REVIEW ON APPLICATION OF AERATED CONCRETE IN LIGHTWEIGHT CONCRETE SLABS

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Abstract

A building constitutes of slab structures on a big volume for about 40 to 60% of its total self-weight. Using a lightweight concrete alternate for the existing conventional concrete mix will create a huge impact in reducing the self-weight of the structure thus improving its efficiency without affecting its load bearing capacity. Aerated concrete is one such good alternate for the conventional concrete mix, which is lighter but possess comparable compressive strength as that of the normal concrete. In most cases, the aerated concrete is applied in the form of precast Autoclaved Aerated Concrete blocks which helps in reducing the cost and construction time of the structure. This article reviews on various journals that have discussed on application of Autoclaved Aerated Concrete (AAC) in creating lightweight concrete slabs and also the efficiency of sandwich concrete slabs, which have been presented by casting slab, performing physical tests and software analysis.

Keywords: *Aerated Concrete, Lightweight Concrete Slabs, Sandwich Slabs, Ferro Cement Panels Etc…*

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1. INTRODUCTION

Concrete, which is being the second most consumed product in the construction industry, proves the need of it in the daily usage and the requirement of a better alternative to create better structures with improved efficiency and economy. The Conventional Cement Concrete with reinforcements are being applied in most cases of the slabs in the current structures, except some special cases where certain alternates are handled, but may be uneconomical to suffice the need of the structure.

The Aerated concrete finds the better usage in lightweight concrete slabs than any other alternate due to its simple and economical process of synthesis and erection. Initially, Aerated concrete was used as insulation materials in walls of the structure in the form of AAC blocks, until scientists like Noor Ahmed Memonet. al. [1] investigated on the application of Aerated Concrete in slabs as a sandwich composite slab structure with ferrocement encasements on both sides of the slab. Here, the Aerated Concrete in applied in-situ and encased with ferrocement panels on the surfaces, and doesn’t use any precast elements.

YavuzYardimet. al. [2] preferred similar slabs, where the aerated concrete were applied in the form of Autoclaved Aerated Concrete (AAC) blocks in layouts with proper intervals for the infill concrete and reinforcements and encased with Ferrocement panels on tension face.

Ade S. Wahyuniet. al. [3] investigated on the shear behavior of the Lightweight concrete blocks with Aerated Concrete. Here, AAC blocks were used in various layouts and thickness to investigate the shape factor in comparison to the conventional RC slab. Slabs with thickness of 250mm were cast with conventional slab reinforcement, tested for shear capacity and results were compared with that in a conventional slab.

K.P.Shivanandaet. al [4] dealt with lightweight concrete slabs in an unique manner where the Autoclaving process were done to Aerated concrete slabs with reinforcement in it, where the steel may get affected by the high thermal stress induced on the autoclaving process and compared the physical and mechanical properties with that of the conventional RCC slabs

1.1 Lightweight Composite Slabs

The concept of sandwich slabs was proved to be effective structural form in the Building and Construction Industry. Slabs with lightweight core and bound with face sheets such as a ferrocement panel on both sides or at the tension face alone are being considered in this article. The composite action of the lightweight core, which may be partially precast AAC blocks bind by in-situ concrete, or a uniform mass of aerated concrete throughout the slab, with the face sheets is to be tested and analyzed. As the slab constitute for about 40-60% of the total weight of the structure, a 10% reduction in the weight of the slabs will create a 5% reduction in the overall weight of the structure.

1.2 Ferrocement Panels

A Ferrocement panel is a thin, lightweight slab structure which contains a steel mesh covered with cement mortar of a specific mix. The steel mesh used for the panel may either be a chicken mesh or a square mesh, also the efficiency varies with the number of meshes used. The ferrocement panels possess good bending capacity and could resist a vast amount of tensile forces. These panels may be used as face sheets covering both sides of a composite slab or also as an effective replacement for the conventional tension reinforcement in a slab. Both these cases are casted and tested to find the most effective batch of specimens.

Till date, there is no novel technique of erecting a composite slab using the Aerated concrete infill and Ferrocement encasements connected using steel connectors [1]. Trial batches of samples with Ferrocement in the tension face and aerated concrete in the compression face [2] were cast for the experiment.

