ISSN XXXX XXXX © 2018 IJESC

Research Article Volume 8 Issue No.4

Comparative Study on Flexure Behavior of Ferrocement Composite SLAB

K.V. Boobala Krishnan[1], P.Jayabharath[2], G.Kesavan[3], V. Bhuvaneswari[4]
Assistant Professor[1, 2, 3, 4]
Department of Civil[1, 2, 3], Department of Chemistry[4]
Dr. NGP Institute of Technology, Coimbatore, India[1], Sri Ramanathan Engineering College, Tirupur, India[2, 4]
Mizan Teppi University, Ethiopia[3]

Abstract:
This project deals with an experimental programme to understood the flexural behaviour of a ferrocement composite slabs under mid third loading. The concept of composite slabs profited shut decking or shear connectors are well established. But still, in countries like India, the application of same is limited due to difficulties in fabrication and also due to concerns like fire resistance durability aesthetics etc. The study is an attempt to exploit the concept of steel –concrete composite to a similar system in which steel sheeting is replaced by ferrocement elements.These elements will act as permanent form work and also participating in the structural performance of the slab.

1. INTRODUCTION

1.1 GENERAL

With an increased demand for the building infrastructure at economical cost, it has lead to use the available materials in an efficient way. The basic idea is utilization of the material strength possessed in it. Today's structures are situated in more aggressive environment. These leads to the development of Ferrocement structures. Ferrocement is a type of thin-wall reinforcement concrete commonly constructed of hydraulic cement mortar, reinforced with closely spaced layers of continuous and relatively small diameter mesh. But in general, Ferrocement can be defined as "A Composite material consisting of a matrix and a reinforcement in a finely distributed manner which act together to form a new material with characteristics superior to either of its constituents.According to American Bureau of shipping it can be defined as "A thin, highly reinforced shell of concrete in which the steel reinforcement is distributed widely throughout the concrete, so that the material under stress acts approximately as a homogeneous material. The strength properties of the material are to be determined by testing a significant number of samples".Ferrocement is considered to be an extension of reinforced concrete technology. It is the uniform distribution of the reinforcement in the resulting composite and its different material performance, strength behaviour and potential applications which create a distinction from conventional reinforced concrete, that it must be classified as a separate material. Ferrocement possesses a degree of toughness, ductility, strength and crack resistance that it is considerably greater than that found in other forms of concrete construction. These properties are achieved in structures with a thickness that is generally less than 25mm, a dimension that is nearly unthinkable in other forms of concrete construction, and a clear improvement over Conventional reinforced concrete. Surprisingly, good performance can be achieved in Ferrocement with almost primitive field conditions and it does not necessarily require highly skilled practitioners. The combination of ferrocement slab with concrete slab, when the two are so connected that they act as a single unit in resisting flexure is called as composite slab.

1.2 PROPERTIES OF FERROCEMENT

- The ability to construct thin shells at any shape.
- The possibility of elimination of shrinkage and temperature cracking due to inherent material properties.
- An improvement in effective tensile strength compared with plain or ordinary reinforcement concrete.
- The capability of constructing with the minimum of heavy equipment and with materials likely to be available in any part of world.

2. INGREDIENTS USED IN FERROCEMENT SLAB

2.1 CEMENT

Cement is the most important ingredient used. One of the important criteria for the selection of cement is its ability to produce improved microstructure. Hence selection of proper grade and quality of cement is important for obtaining rich mix. Some of the important factors, which play a vital role in the selection of the type of the cement or compressive strength at various ages, fineness, heat of hydration, alkali content, tricalcium aluminate (C_3A) content, tricalcium silicate (C_3S) content, dicalcium silicate (C_2S) content and compatibility with admixtures etc., PPC is now available in three grades namely 33,43,53 grades, the number indicating the compressive strength of standard cement sand mortar cubes in MPa at 28 days curing period. Fineness of cement is also one of the parameter, as increasing the fineness will increase the early strength of the concrete, but as the other may lead to rheological problems.

