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ANALYTICAL INVESTIGATION ON BEHAVIOR OF PARTIALLY PRECAST CONCRETE DECK SLABS SUBJECTED TO SHEAR FAILURE

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ABSTRACT

Composite deck slab consists of reinforced concrete cast on top of deck sheet which are bonded together by introducing stiffener, embossment etc. Partially precast technique has many advantages like fast construction, reduction in weight of precast portion during transportation etc. 1mm thick deck sheet is use for this study in which the precast depth taken as 75mm. A total of 3 specimen has been analyzed by varying the material properties during two stage construction. Conventional aggregate concrete and lightweight aggregate concrete are used for this study. Finite element analysis method has been carried out with the help of ANSYS 14 software. Both static linear analysis and non-linear analysis is done to get the actual behavior of the slab. It is expected that by using expanded clay light-weight aggregate it will decrease the weight of slab.

Keywords: deck slab, partially precast, finite element analysis, non linear analysis.

1. INTRODUCTION

Over the years, composite slabs with profiled metallic sheeting are extensively used for the development of steel-framed building. It uses all over the world because of its several advantages like lighter-weight, speedy construction and also cost effective. It includes profiled steel sheet, concrete topping and reinforcement. There are many advantages of using composite slab such as reduce thickness, lightweight, simpler & faster construction, easy to handle.

The profiled sheet acts as an everlasting formwork during the construction stage and as a tensile reinforcement after the concrete hardens. The slab can be made with varying sizes and with cast in-situ concrete topping will make the surface smooth. The thicknesses of profiled sheet available in market for composite construction are 0.8mm, 1mm, 1.2mm.

Expanded clay aggregate concrete is one of the replacements of conventional concrete because of its lighter weight. The cast in-situ concrete topping can also use for increasing the strength and stiffness of the slab. Typically cast in-situ concrete depths vary from 40mm - 100mm.

The shear resistance between concrete and deck sheet are generally provided by the use of some interlocking mechanical devices. Shear studs, embossments, stiffeners are used for the bonding. The transfer of force in composite slab may be characterized by three ways of failures namely: (i) flexural failure, (ii) longitudinal shear failure, and (iii) vertical shear failure. The most common type of failure in composite slabs is longitudinal shear failure.

The researchers has been pointed out that delamination of the sheets has been introduced at an early stage of loading for the sheets without embossments [1]. A total of eighteen specimen has been casted and divided into 6 sets by varying shear span. They have concluded in shorter shear spans the failure is due to shear bond where as in longer shear spans it is due to flexural failure [4]. Tests on a total of four specimen is carried out to find out the modulus of rupture of a precast composite slab with steel fiber at the top. The bonding between the layers is done by making the surface rough. They conclude steel fibers increase the strength as well as ductile performance of the slab [5]. The shear bond mechanism of deck slab is found out by performing pull out test and bending test which is failed in longitudinal shear bond by initiating cracks in concrete [6]. The strength of slab depends on the thickness of sheet [7]. It has also shown that inclusion of shear stud results in the late slippage of concrete and good bonding between deck sheet and concrete [8].

The researchers found out the properties of clay aggregate which are produced from coal, waste brick powder and clay at various temperatures 900^{o}C to 1250^{o}C and they got 0% water absorption for the aggregates produced from clay [9]. The durability of expanded clay aggregate concrete has checked and the results shows that the aggregate which is made by using coal fly ash is giving good response in respect to resistance and durability in corrosive environment [10].

The research gap found out is to take a look on the load-displacement behavior of partially precast composite deck slab and also to check the ultimate load carrying capacity. It can also be seen by using lightweight aggregate the self-weight of the slab decreases by 20%.

2. MATERIALS

2.1 Materials Used

The materials used for the study of partially precast composite deck slab are Ordinary Portland Cement, Fine aggregate, Coarse aggregate, Light-weight aggregate, Metal Deck Sheet, Water. OPC 53 grade cement has been tested to find the properties of cement.

