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Structural Performance of Steel Encased Composite Multilayered Concrete Beam

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Abstract- In this paper, a composite multilayered concrete beam is analyzed by using ANSYS workbench software. An I section which is partially encased with Ultra-High Performance Concrete [UHPC] and Ultra-Light weight Cement Concrete [ULCC]. These composite materials had been arranged horizontally and vertically along the I Section. Compressive strength of various multilayered composite beams has been compared. Instead of using conventional steel or reinforced concrete members, this form of beams offers greater strength and stiffness.

Keywords:- Ultra-High Performance Concrete [UHPC], Ultra-Light weight Cement Concrete[ULCC]

I. INTRODUCTION

Structural steel which is partially enclosed or fully enclosed with concrete are frequently used in building construction. Instead of using conventional steel or reinforced concrete members, this form of beam offers greater strength and stiffness. The steel section is protected from fire, the compression flange is kept from buckling locally, and the resistance of the beam to lateral-torsional buckling is increased by the concrete encasement. Where standard beams are insufficiently serviceable, composite beams are used. We can somewhat minimize the cross-sectional area of the beams by using composite ones made of greater stiffness materials. They are utilized to make the construction stronger. Large areas can be covered by composite beams without the need for an intermediary structure.

UHPC is a cementitious composite material made up of a high proportion of discontinuous internal fiber reinforcement, a water-to-cementitious materials ratio less than 0.25, and an optimized gradation of granular elements. A brand-new category of concrete called UHPC has recently been created due to its extraordinary strength and endurance. The first UHPC bridge in North America was built in Canada in 1997 as a pedestrian bridge. Compressive strength of UHPC is ten times greater than that of conventional concrete. Portland cement, fine sand, pulverised quartz, accelerating admixtures, steel fibres, and water are the main ingredients in UHPC. With low densities of less than 1400 kg/m3 and compressive strengths of up to 60 MPa, ultra-lightweight cement composites (ULCC) are the perfect choice for usage in buildings where material weight is important. In structural applications with low weight and permeability requirements, lightweight aggregate concrete (voids are primarily in aggregates) is often used in place of conventional aggregate. Lightweight concrete is especially beneficial for long-span constructions, high-rise structures, and sandwich structures that must have minimal self-weight.

II. OBJECTIVES

- To study the partially encased composite beams.
- The effect of different composite materials.
- The effect of number of layers.
- The effect of arrangement [Horizontal/ Vertical]

III. SCOPE OF THE WORK

The scope of this study is to develop a high strength multi-layered composite beam instead of using steel or conventional reinforced concrete beams.

IV. PARAMETRIC STUDY

Multiple aspects were taken into consideration when conducting the investigation on the partially encased multi-layered concrete beam. The beams measure 2000mm in length, 250mm in depth, and 200mm in breadth overall. All examples are constructed using WB 225 hot-rolled wide-flange beams. Vertical and horizontal arrangements had been made with the composite cementitious materials. A single beam included three layers of cementitious material, each with an identical layer thickness.

Code of references: Indian Standard codes IS 808(1989)

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V. SUMMARY OF LITERATURE REVIEW

The base journal "Flexural Behaviour of Steel Composite Beams Encased by Engineered Cementitious Composites" was among the literatures studied. Analyses are done on how different composite constructions behave in different environments. Utilising cementitious material will increase the steel member's residual strength. Traditional concrete beams might be considerably heavier than composite beams. In comparison to conventional beams, it can also support higher weight. Large areas can be covered by composite beams without the requirement for any intermediary columns. Many seismic-resistant structures now opt to use concrete-encased steel composite columns. The steel block shear connectors used to join the high-strength steel and precast concrete together create a composite beam with a high bending capacity and stiffness. The flexural strength and ductility of bare steel beams could be greatly improved by the use of ECC and LWC encasements.

VI. MODELLING

The modelling is done in the ANSYS Software.

In the case of horizontal arrangement there are almost 8 specimens in which cementitious material layers are arranged. ULU, LUL, UUL, LLU, UUU, ULL, LLL and LUU. Here U stands for ultra- high performance concrete layer and L stands for ultra-light weight cement concrete layer.

In the case of vertical arrangement there are almost 6 specimens in which cementitious materials are arranged. UU-UU, UL-UL, LU-LU, UL-LU, LU-UL and LL-LL.