2.2 AGGREGATE

Fine aggregate used for cement mortar should be properly graded to give minimum void ratio and be free from deleterious materials like clay, slit content and chloride contamination etc., Grading of fine aggregate should be such that it does not cause increase in water demand for the concrete and should give maximum voids so that the fine cementitious particles fill the voids. Hence it is desirable to use coarser variety of fine aggregate having a high fineness modulus for making workable and strong concrete. The optimum gradation of fine aggregate is determined more by its effect on water requirement than on physical packing. ACI Committee reports that sand with fineness modulus below 2.5 gives a sticky consistency, making it difficult to compact and sand with fineness modulus of about 3 gives the best workability and compressive strength. Properties such as void ratio, gradation, and density have to be accessed to design a dense mix with optimum cement content and reduced mixing water. For the present investigation, locally available river sand was conforming to IS: 383 – 1970. It was sieved through 4.75mm sieve. The fineness modulus of the fine aggregate is 2.51 and specific gravity of fine aggregate is 2.56. Locally available blue metals were used. Crushed granite stones of size passing through 20mm sieve and retained on 4.75 mm sieve as per IS: 383-1970 was used for experimental purposes

2.3 WATER

Water is an important ingredient of concrete as it chemically participates in the reaction with cement to form the hydration product, C-S-H gel. The strength of cement mortar depends mainly from the biding action of the hydrated cement paste gel. A higher w/c ratio will decrease the strength, durability, water – tightness and other related properties. The quantity of water added should be the minimum for chemical reaction of hydrated cement, as any excess of water would end up only in the formation of undesirable voids (capillary pores) in the hardened cement paste. The strength of cement paste is inversely proportional to the dilution of the paste. Hence, it is essential to use as little paste as possible consistent with the requirements of workability and chemical combination with cement. Waterconforming to the requirement of BIS: 456 – 2000 is found to be suitable for making CM. It is generally stated that water fit for drinking is fit for making CM.

2.4 WIRE MESH

Mild steel welded wire mesh layers of 2mm diameter and 25mm spacing of wire mesh. Square mesh is used in this experiment

3. EXPERIMENTAL INVESTIGATION.

3.1 FLEXURE TEST

The test programme consists primarily of tests to determine the flexural behaviour of RCC slab when subjected to two point load, and also to determine the variation in flexural behaviour with composite slab.

3.1.1VARIABLES CHOSEN IN THE SPECIMEN

In the present investigation, tests were conducted on 2 RCC Slab and 2 composite slabs. Ferrocement panel is casted with one layers of welded wire mesh. The variables chosen are the percentage of reinforcement and the number of mesh layers keeping all other parameters such as span, w/c ratio, curing period etc., constant throughout the current investigation the cement sand ratio was kept 1:3 and water cement ratio as 0.45.

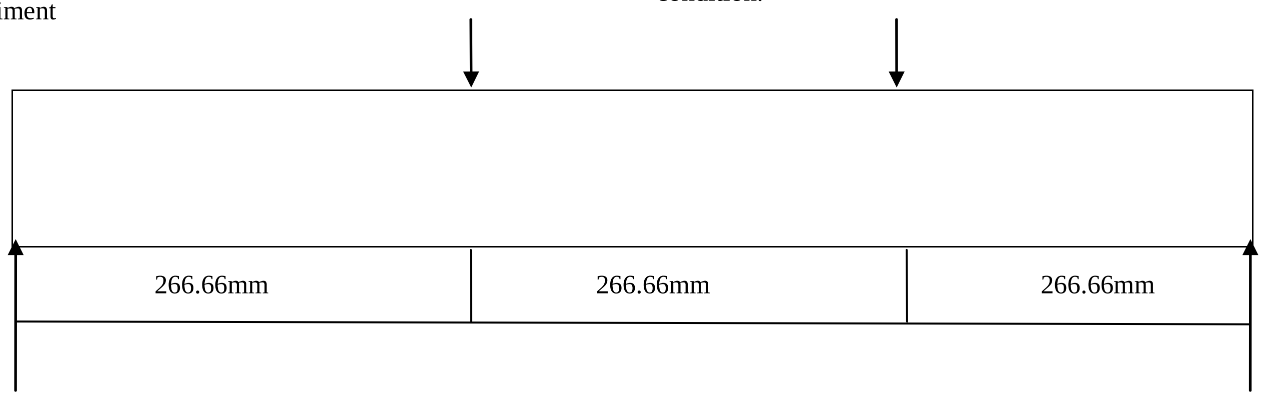
3.1.2 DETAILS OF MODELS

The values below are used for calculating the important parameters required for making the ferrocement composite slab model.

Size of ferrocement panels
: 330mmx200mm
Thickness of ferrocement panels
: 24mm
Size of weld mesh
: 12.5mmx12.5mm
Mesh diameter
: 2mm
No. of weld mesh layer
: 1 layer
Edge conditions
: simply supported
Load setup
: two point load
Mesh type
: square mesh
Loading conditions
: 1/3 of the span from left and right end
Size of composite slab : 330mmx1000mm.

