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FLEXURAL CAPACITY OF COMPOSITE BEAMS USING TRUSS BEAMS

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ABSTRACT

An experimental study was made to assess the flexural capacity of Composite Beams using Truss beams under two point loading with span 2m. Beam consist of top and bottom chord with cold formed light gauge steel plate (width 100 mm and thickness varying from 1.5mm to 2mm) and light gauge angle section welded at the ends of the plate. Top and bottom chord members were connected by steel rods of diameter 8mm making inclined connections with horizontal using Fe 250 grade steel at both faces of angles. Truss was filled with M25 concrete to form a Composite Beam. A comparitive study was made between truss beam and composite beam to assess the ultimate load carrying capacity, Flexural strength, Ultimate Deflection, displacement ductility. Tests were conducted on truss beams and composite beams for different thickness. From the result it was observed that for truss beams as the thickness varied from 1.5mm to 2mm load carrying capacity increased by 1.08 times but when the same truss beam encased by concrete load carrying capacity raised by 2.26 times. When concrete was encased and thickness was increased load carrying capacity increased by 2.6 times. As the thickness increases from 1.5 to 2mm displacement ductility factor increased by 4.8% for truss beam but when concrete is encased displacement ductility factor get increased by 76.47% . Flexural strength of composite beam is 2.46 times more than truss beam when the thickness of light gauge cold formed steel plate is 2mm and when the thickness of light gauge cold formed steel plate is 1.5mm Flexural strength of composite beam is 2.27 times more than the flexural strength of truss beam. A marginal increase in load carrying capacity, flexural strength, displacement ductility occurs after encasing concrete.

KEYWORDS: Truss Beam, Composite Beam,Ultimate load, Flexural Strength, Ductility

INTRODUCTION

Composite Beam are special steel- concrete beam with sectional top chord and bottom chord consist of cold formed light gauge steel plate of width 100 mm and thickness varying from 1.5mm to 2mm and light gauge angle section(6 x 6 x 1) welded at the ends of the plate. Top chord and bottom chord were connected by steel rods of diameter 8mm making an angle of 45° with horizontal using Fe 250 grade steel at both faces of angles with an overall depth of 150mm. Truss was filled with M25 grade with water binder ratio 0.42 to form a Composite Beam. The main features of the truss beam is that they can bear their own weight without any provisional support during the first phase and then they can collaborate with the cast in place concrete. The main advantages that led this structural system to be used in many buildings, especially if compared with ordinary steel concrete composite structures, are the reduction of construction time, both formworks and intermediate supports are not required, the accurate control of construction detailing performed at the workshop without in situ welding or tying, and the consequent optimization in the use of steel.

The completion concrete does not have any additional longitudinal or transverse reinforcement except optional longitudinal bar pieces to recover the continuity of multi-span beams. The property of composite beams depends on both reinforced concrete and the composite steel concrete ones since it has some features of both of them. Original embedment of truss beam is made possible by proper welding. In the future composite truss beams can contribute well in seismic resistant structures. Literature is quite scarce and codes do not properly address composite beams structural behaviour, the relevant equations are mainly adapted from similar composite structures. Some of the suggested codes are Eurocode 3, Eurocode 4, Model Code 2010, ACI 318-08.

Leopoldo Tesser, Roberto Scotta [5] conducted a study on flexure and shear capacity of composite steel truss concrete beams with inferior precast concrete base. During flexural test of Composite beam found that yielding of steel bottom chord occurs in most of the beams and cracks appears on the centre portion of beam. Giorgio Monti , Floriana Petrone [3] developed Shear capacity equations for composite truss beams from a mechanical based shear model. In the shear tests all the Composite beams were affected by inclined cracks in the portion between the load application point closer to the support and the support itself. Cracks were always focussed on the upper portions of the beam.

