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FERROCEMENT: MATERIAL FOR CONSTRUCTION OF HOUSES

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ABSTRACT

The author has now investigated experimentally the possibility of applying the Ferrocement for the construction of houses with straight and flat forms in contrast to the earlier application to curvilinear structures. This finding will be useful for the construction of muti-storeyed buildings to cater to the needs of the surging population in the world. This experimental investigation has established the credentials of this material for the construction of high-rise buildings. It consists of casting different components using the material, curing as per the standard procedure, testing each component individually, and assembling it into one piece called a deck. The panel alone was able to take an ultimate load of 31.6 kN and undergo a deflection of 36 mm whereas the assembled deck could sustain a load of 14 kN with a deflection of 3.16 mm. The panel alone was found to be very flexible and the assembled deck was found to be very stiff. Even at the ultimate load it didn't crush like in the case of reinforced concrete and failed only by sustaining the load and large deflection. This investigation has established the concept that Ferrocement as a construction material is equal to that of reinforced concrete.

I. INTRODUCTION

The origin of Ferrocement is attributed to France and the Netherlands and dates back to 1840. It is the forerunner of reinforced concrete. Joseph Monier and Joseph-Louis Lambot are the two Frenchmen who invented the Ferrocement. The former called his product ciment armé, which means armored cement and the latter used it to construct a boat with this material in 1848. Later in 1855, Joseph-Louis Lambot displayed his vessel at the Exposition Universelle. He christened his product as ferciment stuck. From a patent application submitted by Joseph-Louis Lambot in 1852, the definition of Ferrocement was established and his product ferciment was subsequently translated into iron-cement. According to Lambot, his invention showed a new product that helped to replace timber which normally is jeopardized by moisture as wood flooring, water containers, etc. The new product that Lambot developed consisted of a metal net of wire which was formed like a flexible woven net. He stated further that ferciment had come up very well as he expected. Afterward, he applied hydraulic cement mortar or bitumen tar or mix at the joints. However, this material was not used until 1940 when P. L. Nervi popularized this material for boat construction because it was found to be very expensive and the production of wire mesh was also tedious (Nervi, 1956). Ferrocement is another version of conventional reinforced concrete elements. It is also called Ferro Crete. Ferro means iron and Crete means concrete without coarse aggregate. It contains only cement and fine aggregate or sand. It is a thin concrete element about 10 mm – 50 mm thick with closely spaced reinforcement of skeletal steel or welded steel wrapped with multi-layer of chicken meshes and impregnated with cement mortar on both sides as shown in Fig. 1 (ACI Committee, 1959).

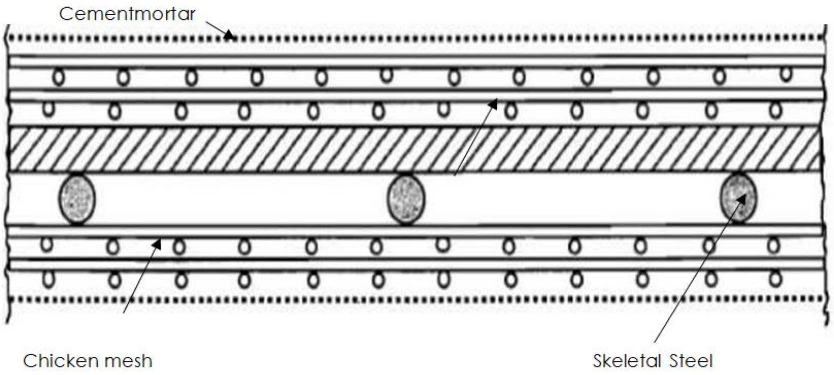

Fig 1: Cross section of skeletal armature method

It is a thin concrete member which is versatile and very flexible. It has properties like high ductility, bendability, easily castable, mouldable, and environment-friendly (Batra, 2017). Its tensile strength is 15 MPa and compressive strength ranges from 28 MPa to 69 MPa. The elastic modulus of the material is 55 MPa. Initially, Ferrocement was used for the construction of curvilinear structures like cylindrical structures such as water tanks, bins, silos, etc., (Fig. 2) and spherical geometry like domes (Fig. 3), auditoria, etc. The material can be used for the repair of damaged concrete elements (Basunbal et al., 1990), and for structural strengthening of concrete if found to be weak when it is not able to take the load (Paramasivam et al., 1998).