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Locally available sand is used as fine aggregate. 20mm coarse aggregates are used for this study. All specification of coarse aggregate is as per IS 383:1970. Light-weight expanded clay aggregate which is made by heating clay to around 1200^{o}C in a rotary kiln. Clay has formed by expanding the yielding gas in the form of bubbles during heating forming a honeycomb structure. This clay particles contain homogenous secret, and little gaps called as porous ceramic. It has good thermal (shrinkage), compression properties as well as it has high fire resistance. 8mm-10 mm size of expanded clay aggregate are used for this study. Metal deck sheets are used for preparation of composite deck slab for more than a decade. It can use in steel framed building, bridges. The use of deck sheet reduce the weight of slab by almost 70% by decreasing the slab thickness. The ultimate yield strength is about 240 N/mm^2. The thickness of deck sheet use for this study is 1mm.

Table-1. Physical properties of cement.

S. No.	Characteristics	Value
1	Fineness Modulus	8%
2	Consistency	33%
3	Specific Gravity	3.1
4	Initial Setting Time	45minutes

Table-2. Physical properties of aggregate.

S. No.	Characteristic	Fine Aggregate	Coarse Aggregate	Light-Weight Aggregate
1	Specific Gravity	2.81	2.84	1.2
2	Water Absorption	1.8%	0.7%	19%

Table-3. Physical properties of deck sheet.

S. No.	Characteristics	Value
1	Density	7850 kg/m^3
2	Yield strength	240N/mm^2
3	Young's modulus	2*10^5 N/mm^2

Figure-1. Expanded clay aggregate.

Figure-2. Metal deck sheet.

3. ANALYTICAL STUDY

3.1 Structural Modeling

The model has been created and assembled using the software CATIA. The model is then transferred to ANSYS 14. For making the proper contact reinforcement bars are modelled using the shell element command in ANSYS. The size of the slab taken as 1000mm X 1000mm X 125mm. The depth of the slab is given in two parts. At first 75mm thick concrete block is modelled and then by making the contact region as bonded another 50mm thick concrete is modelled above the 1st part. The description of the model and the sheet is shown in the figure below:

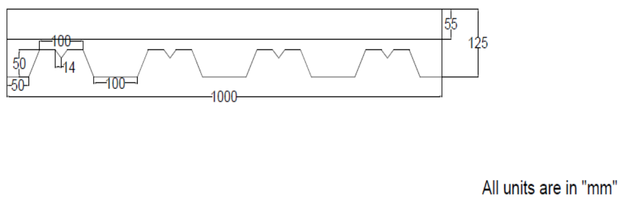

Figure-3. Composite slab details.

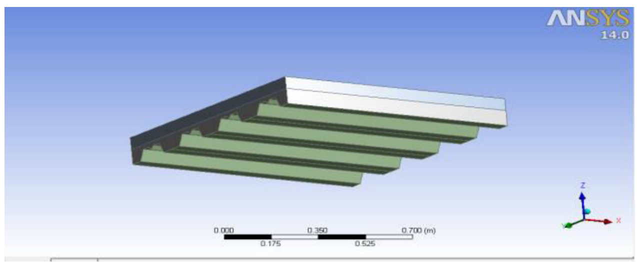

Figure-4. Model of composite deck slab in ANSYS.

3.2 Boundary Condition and Loading

All the four sides are provided with fixed support so that there is no slippage of the material. Vertical load is provided as incremental of 20kN/m^2 with time to calculate the deflection at each stage of loading. The ultimate load

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carrying capacity of the slab is 216 kN/m^2. Support condition and loading diagram is shown in the figure below.

