Analytical Investigation of the Load-Bearing Behavior of Light Weight Hollow Core Composite Slabs*

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Abstract: Slabs are considered the most important structural member but also the heaviest one. Therefore, in the last few years a new type of slabs was introduced, hollow core slabs with steel decks. On the other hand, the use of light weight concrete that has got a density less than (1850 kg/m3) reduces the self-weight of structures considerably. This paper conducts an analytical study of the flexural behavior of five slabs, a solid slab that acts as a reference, a hollow core slab with elliptical voids, a composite slab and two hollow core composite slabs using normal weight and light weight concrete using ANSYS software. All the slabs share the same size (2600 x 1200 x 140) mm. The results show that the use of hollow core slabs increases the load carrying capacity by about 32% while using light weight concrete reduces it by about 34% but it also decreases the self- weight and the deformation considerably. The use of light weight hollow core slabs promises with a wide horizon of privileges and improvements in the construction and research domain

Index Terms: Ansys Software, Composite Slabs, Finite Element Analysis (FEA), Hollow Core Slabs, Hollow Core Composite Slabs, Light Weight Concrete

1. Introduction

In the last two to three decades, the major interest of researchers was to find alternatives to the commonly used slabs, as they contribute the most to the self-weight of the structure due to the need of large thicknesses and the concrete used which is considered as a heavy and expensive material. Three systems were suggested: 1- Hollow core slabs: which are slabs that have longitudinal voids with variety of possible shapes, those slabs have guaranteed a good reduction in the self-weight of slabs which reflects mainly on the needed sizes of the columns and foundations, as the hollow cores cause a reduction in self-weight of thirty percent or more compared with a solid slab of the same depth. (K.Soundhirarajan at al 2018) [6]. The reduced weight of the floor system reduces the needed amount of construction materials (Concrete and steel) for vertical members and foundations considerably and can also decrease seismic load. (Schnellenbach-Held and Pfeffer 2002 [8]; Chung et al. 2010 [5]). 2- Composite slabs: slabs that have steel decks with different profiles acting as tension reinforcement, concrete topping as well as top reinforcement

to resist the shrinkage and temperature effects. The bond be- tween the concrete and the steel sheets is achieved essentially by different 'shear transferring devices' like embossments, transverse wires and holes etc. (S. P. Siddh et al, 2017) [10]. Composite slabs with embossments have shown high load carrying capacity where the load carrying capacity of sheets with embossments was more than that of sheets without embossments. Baskar. R et al (2012) [1].

3- Tubedeck System: The system is a combination of a cast-in-situ RC slab with circular tube voids and profiled steel decks as shown in [figure 1]. This system shares the advantages of half-hollow-core slabs, i.e., less self-weight and the possibility of working without formworks. The environmental performance and constructability are improved because paper tubes are used as void fillers. Steel decks were formerly used only for formwork (Hong et al.2012) [3].

This paper evaluates the flexural behavior of the hollow core composite slabs using light-weight concrete as a less-weight construction material.

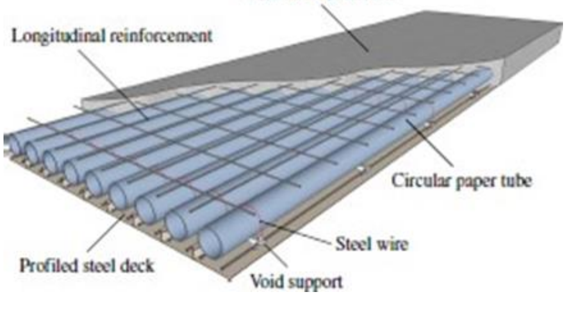

Fig. 1. TUBEDECK Slab.