3.1.3 LOADING SETUP

The test set up is shown in figure. The ferrocement slab specimens were subjected to two point loading (i.e. 1/3rd from left and right end of the slab) with simply supported edge condition.



TEST SETUP FOR SLABS

3.2. SPECIMEN PREPARATION

3.2.1 PREPARATION OF MOULD

- The specimens were made in steel of 24mm thick with their top and bottom open. The mould was made in such a way that two edges connected with bolt so that it could be easily separated from ferrocement element after its initial setting. The inner dimension of the steel mould was 330mm x 200 mm x 24 mm.

- The steel mould was greased before casting the specimen to ease of the dismantling process

- Specimens for composite slab were made in plywood with there top and bottom oppen. The inner dimension of the plywood mould was 330mm x 1000 mm x 150 mm.

3.2.2 MIX PROPORTION

Mix proportion of both RCC slab and ferrocement panel as shown in table 3.1

MIX RATIO	WATER	CEMENT	FINE AGGREGATE	COARSE AGGREGATE
FERROCEMENT PANEL	0.45	1	3	0
RCC Slab	0.5	1	1.49	3.36

3.2.3. CASTINGS

- Placing of wire mesh at the center of the ferrocement panel (24mm).and preparing of cement mortar at the ratio of 1:3 with 0.45 % w/c ratio.

- After that cement mortar is placed inside the ferrocement panel and then compacted & well finished.

- 20 numbers of Shear connector is connected in wire mesh at 250mm spacing for 10 number of ferrocement panel.

- 5 nos of ferrocement panel is arranged horizontally and shear connector is connected with main reinforcement of Rcc slab.

- Then ordinary concrete is placed above the ferrocement panel and it is compacted & well finished





3.3 DEMOULDING AND CURING

The specimens cast, were left in the moulds for 24 hours. After that identification were marked on the exposed face of the specimens, the specimens were demoulded, and immediately placed under water in a curing tank. The specimens were allowed to cure under water for a period of 28 days.

3.4 PREPARATION OF SPECIMENS FOR TESTING

The composite slabs and Rcc slab along with the cubes cast from the same mortar were taken out of the curing tank at the age of 28 days and their surfaces were cleaned, for removing any salt deposits. They were allowed to dry in room temperature for a minimum of three hours. The actual dimensions of the specimens were accurately measured and noted, the weight of the specimens were found out.

All the specimens were given a thin coat of Janathacem, in order to facilitate, easy detection of formation of first crack. Centre lines, load positions, support points and dial gauge positions were marked using pencil in the appropriate places.

3.5 EXPERIMENTAL SETUP AND INSTRUMENTATION

To determine the deflection in the slab subjected to two point loading, dial gauges were used and the load was measured using data logger. The dial gauges are placed under the loading points and the centre of the slab. The simply supported condition was used for the supports

3.5.1 SPECIMEN LOADING CONFIGURATION

The slab was tested on a 50 ton loading frame. The experimental setup of the slab specimen supported on simply support at both the ends was shown in Fig. Effective length of the slab was fixed as 800 mm. Load was applied by means of a manually operated jack which was transmitted through the slab. In addition,. Real-time measurement of the structural response was achieved using a dial gauge at various points. The curvature per unit length of the slab is obtained from the deflection value. The deflection measured by the dial gauge and load measured from the data logger were stored for further calculations. For monotonic loading the load was applied in load increments of 5KN until the ultimate load was reached. At each increment of loading, the reading in dial gauge was noted.

3.6 TESTING

On the bottom face of the slab, the support position(800mm c/c) marked at a distance of 100mm from the edges were provided with two rollers placed in the loading frame. Multi Dial Indicator (range 0.01 – 20mm) was used for deflection measurement. They were supported on magnetic base resting the tip of the dial gauge at positions marked as 1,2,3,4,5 & 6. Initial readings were taken at zero load positioning. Then the specimen is subjected to gradual loading by operating the lever of hydraulic jack and at suitable intervals, for different loads, the deflectometer readings noted.The formation of the first crack was carefully noted using a lens and the load at first crack was noted. The deflectometers were removed when the deflection was at the maximum capacity of the dial gauge or when the specimens were about to collapse. The loading was continued till collapse of the specimens and collapse load noted. The readings were tabulated. On each day of testing the slabs the cubes cast along with the same series of the slab from the same mortar were tested for its compressive strength.

