STRUCTURAL PERFORMANCE OF COMBINED ULTRA-LIGHT WEIGHT CONCRETE CFS COMPOSITE BEAM

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Abstract: *This paper presents the results of experimental study on the behavior of cold-formed steel and Ultra- lightweight cement concrete (ULCC) in a Structure. Cold- formed brand (CFS) sections are truly feathery paraphernalia where their high structural performance is suitable for erecting construction. Conventionally, they are used as purlins and siderails in the structure envelopes of the artificial structures. The results of various researchers indicated that the capability to repel or overcome adverse conditions or rigorous testing of the product (cold-ordered brand concrete) was significantly bettered for both the shear resistance and the flexural resistance. In order to satisfy different engineering construction demands, four types new brand fiber corroborated ultra-featherlight cement emulsion (ULCC) with different viscosity ranging from 1250 kg/ m3 to 1550 kg/ m3 were proposed. Extensive standard compressive and tensile tests were performed to gain the mechanical parcels of these ULCCs with different viscosity, which will offer useful information for the developments of design on engineering constructions with analogous types of ULCC. Predicated on these test results, native laws were established to describe the compressive and tensile stress – strain conduct of ULCC with varying dimension.*

Keywords: **(CFS) Cold-formed steel, (ULCC) Ultralightweight cement composite, (FE) Finite element analysis, cement concrete.**

1. INTRODUCTION

This paper is an output of experimental project conducted on composite concrete structure that is formed by combining cold formed steel section along with ultra-light weight cement concrete, and comparing the cold formed steel results with hot rolled steel in order to understand its property. Ultra-light weight cement compound (ULCC) has attracted expansive exploration interests in both civil and coastal engineering constructions due to its high specific strengths. In order to satisfy different engineering construction demands, four types new sword fiber corroborated ultra-lightweight cement compound (ULCC) with different consistence ranging from 1250 kg/m3 to 1550 kg/ m3 were proposed. Expansive standard compressive and tensile tests were performed to gain the mechanical parcels of these ULCCs with different consistence, which will offer useful information for the developments of design on engineering constructions with similar types of ULCC. Grounded on these test results, native laws were established to describe the compressive and tensile stress – strain behaviors of ULCC with varying consistence. Regarding the operations of the ULCC in engineering constructions, a ULCC flat arbor with viscosity of 1550 kg/ m3 under concentrated lading was tested. The failure mechanisms and ultimate strength behaviors of this ULCC flat arbor were reported. 3D FE model was also developed to pretend the structural behaviors of the new ULCC flat arbor, and its delicacy was verified by the reported test results. With the validated FE model and reported mechanical parcels of ULCC with different consistence, structural behaviors of ULCC flat crossbeams with these ULCCs were delved. Analytical model grounded on the system of bending resistance in Hosts-EPFL was proposed to prognosticate the ultimate resistance of ULCC flat arbor. Erected-up box sections of cold formed sword (CFS) construction are getting decreasingly popular for column members in cold formed sword (CFS) construction; uses of similar sections include CFS trusses, space frames, and portal frames. the erected-up box sections are formed through two identical lipped channels connected at their flanges with tone-drilling screws. In such an arrangement, independent buckling of the individual channels is averted by the screws. This paper presents an experimental disquisition on axial capacity of erected-up CFS box sections. Tests were conducted for different values of slenderness from ray. In total, the results from 16 experimental tests are reported. Of these, 8 tests were conducted on erected-up CFS box sections and the remaining 8 tests were conducted on Two Sigma channel sections. Two Refocused cargo and two support, Cargo-axial relationship, and failure modes are bandied for erected-up ray. Nonlinear finite element (FE) models were developed for erected-up CFS box sections and double single channels. FE models considered material nonlinearities, original defects and modeling of intermediate fasteners. FE results showed good agreement against the test results. A parametric study was conducted which comprises 148 models to probe the effect of fastener distance on axial capacity of erected-up CFS box sections. Both FE and test results were compared against the design strengths calculated in agreement with the American Iron and Steel Institute (AISI) and Australian and New Zealand Norms (AS/ NZS). From the comparison, it was observed that the AISI & AS/ NZS are conservative by around 17 while determining the axial capacity of similar erected-up CFS box ray.

1.1. CFS built up section

The built-up members are formed by connecting two or more cold formed steel members together, such as I section Member built up by connecting two channel sections back to- back. These structural shapes can be used in buildings as eave struts, purling, grits, studs, headers, floor joists, braces and other building Components. Various shapes are also available for wall, floor, and roof diaphragms and coverings. This study is aimed at developing an innovative back-to-back and face to face cold formed steel beam by utilizing the advantages of lacing and Cold Formed Steel (CFS) to enhance flexural capacity at minimum fabrication cost. In this research an attempt has been made to use similar type of a I section beam, by replacing the hot rolled section by cold formed steel sections. This study therefore involves investigations into flexural behavior of buildup beams comprising various steel grades, steel thickness, section sizes and span to fully understand the primary buckling and ultimate failure characteristics suitable built-up CFS flexural members.