Fig 2: Ferrocement cylindrical water tanks

(Courtesy: www.Ferrocement.50web.com/gallery of tanks)

Fig 3: Ferrocement Dome Structure

(Courtesy: www.elocotal-hn.blogspot.com)

Ferrocement is a highly versatile form of reinforced concrete made up of wire mesh, sand, aggregate, water, and cement, which possess unique qualities of strength and serviceability. Over the years, applications involving Ferrocements have increased due to their properties like strength, toughness, water tightness, lightness, durability, and most importantly stability (Verma and Hajare, 2015). Ferrocement was used to construct curvilinear structures including houses as shown in Fig. 4 in the early period of the modern age.

Fig 4: Ferrocement Curved House

(Courtesy: www.ploughonever.com; www.yahoo.com)

It is not possible to have floors above the curved surface. In this modern age, the prices of land are skyrocketing and its availability for house construction is not so encouraging. The reason for this is that the population is explosive as the number of persons to be accommodated in small areas of the land. That is why multi-storeyed construction has become a compulsion in urban society. In such a case the floor and roof of the buildings have to be straight and flat in geometry. This is the reason to investigate the possibility of adopting a straight and flat form. The details of the experiment conducted are given in the following paragraphs.

II. EXPERIMENTAL INVESTIGATION

The author has now investigated experimentally the load-deflection behaviour of Ferrocement panels and assembled units like Madras Terrace which in the olden days were constructed with the wooden reaper, brick on edge, and lime mortar (Fig. 5).

Fig 5: Wooden Reapers, Brick &Lime Mortar Roof in Age Old Building

Similar construction in Ferrocement was explored in this experimental investigation. Instead of the wooden reaper of size 25 mm x 50 mm x 3000 mm, I beam in Ferrocement was fabricated. Instead of brick on edge set in lime mortar, Ferrocement panels of the size of 500 mm x 1000 mm were prepared individually using the Portland cement conforming to IS: 12269 (2002). In this investigation, the length of the I beam was adopted as 2000 mm so that two panels could be arranged on it.

The proposed scheme is shown in Fig. 6.

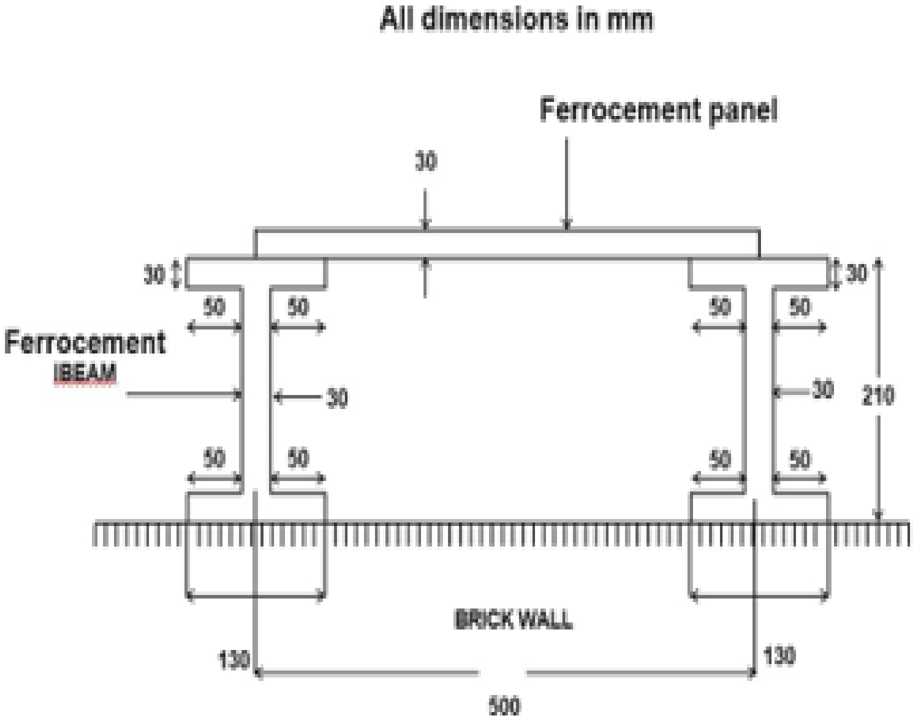

Fig 6: Schematic arrangement of Ferrocement Madras Terrace

(a) Casting of Ferrocement Panel and I Beam

In this experiment, Ferrocement-reinforced mesh was prepared on the ground as shown in Fig. 7(a). It is laid on a sheet of paper well-oiled to facilitate easy removal of the cast specimen. Fine sand sieved to 20 mm grain size downwards from river sand is collected, sieved, and stored separately in heaps (Fig. 7(b)) and taken from this for casting. Cement conforming to IS: 12269 (2013) was used to prepare mortar of 1:2 with a w/c ratio of 0.40. The mortar is then applied to the reinforcement by hand.

