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Ferrocement: A New Material for Construction

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Abstract. The author has investigated experimentally the possibility of applying the ferrocement for the construction of buildings with straight and flat form in contrast to the earlier application to curvilinear structures. This finding will be useful for the construction of muti-storeyed building to cater to the needs of surging population. This experimental investigation has established the credential of this material for the construction of high-rise building. This experimental investigation consists of casting of different components in ferrocement; curing as per the relevant codal provision; and testing of each component individually as well as assembled one as in real structure. The individual panel was able to sustain a maximum load of 31.6 kN and had undergone a deflection of 36 mm under this load without any damage whereas the assembled deck sustained an ultimate load of 14 kN with a failure deflection of 3.16 mm. The individual panel was found to be very flexible and the assembled deck was found to be very stiff. At ultimate load the panel didn't crush like in the case of reinforced concrete and only sustained the load with large deflection. The deck was found to be very stiff. This investigation has established that ferrocement as a construction material is similar to reinforced concrete in strength and behaviour.

Key words: Housing, Ferrocement, Straight & Flat form, Experimental Investigation, Load-deflection curve, Complaint with codal provision

1. Introduction

The origin of ferrocement is attributed to France and Netherland and dates back to 1840. It is the forerunner of reinforced concrete. Joseph Monier and Joseph-Louis Lambot are two Frenchmen who invented the ferrocement. The former called the material as *ciment armé*, this means armored cement and the latter used to construct a boat with this material in1848. 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 in wood flooring, water container, etc. The new product that Lambot developed consisted of metal net of wire which was formed like flexible woven net. He stated further that *ferciment* had come up very well according to his expectation. Afterwards 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, famous Italian Architect and Engineer, popularized this material for boat construction because it was found to be very expensive and production of wire mesh was also tedious (Nervi, 1956).

Ferrocement is another version of conventional reinforced concrete element. It is also called as Ferro Crete. Ferro means iron and crete means concrete without coarse aggregate. This means it contains only cement and fine aggregate or sand. It is a thin concrete element of about 20 mm - 60 mm thick with closely spaced reinforcement of skeletal steel or welded steel wrapped with multilayer of chicken meshes and impregnated with cement mortar on both sides as shown in Fig. 1 (ACI Committee 549, 1999).

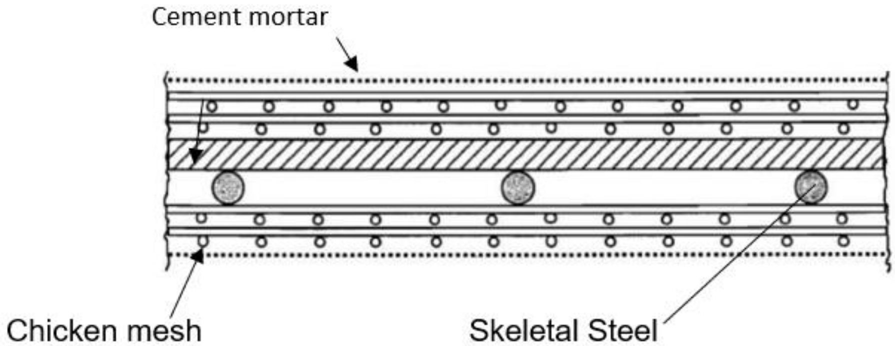

Fig. 1. Cross section of skeletal armature method

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, et al. 2017). Its tensile strength is 15 MPa and its 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., and spherical geometry like domes, auditoria, etc. The material can be used for the repair of damaged concrete element and structural strengthening of concrete if found to be weak when it is not able to take the load (Basunbul, et al., 1990).

Ferrocement is a highly versatile form of reinforced concrete made up of wire mesh, sand, aggregate, water and the cement, which possess unique qualities of strength and serviceability. Over the years, applications involving ferrocements have increased due to its property like strength, toughness, water tight, lightness, durability, and most important stability (Thorat et al., 2017). Initially, ferrocement was used to construct curvilinear structures like cylindrical water tank, bins, silos, etc., and spherical structures like, domes, auditoria, etc., including houses as shown in Fig. 2 in the early period of modern age. This material can also be used for the repairing of damaged concrete member and strengthening of concrete (Pramasivam et al., 1998). At the beginning, the material was used to construct houses which are of single dwelling with curved roof (Fig. 2) because at that point of time it was evolved from boat construction. It is not possible to have floors above the curved surface.

Fig. 2. Curved houses for single dwelling (Courtesy: Ferrocement Society of India)

In this modern age as the prices of the land are sky rocketing and the land availability in urban areas for single dwelling is very scarce. The reason for this is that population is explosive as the number of persons to be accommodated in small area of the land is very high. 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 in straight and flat form.

