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FERROCEMENT FOR THE REPAIR OF TUBULAR JOINTS AND CONSTRUCTION OF HOLLOW CORED SLAB FOR HOUSES

Prof. Dr. T.S. Thandavamoorthy*1

*1Independent Research Consultant & Former Professor, Department Of Civil Engineering, Adhiparasakthi Engineering College (APEC), Melmaruvathur, Tamil Nadu, India.

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ABSTRACT

The paper presents a review of the research conducted by the author on the repair and rehabilitation of damaged tubular joints of offshore platforms using Ferrocement jackets and a specially developed high-performance grout (HPG). The repaired joint was tested under axial brace compression loading and found to be of its original strength. This research was the application of Ferrocement for curvilinear structures for repair. The author wanted to make use of the material for the construction of structures in straight and flat form. With this objective in mind experimental investigation was conducted on the hollow cored Ferrocement floor panel of size 900 mm × 600 mm. This unit was precast with cement mortar 1:2 and cured for 7 days by immersion in a pond of water because only cement mortar is used in its production. Then it was arranged in a loading frame and tested under gradually increasing static loading till failure. The ultimate load sustained by the panel was 85 kN. With a factor of safety of 2, the intensity of the design load works out to 78.7 kN/m^2. The value recommended by the relevant guidelines is 2 kN/m^2. By this consideration, the hollow cored slab is safer for the people to live in. The paper presents the details of the experimental programme and the conclusions drawn therefrom.

Keywords: Ferrocement, New Material For Construction, Geometrically Curvilinear, Repairing Of Damaged Tubular Joint, Straight And Flat Form, Hollow Cored Floor, Housing.

I. INTRODUCTION

Civil Engineers are quite confident in handling problems with reinforced and prestressed concrete because the subject matter is well-versed enough and good guidelines are available. The Ferrocement concrete is of recent origin. It consists of skeleton wire mesh wrapped with chicken mesh as shown in Fig 1(a). The chicken mesh may have many layers. On the combined meshes of required shape and size cement mortar 1:2 with w/c ratio of 0.4 is applied and finished level as shown in Fig. 1(b).

(a) Ferrocement steel reinforcement

(b) Cement mortar applied to the reinforcement

Fig. 1: Manufacturing Ferrocement

Though invented by two French Engineers, viz., Joseph Monier and Joseph Loius Lambot in the 1850s the material did not develop till 1960 when Nervi, an eminent Italian Architect, and Engineer popularized it. Non-availability of facilities in the olden days for the production of meshes and the cost of their production was found to be the main hurdle for the proliferation of Ferrocement in construction. Hence, reinforced concrete with large diameter bars was used throughout the First and Second World Wars.

Ferrocement is another version of regular reinforced concrete. It is a thin stressed skin element in which the stresses lie in the plane of the element. Therefore initially this was used in the construction of the marine structure like boats. Later on, it was applied in the construction of cylindrical water tanks (Fig. 2) and spherical domes (Fig. 3).

(a) Reinforcement cage for water tank

(b) Finished tank

Fig. 2: Ferrocement cylindrical water tank (Courtesy: www.yahoo.com)

Fig. 3: Spherical dome on a frame (Courtesy: www.yahoo.com)

The Fig. 4 depicts of Ferrocement construction of a dome in Gurudwara in Ludhiana, Punjab, India.

Fig. 4: Gurudwara Brahm Bunga, Doraha near Ludhiana in Punjab, India

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(Courtesy: www.bing.com)

Singh mentioned in 2009 that a successful case history of the construction of the main dome of diameter 6.71 m for Gurudwara Brahm Bunga, a Sikh temple, (Fig. 4) is discussed in his paper. The uniqueness of this project lies in the High-Performance FC (Ferrocement concrete) mix used as well as the efficient management of the construction sequence. The dome sits 27.43 m above the ground on top of an RCC-framed structure. Based on a FEM analysis, the dome shell was designed to be 25.4 mm thick with 24 nos. of longitudinal stiffener ribs in the form of truss frames, projecting inwards. Six layers of high-quality G.I. wire meshes were wrapped on the armature. The plaster mix proportions were finalized after significant testing of several trial mixes. For high performance, suitable additives were included to enhance properties like shrinkage cracking, high impermeability, and high long-term strength. At the same time, adequate training for good workmanship was ensured. The plastering was completed in a single one-shot operation. Testing indicated a doubling of compressive strength in 180 days over the 28-day strength.