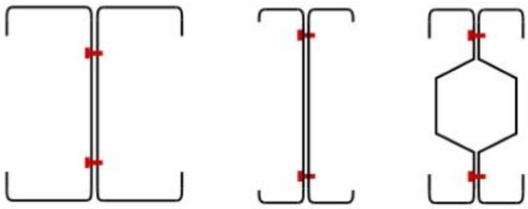

Figure 1. CFS Built Up Section

1.2. Ultra-lightweight cement composite

Ultra-lightweight cement composite (ULCC) is a type of novel composites characterized by combinations of low densities typically less than 1500 kg/m3 , high compressive strengths more than 60 MPa with specific strength of up to 47 kPa/(kg/m3). Besides, ULCC can also be applied to those civil and offshore structures which are sensitive to their self-weight. For example, floors of high-rise buildings, bridge deck, offshore platform and prefabricated submerged tunnels, the application of ULCC could significantly reduce the self-weight by around 36% to 52% compared with the normal weight concrete of the same strength. Thus, it could dramatically reduce the transportation fees and costs of foundations as well as improving seismic responses. Ultra-lightweight cement composite (ULCC) contains smooth steel fibers ordinary Portland cement, water, silica fume, chemical admixtures, cenospheres .The cenospheres are hollow alumino-silicate spheres with particle sizes ranging from 10 to 300 mm. The density of cenosphere used in this paper was 820 kg/m3. The low density of cenosphere promises the different low densities of the ULCC. Considering the low water-to-binder ratio, the superplasticizer was used to achieve good workability. Shrinkage reducing admixture was used in the mixture to reduce air contents and minimize shrinkage strains. Straight steel fiber with a diameter of 0.16 mm and a length of 13 mm was used to improve the tensile strength of the ULCC. The volume fraction of steel fiber for ULCC in this According to the design method of ULCC with different density, the mix proportions of four types of ULCC with densities ranging from 1250 kg/m3 to 1550 kg/m3 can be obtained. The densities of these ULCC given measured immediately after demolding at 48 hrs. according to BS EN 12390- 7:2009.

1.3. ANSYS simulation

ANSYS simulation gives engineers the ability to explore and predict how products will work — or won't work — in the real world. It's like being able to see the future, enabling engineers to innovate as never before. This simulation superpower also speeds time-to-market, lowers manufacturing costs, improves quality and decreases risk. Based on the fundamental principles of modeling, physics, mathematics and computer science, simulation gives engineers the power to see how their designs will behave in millions of real-world scenarios, while reducing or even eliminating the need for costly physical testing

2. SPECIMEN GEOMETRY

The two different cross-sectional geometries considered in this experimental programmed are illustrated in Figure. The first geometry was chosen because it resembles the traditional, I shaped cross section widely used for beams. Based on the commonly encountered back-to back-channel arrangement, this built-up geometry included two additional channels to increase the flange area and provide improved bending efficiency. The second built-up geometry was selected in consultation with CFS manufacturers/contractors, who pointed out that this built-up geometry is regularly used as a solution to bridge large openings in structural framing systems made of CFS. The back-to-back channels thereby work as a lintel, while the top channel is used as a track to receive the studs of the wall above the opening. Due to the lack of design guidance, however, only the capacity of the back-to-back channels is currently counted on in practice.

2.1. Test set-up

Specimens were bent about their major axis using a four-point bending configuration. The test specimens were supported at their ends on rollers located 3000 mm apart. The actuator was connected to a spreader beam, which exerted concentrated loads onto the specimen through loading points which were implemented as simple supports (one roller and one pin) located 1600 mm apart. An adjustable lateral support system was used to restrain the spreader beam against any out of-plane movement, as shown in. Nylon blocks were used as bearing pads between the spreader beam and the uprights of the support system in order to reduce friction. The loading points under the spreader beam consisted of top and bottom assemblies, which were bolted to the spreader beam and the test specimen, respectively, and contained vertical flanges to prevent out-of-plane displacements of the top flange of the test specimen. The cross-sections of the test specimens above the supports were packed with wooden blocks which tightly fitted within the web and flanges. This eliminated possible bearing failure and also prevented a distortion of the cross-section characterized by a lateral displacement of the compression flange combined with bending of the web about a horizontal axis in its plane.

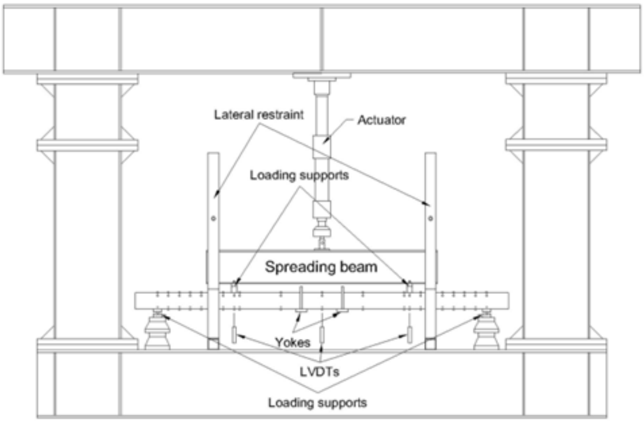

Figure 2. Point bending test

3. GEOMETRIC MODELLING

The FEA calibration study included modeling a CFS build up beam with the dimensions and properties corresponding to beam column tested by experimentally to create the finite element model in ANSYS workbench 21 R2 version there are multiple tasks that have to be completed for the model to run properly for this model, ANSYS design modeler environment was utilized to create the model of CFS beams in solid (3D model) by using extrude tool as shown in the figure below.

