Finite Element Modeling And Analysis Of Laced Steel Concrete Composite Beam

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Abstract— In this study, finite element modelling of LSCC beam was conducted in ANSYS Workbench 16.0. Main aim of this thesis to understand the basic characteristics of LSCC system. Parametric studies are carried out by considering different parameters as angle of lacing, spacing between lacing, span of LSCC beam, grade of concrete and inclination of lacings, under simply supported condition. Based on these studies design curve was plotted against the span vs. thickness of cover plate. The main attraction of this system is even after increasing length to maximum extent, it has high ductility and load carrying capacity and also we have to maintain the minimum depth of section compared to other alternative systems. Compared to RC beams, LSCC possess high energy absorption capacity and load capacity under increasing number of cycles of reverse loading condition even larger spans, which indicates that LSCC beams are unlikely to fail in shear even under low shear span to depth ratios.

Index Terms— Doubly skin composite system, ductility, fatigue analysis, Finite element modeling, Laced Steel Concrete Composite, lacings, parametric study.

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1 INTRODUCTION

A new form of DSC system, namely, Laced Steel-Concrete Composite (LSCC) with continuously inclined shear connector in the form of lacing, the provision of continuously inclined shear connectors was found to increase the ductility and support rotation of LSCC flexural members. It possess high shear capacity when compared to LRC beams, thus prevent brittle failure. Laced Steel Concrete Composite (LSCC) system consists of thin perforated cover plates at top and bottom which are connected using lacings and cross rods with concrete filled in between the plates. The cover plate performs the role of longitudinal reinforcement. Lacings transfer forces between steel and concrete while cross rods are used to anchor the lacings in position.

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Numerous studies were conducted in the past on doubly skin composite systems and laced composite structures. The concept of a double skin profiled composite beam using mechanical shear connectors is new and design methods are not currently available. This research provides information on the strength, stiffness, load-deformation response and also interaction between profiled steel sheets and concrete, based on the analytical investigations. The results of this research contribute significantly to the understanding of the behaviour of this type of structural element and might be of help to the design of laced steel concrete composite beam based on design chart.

The new configuration which overcomes these difficulties is thought of. Practical feasibility and construction /fabrication of specimen as well as application in field are kept in mind, while evolving and evaluating the different alternatives.

2 FINITE ELEMENT MODELING

2.1 General

The finite element (FE) method in comparison with the most common analytical methods is a powerful tool to study the behaviour of the composite slabs. A general purpose finite element code, ANSYS 16 is utilized in this study to analyze the behaviour of the composite deck slabs. ANSYS 16, including a variety of its routines, allows for the implementation of specific material models (Profiled sheet, concrete, steel, and shear stud), and boundary conditions, and bond behaviour. The interaction between the profiled deck sheet (which act as reinforcement) and concrete, minimum reinforcement (provided to take care of shrinkage and handling stresses) and concrete could also be considered.

2.2 Modeling

This approach is adopted in this study, since it is computationally efficient. Concrete is created as a volume of dimension 150 mm x 300 mm x 2400 mm. Solid elements are used to discretize the concrete volume. Steel plates which are bent into lipped channel are geometrically modeled as areas of size 2400 mm x 300 mm and discretized using shell elements. Lacings are represented using lines and link elements.

The interaction between the loading plate and the top steel plate, and interaction between the steel plates and the concrete core employs surface-to-surface contact with a penalty algorithm. For two deformable surfaces in contact, the master surface refers to the stiffer body or the surface with a coarser mesh if the two surfaces have comparable stiffness.

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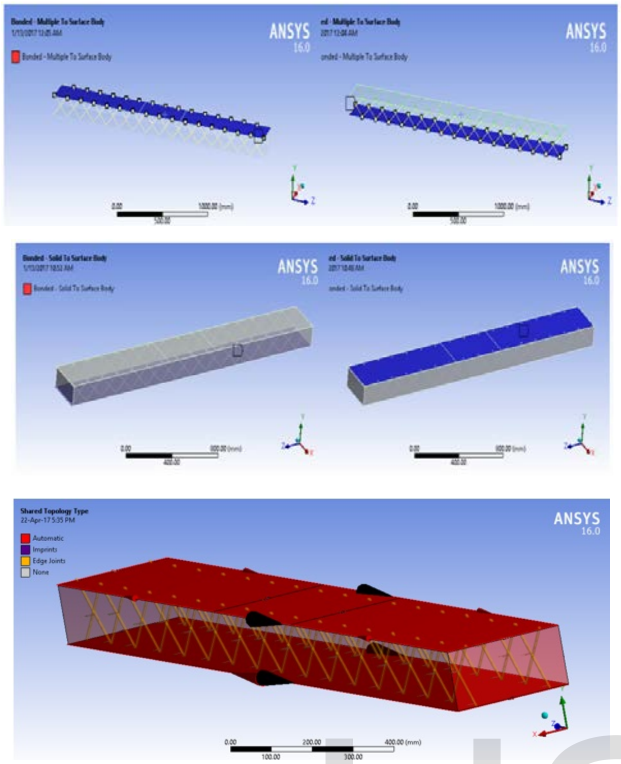