2. Related Research Work

Nanang et al (2017) [9] did an experimental study to investigate the behavior of hollow core slabs using two types of materials for cavity: PVC pipes and Styrofoam. They

have used various diameters for the reinforcing bars too. The results have shown that the flexural stiffness values have been decreased because of the cavity, when compared to the solid slab. On the other hand, the flexural strength of the hollow core slab type 2 is higher than the hollow core slab type 1. Siddh et al (2017) [10] conducted an experimental study to investigate the behavior of composite slabs in mid span. Two specimens of different profile sheets thicknesses were tested

: 0.8 mm profile sheet thickness with V notch and without notch and the other two for 1.2 mm thickness with V-notch and without notch. Shear studs were introduced at both end of the sheet. They have found that the steel sheet with 1.2 mm thickness and V notch had the highest load carrying capacity with a good ductile behavior. Chang-Hwan Lee et al (2019)

[2] have clarified the flexural behavior of TUBEDECK slabs. Their results show that TD slabs subjected to positive bending showed gradual propagation of flexural cracks until the middle stage of loading, but at the end, the strength decreased rapidly due to the loss of interfacial resistance between the concrete and the steel deck. Immediately after bond failure, diagonal cracks also occurred in the shear span. Yousif Dhari Awad and Ali Hussein Ali Al-Ahmed (2019) [11] have clarified that the use of steel tubes embedded in one-way concrete slabs caused delay in the appearance of first cracks and that they have a huge effect on increasing the slab ultimate capacity load. The use of the embedded steel tubes in slabs decreases the mid-span deflection. An experimental and analytical study was conducted by Luiz et al (2020) [7] to estimate the ultimate shear force of composite slabs with additional reinforcement, the results showed that adding additional reinforcement im- proved the structural behavior of composite slabs, increased the carrying load capacity and longitudinal shear ductility, which allowed a greater use of plastic bending capacity of the composite sections, resulting in better use of the steel decking and concrete slab strength.

3. Research Significance

Many researches have been conducted on the performance of hollow core slabs and composite slabs separately. However, very few researches were done on voided composite slabs as it is considered a new system that is still under study and investigation. This analytical study attempts to study and compare the flexural behavior of hollow core composite slab using normal weight and light weight concrete as one of the first studies to be done in this area of research.

4. Methodology

A. Modal Description and Materials Properties

A solid slab that acts as a reference was designed in accordance with IS 456: 2000 [4]. The concrete grade used is M35 and the yield strength of steel fy=415 Mpa. Poisson’s ratio for concrete and steel are 0.2 and 0.3 respectively while the modulus of elasticity of steel is 2x105 Mpa and for normal weight and light weight concrete is 29580 and 18071.8 Mpa in their mentioned sequence. The density of normal weight concrete and light-weight concrete are 2300 kg/m3 and 1800

kg/m3 respectively. The solid and hollow core slabs (HCES) share the same reinforcement which are 10 mm for main reinforcement and 8 mm for transverse reinforcement as shown in [figure 2]. [figure 3] shows clearly that the voids shape of the hollow core slab is elliptical. The composite slab (CS1) has got top reinforcement to resist shrinkage and temperature effects and the steel sheet has got embossments on the top flange and the web as well as two dimples as it is clear in [figure 4].