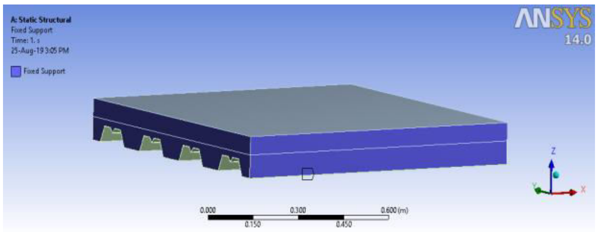

Figure-5. Support condition.

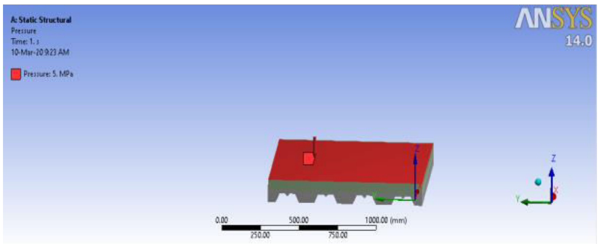

Figure-6. Loading diagram.

3.3 Analytical Results

3.4 Load and Deflection

The load versus deflection graph shows that the deflection is well within the limit. The maximum deflection for M20 grade concrete occurred at the center of the slab with a value of 0.2mm which is well below L/300 as given in EN 1994-1-1. The linear and nonlinear results are put on the graph for M20, M25 and M30 grade concrete. To get the nonlinear result the load need to increase to a higher value. It increases up to 5000kN/m^2.

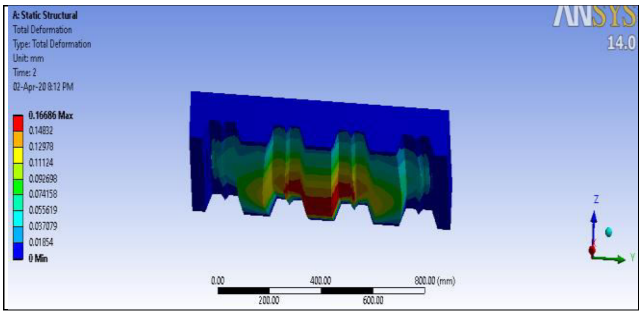

Figure-7. Deformation diagram of partially precast composite deck slab.

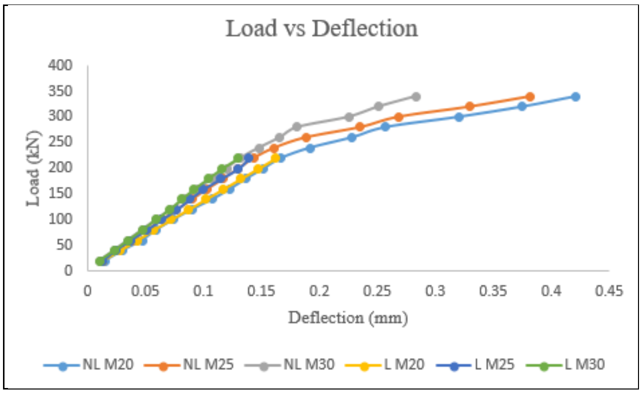

Figure-8. Load vs Deflection.

3.5 Shear Stress and Shear Strain

For both linear and nonlinear analysis, the results of shear stress vs shear strain graph shows straight line because it follows Hook's law. A maximum strain of 0.0004mm is achieved for a stress of 30N/mm^2 in linear analysis and for an ultimate load. Due to the increase of load it can be seen stresses towards the support is maximum.

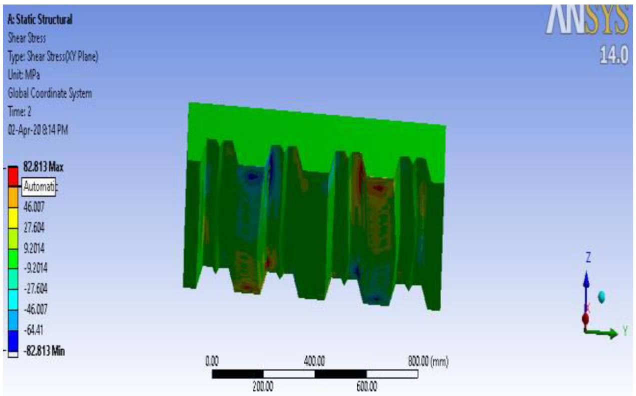

Figure-9. Shear stress diagram of partially precast composite deck slab.