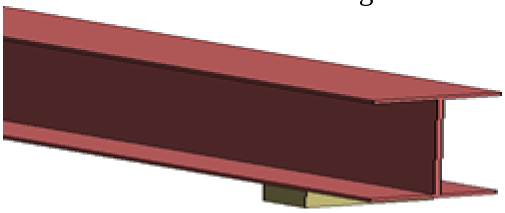

Figure 3. ISMB-150- HOT ROLLED

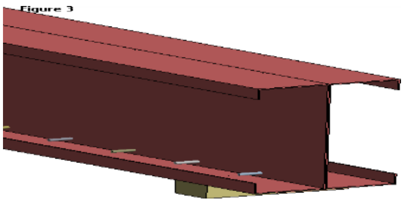

Figure 4. S-B2B WEB LAPED

4. MATERIAL PROPERTY AND ELEMENT TYPE USED

ULCC 1250	**Compressive Strength– 48.03**
	Density, ρ – 1250 kg/m^3
	Youngs modulus, E – 10.79 GPa
	Tensile Strength– 2.03 MPa
	Poisson's ratio, μ – 0.15

CFS	**Density, ρ – 7830 kg/m^3**
	Young's modulus, E – 2 × 10^5 MPa
	Tensile yield strength, f_y – 489 MPa
	Poisson's ratio, μ – 0.3

ISMB 150	**Density, ρ – 7830 kg/m^3**
	Young's modulus, E – 2 × 10^5 MPa
	Tensile yield strength, f_y – 230 MPa
	Poisson's ratio, μ – 0.3

5. DEVELOPMENT OF ULCC

Development of ULCC with different density Ultra - lightweight cement composite (ULCC) contains smooth steel fibers, ordinary Portland cement, water, silica fume, chemical admixtures, cenospheres. The cenospheres are hollow alumino - silicate spheres with particle sizes ranging from 10 to 300 µm. The density of cenosphere used in this paper was 820 kg / m³. The low density of cenosphere promises the different low densities of the ULCC. Considering the low water - to - binder ratio, the superplasticizer (ADVA 181) was used to achieve good workability. Shrinkage - reducing admixture (Eclipse Floor).

5.1. Mix proportions of ULCC with different densities

Table 1 Mix proportions of ULCC with different densities

Type	Density	Water	OPC	Silica fume	SRA	Cenosphee	Fiber	SP ADVA 181	SRA
U1250	1257.6	236.9	49955	55.52	8.21	36633	73.64	15.48	8.21
U1350	1355.8	240.0	611.7	67.95	833	345.41	73.81	6.62	833
Ul450	1458.2	264.9	716.7	79.64	9.21	307.05	74.84	3.84	9.21
Ul550	1552.l	283.7	801.3	88.52	8.51	290.61	73.78	3.81	8.51

Table 2 Properties or the steel fiber

Diameter (mm)	Length (mm)	Aspect ratio	Density (g/cc)	Tensile strength (MPa)	Elastic modulus (GPa)
0.16	13	81.3	7.8	2500	200

5.2. Compressive behaviors of the four types ULCC

Table 3 Parameters used to define the compressive behaviours of toe four types ULCC

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Type	ε_{uc}	Fuc (MPa)	ε_{uc}	ƒuc1 (MPa)	E1 (GPa)	*E'1* (GPa)	E2, (GPa)	E3, (GPa)
Ul250	0.0045	48.03	0.0051	21.54	10.79	11.88	45.48	0.55
Ul350	0.0042	52.12	0.0051	24.11	12.41	13.64	29.03	0.26
Ul450	0.0044	61.07	0.0052	27.85	14.04	15.52	43.33	0.14
U1550	0.0044	70.06	0.005	30.37	15.78	17.65	76.42	1.3·1

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

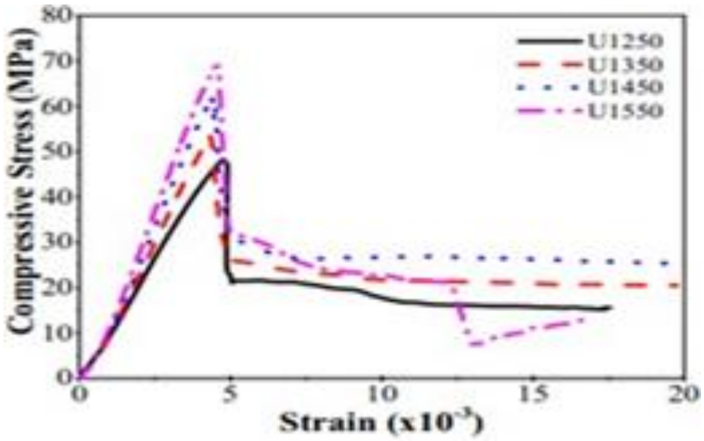
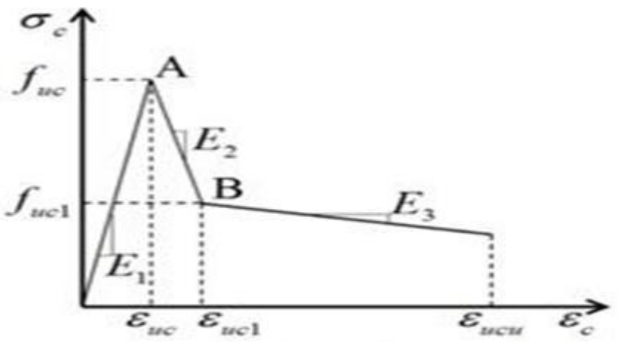


