight concrete is filled inside the CFS sections to increase the stiffness and strength. This study deals with parametric optimization of concrete filling aspect ratio to avoid the buckling and various CFS section alignment to resist more load. The complete investigation of this research is carried on ANSYS software and results are compared with convention system along with this cost comparison is also discussed in considering the economic design.*

KEYWORDS– *ANSYS, CFST, Economic, Optimization*

Date of Submission: 25-06-2021 Date of Acceptance: 07-07-2021

I. INTRODUCTION

Structural engineering applications for cold-formed steel (CFS) sections are increasing steadily and the use of CFS built-up box sections is becoming popular. This article presents the results of finite element analyses on CFS built-up box sections; for comparison, the results of 8 single channels under compression are also presented. The cross sectional details of the CFS built-up box section are shown in Fig. 1.1. As can be seen, the built-up box section is formed from two identical lipped channel-sections connected front-to-front. Such CFS built-up box sections are used in CFS construction due to the advantages of high load-carrying capacity, stability, and higher moment of inertia, when compared to the back-to-back built-up CFS channel sections.

In the literature, no previous work has described any built-up box sections, composed of channels, connected front-to-front through bolts or screws, under axial compression. While Reyes and Guzman [1], did describe experimental tests on front-to front channels, these were welded. It was shown that if the seam weld spacing was less than or equal to 600 mm, a modified slenderness ratio could be used instead of the actual slenderness ratio for materials 1.5 mm and 2.0 mm thick. On the other hand, Li et al. [2] conducted experimental and numerical investigations on flexural strength of CFS thin-walled beams with built-up box section which consists of nested C and U sections with the self drilling screws. For U section beam bending about strong axis, the failure was more “local” than that of C section beams. For built-up box sections, the failure modes were the local buckling of flanges and webs.

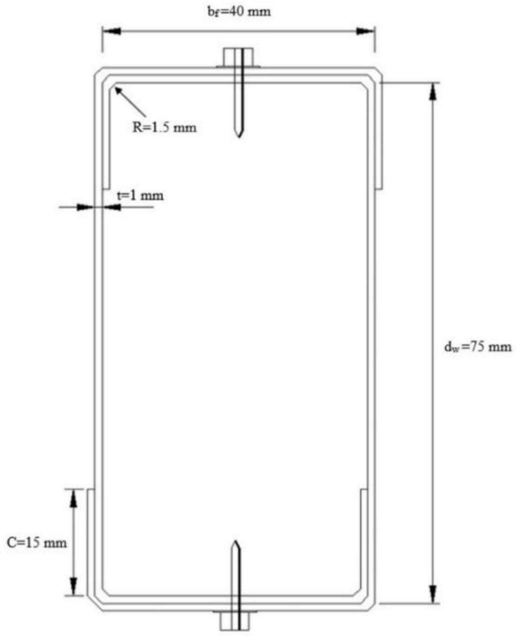


Fig 1 Nominal cross-sections of CFS built-up box section considered

A composite section can be made by partially and fully filling of ultra-light weight concrete. Ultra lightweight cement composite (ULCC) is a type of novel composites characterized by combinations of low densities typically less than 1500 kg/m^3, high compressive strengths more than 60 MPa with specific strength of up to 47 kPa/(kg/m^3). In order to satisfy different needs for those structures sensitive to their self-weight, for example, flat slabs and bridges decks, novel steel fiber reinforced ultra-lightweight cement composites (ULCC) with densities ranging from 1250 kg/m3 to 1550 kg/m3 and compressive strength more than 48 MPa were developed by Jun-Yan Wang et al [3]. ULCC 1250 concrete is using throughout for this work.

II. METHODS OF IMPROVISATION

2.1. Multi limb built-up sections

Cold-formed steel built-up sections are applied as structural members in the construction industry for more structurally efficient cross-section shapes when higher capacity is required. Two or more single CFS members are connected for a built-up section in order to carry higher loads as well as to cross a larger span.