FIG1: MODELING OF LSCC BEAM

3 NUMERICAL STUDIES

As no design specifications are available on LSCC beam it is important to conduct a preliminary study. For the preliminary study, parameters such as angle of lacings, thickness of plate, grade of concrete, spacing between lacings, span of section, inclination of lacing have been chosen.

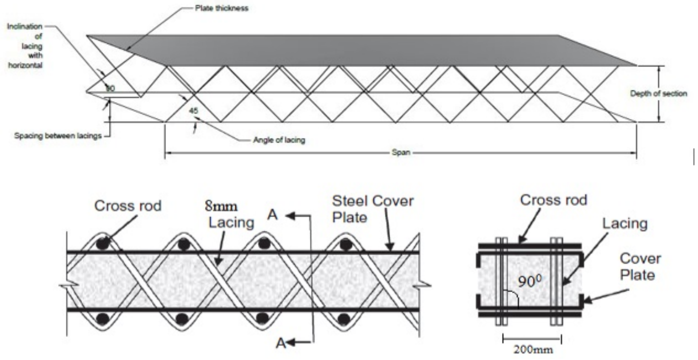


FIG 2: GEOMETRY OF LSCC BEAM

3.1 Effect of lacing angle of LSCC beam

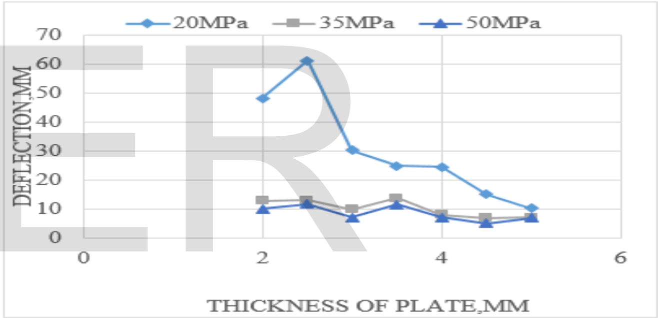
2.4 m long LSCC beam having a cross section of 300 mm x 150 mm is chosen for study. Four specimens with lacing angle of 300 450, 600 and 700 are modeled. Thicknesses of compression and tension plates are 3mm and diameter of lacing is kept as 8mm. From the table 6.2 we can conclude that better performance was observed in LSCC45 and LSCC60 lacing angles ,but among these two specimen LSCC60 was found to have better performance even though the show approximately the same behavior behavior under static loading.

TABLE 1
SPECIMEN DETAILS

SPECIMEN	SPAN(M)	LACING ANGLE	LOAD @ 20mm DEFLECTION (KN)
LSCC30	2.4	30^0	120
LSCC45	2.4	45^0	148
LSCC60	2.4	60^0	154
LSCC 70	2.4	70^0	140

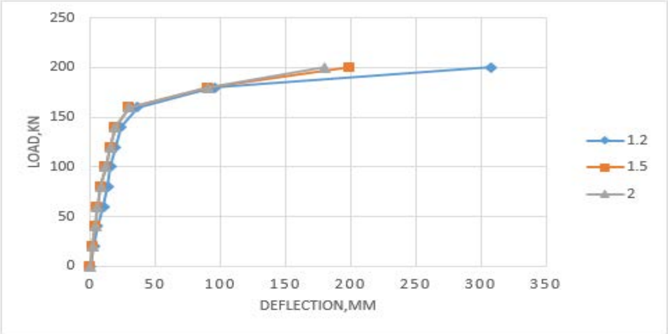
3.2 Effect of plate thickness of LSCC beam

From this study it was observed that the deflection decreases with increasing plate thickness of LSCC section and 30 and above MPa grade of concrete perform better in terms of ductility and load carrying capacity. That is high strength grade of concrete give better ductile behavior. Thus study concludes that 35MPa grade of concrete is the minimum grade of concrete that exhibit agreeable performance in the case of LSCC beam.