Figure Compressive stress-strain curve



Constitutive law of compressive behaviors

6. CONFIGURATIONS OF CFS COMPOSITE BEAMS

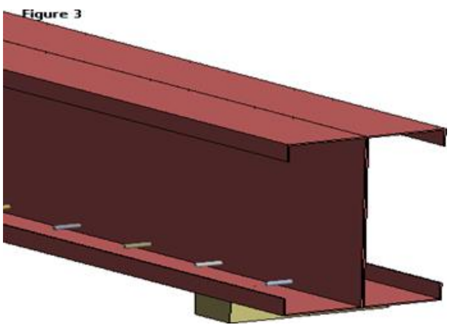


Figure 5 S-B2B WEB LAPED

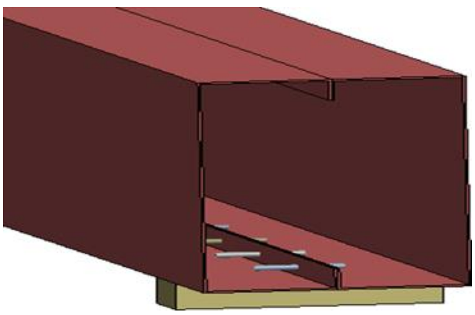


Figure 6 S-F2F-LIP LAPED

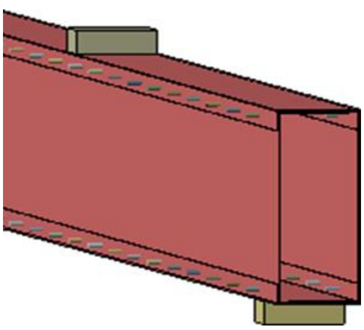


Figure 7 S-F2F -OVERLAPPED

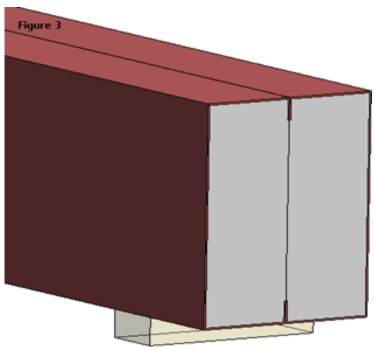


Figure 8 LIP LAP-F2F

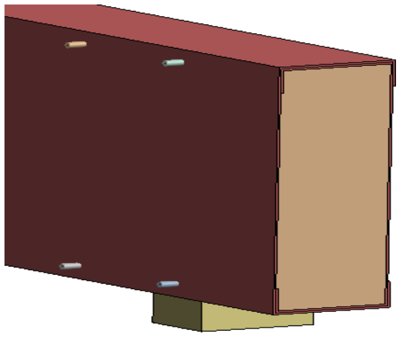


Figure 9 FF - FLANGE LAPPED-F2F

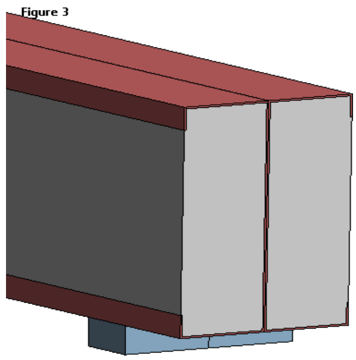


Figure 10 FF-B2B-WEB LAPPED

7. ANALYSIS USING ANSYS

7.1. Analysis of ISMB-150

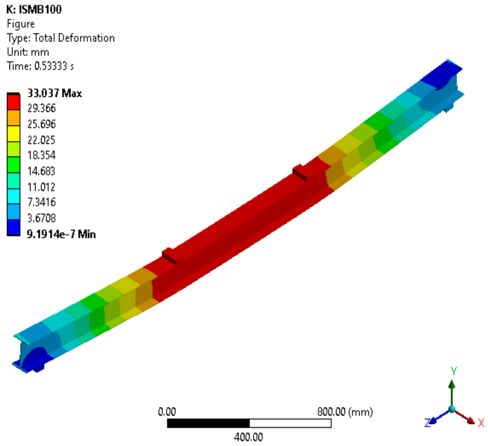


Figure 11 deformation

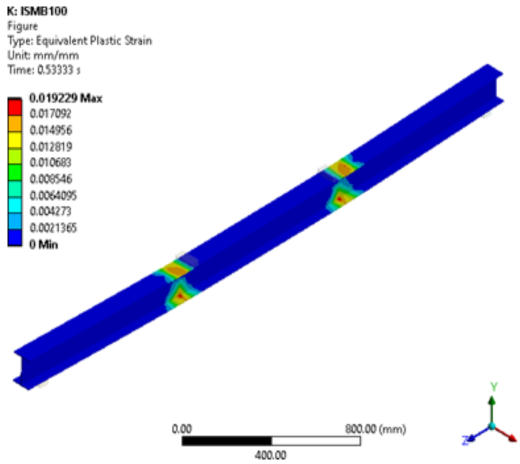


Figure 12 Equivalent plastic strain ISMB-150

7.2. Analysis of S-F2F - flange overlapped

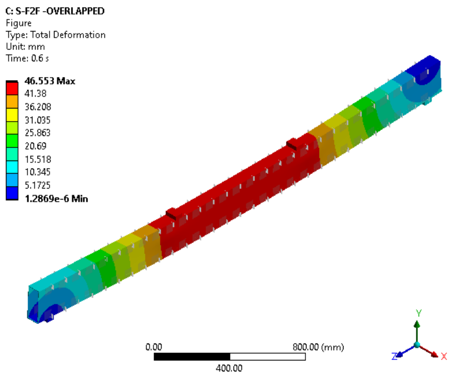


Figure 13 Total deformation S-F2F – FlangeOverlapped

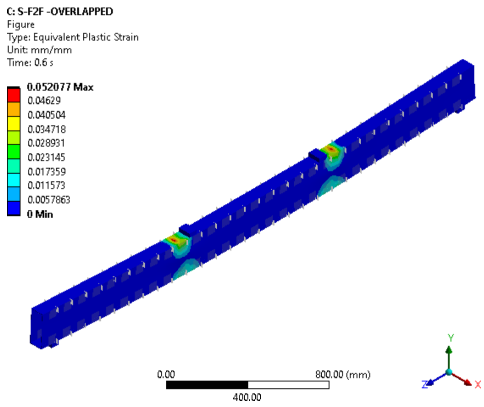