4. RESULTS AND DISCUSSIONS

4.1 TEST RESULTS

4.1.1 TENSILE STRENGTH OF WIRE MESH

The ferrocement reinforcement was a welded square wire mesh of 2 mm diameter and 25 mm openings. The tensile strength of the mesh was found using the method proposed by ACI Committee. Three specimens taken from the longitudinal direction of the mesh were tested. The average yield strength was found to be 390 N/mm^{2}as shown in figure 4.1

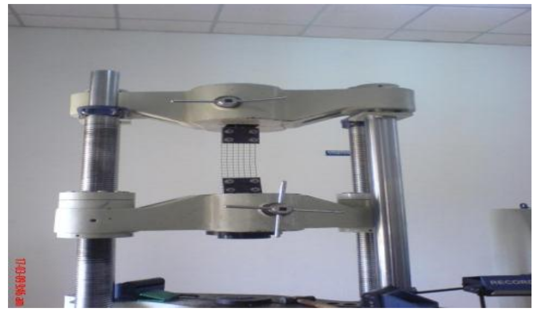


Fig 4.1 Testing of wire mesh

4.1.2 COMPRESSIVE STRENGTH OF CUBE SPECIMENS

6 Cubes of size 150 mm x 150 mm x 150 mm, and 6 Cubes of size 70.6 mm x 70.6 mm x 70.6 mm, were cast along with the slab as control specimens were cast. These specimens were moist cured for 7 and 28 days and tested for strength in compression..

4.1.3 COMPRESSIVE STRENGTH TEST

Compressive strengths tests were conducted on cube specimens using compressive testing machine of capacity 100 tonnes. The load was applied as per IS: 516 – 1964. The average compressive strengths are tabulated in Table 4.1 for mortar and Table 4.2 concrete cubes.

MORTAR CUBES	7 Days N/mm2	28 Days N/mm2
1	19.79	29.42
2	19.56	29.50
3	18.50	28.56
Average Value	19.28	29.16

Table 4.1 Compressive Strength of Mortar Cubes

S.NO	7 DAYS RESULT IN N/mm^2	28 DAYS RESULT IN N/mm^2
1	15.11	24
2	15.37	24.17
3	16.04	23.55
Average Value	15.50	24.08

Table 4.2 Compressive Strength Of Concrete Cubes

4.1.4 LOAD CARRYING CAPACITY OF SPECIMENS

The table 4.3 and 4.4 shows that, the load carrying capacity, and deflection of Rcc slab and ferrocement composite slab respectively.

TYPES OF LOADING	LOAD CARRYING CAPACITY IN (N)	FLEXTURAL STRENGTH (N/mm^2)
TWO POINT LOADING	4100	9.42
CENTRE POINT LOADING	3000	6.89

Table 4.3 Flexural Strength of Ferrocement Panel

Load in KN	0	5	10	15	20	25	30	35
Deflection of slab1 in mm	0	0.5	0.87	1.35	1.857	4.114	6.763	8.57
Deflection of slab2 in mm	0	0.515	0.869	1.349	1.857	4.057	6.76	8.48

Table 4.4 Flexural Strength Of RCC Slab

Load in KN	0	5	10	12	12	15	20	25	30	35
Deflection of slab1	0	0.5	0.88	1.1	1.4	1.65	1.9	3.2	6.1	7.9
Deflection of slab2	0	.58	1.02	1.22	1.52	1.68	2.02	3.9	6.7	8.6