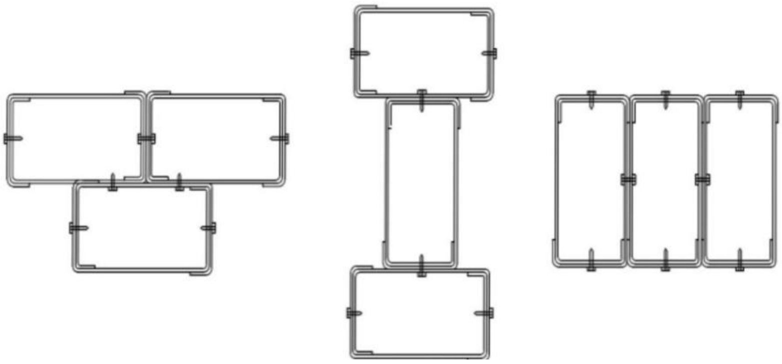


Fig 2 T shaped, I shaped and composite rectangular shaped multi limbed built-up box columns

Built-up sections have advantages of lightness, fast production, transportation and erection. They have high strength-to weight ratio, high structural efficiency and so on over hot rolled members. Normal built-up sections having single limb can't attain a strength comparing to conventional column sections and it can be easily achieved by multi-limb built-up sections. Various types of multi-limb built-up section are shown in Fig 1.2.

2.2. Usage of ULCC

ULCC can be used partially and fully on multi-limb sections . In this project we are filling partially in web and flange in different manner, also fully filled sections are considered for a better result.

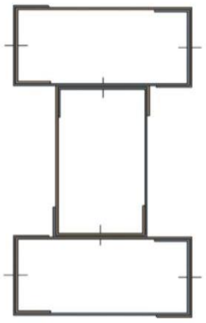


Fig 3 I-CFS(Three limb I section)

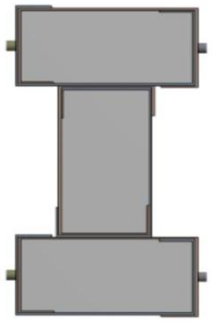


Fig 4 FCF-I (Fully ULCC filled I section)

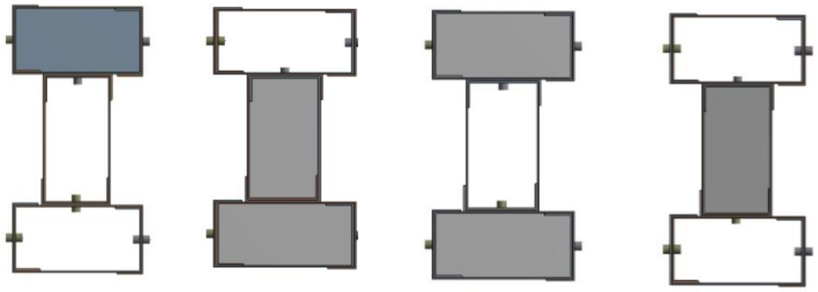


Fig 5 Partially ULCC filled I sections(PCF-I-1F,PCF-I-1F+W,PCF-I-2F,PCF-I-W)

III. OBJECTIVES

Built-up box sections are becoming increasingly popular for column members in cold-formed steel (CFS) construction; uses of such sections include CFS trusses, space frames, and portal frames. The built-up box sections are formed through two identical lipped channels connected at their flanges with self-drilling screws and they are connected to each other to form different shapes to get an economical primary section.

1. To study the structural behavior of 3 limbed multi-section CFS columns with ‘I’ shape arrangement
2. Optimize the structural performance and buckling stability by filling the light weight concrete in to CFS column
3. Comparing the structural performance with conventional steel column

IV. MODELLING AND ANALYSIS

Modelling of full steel CFS multi limbed column using ANSYS design modeler software. ANSYS is a software company that can design simulation software products for companies/researchers/enthusiasts to simulate their designs. It can be used in several fields like mechanical, electrical, aeronautical and fluid mechanics. Their products for mechanical design are much famous and important for a lot of mechanical companies. ANSYS Workbench platform is the basis for delivering a comprehensive and integrated simulation. It is used to perform various types of structural, thermal, fluid, and electromagnetic analyses. The entire simulation process is tied together by a project schematic, from which you can interact with applications that are native to ANSYS Workbench or launch applications that are data-integrated with ANSYS Workbench. It includes CAD connectivity, automated meshing, a project-level update mechanism, and optimization tools. The user interface of ANSYS workbench is much easier than APDL. The basics of simulation process includes geometry, importing, meshing, application of loads and supports, different procedure for performing FEA simulations like linear static, modal and heat analysis.