3.3 Effect of spacing between lacings of LSCC beam

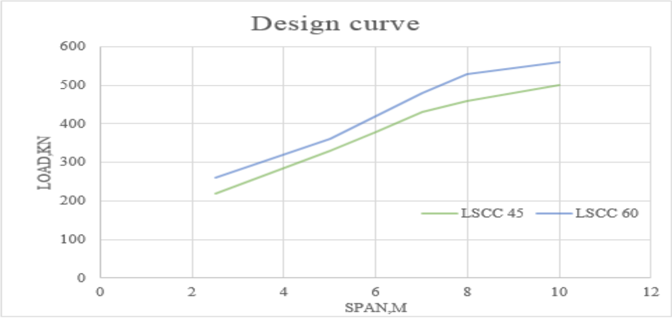
As the variation of spacing between lacings influences the performance of lscc beam.the variation of spacing is done by considering width to spacing of lacings ratio (2 1.5, 1.2) for 3 different width (200,250 and 300mm).it was found that the variation of spacing shows no significant effect on displacement for width to spacing of lacings ratio less than 1.2 and also the behavior of lscc beam is similar for all the three widths considered. From this we can conclude that 1.2 width to spacing ratio is found to be the optimum value.



3.4 Effect of span of LSCC beam

Total five beams of different span were considered based on deflection criteria (20mm deflection) and also the thickness of plate of each beam varying correspondingly. As span length of LSCC beam increases the value of deflection and load carrying capacity increases. This situation is required for making the section economical, because it ensures at the same time the load carrying capacity which requires sometimes high sections of steels which implies a reduction of ductility. So it is ideal to find an intermediate position for maximum strength and maximum ductility. In the lights of this observations design curve was developed against span and thickness of plate.

FIG 3: DESIGN CURVE



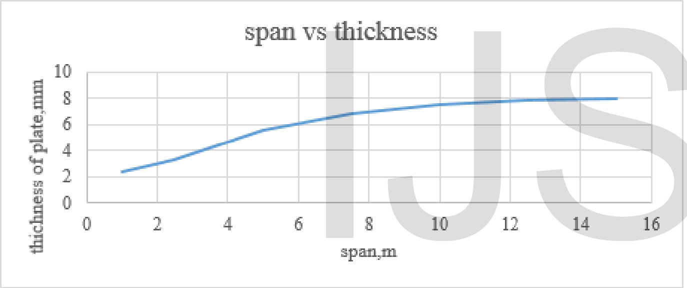
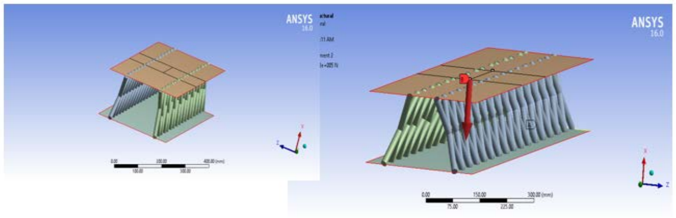


FIG 4: SPAN VS THICKNESS OF LSCC BEAM

3.4 Effect of span of LSCC beam

We studied the effect of inclination of lacing on performance of LSCC system under static loading condition and an exclusive configuration of LSCC system was evolved by changing the inclination of lacing. Concrete is created as a volume of dimension 150 mm x 300 mm x 2400 mm. Solid elements are used to discretize the concrete volume. Steel plates which are bent into lipped channel are geometrically modeled as areas of size 2400 mm x 300 mm and discretized using shell elements. Lacings which are bent at an angle of 45°are representing using beam elements. Cross rods of length 300 mm are represented using lines and wire elements.

By analyzing the obtained result, performance of LSCC beam increases with decreasing w/s ratio. It is observed that the deflection increases with decreasing angle of inclination up to 60°, but it is interesting to note that at the higher angle of inclination of lacing (90°) exhibits uniform distribution of loading. Modified configuration of lacing inclination is limited to the range of 60°to 90°.