N. Tullini , F.Minghini [6] conducted Nonlinear analysis of composite beams with concrete-encased steel truss found that the web member of the steel truss behaves like a deformable shear connection. Nonlinear analysis which is based on Newmarks classical model found that the solution obtained was reliable to predict beam behaviour up to yielding of the shear connections.Not only truss, different members was encased in concrete[6,4] and studied by the researchers. One such an element was CFST box member. Lin-Hai Han, Yu-Feng An [6] studied and conclude that CFST component can increase the tensile reinforcement of the concrete-encased CFST box member. It act as a well confined high strength compressive element to enhance the flexural performance of the composite member. Kwan Wai Hoe,Mahyuddin Ramli [4] studied about Performance of fiber reinforced polymer encased beam in flexure . Study was aimed to enhance the ductility of FRP reinforced structure by proposing a novel FRP encased beam design. Structural behaviors of different encased beams were studied under four point flexural loading. It was concluded that the FRP in the I-beam form could enhance the ductility performance of the FRP reinforced concrete beam which satisfied the ductility requirements as stated in the Canadian Highway Bridge Design Code. Experimental and analytical investigation of buckling behaviour of bare steel and concrete-filled steel columns was studied by M.Fong, S. L Chan [8]. Beneficial effects of in filled concrete and the offered resistance are investigated both experimentally and analytically. The results indicated that the second order analysis and design method not only provided an accurate design solution, but also effective lengths, determination of buckling mode shape have importance in deciding the behaviour.

Research has covered the following aspects: the flexural strength, displacement ductility ratio, ultimate deflection of truss beam and composite beam; the influence of concrete encasement on the Flexural strength,Load carrying capacity, ultimate deflection, displacement ductility of composite beams; the influence of thickness on the Flexural strength,Load carrying capacity, ultimate deflection, displacement ductility of composite beams and truss beams Thus, experimental studies and theoretical analyses are conducted to understand the structural performance.

EXPERIMENTAL INVESTIGATION

Fabrication and Casting of Truss beams and Composite Beams

Truss beams and composite beams were made for two different thickness of cold formed steel plates, which was used as top and bottom chords. Steel rods which connects top and bottom chord was made at 8mm diameter for both cases. Fig1(a) shows fabricated truss beam. Truss beam was filled with M25 concrete having water binder ratio 0.42 to form Composite beam. Fig1(b) shows casted composite beam. Before conducting two point loading on the beam specimens, yield strength of cold formed steel plate was determined. Light gauge Cold formed steel plate used in top and bottom chord posses an yield stress of 350 N/mm^2 corresponding to yield strain of 0.012.

Fig.1(a) FabricatedTruss beams

Fig.1(b) Casted Composite Beams

Specimen details

In this study, truss beams consist of top chord and bottom chord which was made of Light gauge cold formed steel plate and shear reinforcement given by steel rods making inclined connections with top and bottom chords.Shear reinforcement was made of Fe 250 having diameter 8mm. Here truss beam of two thickness was studied by changing the thickness of light gauge cold formed steel plate as 1.5mm and 2mm. Composite beam was made by filling concrete in truss beam. Composite beam was also casted for two thickness 1.5mm and 2mm. Structure have a width 100mm and overall depth 150mm.

Table 1. Beam Designation

Designation	Width (mm)	Thickness (mm)	Overall depth (mm)	Concrete infilled or not
TB 1.5	100	1.5	150	Not infilled
TB 2	100	2	150	Not infilled
CB 1.5	100	1.5	150	infilled
CB 2	100	2	150	infilled

Test set-up

All the specimens were tested for flexural strength under two point loading. Truss beam and composite beams was tested in a beam testing machine having capacity 40T The specimens were arranged with simply supported conditions, centered over bearing blocks adjusted for a effective span of 1.7 m. Loads were applied at one- third distance from the supported without shock, increased at a uniform rate till the ultimate failure.

Deflection of the beam was measured by 3 LVDT's placed one at mid span, two below point of loading. Strain gauges were also fixed to record strain measurements. For each load increment the deflection, strain and crack were observed and tabulated. In addition to the above, load cell and LVDT were connected to data logger and the observations were recorded automatically in the DATA logger.

Fig. 2(a) Testing of Truss beam

Fig. 2(b) Testing of Composite beam

RESULTS AND DISCUSSIONS

Flexure test results

All the specimens were tested for flexural strength under two point loading. Deflection and strain readings are observed from DATA logger. The following observations were made during the progress of the tests. The observations are summarized in the following table.

Table 2. Ultimate Load and Deflection of specimens

Specimen	Ultimate Load (kN)	Ultimate Deflection (mm)
TB 1.5	32.3	23.4
TB 2	35.2	22.2
CB 1.5	73.32	17.9
CB 2	86.7	16.8

From above table it was clear that ,when concrete was infilled beam possess greater ultimate load carrying capacity with lower ultimate deflections. In addition to that when thickness was increased load carrying capacity also get increased.Table 3 shows the effect of tensile strain in beam specimens. Load corresponding to yield strain was greater for composite beam of 2mm thickness compared to truss beams and composite beam of 1.5mm thickness.