There is another reason for this. In the olden age the single dwelling consisted of sloped titled roof. Later, with the availability of lime mortar (l.m.) flat roof were built with l.m. Subsequently, when cement also was introduced for use in the construction as cement mortar (c.m.) the house construction using straight and flat form was introduced. This system of construction is called Madras Terrace. This was quite popular in India. In this type of construction wooden repears of size 25 mm × 50 mm × 3000 mm of the room size and bricks on edge in l.m. were used on the reaper. Now with the advent of ferrocement house construction has become cheaper. As ferrocement is very flexible, it should derive its stiffness by virtue of its geometry. This is what the objective of this experimental investigation presented in the paper. This is the reason to investigate the possibility of adopting straight and flat form because it would facilitate construction of high-rise structures. The details of the experiment conducted are given in the following paragraphs.

2. Experimental Investigation

First the panel is cast using c.m. 1:2 with a w/c ratio of 0.4 and cured in water. In this investigation the panel and the supporting I beam were all cast using ferrocement which was prepared using skeletal steel of 3 mm diameter wire and wrapped with chicken mesh of 24 gauge. On this prepared skeletal mesh, the c.m. prepared is applied. After initial hardening the panel and I beam were cured in water.

The author has now investigated experimentally the load-deflection behaviour of ferrocement panel and assembled unit like Madras Terrace which in olden days constructed with wooden reaper, brick on edge and lime mortar. 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 for room size, I beam in ferrocement was also fabricated. Instead of brick on edge set in lime mortar, ferrocement panels of size of 500 mm x 1000 mm were prepared. The flange width of 130 mm, depth of 200 mm and length of 3000 mm was adopted in the case of I beam. The space between the I beam was presumed as 500 mm in contrast to the earlier practice of 150 mm between wooden reapers. All the components were cast individually using the Portland cement conforming to Bureau of Indian Standards (2013). The geometrical scheme of the arrangement is shown in Fig, 3.

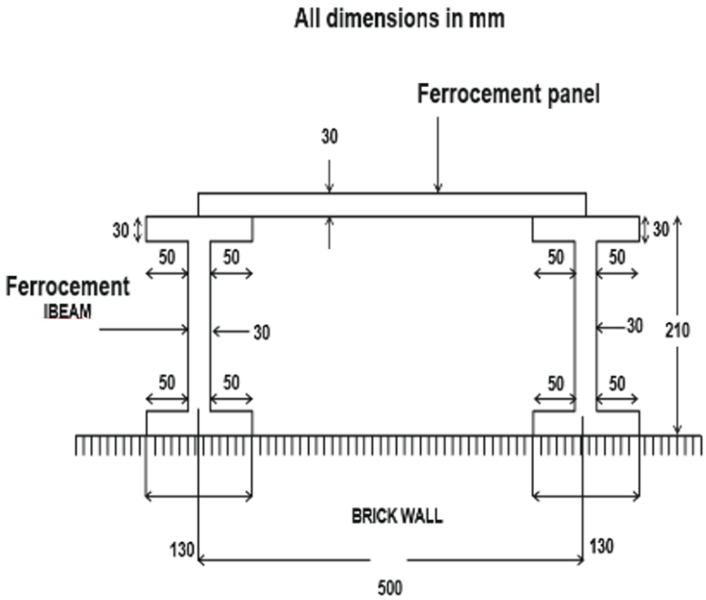

Fig. 3. Scheme of the proposed Madras Terrace in ferrocement.

The component was tested first as a panel in loading frame by means of a hydraulic jack as shown in Fig. 4 and Fig. 5.

Fig. 4. Testing of single panel

Fig. 5. Loading arrangement of the deck in the frame.

Discussion of result: The load deflection relation of a panel is shown in Fig. 6. In the case of the panel, the curve is linear up to a load of 3 kN with a deflection of 0.45 mm. Afterwards the curve becomes nonlinear up to a maximum load of 31.6 kN and the ultimate deflection was found to be 36 mm. The load vs. deflection curve looks similar to the mirror image of the stress block across-section of an reinforce concrete element as per the British code EN-1992 (European Committee for Standardization, 1992). The code has recommended two types of stress blocks. One for the design and other for analysis. The stress block for design comprises of a rectangular and triangular distribution. The stress distribution of linear and parabolic type is used for analysis. The load-deflection in the case of single panel resembles to the latter one.

The load-deflection relation of the deck under the load in shown in Fig. 6. The curve is linear upto 3 kN with a deflection of 0.045 mm. Afterwards the curve becomes non-linear till maximum load is reached.S The ultimate load was 14 kN and the resulting deflection was 3.6 mm.