Table 1 Mechanical properties of cold form steel

Section	Nominal thickness	Base metal thickness	Gauge length	Yield stress	Gauge width	Ultimate stress	Young's modulus
	t	T	L_0	$\sigma_{0.2}$	b	σ_u	E
	(mm)	(mm)	(mm)	(MPa)	(mm)	(MPa)	GPa
Longitudinal	1.01	1.0	50	559	12.5	678	207

Modelling of composite CFS multi limbed column by partial fill and fully filled condition. A Nonlinear static analysis with axial compression load testing is carried to investigate the structural performance using ANSYS workbench software. The futuristic technology application in terms of cold formed steel in steel structures and also to increase the usage of cold roll steel as primary structural member in light weight structures. The further study on the cold form steel with types of configuration and connection would provide to the various beneficial properties. Application of ULCC in cold form section will give a effective light structure to replace the primary conventional steel sections

Table 2 Mechanical properties of ultra light weight concrete

Parameters used to define the compressive behaviors of the four types ULCC.

Type	ε_{uc}	f_{uc} (MPa)	ε_{uc1}	f_{uc1} (MPa)	E_1 (GPa)	E_1' (GPa)	E_2 (GPa)	E_3 (GPa)
U1250	0.0045	48.03	0.0051	21.54	10.79	11.88	45.48	0.55
U1350	0.0042	52.12	0.0051	24.11	12.41	13.64	29.03	0.26
U1450	0.0044	61.07	0.0052	27.85	14.04	15.52	43.33	0.14
U1550	0.0044	70.06	0.0050	30.37	15.78	17.65	76.42	1.31

Note: E1 is the eastic modulus calculated directly from the compressive stress strain curve; E1′ is the elastic modulus tested according to ASTM C469.

4.1. I section without filling

One box section act as web and the others will flanges of I section. It will more stronger than single box section as we know it is three times cross-sectional area. Current design guidelines as per the AISI [16], and AS/NZS [17], recommends the use of a modified slenderness approach to consider the spacing of fasteners while calculating the axial capacity of CFS built-up box sections. It is worth mentioning that the applicability of the modified slenderness method, which has been adopted from the design guidance for hot-rolled steel, has never been demonstrated for CFS built-up box sections.

The nominal cross-sectional geometry of the CFS built-up box columns investigated in this article is shown in Fig. 1. Length of 1500mm were considered for analysis. The properties and initial imperfections were measured for all test specimens. The axial capacity and deformation patterns of CFS built-up columns are reported.

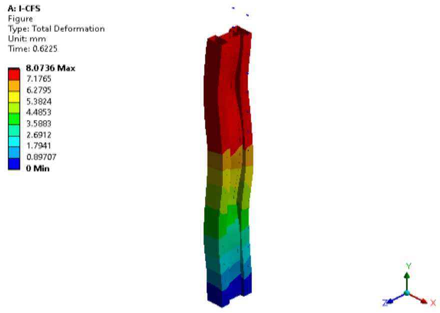


Fig 6 Total deformation of I-CFS

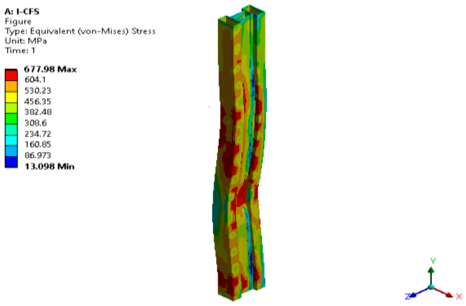


Fig 7 Stress distribution of I-CFS

4.2.Partially filled I sections

Partially filling can be done in different forms such as one flange filled, two flange filled, web filled and 1flange and web filled

- PCF-I-1F: In this section only one flange of the section is filled with ULCC 1250

