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REVIEW PAPER ON USAGE OF FERROCEMENT PANELS IN LIGHTWEIGHT SANDWICH CONCRETE SLABS

K. Vetri Aadithiya[1], Dr. P. Chandrasekaran[2]

[1]*PG Student, Department of Civil Engineering, Kongu Engineering College, Erode, India.*
[2]*Professor, Department of Civil Engineering, Kongu Engineering College, Erode, India.*

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Abstract – *The construction of sandwich concrete slabs is an emerging trend in the field of Civil Engineering, where a thick, low strength, lightweight core infill is encased by a thin high performance face sheet. These slabs are widely accepted due to their high strength-to-weight ratio, reduced weight, and good thermal insulation characteristics. This article reviews on journals which have considered Ferrocement as the high performance face sheets encasing aerated concrete as lightweight infill material. The ferrocement panels which are known for their high bending capacity without capacity are suggested to replace the conventional rebar mat in the tension face of the slab and also used as encasements on both the sides of the slabs.*

***Key Words*: Ferrocement panels, Lightweight Slabs, Sandwich Concrete Slabs, Aerated Core.**

1. INTRODUCTION

Ferrocement is a thin, lightweight composite material which has layers of steel meshes as the tensile reinforcement encased by cement mortar. These panels possess high strength-weight ratio and extreme bending ability. The steel meshes used for these panels differ, based on the design load of the slab and multiple layers of meshes may also be used to increase the tensile resistance of the slab.

The concept of sandwich slabs using Ferrocement panels with the development of high workability and high performance slag-cement based mortar mix to cast encasement for the lightweight aerated concrete infill is given by Salihuddin R. Sumadi et. al. [1].

The manufacturing process of these panels is explained by Swayambhu Bhalsing et. al. [2], which illustrates the materials needed and the proportion of the materials to be added in making of slab to achieve maximum tensile strength.

The testing and analysis of the Ferrocement encased lightweight slabs, done by Noor Ahmed Memon et. al. [3], from casting various batches of cube and prism samples using different types of steel meshes and varying number of layers in the ferrocement panel, projected the compressive strength and flexural capabilities of such sandwich slabs.

Ade S. Wahyunil et. al. [4] researched on replacing the conventional rebar mat in the tensile zone of a slab with the ferrocement panel and analysed the shear behaviour of the sandwich composite slab with various layouts of precast aerated blocks bound by in-situ concrete as the lightweight infill.

1.1 Lightweight Ferrocement Sandwich Panels

Ferrocement is a cementitious composite type of thin walled reinforced concrete, which commonly consists of cement mortar reinforced with closely spaced layers of continuous and relatively small steel wire mesh (ACI 549R-1997; ACI 549 2R-2004). The closely-spaced and uniformly-distributed steel mesh reinforcement in ferrocement, transforms the brittle nature of the cement concrete into a superior ductile composite. This proves the highly versatile nature of ferrocement panel possessing unique properties of strength and serviceability.

However, due to the small thickness and labour intensive production method of the panel, they are not accepted worldwide, which gave rise to the concept of Sandwich panels with ferrocement, which uses the tensile strength of the high performance panel as face sheet with lightweight, thick, low strength core. This also possess good thermal insulation properties.

1.2 Need for Ferrocement Panel

Though there are various alternatives in producing a lightweight sandwich slab, the need for ferrocement is due to its unique features such as follows:

- Ferrocement possess many advantageous properties such as strength, toughness, water tightness, lightness, durability, fire resistance, and environmental stability which cannot be matched by any other thin construction material.
- The ferrocement panels may be used as a precast element or cast in site depending on the need.
- The handling of the ferrocement panels are simple and don't require heavy machineries for erection

2. MATERIALS

The basic constituents of ferrocement is a steel mesh and cement mortar with certain admixtures for effective bonding. The description of the materials required can be obtained from the paper of Swayambhu Bhalsing et. al. [2].

2.1 Cement

Ordinary Portland Type 1 cement conforming to the specifications laid down by IS 269-1976 is used for both the ferrocement and the infill concrete core.

2.2 Aggregates

Aggregates normally used are natural sand, confirming to the specifications of IS 383-1970 and passing through IS Sieve 2.36 mm. These aggregates must be strong, impermeable and capable of producing a sufficient workable mix with a minimum water/cement ratio to produce high performance cement mortar for proper penetration through the steel mesh.

2.3 Steel Mesh

Steel mesh is the most important component of ferrocement which spreads throughout the panel as tensile reinforcement. The steel mesh has a wide range of shapes to choose from, depending on the design load of the slab.