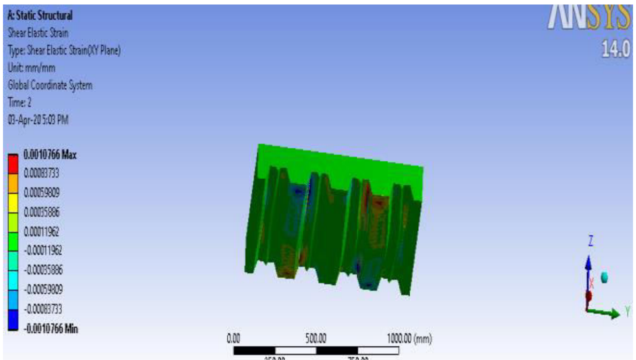

Figure-10. Shear strain diagram of partially precast composite deck slab.

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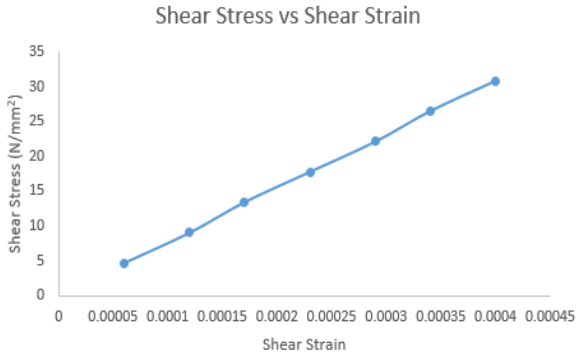

Figure-11. Linear analysis result of shear stress vs shear strain.

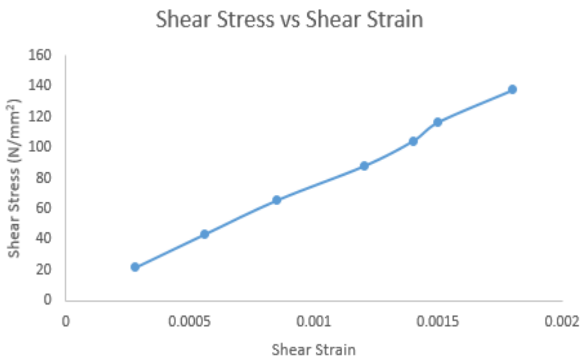

Figure-12. Non-linear analysis result of shear stress vs shear strain.

3.6 Equivalent Stress and Equivalent Strain

Equivalent Stress vs Equivalent Strain graph and Principal Stress vs Principal Strain graph also shows the material non-linearity. In both the graphs the yielding of the material starts at a stress of 250N/mm^2. The principal strain for this stress is 0.00005mm which is much smaller than equivalent stress which is 0.0015mm. The failure in the composite slabs is not that dominant or clearly seen crack. In most of the slabs it shows small cracks. In respect to elastic region, the region in plastic models shows considerable errors due to the shorter size of the slab.

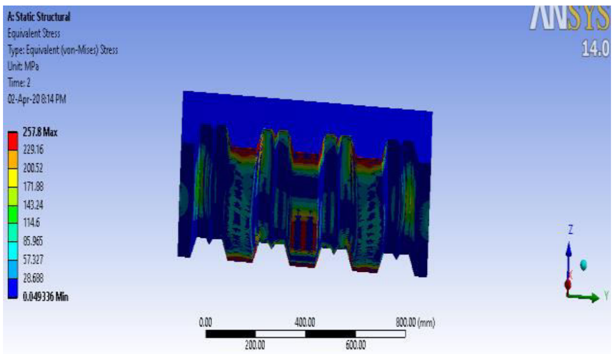

Figure-13. Equivalent stress diagram of partially precast composite deck slab.