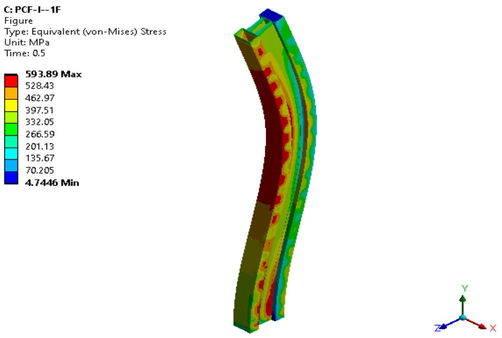


Fig 8 Total deformation of PCF-I-1F

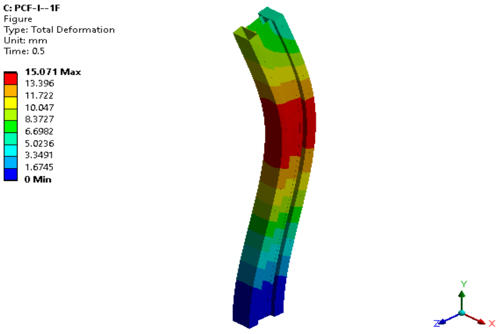


Fig 9 Stress distribution of PCF-I-1F

- PCF-I-2F (two flanges filled)
  In this case we analyse the built-up column with both flanges are filled with ULCC

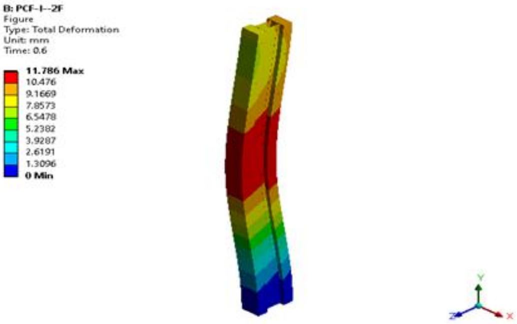


Fig 10 Total deformation of PCF-I-2F

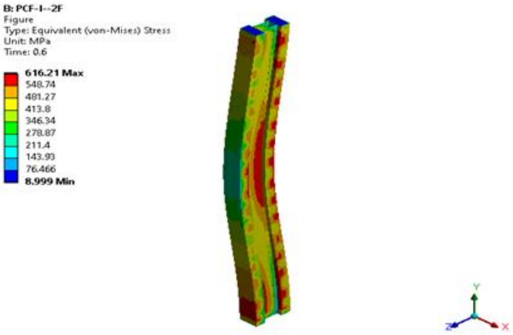


Fig 11 Stress distribution of PCF-I-2F

- PCF-I-W(web filled)
  In this section only web of the section is filled with ULCC 1250

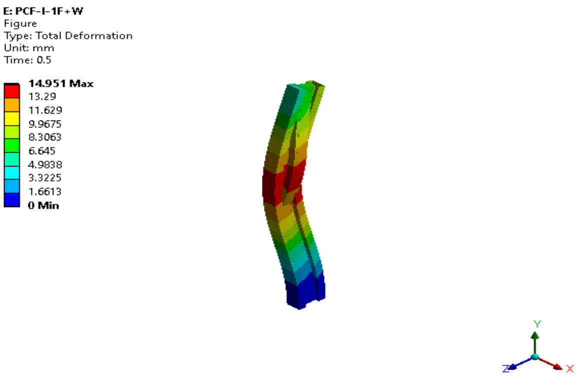


Fig 12 Total deformation of PCF-I-W

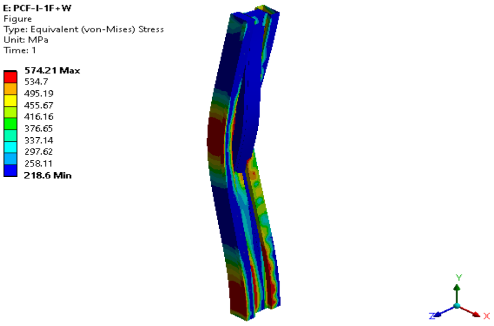


Fig 13 Stress distribution of PCF-I-W

- PCF-I-1F+W(filled in 1 flange and web)