(a) Fabrication of Reinforcement

(b) Sand is Sieved to Required Size Mesh

Fig 7: Preparation of Materials for Ferrocement Casting

First of all a level ground was selected for casting and this site was well-oiled which would help remove the specimen after casting. In this area, already prepared Ferrocement reinforcement was placed with a 2 mm cover to the extreme wire mesh. Then on this reinforcement mesh cement mortar of 1:2 was applied and squeezed well to see that the mortar had penetrated through the mesh and came out on the other side. Finally, the surface of the mortar was finished level. After the initial setting, the specimens were removed from the casting yard. The specimens were placed in a water pond for 28 days along with the control specimen as shown in Fig. 8.

Fig 8: Curing of Specimen by immersing them in Water Tank

The I-beams were also cast and cured similarly as shown in Fig. 9.

Fig 9: Casting of I Beam and Curing in Pond of Water

(b) Testing of Panel and Deck

The panel as a single unit was tested under central load as shown in Fig. 10.

Fig 10: Testing of Panel

The I beam was arranged in the loading frame as shown in Fig. 11 for testing.

Fig 11: Testing of I Beam in the Loading Frame

In all tests of panels and I beam, dial gauges were installed underneath the specimens for measuring the deflection shown in Fig. 10 and Fig. 11. The crack pattern of the tested panel is shown in Fig. 12.

(a) Crack at the Bottom of the Tested Panel

(b) Crack Across Thickness

Fig 12: Crack Pattern & Measurement of Deflection with Dial Gauge

The Ferrocement deck was arranged in the loading frame for testing as shown in Fig. 13

Fig 13: Loading arrangement of the deck in the frame proper

In Fig. 13 it is shown that a plate across the width of the deck has been arranged to distribute the load on the deck. The deflection of the deck at its centre was measured by a dial gauge placed underneath it.

III. DISCUSSION OF RESULT

The load-deflection relation of a panel is shown in Fig. 14.

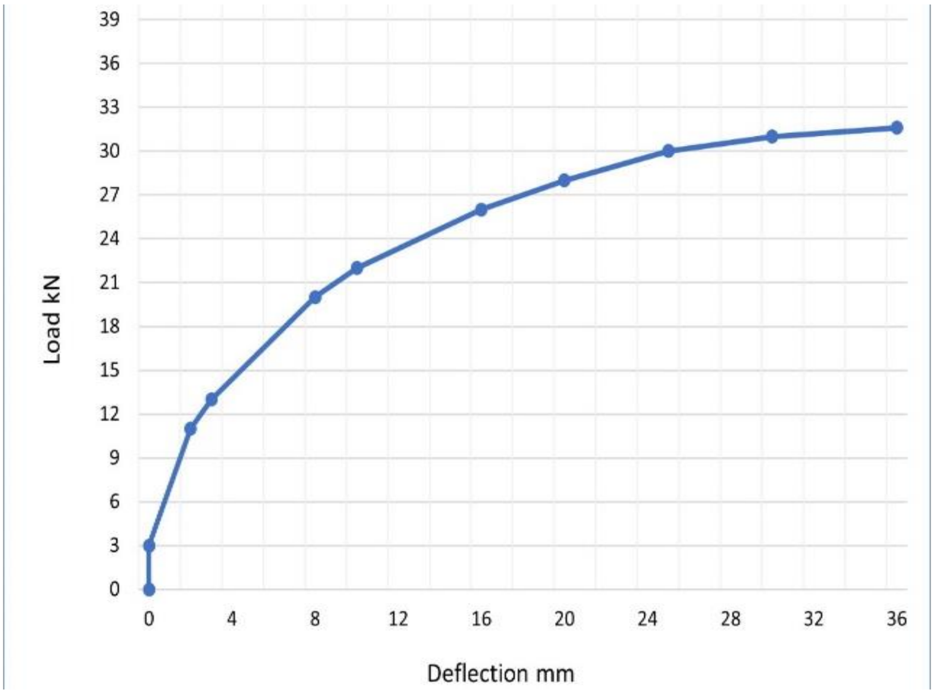

Fig 14: Load–deflection relation of the panel

In the case of the panel, the curve is linear up to a load of 3 kN with a deflection of 0.45 mm. Afterward, the curve becomes nonlinear up to an ultimate failure load of 31.6 kN, and the ultimate deflection at the failure load was found to be 36 mm. The load vs. deflection curve looks similar to the mirror image of the stress block across the section of a reinforced concrete element as per the British code EN-1992 (2002). The code has recommended two types of stress blocks. One for the design and the other for analysis. The stress block for design comprises a rectangular and triangular distribution. The stress distribution of linear and parabolic types is used for analysis. The load-deflection in the case of a single panel resembles the latter one.