2. MATERIALS

The lightweight composite slabs are considered in two different layouts as mentioned by Ahmed Memonet. al [1] and YavuzYardim et. al. [2]. The core elements of the slabs remain the same, but the difference lies in the making of slab.

2.1 AAC Block

The Autoclaved Aerated Concrete blocks are precast in a special process of Autoclaving as explained by K.P.Shivanandaet. al [4]. An autoclave is a pressure chamber used to cureaerated concrete by high-pressure saturated steam at196 °C and pressure of 13.5 bars for around 780minutes. The size of autoclave is33-meter length and 2.5 meter diameter. The process of curing the green mass is done by giving steam, with the steam pressure is contently monitored throughout the process. Before starting the autoclave cycle, the last cutting mould should be given a waiting period of minimum three hours. After hardening process is completed, the mass is loaded in to the autoclave after closing the doors, close the drain valve, trap valve, and air vent valve. After closing, the valves give the steam pressure to both the doors very slowly. The dry density of AAC lies within the range of 450-1000 kg/m³. AAC is up to 3-4 times lighter than traditional concrete, representing great advantages in transportation and material handling. The dry density of AAC block is 640 kg/m³.

2.2 Aggregates

Ordinary Portland Cement (OPC) in compliance with Type I in ASTMC 150-92 and Ground Granulated Blast Furnace slag (GGBFS) confirming the specifications of ASTMC 989-89 were used as binders [3].Local sand was taken in two grades, one in accordance with ASTMC 33-92 for the ferrocement box and the other passed from 600 µm sieve for the aerated concrete core.

2.3 Agents

Type F, high range water reducing admixture from group SNF in powder as per ASTMC 494-92 was used. To produce core, aluminium powder type Y250 was used as the gas-forming agent.

2.4 Steel Wire Meshes

Locally available square welded wire mesh, about 0.85 mm in diameter and 13 mm square grid and chicken (hexagonal) wire mesh with diameter of 0.5 mm and 18×14 mm wire spacing were applied in ferrocement box. Both the meshes used confirmed to the Ferrocement model code, IFS-2001.

3. PREPARATION OF SPECIMENS

Specimens were cast in various batches differing in the type of mesh used, volume of aerated concrete and the placement of face sheets. Ahmed Memonet. al [1] cast specimens with face sheets on both the sides of the slab while YavuzYardim et. al. [2] used specimens with ferrocement sheets on the tension zone alone and Ade S. Wahyuniet. al. [3] used specimens with various layouts of AAC block as the core and ferrocement as the face sheet on the tension zone alone.

3.1 Composite Slabs with Face Sheets on both Sides

Nine batches of specimens were cast with each batch consisting of cube and prism beam specimens of standard size. Table 1 presents the details of the specimen cast and tested.

Table -1: Details of specimens

Batch Designation	Batch Description
AC	Control specimens made of aerated concrete
0L	Sandwich specimens without mesh
SCW1	Sandwich specimens with one layer of chicken mesh
SCW2	Sandwich specimens with two layer of chicken mesh
SCW3	Sandwich specimens with three layers of chicken mesh
SCW4	Sandwich specimens with four layers of chicken mesh
SSW1	Sandwich specimens with one layers of square mesh
SSW2	Sandwich specimens with two layer of square mesh
SSW3	Sandwich specimens with three layer of square mesh

The sandwich specimens were cast in two stages; casting of core on one day followed by the wire mesh wrapping and casting of ferrocement box on the next day. The specimens were cured in water for 28 days (age of testing).

Aerated concrete which is the core of the specimens is cast by using a mortar mix of 1:2 proportion with aluminium powder as the foaming agent for the required dimensions based on the batch of specimen and the ferrocement layer is also made with the 1:2 cement mortar wrapped around the core in a constant thickness of 15mm with either square mesh or chicken mesh as required by the batch.

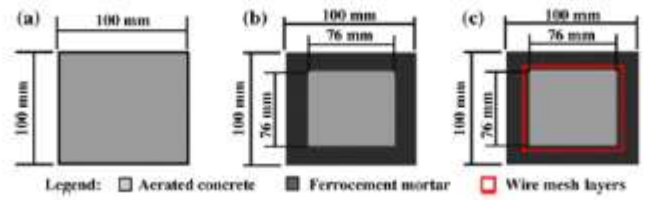

Fig -1: Dimensional view of the cross-section of the specimens. (a) Aerated concrete core, (b) sandwich without wire mesh and (c) sandwich with wire mesh.