Table 4.5 Flexural Strength of Composite Slab

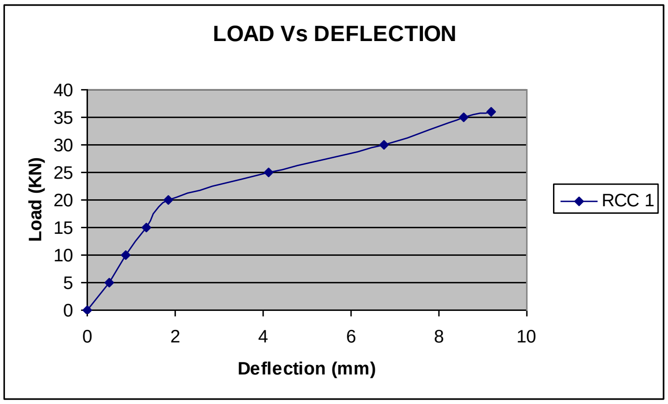


Chart-4.1 Load vs Deflection curve for RCC Slab 1

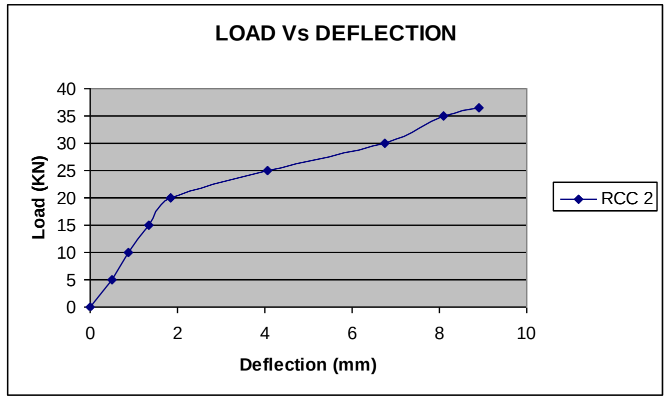


Chart-4.2 Load vs Deflection curve for RCC Slab 2

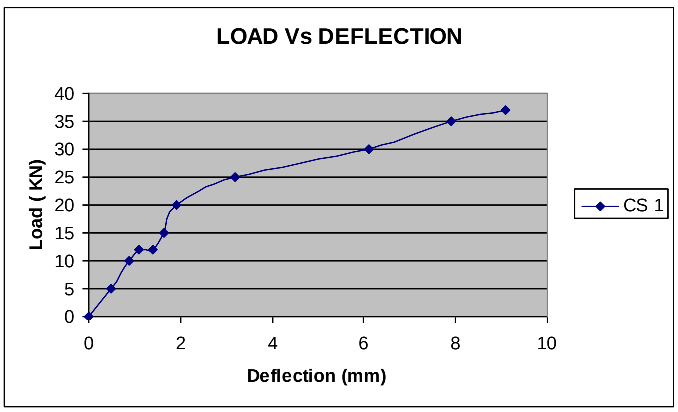


Chart-4.3 Load vs Deflection curve for composite slab 1

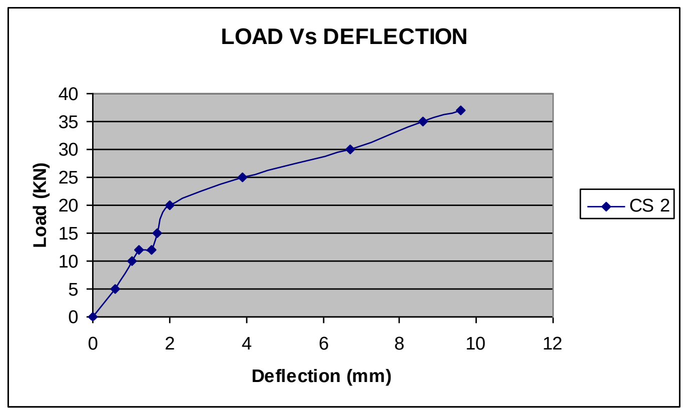


Chart-4.4 Load vs Deflection curve for composite slab 2

5. PHOTOGRAPHS OF TESTED SPECIMEN

5.1Testing of ferrocement panel

5.2 Test setup of slab

5.3RCC Slab after Testing

5.4 Composite slab after Testing

6. COMPARISION OF RCC SLAB AND COMPOSITE SLAB

6.1 TYPICAL FAILURE MODES OF COMPOSITE SLAB

Stage-1

- The load taken by both Rcc slab and Ferrocement panel

Stage-2

- The load taken by both Rcc slab and ferrocement panel
- 1st crack developed near to the second panel .
- Point 'A' opening development in between the ferrocement panel.

Stage-3

- It Behaves as a Rcc slab. Load taken by only Rcc slab due to all ferrocement panels are opened. Cracks developed above all opening of ferrocement panels.