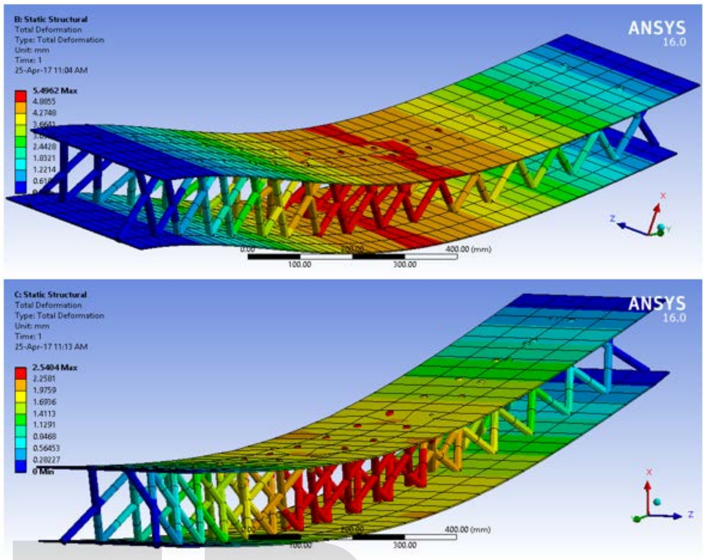


FIG 5: DEFORMED SHAPES

4 FATIGUE ANALYSIS

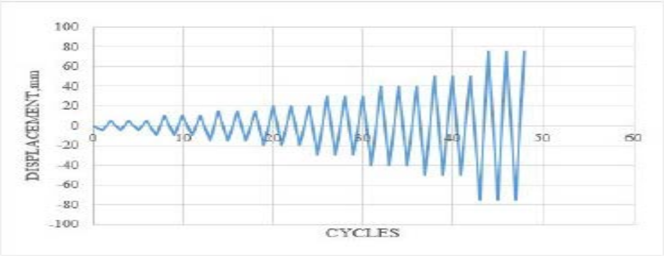
The basic behaviour of a structural component is obtained under monotonic loading. Yield and ultimate loads, yield and maximum displacements can be obtained from such a loading. Energy absorption and deterioration of strength and stiffness on the unloading and reloading paths will provide information about the suitability of structural system to resist suddenly applied dynamic loads such as blast, impact or earthquake. These values can be obtained by conducting a reversed cyclic load experiment on the structural system. Reversed cyclic load is applied on two LSCC beam specimens, one with 45° lacing and another with 60° lacing. The 3D model of LSCC beam section is generated in ANSYS Design modeler. Same section which was used for nonlinear static analysis was modeled in ANSYS. Small elementary areas having negligible thickness were created to apply point loads on top and bottom plate. To simulate the supporting condition used in static test support sections were modeled. The length of the beam was taken as 2.4m, 10m and 12m. The fully reversed cyclic loading was applied on the beam up to 80 cycles. In Ansys for fatigue analysis Goodman's fatigue theory is used. Soderberg theory gives conservative results compared to Goodman theory and Gerber theory.

4.1 LSCC 45

Initial amplitude of displacement is taken as 5mm. Amplitude is gradually increased from 5 mm to 100 mm, with intermediate amplitudes being 10, 15, 20, 30, 40, 50 and 75 mm. Three cycles are repeated for each value of displacement amplitude. Loading upto value of imposed displacement and unloading,

loading in the reverse direction and unloading constitutes one cycle. Difference between the peak loads in the first and in the second cycle and the difference between the peak loads in the second and in the third cycle is found to be nearly the same for displacement cycles up to 30 mm. same type of behavior was observed in 10m and 12m span.

FIG 6: LOADING PATTERN FOR LSCC45



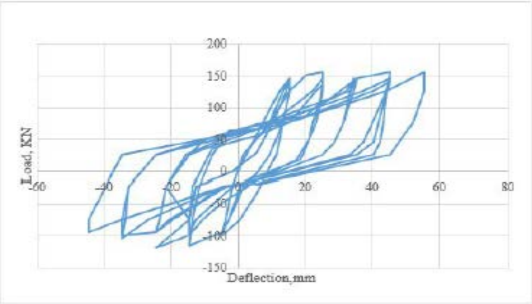
It is observed that the minimum fatigue life of our beam is 55222 cycles for 2.4m span and this value is reached at the location where maximum stress occurs, as expected.