3.2 Composite Slabs with Face Sheets on Tension Face

For testing the composite action in shear behavior and bearing capacity, slab specimens were cast with a particular layout of precast AAC blocks with the Ferrocement layer in the tension face.

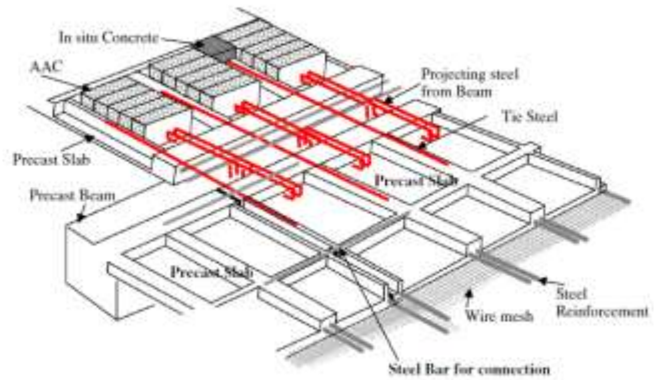

Fig -2: Ferrocement–AAC composite Slab.

In order to determine the behavior of composite slab under flexure [2], one way slab specimens with size of 1m x 3m x 0.130 m (W x L x D) have been chosen for investigation. The constructions of the specimens can be summarized in three stages: preparation of precast layer, placing of AAC blocks and filling of cast-in situ topping.

Twelve 100 x 100 x 100 mm AAC blocks were chosen based on specifications in BS 8110 for quality control of AAC (BS8110-2 1998 clause 6.4.2), and were tested to determine compressive strength of AAC. The density of aerated autoclaved concrete was found as 5.8 KN/m^3 and saturated compressive strength of from 12 specimens is 6 N/mm^2.

Both the infill and the topping were made using concrete grade 40 with the nominal 28 day compressive strength of 43.3 MPa.

For testing the Shear Behavior [3] of the composite slabs, slabs were cast in the following layouts as in Fig -3.