Figure 14 Equivalent plastic strain S-F2F - FlangeOverlapped

7.3. Analysis of S-F2F-lip laped

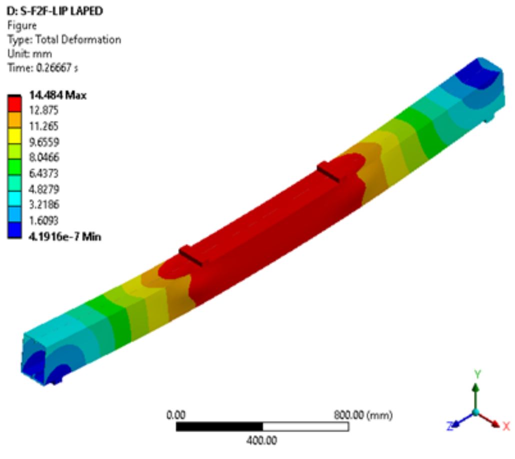


Figure 15 Total deformation S-F2F Lip Lapped

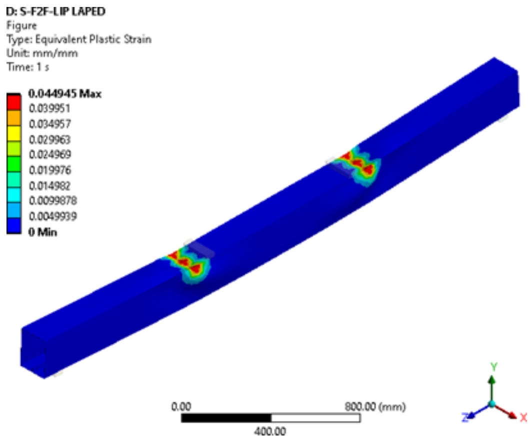


Figure 16 Equivalent plastic strain S-F2F Lip Lapped

7.4. Analysis of S-B2B web lapped

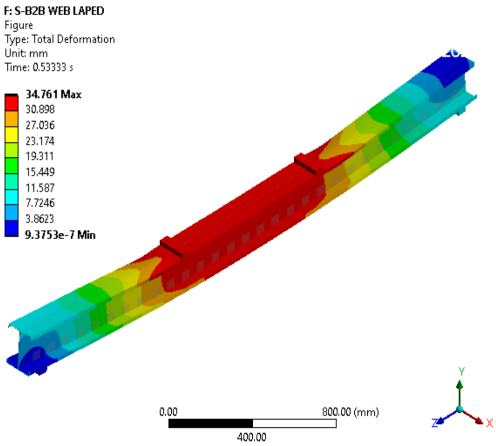


Figure 17 Total deformation of S-B2B web lapped

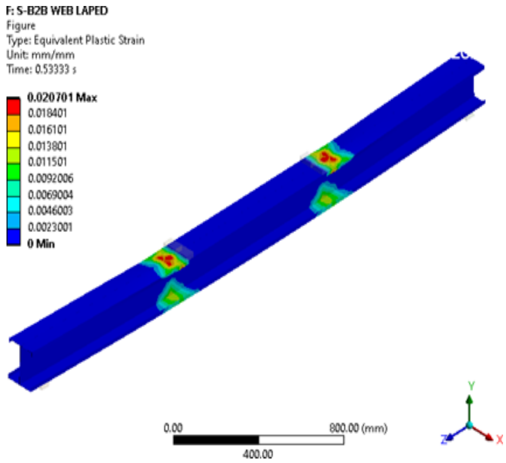


Figure 18 Equivalent plastic strain of S-B2B web lapped

7.5. Analysis of FF-B2B web lapped

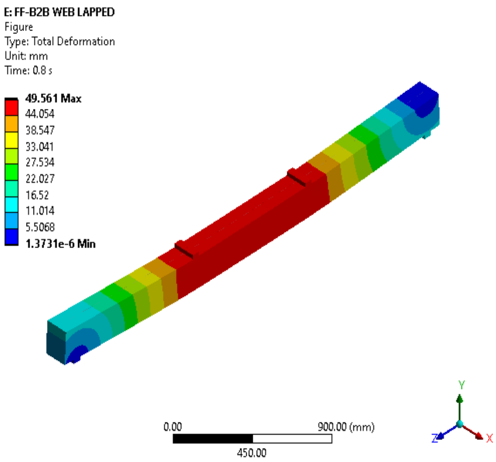


Figure 19 Total deformation of FF-B2B web lapped

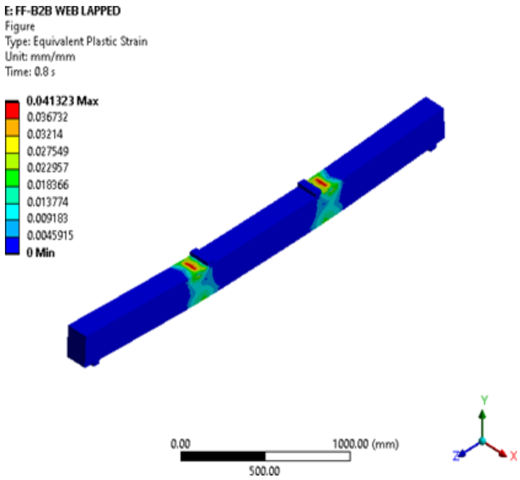


Figure 20Equivalent plastic strain of FF-B2B web lapped

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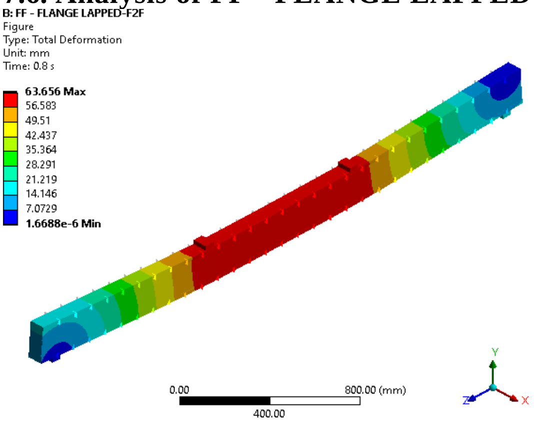
7.6. Analysis of FF - FLANGE LAPPED-F2F



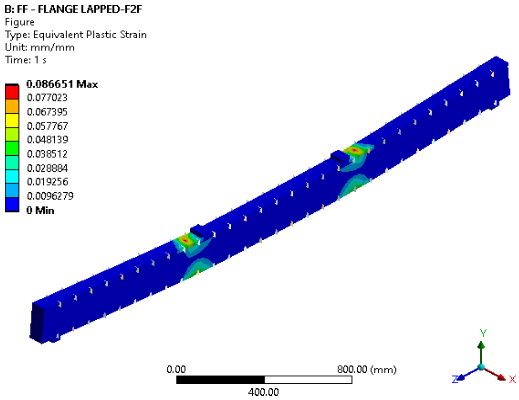
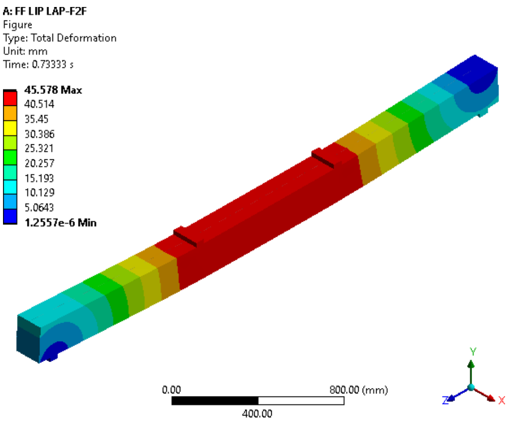


Figure 22 Equivalent plastic strain of FF – flange lapped-F2F