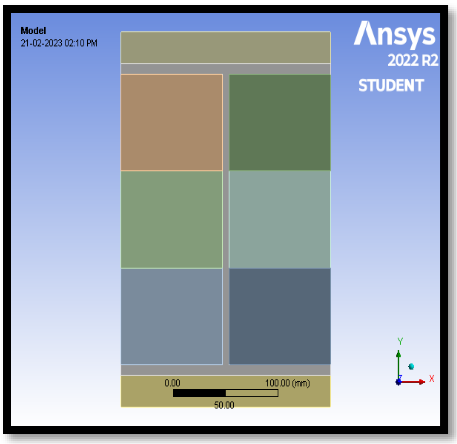

Fig 1: Horizontal Arrangement

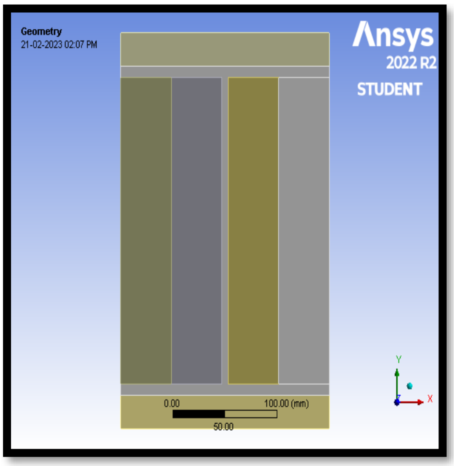

Fig 2: Vertical Arrangement

A. *Material Properties*

Two different cementitious material are selected and arranged in different layers in vertical and horizontal manner along the hot rolled wide flange beams WB225.

TABLE 1: MATERIAL PROPERTIES

	UHPC	ULCC	STEEL
Density(kg/m3)	2350	1250	7850
Young's Modulus[MPa]	44500	10620	200000
Poisson Ratio	0.12	0.12	0.3

VII. TEST RESULT AND DISCUSSION

Among the 8 specimens of horizontally arranged cementitious material, two models are uniformly layered [UUU, LLL]. The weight and the maximum load carrying capacity of these various specimens are studied.

TABLE 2: WIGHT OF HORIZONTALLY LAYERED SPECIMENS

	WEIGHTS[kg]
ULU	266.66
LUL	233.77
LUU	266.66
UUL	266.66
LLU	233.77
UUU	299.55
ULL	233.77
LLL	200.89

When comparing ultra-high performance concrete composite beams with ultra-light weight cement composite beams, the weight increases by 49.11% that of LLL.

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TABLE 3: LOAD CARRYING CAPACITY OF HORIZONTALLY LAYERED SPECIMENS

	LOAD[kN]
ULU	723.32
LUL	669.12
LUU	720.63
UUL	689.24
LLU	758.01
UUU	696.43
ULL	669.92
LLL	704.11

The model with uniform layered ultra-high performance concrete has higher load carrying capacity than model with uniform layered ultra-light weight cement concrete composite beam.

The percentage of increase in load is 13.149

When compared with composite sections, ULL performs effectively with least weight. ULU performs effectively with most weight.

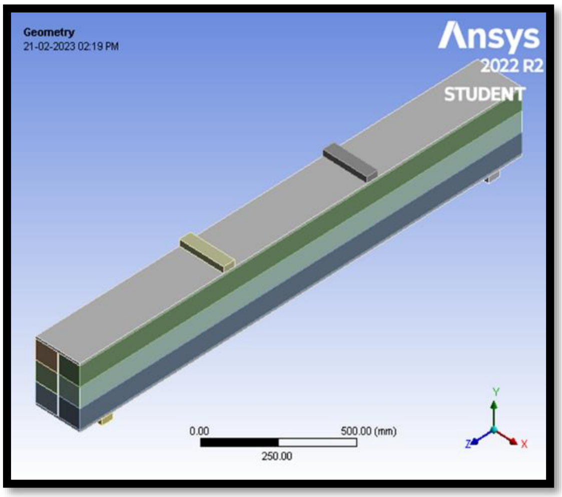

Fig 3: Geometry of ULU

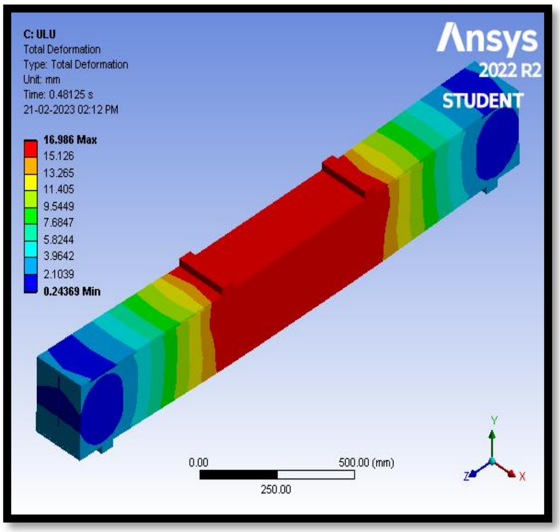

Fig 4: Deformation of ULU

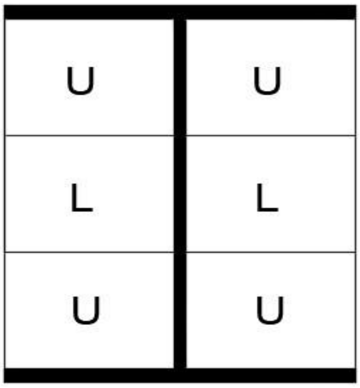

Fig 5: Cross section of ULU model

Among the 6 specimens of vertical layered cementitious material, two models are uniformly layered [UU-UU, LL-LL]. The weight and the maximum load carrying capacity of various specimens are studied.