SS1 – Conventional Solid Slab

LS1 – Slab with 64 standard AAC blocks

LS2 – Slab with 32 Standard AAC blocks

LS3 – Slabs with 64 chamfered AAC blocks

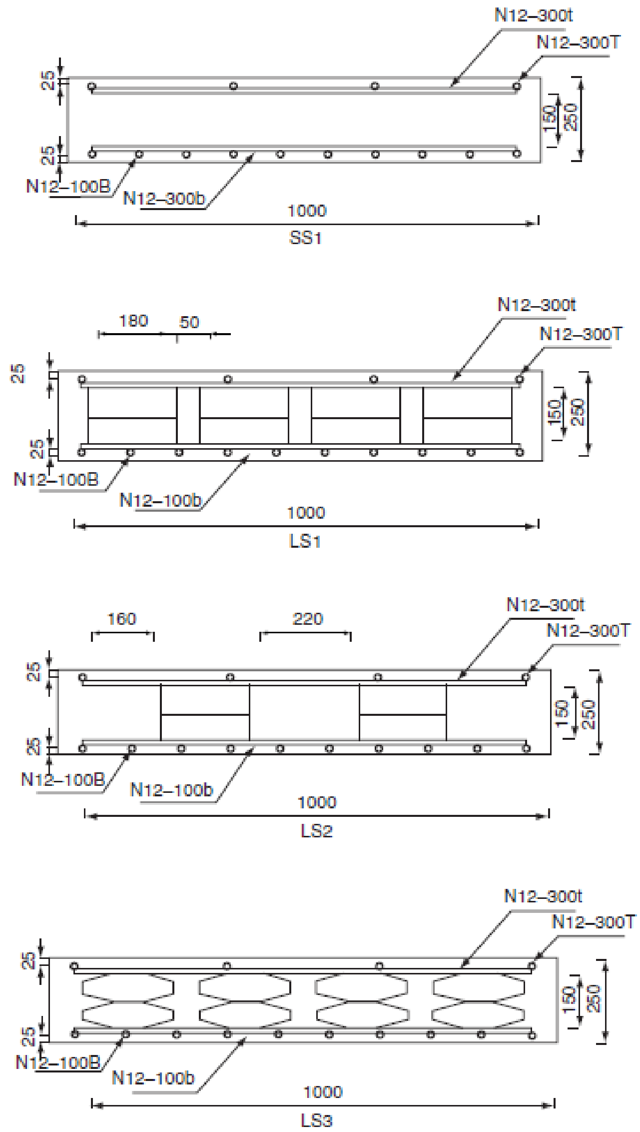

Fig -3: Sectional details of the slabs

4. TESTS CONDUCTED

Three major tests, namely the Compression test, flexure test and the shear test were conducted on the specimens and the results were as described below.

4.1 Tests on Cube and Prism Specimens

The cube and prism specimens which were cast with ferrocement face sheets on both the sides were subjected to Compressive strength, flexural strength and water absorption tests carried out according to ASTMC109-92, ASTMC 78-84 and BS1881: Part 122-1983 respectively. Entire specimens were weighed to determine the saturated unit weight at the time of testing and the results are expressed in Table -2 and Fig -4.

The enhancement in compressive strength as high as 203% of the control was achieved (SSW3), whereas, flexural strength also increased manifold (SSW3). The average value of water absorption drastically lowered to fractions (0.2) to that of the control. The performance of the comprising SSW specimens was better in all aspects than SCW specimens.

Table -2: Summary of the Results of Cubes and Prisms

Batch designation	Average compressive strength (MPa)	Average flexural strength (MPa)	Average water absorption (%)
AC	7.4	1.46	16.72
0L	15.3	2.45	4.15
SCW1	15.9	2.92	3.94
SCW2	16.9	3.54	3.74
SCW3	17.8	3.98	3.86
SCW4	18.1	4.7	3.91
SSW1	20.3	3.29	3.79
SSW2	21.7	5.64	3.31
SSW3	22.4	7.2	3.6

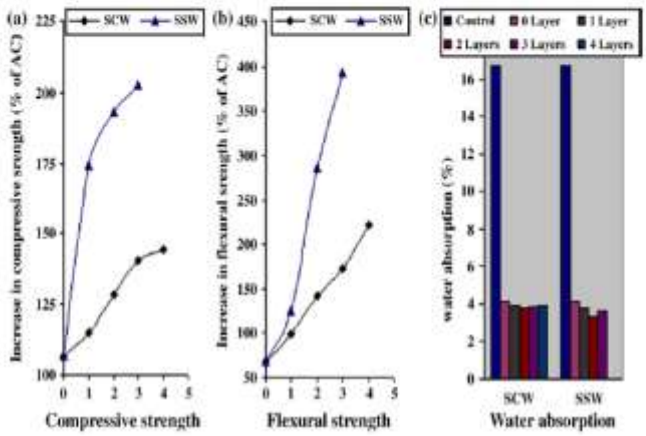

Fig -4: Results of the Respective tests

In the compressive strength and flexural strength tests, the failure modes did not show any sign of failure at the interface of aerated concrete and ferrocement box in any slab, which confirms the composite behavior of slab with the ferrocement layer. The plain aerated concrete core showed first crack at about 90–96% of its failure load collapsed suddenly. The sandwich specimens with wire mesh showed ductile behavior and the first crack appeared at 60% to 80% of their failure load varying according to the type and number of wire mesh layers provided. Though the specimen failed and distorted in shape, the element remained intact, whereas in flexure, two broken portions of the sandwich prism beams were connected by means of a wire mesh after its failure, which is some sort of warning prior to the complete collapse of the structure. This shows that the sandwich elements can be applied especially in the earthquake borne areas.

4.2 Tests on Slab Specimens

The slab specimens were subject to two point load test [2] & [3] to determine the Shear behavior of the composite slab.

The test setup of the slab is shown in Fig -5 where the slab is placed on supports along the shorter span and two load points with equal intervals along the length with a deflection gauge at the mid span are placed.