Table 3. Ultimate Load and Tensile strain of specimens

Specimen	Ultimate Load (kN)	Tensile strain	Load at Yield (kN)
TB 1.5	32.3	0.0247	19
TB 2	35.2	0.022	24.5
CB 1.5	73.32	0.019	62
CB 2	86.7	0.0182	66

Table 4 shows the compressive strain obtained for different beam specimens corresponding to ultimate load. Using the data ductility, Flexural strength of all specimens was summarized in table5, table6

Table 4. Ultimate Load and Compressive strain of specimens

Specimen	Ultimate Load (kN)	Compressive strain
TB 1.5	32.3	0.017
TB 2	35.2	0.012
CB 1.5	73.32	0.010
CB 2	86.7	0.008

Table 5. Ultimate Load and Ductility of specimens

Specimen	Ductility
TB 1.5	1.87
TB 2	1.96
CB 1.5	3.11
CB 2	3.3

Table 6. Ultimate Load and Flexural strength of specimens

Specimen	Flexural Srength (kNm)
TB 1.5	13.72
TB 2	14.96
CB 1.5	31.16
CB 2	36.84

Load Vs Deflection

Deflections corresponding to different load values was obtained by placing Linear Variable Displacement Transducers at three positions.

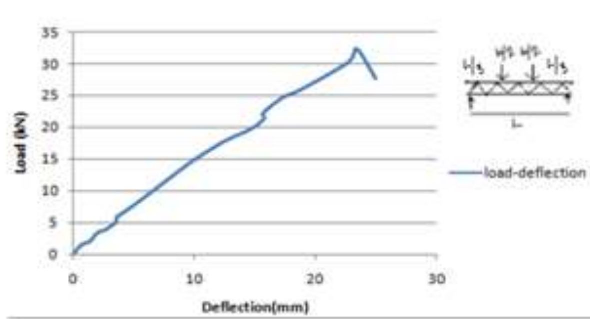

Fig. 3 Load –Deflection of truss beam of 1.5mm thickness

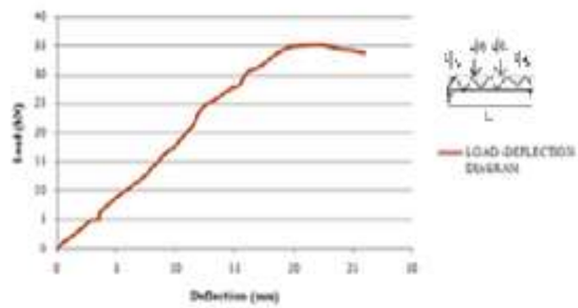

Fig. 4 Load –Deflection of truss beam of 2mm thickness

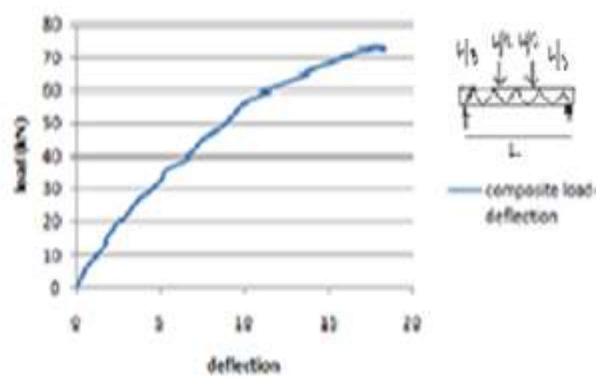

Fig.5 Load –Deflection of composite beam of 1.5mm thickness

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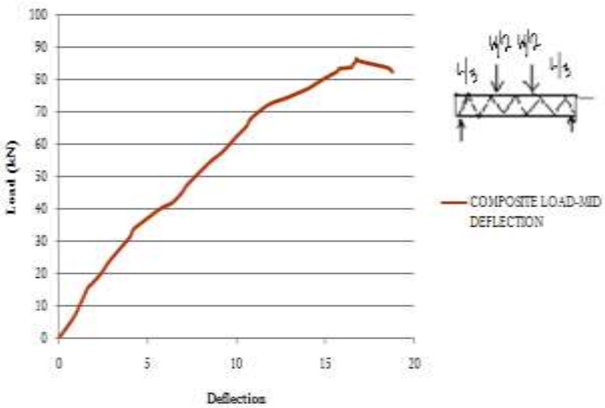