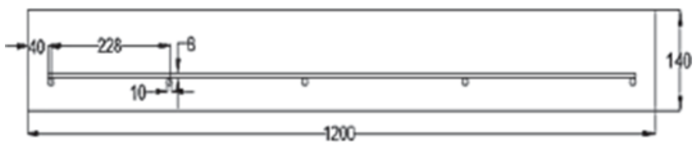

Fig. 2. Cross Section of the Solid Slab

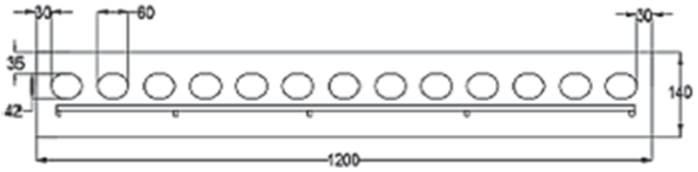

Fig. 3. Cross Section of the Hollow Core Slab

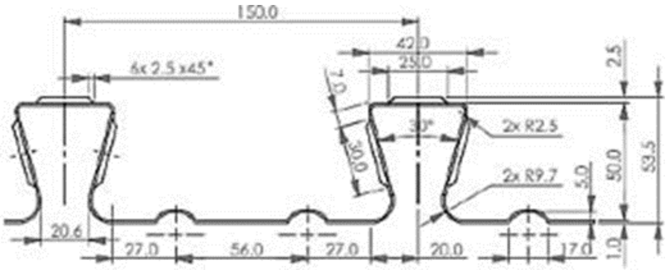

Fig. 4. Cross Section of the Steel Sheet

The voided composite slabs (HCCS, LWHCCS) are the result of merging both the hollow core and the composite slab as shown in [figure 5]. [figure 6] presents a 3D view of the hollow core composite slab that was modelled using SOLIDWORKS software.

B. Application of Load

All the slabs are analyzed using finite element analysis software (FEA) Ansys, under two point loads at L/4= 850 mm from each side and they are simply supported as shown in [figure 7] which is the application of loads on the solid slab and it represents the same way of load application for all the slabs.

5. Analytical Investigation

The load was applied gradually until the reinforcement of the specimens reach their yield strain. Deflections and ultimate

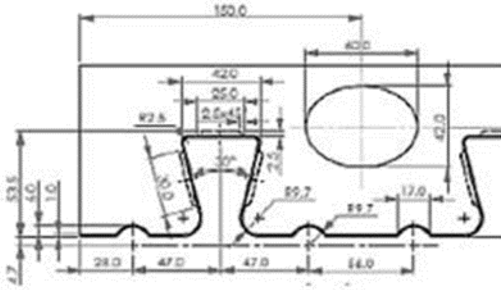

Fig. 5. Cross Section of the Hollow Core Composite Slab

Fig. 6. 3D View of the Hollow Core Composite Slab

loads were measured and compared at the middle of the span and their ductility was calculated too.

6. Results And Discussion

The analysis of the slabs gave the results shown in [table 1].

Table I Table Of Results

Slab	Ultimate load	Deformation	Deformation	Behavior
-	(kN)	(mm)	Ductility	-
Solid	800	20.5	-	-
HCES	460	7.86	-	-
CS1	820	6.96	3.38	Ductile
HCCS	676	6	2.18	Ductile
LWHCCS	440	5.9	2.14	Ductile

[Figure 8] and [figure 9] shows the differences in the ultimate load and deformation of the different types of slabs. It can be understood from the figures and the table that the Hollow core composite slab with conventional concrete shows