It was found that the load vs. deflection of the panel resembled the load-deflection curve in Bong and Ahmad (2009) in which Ferrocement laminate 30 mm thick was attached to the soffit of the beam. The writer has also compared the result of the regular beam without Ferrocement laminate. In this case, the load-deflection relation is similar but the ordinates of all the points were reduced considerably. Also, the load-deflection curve of the panel shown in Fig. 14 resembles the load vs. deflection relation of beam corresponding to series C investigated by Honcho in 2016 in connection with an experimental study on the behaviour and strength of rectangular Ferrocement beams in shear.

The load-deflection relation of the deck under the load is shown in Fig. 15. The curve is linear up to 3 kN with a deflection of 0.045 mm. Afterward, the curve becomes non-linear till failure. The ultimate load was 14 kN and the resulting deflection was 3.6 mm. The load remains constant at 14 kN from the deflection of 3.6 mm to 3.7 mm beyond which there was no further increase in load.

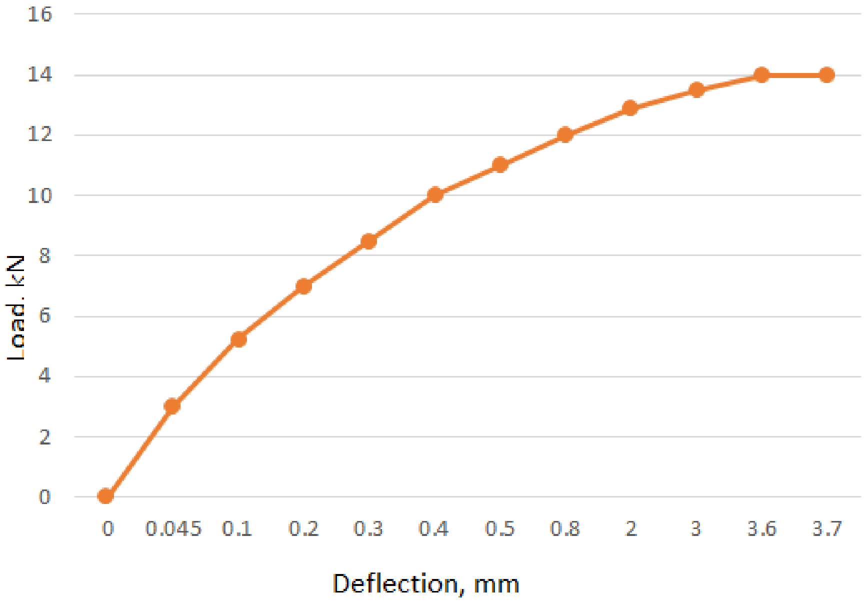

Fig 15: Load deflection relation of the deck

It was found that the load vs. deflection of the deck resembled the load-deflection curve in Bong and Ahmad (2009) in which Ferrocement laminate 30 mm thick was attached to the soffit of the beam. The writer has also compared the result of the regular beam without Ferrocement laminate. In this case, the load-deflection relation is similar but the ordinates of all the points were reduced considerably.

Also, the load-deflection curve of the panel shown in Fig. 15 resembles the load vs. deflection relation of the beam corresponding to series C investigated by Honche in 2016 in connection with an experimental study on the behaviour and strength of rectangular Ferrocement beams in shear.

IV. CONCLUSION

In this paper author has attempted to use Ferrocement for straight and flat forms that can be used in industrial and residential applications in contrast to the curvilinear forms which cannot have multi-level floors and roofs. One such application is roof and floor for residential construction. The paper describes in detail the fabrication of different components of the erstwhile Madras Terrace roof as it was originally called. Earlier it consisted of wooden rafters and bricks laid on edge and covered with lime mortar. In this investigation instead of wooden rafters, a Ferrocement I beam was used and the gap between them was filled with Ferrocement panels. First, the I beam was placed in between the walls at intervals of 500 mm centers. On these I beams Ferrocement panels were placed without any gap between them. Finally, the top surface was finished level with screed concrete. Similar construction can be carried out as required for other floors too. Then the entire cement work was cured for two weeks. After the specimen is cured it is ready for occupation. This is best suited for any type of occupancy and is also very cost-effective. From this investigation, the conclusion drawn was that Ferrocement is as good as the reinforced concrete and economical also. In the case of the single panel, the ultimate failure load was 31.6 kN and the ultimate deflection was 36 mm. The ultimate load in the case of the deck was 14 kN and the failure deflection was 3.7 mm. The panel as a single unit is more flexible than the deck which is found to be very stiff. The load-deflection curve of the panel looks similar to the mirror image of a stress block across the section of an RCC element.

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