FIG 7:LOAD-DEFLECTION CURVE FOR 2.4M SPAN

FIG 8: LOAD-DEFLECTION CURVE FOR 10M SPAN

FIG 9: LOAD-DEFLECTION CURVE FOR 12M SPAN

4.2 LSCC 60



Initial amplitude of displacement is fixed as 10 mm. Figure shows the loading sequence. LSCC 60 configuration was analyzed 2.4m, 10m and 12m span. Load-displacement response of LSCC-60-C beam is shown in Figure. Beyond this the peak load decreases for next two displacement amplitudes. There is slight increase in peak load, when the displacement amplitude increases from 50 mm to 75 mm. Within each displacement amplitude, the peak load attained in the first cycle is more than the next two cycles.

FIG 10: LOADING PATTERN OF LSCC45

Fatigue life shows the available life for the given fatigue analysis which represents the number of cycles until the part will fail due to fatigue. It is observed that the minimum fatigue life of our beam is 55000 cycles and this value is reached at the location where maximum stress occurs.

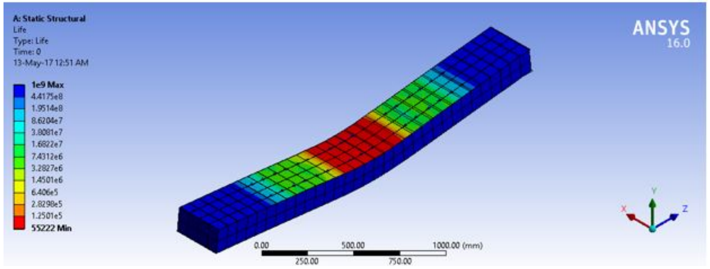


FIG 11: LIFE CYCLES

In fatigue analysis, fully Reversed cyclic load has been applied on two type of LSCC beams with lacing angle 450 and 600. Both angle of beams are found to exhibit almost similar behaviour and Maximum load attained under both sagging and hogging moment conditions are found to be nearly equal. Even though LSCC-45 is found to withstand maximum cycles of loading than LSCC-60.

Energy absorbed by the beam in each load cycle is calculated from the load deformation curves. Among the three load cycles at a level, it is always the first cycle which is found to absorb more energy. Energy absorbed in the second and in the third cycles are found to be in the range 70-95% and 65- 85% respectively of that absorbed in first cycle for all configurations. However, energy absorbed is estimated to be nearly the same for the load applied in the upward as well as in the downward directions. It is observed that maximum strain is attained in the lacing at the edge of the segment applied with uniform loading in both the beams.

CONCLUSION

The paper presents the concepts of a construction-friendly structural system- Laced Steel-Concrete Composite (LSCC) system- that can resist the dynamic loads and possess high ductility, after analyzing the limitations of existing systems. A new Laced Steel-Concrete Composite (LSCC) system is proposed. It consists of two thin steel cover plates connected using lacings and cross rods, and filled with concrete. This method of fabrication avoids welding in total. Monotonic load testing under four point flexure on two specimens, one with

45° lacing and another with 60° lacing, are conducted under displacement control mode. Finite element model with solid, plate and link elements representing concrete core, cover plates and lacings respectively is generated for numerical analysis. Energy absorbed is calculated from the load-displacement response and is found to be in close agreement with experimental results. This model is extended until 25% degradation in strength is achieved to get the cumulative energy absorbed by the LSCC beams. A model to predict the shear strength of LSCC beams is proposed based on the observation of strain variation in lacings.

- LSCC45 and LSCC60 beams exhibit comparatively a similar performance under static load. Ductility of LSCC beam with 60° lacing is found to be more than that of beam with 45° lacing, while their moment carrying capacities are nearly equal.
- Deflection was found to decrease with increasing plate thickness of LSCC section and 30 and above MPa grade of concrete perform better in terms of ductility and load carrying capacity
- The variation of spacing between lacing shows no effect on displacement for spacing of connector less than 200mm, from the lights of result 200mm spacing was considered optimum value.
- LSCC beam gives better performance even after increasing length to maximum extent, it has high ductility and load carrying capacity and also we have to maintain the minimum depth of section compared to other alternative systems.
- A new modified configuration was analyzed on basis of varying inclination of lacing angle. This phase explains, the better performance is seen at lower value of width to top spacing ratio up to 1.5 for bottom spacing 200mm.
- Under reverse cyclic loading, both the specimens are found to exhibit almost similar behavior. Maximum load attained under both sagging and hogging moment conditions are found to be nearly equal for 45° and 60°.
- LSCC beams can maintain better energy absorption capacity even under larger spans.

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