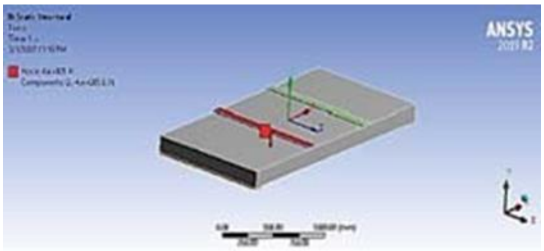

Fig. 7. Load Application on the Solid Slab

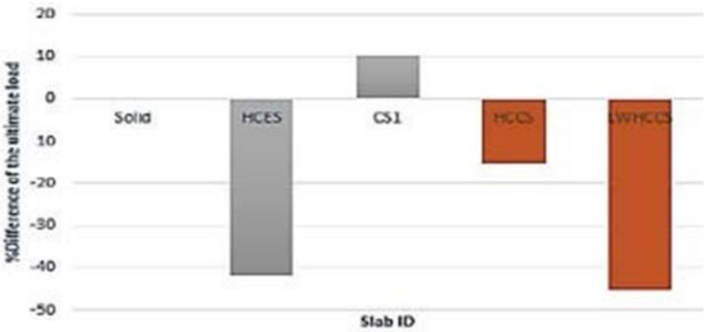

Fig. 8. Comparison of the Reduction of the Load Carrying Capacity of the Slabs

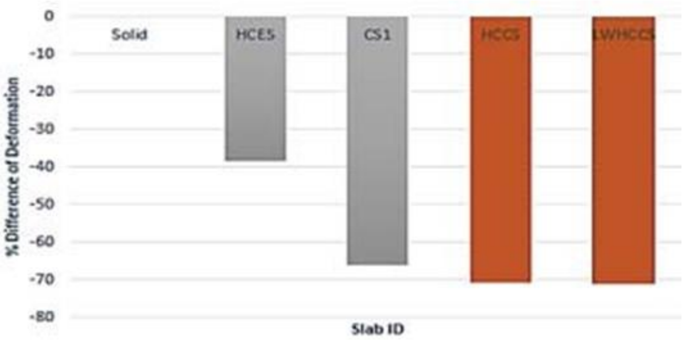

Fig. 9. Comparison of the Deformation of the Slabs

an ultimate load of 32% more than the hollow core slab but 17% less than the composite slab, the reason is due to the presence of voids which makes the slab lighter but less capable of carrying loads. On the other hand, using light weight concrete reduces the load carrying capacity by 35% compared to the conventional concrete but it can be improved using fibers, other additives or any other different type light weight concrete with higher densities, this gives a wide aspect for researchers to do other analytical and experimental investigations to find the best method to increase the load carrying capacity of the voided slabs using light weight concrete.

From [Figures 10-11-12-13-14] it is clear that the deformation of both hollow core composite slabs is less than the solid, hollow core and composite slabs. The hollow core composite slab using light-weight concrete shows the least deformation with less than 1% difference compared to the voided composite slab with conventional concrete. However, it shows a deformation of 15% less than the composite slab, 25% less than the hollow core slab and 72% less than the solid slab. All the slabs show good ductility with a very small difference between the voided slabs of about 1%.

[Figure 15] is the plot of the deformation versus the load carrying capacity of voided composite slabs with normal weight and light weight concrete.

7. CONCLUSION

This paper presents an analytical study on the flexural be- havior of hollow core composite slabs using normal weight and