Figure 21 Total deformation of FF - flangelapped-F2F

7.7. ANALYSIS OF FF LIP LAP-F2F



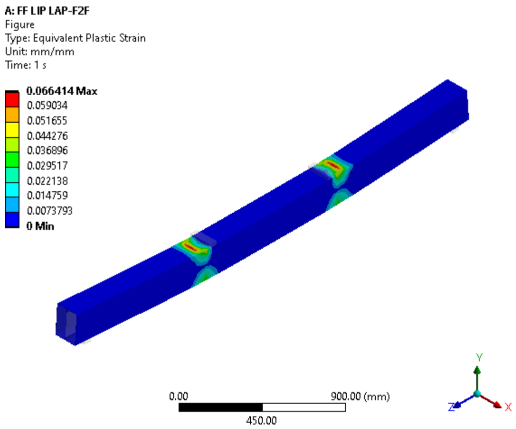


Figure 24 Equivalent plastic strain of FF lip lap-F2F

Figure 23 Total deformation of FF lip lap-F2F

8. RESULTS OF STUDY

The nonlinear Newton-Raphson approach was utilized to trace the equilibrium path during the load-deformation response. It was found that convergence of solutions for the model was difficult to achieve due to the nonlinear behaviour of CFS material at certain stages in the analysis, load step sizes were varied from large (at points of linearity in the response) to small (when instances of cracking and steel Yielding occurred). After successfully solving is completed, post processing of the results can be obtained the models of Beam column connection. The deformation behaviour, stress, strain, failure pattern and load deflection capacity are evaluated and compared withexperimental work.