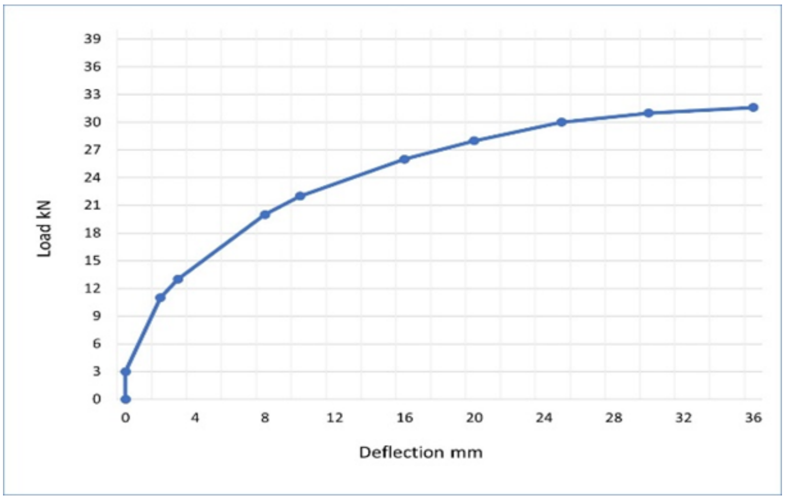

Fig. 6. Load – deflection relation of panel

In the case of the panel, the curve is linear up to a load of 3 kN with a deflection of 0.45 mm. Afterwards the curve becomes nonlinear up to a maximum load of 31.6 kN and the associated deflection was found to be 36 mm. It was found that the load-deflection of the panel resembled to the load-deflection curve obtained by Bong and Ahmed (2000). The load vs. deflection curve looks similar to the mirror image of the stress block across the section of reinforced concrete element as per the British code EN-1992 (European Committee for Standardization, 1992). The code has recommended two types of stress blocks. One for the design and other for analysis. The stress block for design comprises of a rectangular and triangular distribution. The stress distribution of linear and parabolic type is used for analysis. The load-deflection in the case of single panel resembles latter one.

The load-deflection relation of the deck under the load is shown in Fig. 7. The curve is linear up to 3 kN with a deflection of 0.045 mm. Afterwards the curve becomes non-linear till the ultimate the ultimate load was 14 kN and the resulting deflection was 3.7 mm. From a deflection of 3.6 mm to 3.7 mm the ultimate load remains constant.

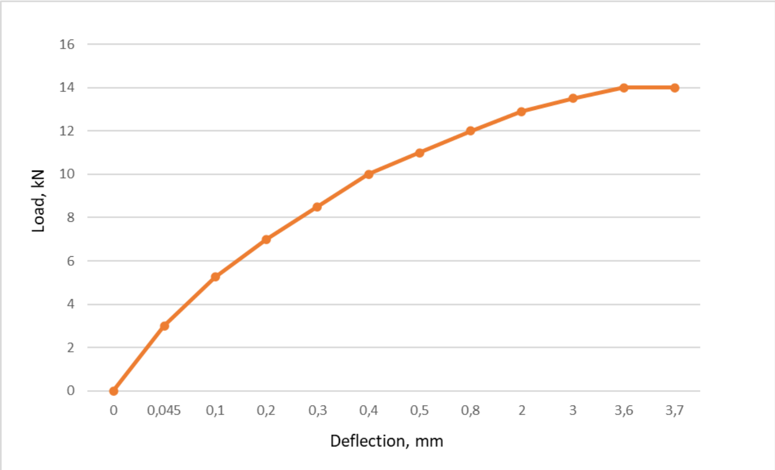

Fig. 7. Load deflection relation of the deck.

The curve is linear upto 3 kN with a deflection of 0.045 mm. Afterwards the curve becomes non-linear till failure. The ultimate load was 14 kN and deflection attained at this load was 3.6 mm. The curve is similar to that shown in Fig. 6 for load - deflection for panel.

Conclusions

In this paper author has made an attempt to use ferrocement for straight and flat form 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 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 centres. 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 was carried out as required for other floors too. Then the entire cement work was cured for four weeks. After the speciman is cured it is ready for construction. This is best suited for any type of occupancy and also very cost effective. From this investigation the conclusion was drawn is that ferrocement is as good as the reinforced concrete in strength and behaviour and economical also. In the case of single panel, the ultimate failure load was 31.6 kN and the ultimate deflection was 36 mm. The failure load in the case of the deck was 14 kN and the failure deflection was 3.6 mm. The panel as a single unit is more flexible then 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 a reinforced concrete element.

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