Fig. 6 Load –Deflection of composite beam of 2mm thickness

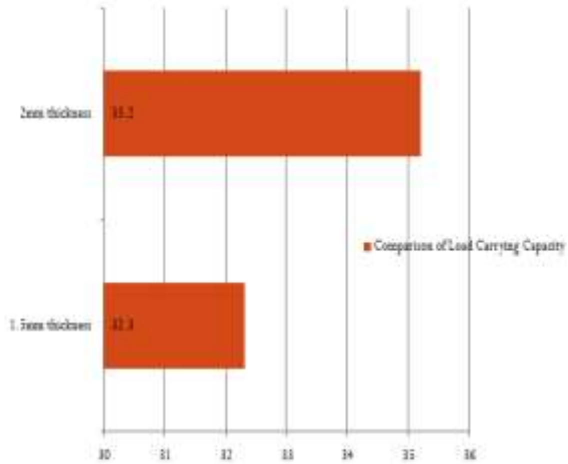

Fig. 7 Comparison of ultimate load carrying capacity of truss beams of 1.5mm and 2mm thickness

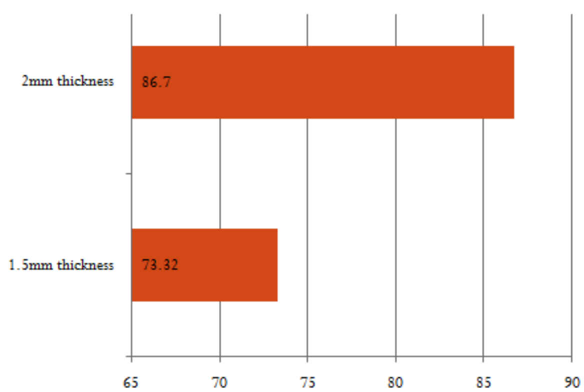

Fig. 8 Comparison of ultimate load carrying capacity of composite beams of 1.5mm and 2mm thickness

Load-Deflection of all beams shows almost linear pattern upto their yied value after that it follows a non linear pattern. In the case of truss beam, with increase in thickness from 1.5mm to 2mm ultimate load carrying capacity get enhanced only 1.08 times but when the truss beam of same thickness 1.5mm is encased by concrete load carrying capacity get enhanced by 2.26 times.When concrete is encased in a truss beam of 2mm thickness then load carrying capacity get enhanced by 2.46 times. Truss beam of 2mm thickness have 4.8%increase in displacement ductility ratio compared with truss beam of 1.5mm thickness. Composite beam of 2mm thickness posses 6.1% increase in displacement ductility ratio compared with composite beam of 1.5mm thickness**.** Composite beam of 1.5mm thickness have 66.31% increase in displacement ductility ratio compared with truss beam of 1.5mm thickness**.** Composite beam of 2mm thickness have 68.36% increase in ductility compared with truss beam of 2mm thickness. A marginal increase was found in ultimate load carrying capacity, ductility in the composite beam compared to truss beams.

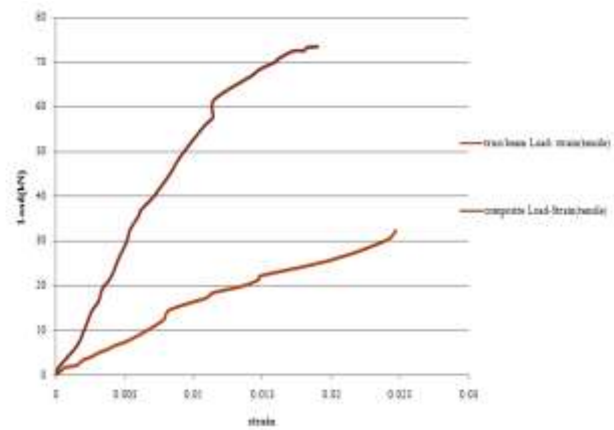

Fig. 9 Load – strain (tensile) of truss beam and composite beam of 1.5mm thickness