II. REVIEW OF FERROCEMENT JACKETING OF TUBULAR JOINT FOR REPAIRING OF OFFSHORE PLATFORMS

The author had developed an innovative solution in 1998 to repair and rehabilitate the damaged tubular joints of offshore platforms as part of his Ph.D. programme. Offshore platforms are artificial bases for drilling and production of oil from the sea bottom. These platforms have to serve in hostile environment and corrosive atmosphere due to marine climate. They are also subjected to wave attack continuously and are liable to be damaged by impact due to collision of marine vessels . The platforms are divided into fixed and floating as per the depth of water obtainable at the site of their installations. Though a number of platforms are available for drilling and production, the popular one for shallow water depth of about 1000 m is the fixed offshore platforms. A typical fixed platform for shallow water depth about 300 m is shown in Fig. 5. It is a vertical lattice tower with main legs called chord connected by steel tubular members called brace. On the top of the tower a platform arranged to accommodate a tower to flare up unwanted the gases and cranes to handle the equipment and other accessories

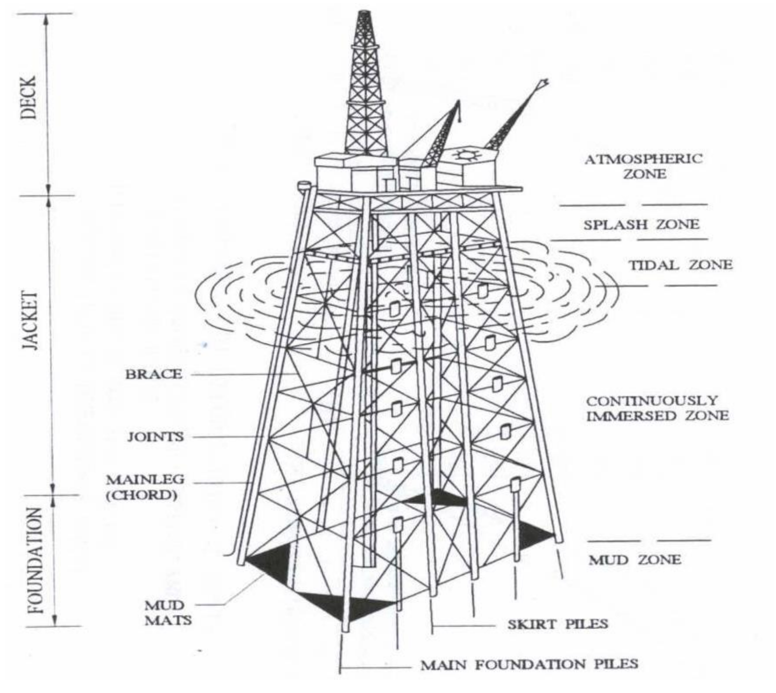

Fig. 5: Typical Jacket Platform

Tubular joints are vulnerable wave attack which causes crack in the welded joint along its periphery. If the crack penetrates through the thickness of the plate a hole is created though which corrosive marine water ingresses and causes corrosion from inside of the tubular member with the result the platform loses its integrity. Therefore it has to be invariably repaired.

Thandavamoorthy (2011) has applied Ferrocement a low-end material innovatively to repair damaged tubular joints of offshore platforms, a high-end structure as discussed below. The proposed repair scheme consists of casting ferrocement jackets into two-haves of the joint. Accordingly, Ferrocement jackets in two parts were cast using a masonry mould (Fig. 6) and cured *in-situ*.

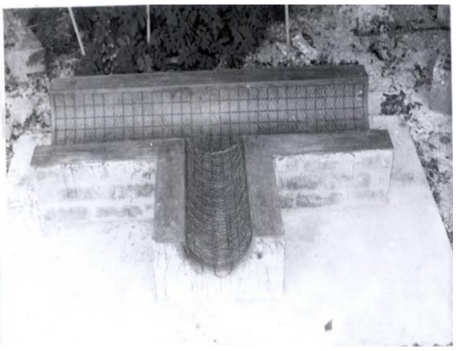

Fig. 6: Brick mould with the reinforcement

The jackets were deployed on the tubular joint with a gap of about 5 mm all around and held with clamps as shown in Fig. 7.

Fig. 7: Ferrocement jacketed joint

To bond the jacket with the tubular member High-Performance Grout was developed for this purpose. This grout comprised of fly ash ,and dry sand in the ratio of 1:2 as depicted in Fig. 8(a). With this dry mixture epoxy made up of 0.5 part of hardener and one part thinner is added and the grout became a liquid as shown in Fig. 8(b).

(a) Dry flyash and sand

(b) High Performance Grout (HPG)

Fig. 8: High Performance Grout (HPG)

With liquid consistency the grout was poured into the annular space manually as shown in Fig. 9. The repaired joints were tested under axial brace loading and compared with the original joint as shown in Fig. 10.

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Fig. 9: Pouring of Grout

The repaired joint is tested in a loading frame as shown in Fig. 10.

Fig. 10: Testing of repaired joint

After the test it was found that the repaired joint gained its original strength before the damage. It was also observed that the portion of the brace between the top of the jacket and up to its loading point was bulged out (Fig. 11).

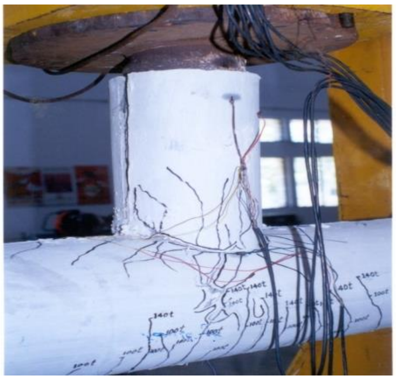

Fig. 11: Bulging out of tubular member under loading

It was surprising that to note that a weak element like Ferrocement combined with HPG was able to resist the applied load effectively of a high-end structural component. It showed that the bond between the HPG and the tubular member was excellent. This was exhibited categorically by chipping open the Ferrocement jacket from the tubular member. It was quite obvious when the colouration of the grout adhered to that of the steel tubular as depicted in Fig. 12.