- The moment capacity result obtained from ANSYS software is compared with the experimental result in journal.
- Percentage error is within the acceptable limit (<10%).
- Therefore, model in the ANSYSsoftware is validated

8.1. Consolidated results

Table 4 Consolidated results

MODEL	WEIGHT (KG)	ULTIMATE DEF (mm)	PU-LOAD (KN)	YEILD-DEF (mm)	DUCTILITY	% of increse in load
ISMB-150	40.035	33.037	56.468	4.3664	7.57	1.00
FF LIP LAP-F2F	141.64	45.58	133.09	5.60	8.14	135.70
FF-FLANGE LAPPED-F2F	85.034	63.66	130.85	5.47	1.64	131.72
FF-B2B-WEB LAPPED	141.64	53.579	134.29	4.3462	12.33	137.82
S-F2F - FLANGE OVERLAPPED	30.944	46.55	98.64	5.47	8.52	74.68
S-F2F-LIP LAPED	30.944	14.48	75.37	3.64	3.97	33.46
S-B2B WEB LAPED	30.944	34.761	93.428	4.3661	7.96	65.45

9. PERFORMANCE GRAPH AND CHART

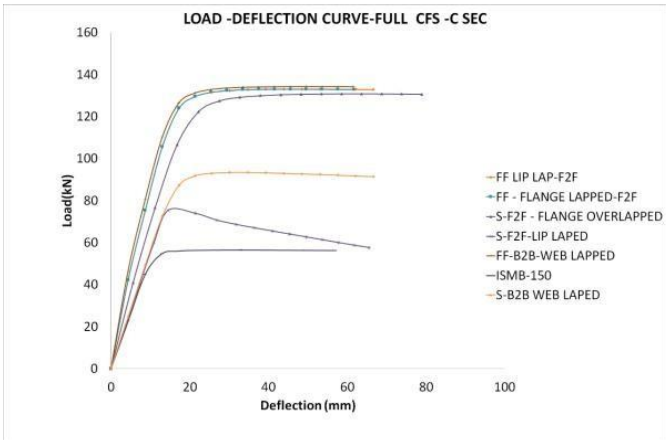


Figure 25 load-deflection curve-full CFS-C Section

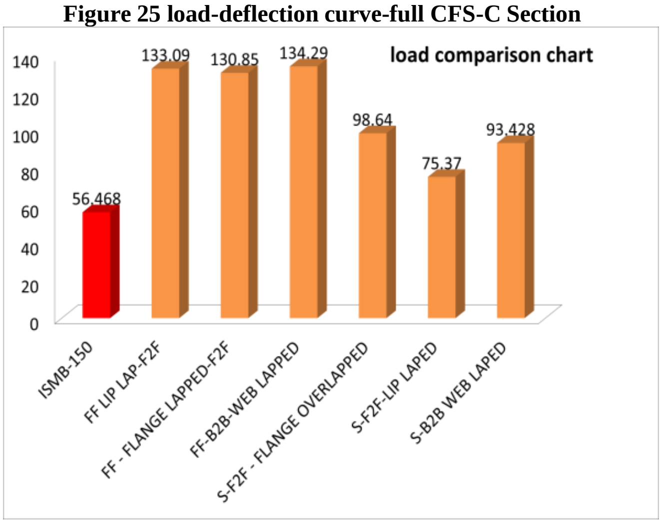


Figure 26 Load comparison chart

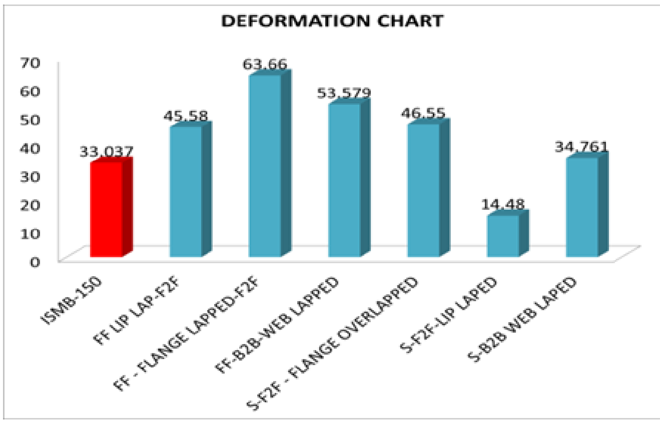


Figure 27 Deformation chart

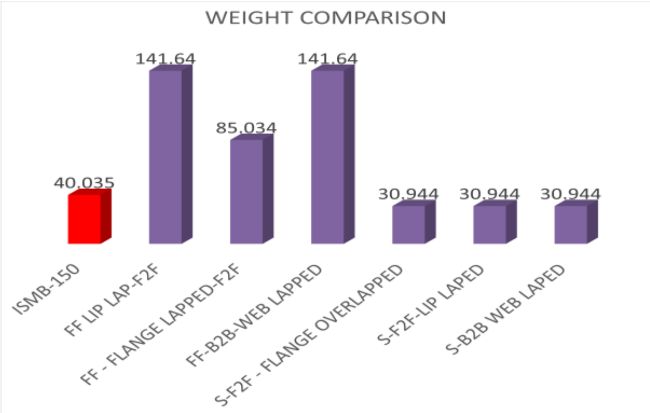


Figure 28 Weight comparison

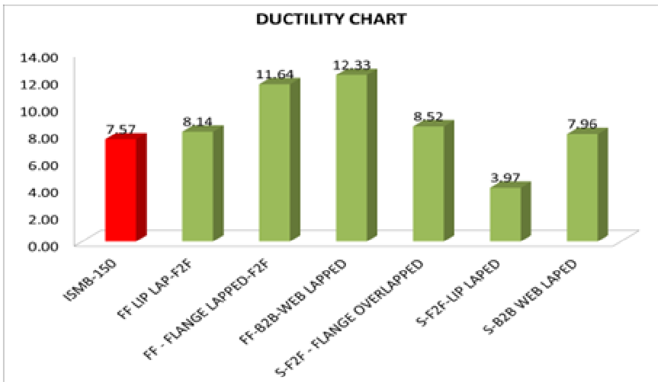


Figure 29 Ductility chart

10.COMPARISON

- The moment capacity result obtained from ANSYS software is compared with the experimental result in journal.
- Percentage error is within the acceptable limit (<10%).
- Therefore, model in the ANSYS software is validated

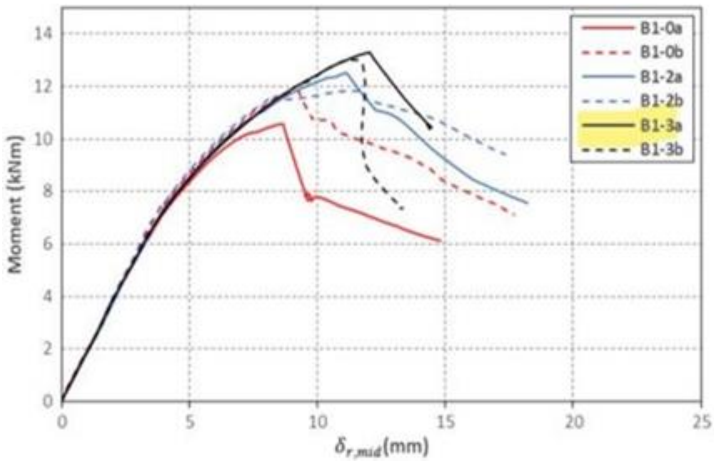


Figure 30 moment versus relative deflection at midspan

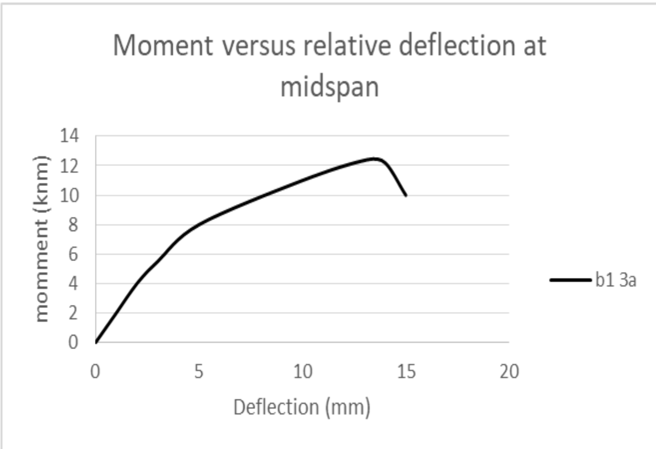


Figure 31 moment versus relative deflection atmidspan

11.CONCLUSIONS

The first phase of work primarily focused on literature review, data collection for future work such as material properties of ULCC, model dimensions, and analytical modelling of CFS build up beams, and analysis procedure of experimental approach in ANSYS software. Following validation, it is demonstrated that the experimental method of testing the CFS build up beam can be performed using ANSYS software, allowing further investigations for ―Ultra-light weight CFS Composite Beams‖ proposed in objective to be evaluated using the Analytical study in the next phase. The performance of CFS channel sections installed back-to-back and front-to back with only steel and fully filled with ULCC was studied in this study. The following is a summary of the findings from the analysis. The model with the channel sections positioned back-to-back and entirely filled with ULCC had the highest load bearing capacity and deformation resistance of all the models with 137.82% than conventional beam. On the study with steel only CFS sections, sections placed face-to-face in overlapped manner showed maximum load bearing capacity with 74.68 % than conventional beam. FF-FLANGE LAPPED-F2F model has less weight in concrete filling beam than other concrete filled models which shows 131.72% of higher strength than conventional and this is effective model in fully filled case. Due to high strength in CFS, strength capacity increase and weigh also reduced than conventional steel beam which satisfy the scope of the project.

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