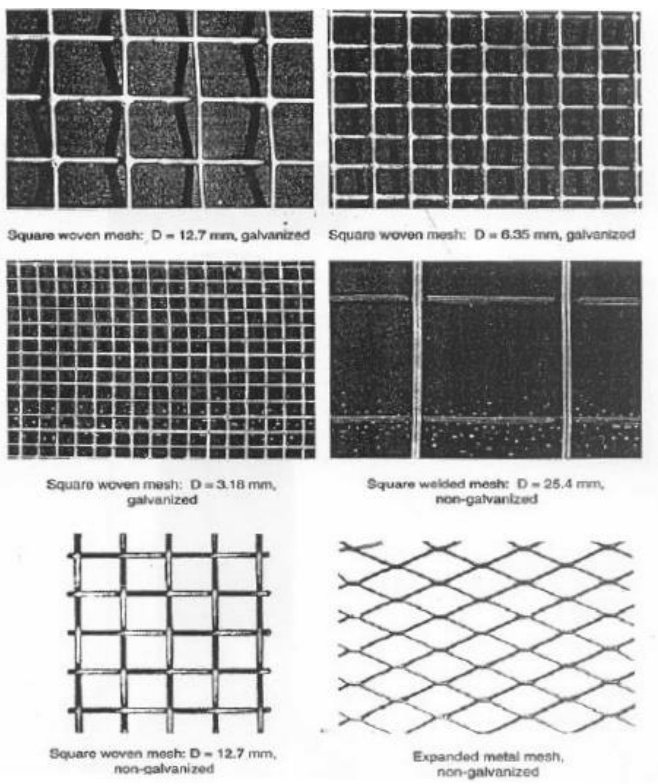

Fig – 1: Types of Steel Mesh

Square Steel mesh, Hexagonal Chicken mesh, Welded mesh and Woven mesh are the types of meshes available in the market. Samples are cast using square steel welded mesh and Hexagonal Chicken mesh and comparative test results are analyzed.

2.4 AAC Blocks

The Autoclaved Aerated Concrete blocks are precast in a special process of Autoclaving. An autoclave is a pressure chamber used to cure aerated concrete by high-pressure saturated steam at 196 °C and pressure of 13.5 bars for around 780 minutes. The size of autoclave is 33-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/m^3. 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/m^3.

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. Noor Ahmed Memon et. al [3] cast specimens with face sheets on both the sides of the slab while Ade S. Wahyuni et. 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.

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.

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

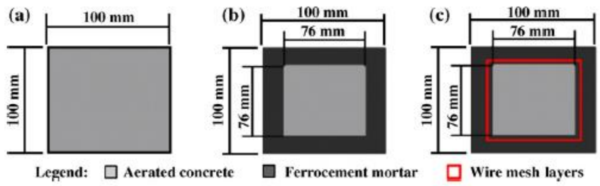

Fig -2: Dimensional view of the cross-section of the specimens. (a) Aerated concrete core, (b) sandwich without wire mesh and (c) sandwich with wire mesh.

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.

In order to determine the behavior of composite slab under flexure [3], one way slab specimens with size of 1m x 3m x 0.250 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 [4] 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

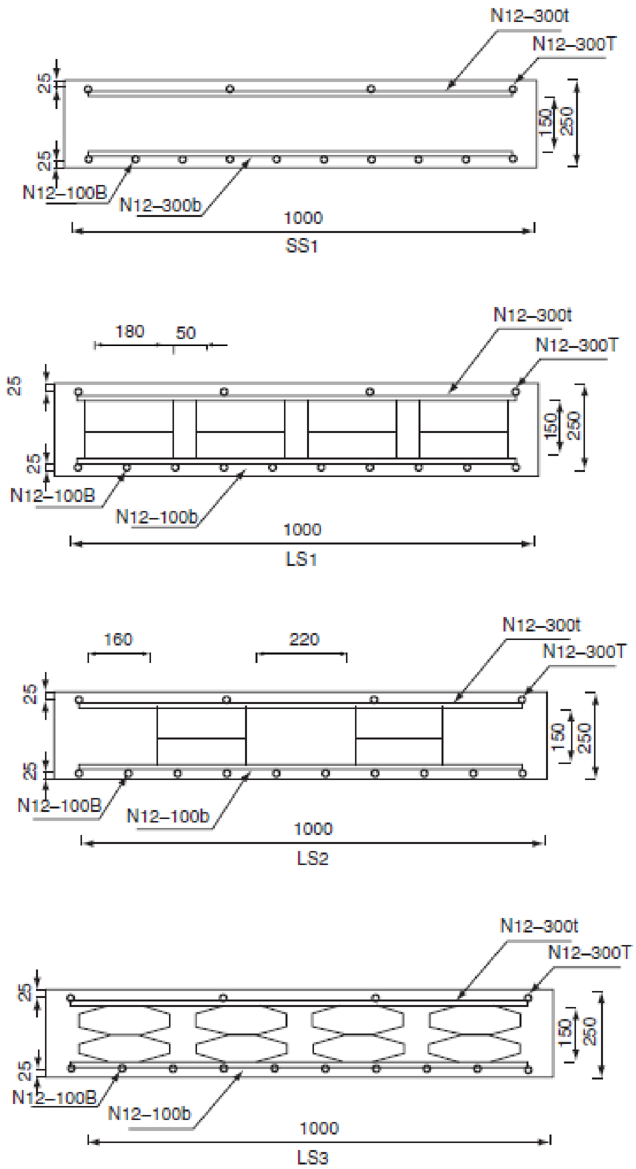

Fig -3: Sectional details of the slabs

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 BS 1881: 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.