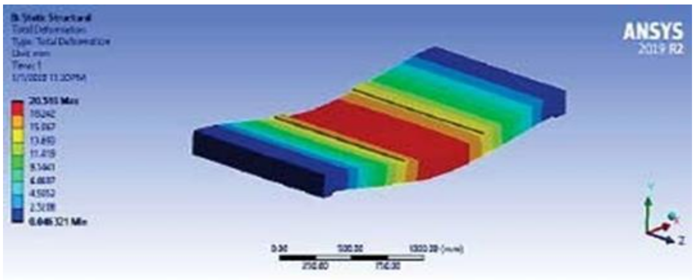

Fig. 10. Deformation **of the Solid Slab**

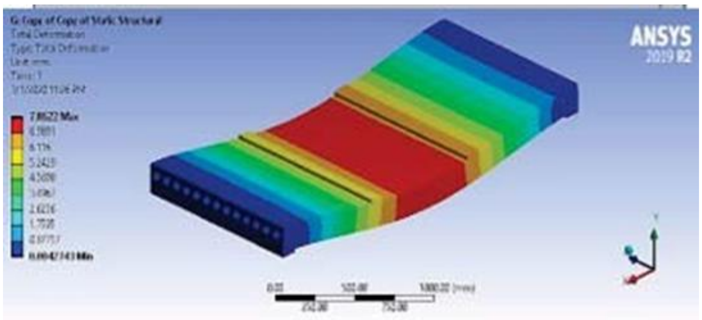

Fig. 11. Deformation of HCES

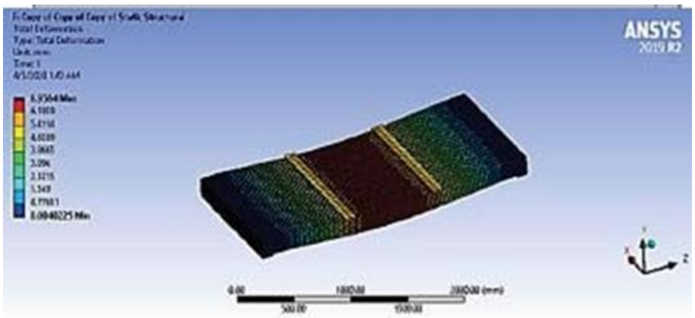

Fig. 12. Deformation of CS1

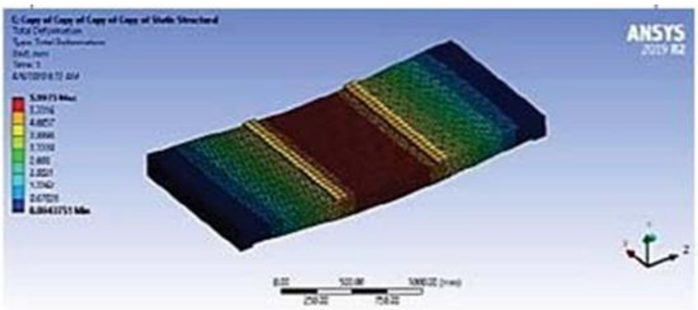

Fig. 13. Deformation of HCCS

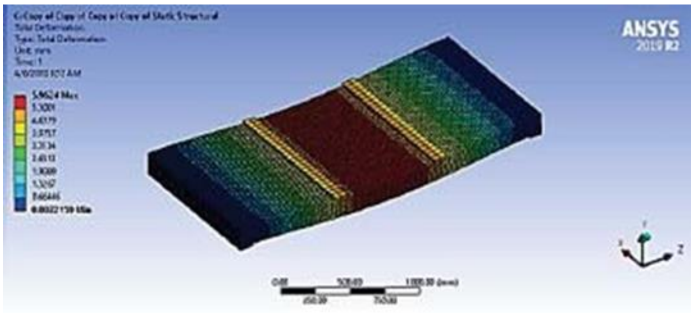

Fig. 14. Deformation of LWHCCS

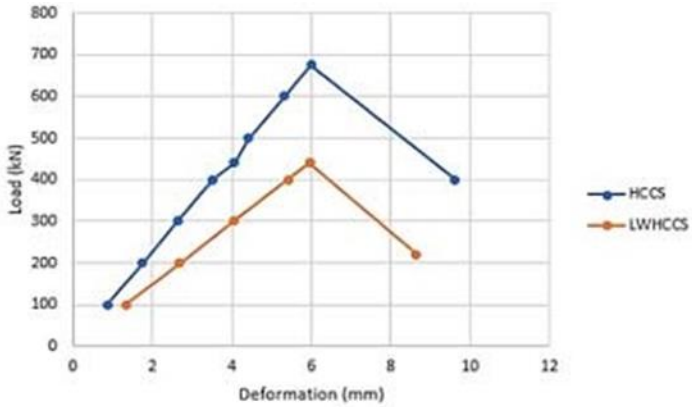

Fig. 15. Relationship Between the Load Carrying Capacity and Deformation of Hollow Core Composite Slabs

light weight concrete using finite element analysis software Ansys. Concluding the study:

- Using hollow core composite slab which is the result of merging two types of slabs: hollow core and composite slabs, improves the properties of the slab. The load carrying capacity of the slab more by about 32% than the hollow core slab alone, and the self-weight of it is less than the composite slab alone due to the presence of voids.
- Using light weight concrete in the hollow core composite slab decreased the ultimate load but also decreased the deformation due to the reduced stiffness.
- Hollow core composite slabs show good ductility using both conventional and light weight concrete with a difference of about 1%.
- More analytical and experimental studies are recommended to be conducted in order to find proper methods to improve the load carrying capacity of the light weight hollow core composite slab as the conducted study is the first of its kind.
- Using hollow core composite slabs with normal weight and light weight concrete in construction will make the process more economical as the consumed materials will be less and longer spans will be possible

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