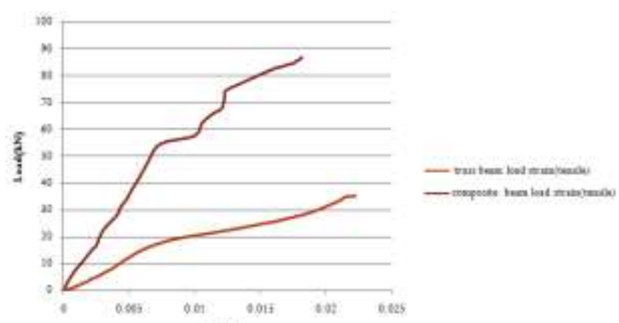

Fig. 10 Load – strain (tensile) of truss beam and composite of 2mm thickness

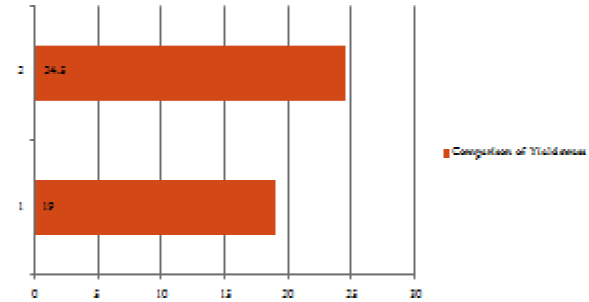

Fig. 11 Comparison of load at yield truss beams of 1.5mm and 2mm thickness

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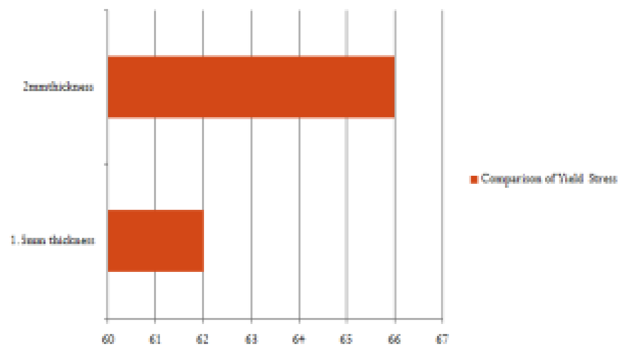

Fig. 12 Comparison of load at yield composite beams of 1.5mm and 2mm thickness

Figure 9,10 shows that Truss beam of 1.5mm thickness reach their yield tensile stress nearly at 19 kN whereas truss beam of 2mm thickness reach their yield stress nearly at 24.5kN. In the case of Composite beam of 1.5mm thickness it reach yield stress nearly at 62kN while composite beam of 2mm thickness reach yield stress nearly at 66kN. Truss beam suffers more tensile strain compared to composite beam. Load –tensile strain diagram shows a linear variation near to that range after that large deflections occurred for small load changes. While evaluating Fig.11 and Fig.12 it was found that yield load of truss beam of 2mm thickness is 1.28 times more than the yield load of truss beam of 1.5 mm thickness. When thickness increases from 1.5mm to 2mm tensile stress get reduced by 12.27% . Yield load of composite beam of 2mm thickness is 1.06 times more than the yield load of composite beam of 1.5 mm thickness. When thickness increases from 1.5mm to 2mm tensile stress get reduced by 4.39%. Truss beam of 2mm thickness have 1.21 times tensile strain more than Composite beam of 2mm thickness.Truss beam of 1.5mm thickness have 1.3 times tensile strain more than Composite beam of 1.5mm thickness. Truss beam suffers more tensile strain compared to composite beam. Load at yield stress of composite beam of 2mm thickness is 2.7 times more than the yield stress of truss beam of 2mm thickness Load at yield stress of composite beam of 1.5mm thickness is 2.4 times more than the yield stress of truss beam of 2mm thickness

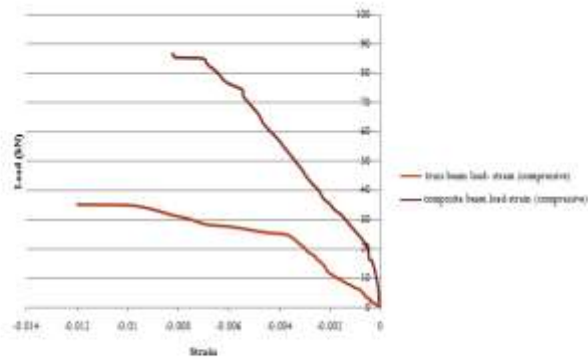

Fig. 13 Load – strain (tensile) of truss beam and composite beam of 2mm thickness

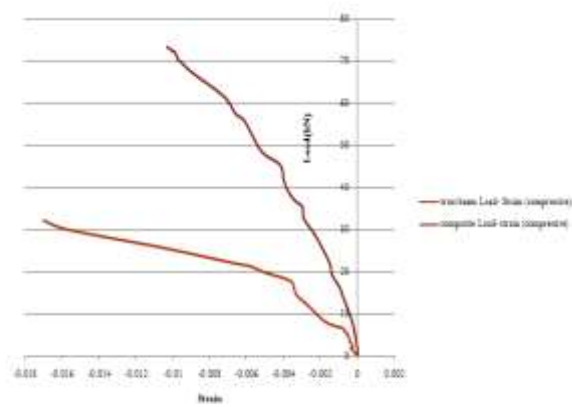

Fig. 14 Load – strain (tensile) of truss beam and composite beam of 1.5mm thickness