Fig -4: Test setup of the Slab

The deflection of the various layouts of slabs at the midspan with respect to the two point loading is shown in Fig -5. Each slab was subject to two tests to find the average of the results as the shear capacity of the slab. Table -3 states the summary of the load results on each type of slab. At failure, the ultimate loads varied between 340–402 KN. The corresponding deflections at maximum loadings were21–25 mm in all slabs.

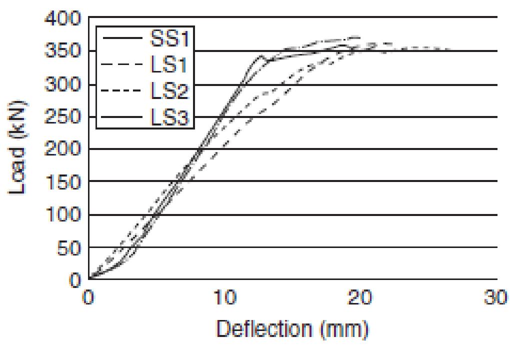

Fig -5: Load versus mid-span deflection of tested slabs

Table -3: Summary of the Load Results of Slabs (in kN)

Slab	Test	1st flexural Crack	1st Shear Crack	2nd Shear Crack	Ultimate Load	Ultimate Shear
SS1	1	100	340	340	400	300
SS1	2	100	340	340	358	268
LS1	1	100	290	304	376	282
LS1	2	100	270	300	360	270
LS2	1	100	290	340	350	262
LS2	2	70	290	340	340	255
LS3	1	80	320	330	402	301
LS3	2	100	320	370	373	278

The test results of these slabs were compared with the nominal values required for a slab as per the codes AS3600-2009,ACI 318M-08 and Eurocode 2 which state that the shear capacity as 195kN and the Flexural shear capacity varying from 147kN to 245kN. The ratio between the test values and these design value in shown in table -4.

Table -4: Ratio between test results and predicted Shear capacity

Slab	Test	AS3600	ACI 318-08	Eurocode 2
SS1	1	1.54	1.22	2.04
SS1	2	1.37	1.09	1.82
LS1	1	1.45	1.15	1.92
LS1	2	1.38	1.10	1.84
LS2	1	1.34	1.07	1.79
LS2	2	1.30	1.04	1.73
LS3	1	1.54	1.23	2.05
LS3	2	1.43	1.14	1.90

It can be clearly seen that all the values are above the design values which show that the sandwich slabs are good to be used and also the layout of the AAC blocks have significant improvement in the shear capacity of the slab.

All the slabs showed brittle failure which mainly occurred due to shear compression. However, the AAC blocks in the core had a good bonding with the infill concrete and the composite action of the slab was achieved. Though composite action was achieved, the crack propagation occurred through the shear interaction of the AAC block and the concrete.

Regarding the Post-Cracking behavior of the slab, it could resist a certain load after the shear failure and this capacity was due to the uncracked concrete, dowelaction of the longitudinal reinforcement and aggregate interlocking in the middle region of the section.

5. CONCLUSION

The main objective of this article was to evaluate the performance of the Lightweight concrete slab that are made using aerated concrete. The ferrocement layer, which added to the objective of achieving a lightweight structure, was discussed in two layer where it was used as the face sheet in both the sides of the slabs and only along the tension zone.

Though these slabs may seem costlier when compared to the conventional slabs, they show an indirect impact in economy by reducing the load of the structure imposed on to the foundation, which reduce the design load of the footings and also make the erection process of the slabs easier.

Regarding the slabs with ferrocement face sheets on both the sides, the results showed that they possess compressive strength similar to the normal slab and also good flexural capabilities which show warning sign when Square meshes are used, improving its applicability in Earthquake borne areas.

Similarly, the test results of the slabs with ferrocement panel on the tension zone alone, which were about 30% lesser weight than the conventional slabs, showed a good composite action of the AAC block and the infill concrete and all the experimental values were safe above the design values obtained from the codes. But, the shear interaction between the AAC blocks and the concrete layer should be improved to improve its applicability in several areas.

Considering both the type of slabs, though the tests results of the slab with face sheets on both sides prove very effective, the practicality and economy of the slab with ferrocement in its tension face is more compared to that of the former slab. With further study for improving the shear interaction between the AAC block and the concrete layer, the applicability slab with ferrocement in the tension face can be improved.

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