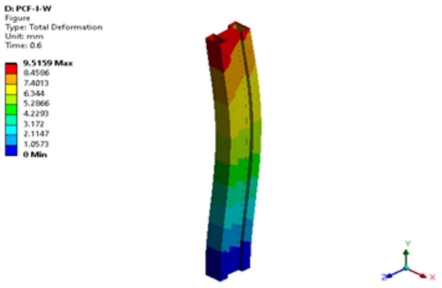


Fig 14 Total deformation of PCF-I-1F+W

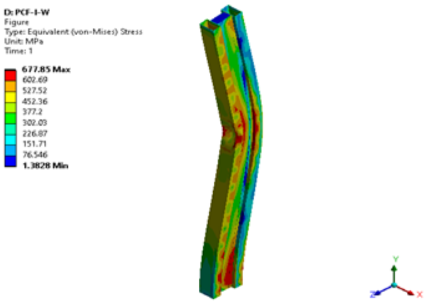


Fig 15 Stress distribution of PCF-I-1F+W

In this section we tried a infill of ULCC 1250 in one of the flange along with the web of the I section.

4.3.Fully filled I section (FCF-I)

The whole box sections are filled in this case to attain a maximum strength.

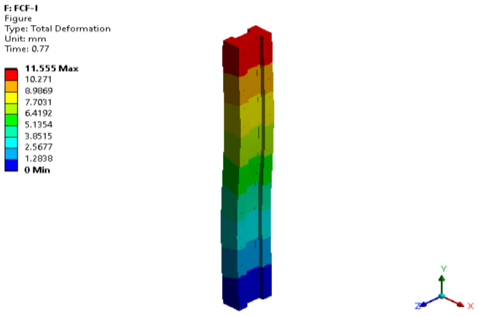


Fig 16 Total deformation of FCF-I

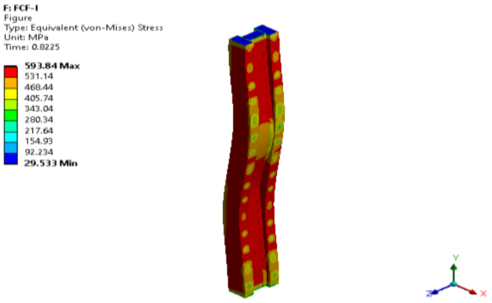


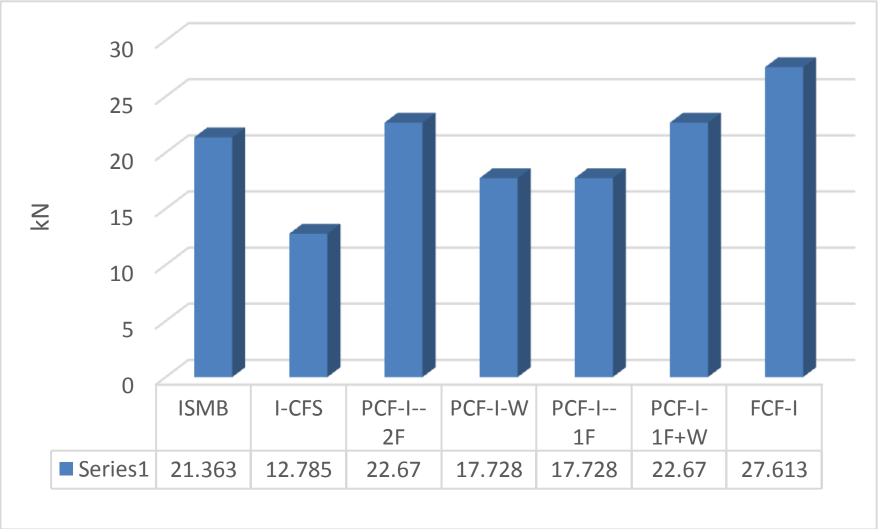
Fig 17 Stress distribution of FCF-I

V. RESULTS AND DISCUSSIONS

5.1. Weight comparison

The weight of the total 1500mm specimens are compared here with ISMB 150 which have a relative weight, also it is most commonly used primary section. I-CFC having almost half in weight compared to ISMB. PCF-I-2F, PCF-I-1F+W and FCF-I have more weight than conventional section shown in chart 1.