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

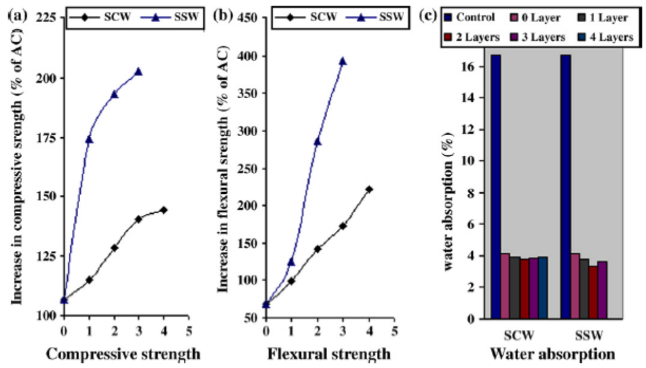

Fig -4: Results of the Respective tests

The compressive strength varied with the arrangement of the AAC blocks, but the flexural strength of the structure was aided by the ferrocement panel. This is evident from the results, where the flexural strength of specimens with ferrocement encasement is almost twice than that of the conventional type specimens.

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 the significance of the ferrocement encasement for structures in Earthquake borne areas.

4.2 Tests on Slab Specimens

The slab specimens were subject to two point load test [4] 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.

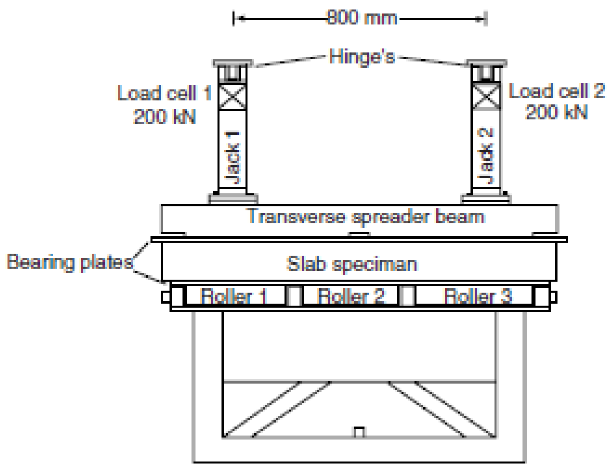

Fig -5: Test setup of the Slab

The deflection of the various layouts of slabs at the midspan with respect to the two point loading is shown in Fig -6. 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 were 21–25 mm in all slabs.

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.

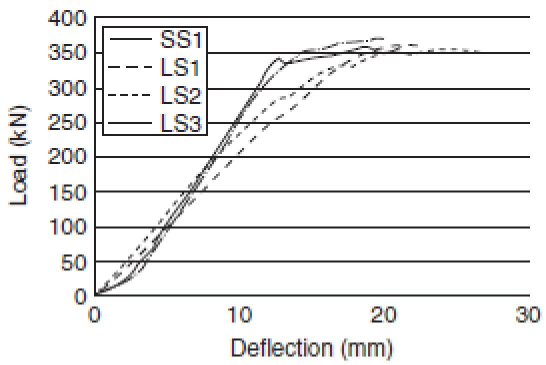

Fig -6: Load versus mid-span deflection of tested slabs

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

Here, the AAC blocks improved the shear capacity of the slab, but considering 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, dowel action of the ferrocement and aggregate interlocking in the middle region of the section. This proves that, even though the core of the slab is of low strength showing a brittle failure, providing a longitudinal reinforcement along the slab in the form of ferrocement increases the post cracking behavior of the lightweight slab.

5. CONCLUSION

Ferrocement panel, which is a thin and lightweight component, being an emerging technology in the construction field, has many advantages when compared to that of conventional methods of reinforcements. Though these slabs can't be used as a structural element due to its less thickness, it can be cast as a part of a slab as discussed in the article.

Flexural capacity being one of the most advantageous property of ferrocement, it imparts this on to the slab which improves the post cracking behavior of the slab and makes it applicable on earthquake borne areas.

The usage of various types and the number of layers of meshes provided in ferrocement has its own advantages, where the Steel mesh proves to be the best in flexure evident form the results of Noor Ahmed Memon et. al. [3]. Thus, depending on the design load of the slab, the number of mesh layers to be provided shall be increased.

Also, when ferrocement is applied to the tension zone of a slab, it reduces the self-weight of the structure to about 30%. Though, the cost of ferrocement may be higher, it is well compensated by the reduction in self-weight, which obviously reduces the design load of the foundation.

The ferrocement panel exhibits a good composite action with the AAC core, which is evident from the increase in shear capacity of slabs. Thus, Ferrocement proves to be a very good alternative for the conventional reinforcement in slabs, though it may seem costlier and laborious initially, considering its advantages, it improves the overall economy and efficiency of the structure.

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