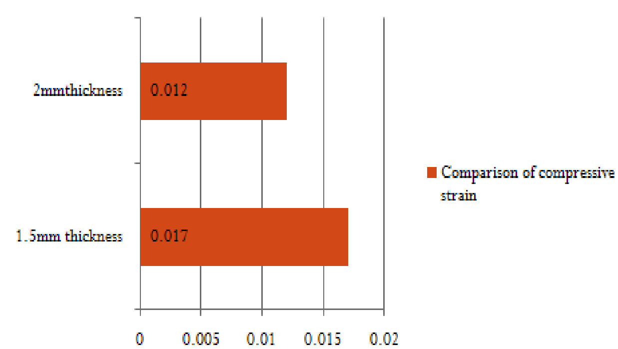

Fig. 15 Comparison of Compressive strain of Truss beams

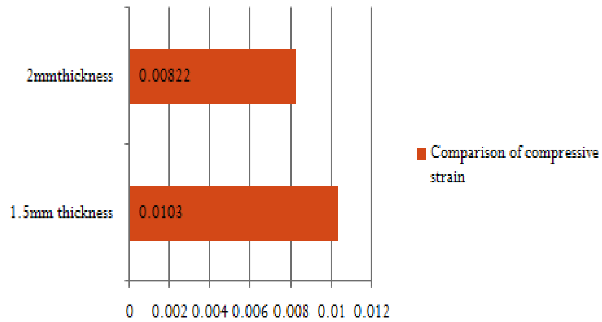

Fig. 16 Comparison of Compressive strain of Composite beams

From the above comparison figures It was found that truss beam suffers greater compressive strain compared to composite beam for same load. Truss beam of 1.5mm thickness have greater compressive strain compared to all other beams. When thickness increases considerable decrease in compressive strain occurs. Truss beam of 2mm thickness have 1.42 times decrease in compressive strain compared to truss beam having 1.5 mm thickness. Composite beam of 2mm thickness have 1.21 times decrease in compressive strain compared to composite beam having 1.5 mm thickness.

Failure Modes of Beams

Truss beam showed deflections at higher loads. There wasn't much difference between the failure undergone by truss beam of 2mm thickness and truss beam with 1.5mm thickness.In the case of composite beam, Intially beam specimens suffered yielding of steel truss portion. When mild steel reaches its maximum stress it get deflected and crack pattern similar to encased truss appears on the surface. The load was further increased, reaches yield stress of cold formed steel to ultimate and remaining loads was carried by concrete then concrete crushing occurs.Failure of both composite beam of 2mm thickness and 1.5mm thickness was by concrete crushing. Most of the crack appears at the centre portion Crack patterns obtained was similar in the case of composite beam of 2mm thickness and 1.5 mm thickness.

Fig. 16 Truss beam failure

Fig. 16 Composite beam failure

CONCLUSION

The flexural strength of Composite beam was assessed using truss beams and found that thickness adopted to chords and concrete encasing have effect on the flexural strength of composite beam. When concrete is encased in a truss beam of 2mm thickness then load carrying capacity get enhanced by 2.46 times. Truss beam of 2mm thickness have 4.8%increase in displacement ductility ratio compared with truss beam of 1.5mm thickness. Composite beam of 2mm thickness posses 6.1% increase in displacement ductility ratio compared with composite beam of 1.5mm thickness. Composite beam of 1.5mm thickness have 66.31% increase in displacement ductility ratio compared with truss beam of 1.5mm thickness. Composite beam of 2mm thickness have 68.36% increase in ductility compared with truss beam of 2mm thickness. Truss beam of 2mm thickness have 9.04% increase in flexural strength compared with truss beam of 1.5mm thickness. Composite beam of 2mm thickness posses 18.22% increase in flexural strength compared with composite beam of 1.5mm thickness. Composite beam of 1.5mm thickness have 2.27 times greater flexural strength compared with truss beam of 1.5mm

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thickness. Composite beam of 2mm thickness have 2.46 increase in Flexural strength compared with truss beam of 2mm thickness

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