Chart 1 comparison of the total weight of sections

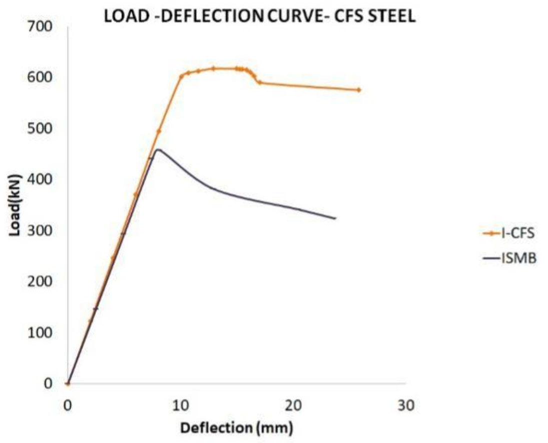


5.2. Axial load

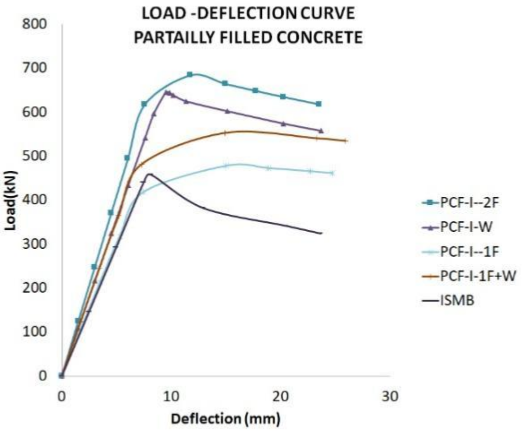
All section are failed due to minor axis flexural buckling. We have to compare all built-up sections with conventional primary steel section ISMB 150 , similar cross sectional area. All built-up sections have high strength than the conventional I section. We have compared to I section individually for partially and fully filled sections

Table 3 Deflection, Load and Percentage of increase in load

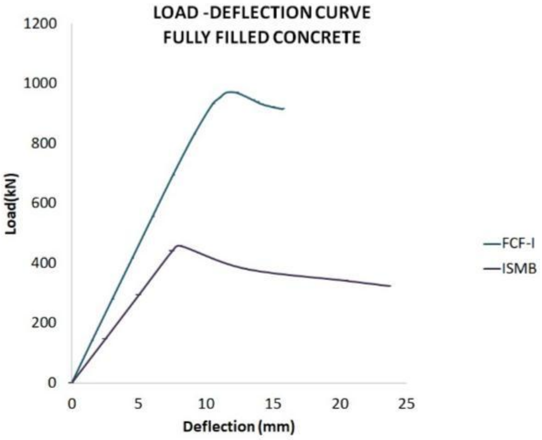
	MODEL	WEIGHT	U-DEF(mm)	PU-LOAD (KN)	% of increse in load
	ISMB	21.363	8.1253	458.43	1.00
FULL STEEL	I-CFS	12.785	12.92	617.55	34.71
PARTIALLY FILLED	PCF-I--2F	22.67	11.79	683.97	49.20
	PCF-I-W	17.728	9.52	645.12	40.72
	PCF-I--1F	17.728	15.07	478.61	4.40
	PCF-I-1F+W	22.67	14.951	553.36	20.71
FULLY FILLED	FCF-I	27.613	11.555	971.07	111.83



Graph 1 Load vs deflection of I-CFC



Graph 2 Load vs deflection of partially filled sections



Graph 3 Load vs deflection of fully filled section

VI. CONCLUSIONS

In this paper, an analytical investigation on the axial capacity of multi-limb built-up CFS box sections with and without ULCC filling is presented. Material properties and initial imperfections were referred from respective journals. Axial load versus displacement were discussed. A nonlinear FE model is developed, which includes nonlinear material properties, initial imperfections and modeling of intermediate fasteners. The axial capacity of the built-up CFS box columns, determined from the test and FE analysis are compared against the strengths of conventional Indian standard steel section. All multi-limb built-up CFS box sections given a better axial load capacity. The weight comparison is also carried out, it gives a complete clarification about the light weight sections introduced in this paper.