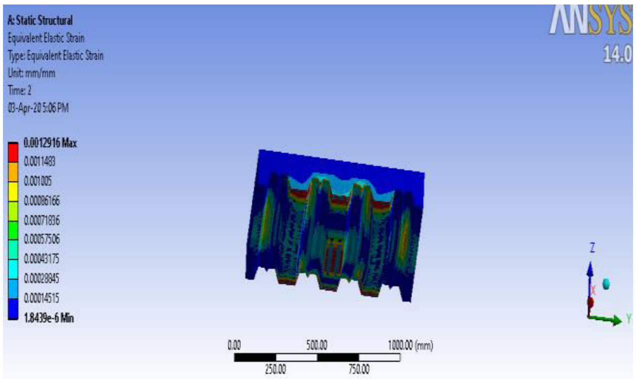

Figure-14. Equivalent strain diagram of partially pre-cast composite deck slab.

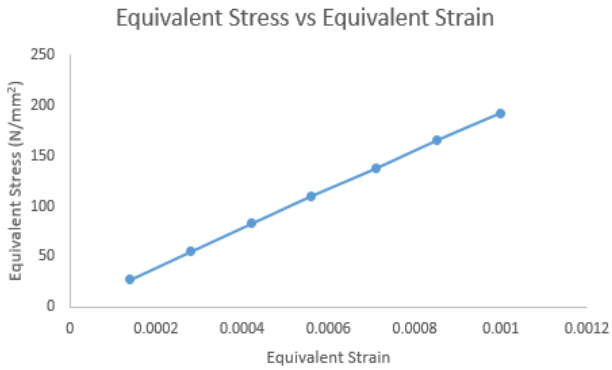

Figure-15. Linear analysis result of equivalent stress vs equivalent strain.

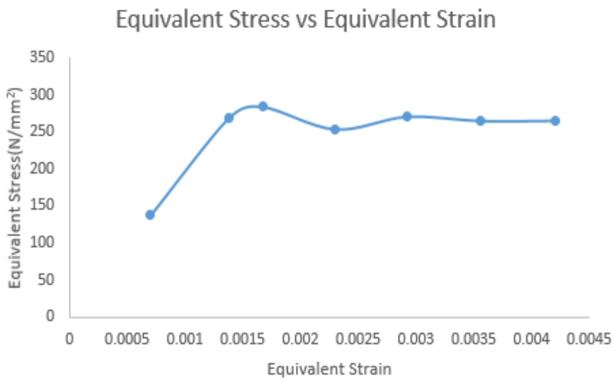

Figure-16. Non-linear analysis result equivalent stress vs equivalent strain.

4. RESULTS AND DISCUSSIONS

- The ultimate load carrying capacity of slab is 200kN for which the deflection value came as 0.2mm which is much lesser than L/300.
- Nonlinear analysis result shows the flexural crack starts at a stress of 275N/mm^2.
- The self-weight of the slab decreases by 3 times by using light-weight aggregate concrete.

5. CONCLUSIONS

The following conclusion can be drawn from the analytical study on composite deck slab by using conventional concrete and lightweight aggregate concrete shows:

- The self-weight of the slab made by conventional and lightweight concrete reduced by 7% and that of lightweight concrete reduced by 17% in respect to the slab made up of conventional concrete which is most valuable for the pre-casting technique.
- The proposed method of using lightweight aggregate concrete on the cast-in-situ portion by making the surface rough of the pre-casting portion is an effective method. Since the bond between pre-casting portion and cast-in-situ portion was found to be intact indicating monolithic behavior of the slab.
- The failure in the slab is vertical shear failure as all the four sides are kept as fixed.
- The crack pattern shown by finite element method of analysis is in the bottom of slab which gives sufficient information to study the shear behavior of slab.

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