Stage-4

- Ultimate failure of Rcc slab**.**

6.2 COMPARISON OF RCC SLAB AND COMPOSITE SLAB

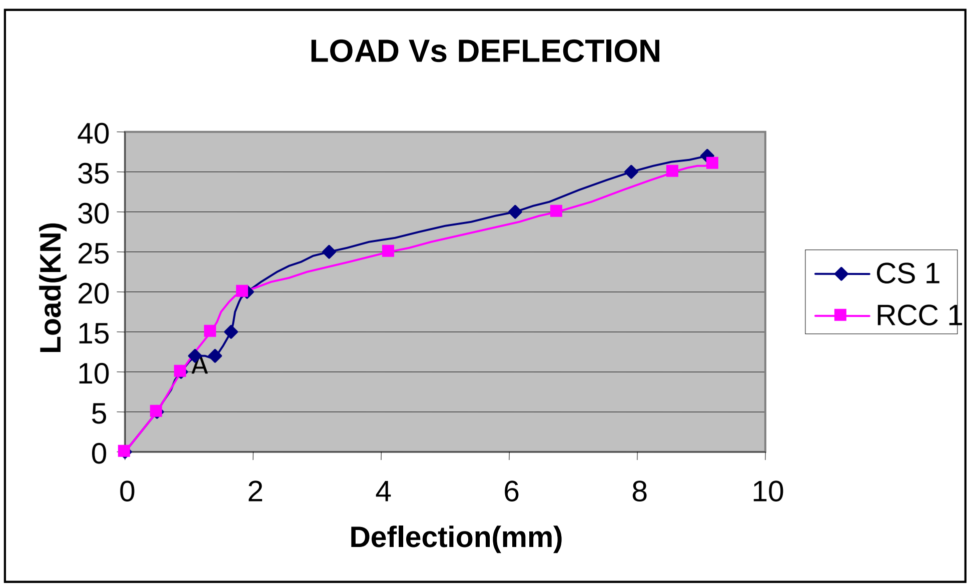


Chart-6 Load vs Deflection curve for comparison of Rcc slab and composite slab

- Up to the point 'A' it is composite in nature
- After point A the slab behaves as a ordinary Rcc slab
- This is due to the opening of all the joints in the ferrocement slab.
- Even with the opening the ultimate value of composite slab increases by 10% compare to Rcc

slab. This is due to the improvement in ductility of ferrocement panel.

Ductility = Ultimate deflection/yield deflection

Ductility= 0.152

7. CONCLUSION

This paper proves that reinforced concrete slabs with ferrocement tension zone cover is superior in crack control, stiffness and first crack moment to similar slabs with normal concrete cover. Construction costs with ferrocement cover will, of course, be higher. However, this could be greatly offset by sparing millions of pounds spent on repairing damaged structures caused by cracked or spelled normal concrete covers. Moreover, it allows existing conventional concrete materials and practices to be used. Further research work will be required to investigate the use of ferrocement cover for other applications, especially the use of deep covers, usually advocated in corrosive conditions, without giving rise to wide surface cracks.

Within the range of the variables covered by the present study, the following conclusions may be drawn:

- The preliminary investigation reported in this study indicates that ferrocement cover can be successfully used for reinforced concrete slabs.
- Crack width of the tested reinforced concrete slabs was considerably narrowed by the use of ferrocement. Specimens with ferrocement cover showed higher stiffness and higher cracking moment than those with normal concrete cover. Deflection near service load was significantly reduced in the specimens with ferrocement cover.
- A slight improvement in the bending capacity of the specimens with ferrocement cover was observed
- Full composite action can be achieved by shear connecter used to inter connect between the shear loading panel of ferrocement slab, then it increases the shear behaviour.

8. REFERENCES

[1] "Concrete technology" by M.S.SHETTY

[2] M.A.MANSUR, AHMED.I and PARAMASIVAM.P, "Punching shear behaviour of restrained slab" in the ACI JOURNAL sep – oct 2000

[3] M.A. AL-KUBAISY , MOHD ZAMIN JUMAATB " Flexural behaviour of Reinforced concrete slab with Ferrocement tension zone cover"

[4] S.K.KAUSHIK, D.N.TRIKHA and R.R.KODAWALA journal of Ferro cement 1982

[5] PARAMASIVAM.P, and TAN K.H Punching shear strength of Ferro cement slabs ACI structural journal

[6] M.A.MANSUR, MOHAMED MAALEJ AND MOHAMMAD ISMAIL

a. (Study on corrosion durability of Ferro cement) ACI material journal feb-2008

[7] Z.REICHVERGER and I.SOROKA (investigation of ferrocement with grouped reinforcement). journal of Ferro cement 1982

[8] A.WINOKUR AND I. ROSENTHAL journal of Ferro cement (1982)

[9] Md.ZAKARIA HOSSAIN ACI material journal, Apirl-2008