REFERENCES

[1]. W. Reyes, A. Guzman, Evaluation of the slenderness ratio in built-up cold-formed box sections, *J. Constr. Steel Res. 67*,2011.

[2]. Y.L. Li, Y.Q. Li, Z.Y. Shen, Investigation on flexural strength of cold-formed thinwalled steel beams with built-up box section, *Thin-Walled Struct,. 107*, 2016.

[3]. Jun-Yan Wang, Xiao-Long Gao, Jia-Bao Yan, Developments and mechanical behaviors of steel fiber reinforced ultra lightweight cement composite with different densities, *construction and building material,* 2018.

[4]. T.C.H. Ting, K. Roy, H.H. Lau, J.B.P. Lim, Effect of screw spacing on behavior of axialy loaded back-to-back cold-formed steel built-up channel sections, *Adv. Struct. Eng. 21 (3)* ,2017.

[5]. K. Roy, T.C.H. Ting, H.H. Lau, J.B.P. Lim, Effect of thickness on the behaviour of axially loaded back-to-back cold-formed steel built-up channel sections - *experimental and numerical investigation, Structures 16* ,2018.

[6]. K. Roy, T.C.H. Ting, H.H. Lau, J.B.P. Lim, Nonlinear behaviour of back-to-back gapped built-up cold-formed steel channel sections under compression, *J. Constr. Steel Res.147* ,2018.

[7]. K. Roy, T.C.H. Ting, H.H. Lau, J.B.P. Lim, Experimental investigation into the behaviour of back-to-back gapped built-up cold-formed steel channel sections under compression, *Proceedings of the 'Wei-Wen Yu International Specialty Conference on ColdFormed Steel Structures 2018, pp. 7–8* ,November, 2018.

[8]. A. Crisan, V. Ungureanu, D. Dubina, Calibration of design formula for buckling strength of built-up back-to-back cold-formed steel members in compression, *Procedings of the ICTWS 2014 7th International Conference on Thin Walled Structurees, ICTWS, Busan, Korea*, 2014 , 28th September to 2nd October 2014.

[9]. J. Rondal, M. Niazi, Stability of built-up beams and columns with thin -walled members, *J. Constr. Steel Res. 16* ,1990.

[10]. K. Roy, T.C.H. Ting, H.H. Lau, J.B.P. Lim, Nonlinear behavior of axially loaded back-toback built-up cold-formed steel un-lipped channel sections. Steel and composite structures, *Int. J. 28 (2)* ,2018.

[11]. I. Georgieva, L. Schueremans, L. Pyl, Composed columns from cold-formed steel Zprofiles:experiments and code based predictions of the overall compression capacity, *Eng. Struct. 37* , 2012.

[12]. J.H. Zhang, B. Young, Compression tests of cold-formed steel I-shaped open sections with edge and web stiffeners, *Thin-Walled Struct.* 52 , 2012..

[13]. M. Dabaon, E. Ellobody, K. Ramzy, Nonlinear behavior of built-up cold-formed steel section battened columns, *J. Constr. Steel Res*. 110 , 2015.

[14]. T.A. Stone, R.A. LaBoube, Behaviour of cold-formed steel built-up I-sections, *ThinWalled Struct. 43* , 2015.

[15]. J. Whittle, C. Ramseyer, Buckling capacities of axially loaded, cold-formed, built-up channels, *Thin-Walled Struct. 47* , 2009.

[16]. American Iron and Steel Institute (AISI), *North American Specification for the Design of Cold-Formed Steel Structural Members*, AISI S100–16, 2016.

[17]. Australia/New Zealand Standard (AS/NZS), *Cold-Formed Steel Structures*, AS/NZS 4600:2018, Standards Australia/ Standards New Zealand 2018.

Abhijith B Nair, et. al, "Structural optimization and cost effective light weight composite Cold-form steel structures." *International Journal of Engineering Science Invention (IJESI)*, Vol. 10(07), 2021, PP 22-29. Journal DOI- 10.35629/6734