TABLE 4: WEIGHT OF VERTICALLY LAYERED SPECIEMEN

	WEIGHT[kg]
UU-UU	299.55
UL-UL	250.22
LU-LU	250.22
UL-LU	250.22
LU-UL	250.22
LL-LL	200.89

The model UU-UU has most weight compared to other models. The model LL-LL has the least weight compared to other models. The increase in weight of UU-UU is about 49.11% compared to the model LL-LL.

TABLE 5: LOAD CARRYING CAPACITY OF VAERTICALLY LAYERED SPECIMEN

	LOAD [kN]
UU-UU	760.2
UL-UL	717.54
LU-LU	718.03
UL-LU	716.55
LU-UL	717.87
LL-LL	670.69

When multi layered composite models are compared with uniform layered composite model UU-UU, the composite model with layer LU-LU has the least amount of percentage decrease in load.

When multi layered composite models are compared with uniform layered composite model LL-LL, the composite model with LU-LU layered has the most % increase in load.

When multi layered composite models compared with each other, LU-LU has the maximum load carrying capacity. UL-LU has the minimum load carrying capacity.

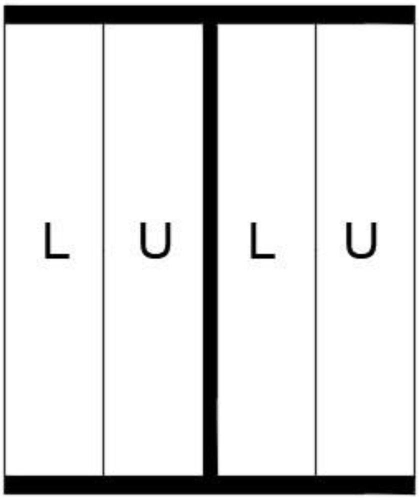

Fig 6: Cross section of LU-LU model

TABLE 6: LOAD CARRYING CAPACITY OF I SECTION

	LOAD[kN]
HOT ROLLED I SECTION [WB225]	6.18.06

The hot rolled wide flange beams [WB225] has a load carrying capacity of 618.06KN.

TABLE 7: COMPARISON OF ULU WITH I- SECTION [WB225]

	LOAD (kN)	% INCREASE IN LOAD
I-SECTION	618.06	0
ULU	723.32	17.03

When ULU is compared with normal I-Section its load carrying capacity increases by 17.03%.

TABLE 8: COMPARISON OF LU-LU WITH I SECTION [WB225]

	LOAD (kN)	% INCREASE IN LOAD
I –SECTION	618.06	0
LU-LU	718.03	16.17

When vertically layered LU-LU model is compared with I-SECTION its load carrying capacity increases by 16.17%.

TABLE 9: Comparison of ULU & LU-LU

	LOAD(kN)
ULU	723.32
LU-LU	718.03

From this table we can find that cementitious material horizontally arranged composite model ULU has higher load carrying capacity than cementitious material vertically arranged composite model LU-LU.

VIII. CONCLUSION

In the case of multi-layered composite models with horizontal arrangement following conclusions are made,

The model with uniform layered ultra-high performance concrete has higher load carrying capacity than model with uniform layered ultra-light weight cement concrete composite beam. The percentage of increase in load is 13.149. When compared with ultra-light weight cement composite beams with ultra -high performance concrete composite beams, the increase in weight is 49.11% that of LLL. When multilayer models are compared with uniform layered model UUU, ULU has the least percentage decrease in load. When multilayer models are compared with uniform layered model

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LLL, ULU has the maximum percentage increase in load. When ULU is compared with normal I-Section its load carrying capacity increases by 17.03%. Hence in the case of multi-layered composite models with horizontal arrangement ULU is the most efficient model in the case load carrying ability.

In the case of multi-layered composite models with vertical arrangement following conclusions are made,

The model UU-UU has most weight compared to other models. The model LL-LL has the least weight compared to other models. The increase in weight of UU-UU is about 49.11% compared to the model LL-LL. When compared with uniform layered composite model UU-UU, the composite model with layer LU-LU has the least amount of percentage decrease in load. When compared with uniform layered composite model LL-LL, the composite model with LU-LU layered has the most amount of percentage increase in load. When compared with composite sections, LU-LU has the maximum load carrying capacity, UL-LU has the minimum load carrying capacity. When vertically layered LU-LU model is compared with I-SECTION its load carrying capacity increases by 16.17%. Hence we conclude that among the various multi-layered composite beam model, LU-LU is most efficient in case of load carrying ability.

Cementitious material horizontally arranged composite model ULU has higher load carrying capacity than cementitious material vertically arranged composite model LU-LU.

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