Fig. 12: Excellent bond of the HPG with the tubular member

All the structures constructed before 1960 were curvilinear in geometry and in marine environment. Due to the concerted efforts of Professors, Shah, Namaan and Balaguru the material is being used nowadays in the construction of terrestrial structures. Last two decades substantial progress has been made in the application of Ferrocement in the field of engineering and agriculture (Awal, 1987). Ferrocement is likely to remain the primary thin reinforced product of choice for many years to come in applications dealing with housing structures. It has a great potential to develop into high-level industrialized systems using prefabrication lightweight structural sections, like T, I, channel, and box sections. Making use of these elements as building blocks, several industrialized and semi-industrialized housing systems have been proposed by Naaman (2000). To translate such a concept into reality, a thorough investigation into the response of each element under various types of structural actions, behaviour of connections between these elements, and the global response of the structure built by assembling these elements is essential. Mansur et al. (2000) have carried out experimental investigations to evaluate the response of elements under pure bending and developed design charts based on testing. However, instead of fabricating the panel from out of individual elements, it is preferable to fabricate room-size panels because they can be integrated monolithically with the other supporting elements of the buildings. With this objective in mind, a Ferrocement panel of size 900 mm × 600 mm was precast and tested under static loading to study its strength and failure pattern.

III. EXPERIMENTAL INVESTIGATION

Prof. S. P. Shah (1981), USA, has conducted an extensive study right from the basics of Ferrocement to establish its credentials as a building material for construction. First, he along with Namaan conducted in 1971 the tension test on the Ferrocement flat specimen to study its tensile strength. Since then he has been promoting research on Ferrocement as a construction material and traveling globally visiting different universities and delivering lectures to the students on the prospects of Ferrocement construction. His pioneering research on Ferrocement along with other Professors Naaman and Balaguru helped to lay a strong foundation for further research on Ferrocement.

A hollow cored welded mesh without chicken mesh was prepared as shown in Fig. 13.

Fig. 13: Fabricated Weld Mesh

The cement mortar 1:2 was applied on the steel reinforcement as shown in Fig. 14.

Fig. 14: Mortar applied on weld mesh

The finished specimen was cured for 7 days. The panel was arranged in a loading frame supported at one end on a hinge and the other end on the roller. On top of the panel a distribution plate was placed across the width of the panel as shown in Fig. 15.

Fig. 15: Test arrangement in the lading frame

A hydraulic jack of 500 kN capacity was mounted between the specimen and the loading frame. Three dial gauges were arranged beneath the panel (Fig. 16), one at mid-span and the other two at third points to measure the deflection of the panel under loading. The load was applied in increments and dial readings for each increment were recorded. The load was increased till the failure of the panel.

Fig. 16: Dial Gauge Locations

The failure pattern of the hollow cored slab is depicted in Fig. 17.

(a) Crushing of web at ultimate load

(b) Buckling of web reinforcement

(c) Longitudinal crack in the bottom of the panel

Fig. 17: Failure pattern of the hollow cored floor panel

IV. RESULTS AND DISCUSSION

The ultimate load observed was 85 kN. This load was distributed on the panel with an intensity of 157.4 kN/m². With a factor of safety of 2, the design load on the panel is 78.7 kN/m². Even though the workmanship of the fabrication of the panel was not so good there was no distress at all at the design load of 78.7 kN/m² on the panel. Some of the failure patterns are shown in Fig. 17. However, the preliminary findings are quite promising and successful.

V. CONCLUSION

From the review of novel method adopted for the repair and rehabilitation of damaged tubular joints of offshore platforms the conclusions derived are:

- Offshore platforms are high-end structures.
- It is a lattice tower erected on sea bed for drilling and production of oil from the bottom of the sea.
- It mainly consists of welded tubular members and joints
- The joints are vulnerable to wave attack and consequent damages due to fatigue
- This problem was solved by adopting a low-end Ferrocement technology aided with the development of High-Performance Grout.
- Repaired joints were tested in the loading frame and found that the original strength was attained.

To apply the Ferrocement concept to straight and flat form test was conducted. A hollow cored Ferrocement panel of size 900 mm × 600 mm was precast and tested under monotonic loading. The design load on the panel was 78.7 kN/m². As per IS: 875 (part 2) - (1987) the live load recommended on the floor is only 2 kN/m². Going by this consideration the load capacity of the hollow cored Ferrocement floor panel is phenomenal. Therefore the concept of a full room-sized panel is realistic and feasible. Since there is a gap between the top and bottom flanges of the slab, there is a possibility of transfer of heat reduction in the room. As the slab is about 600 mm thick the headroom of the building is raised allowing more air to circulate within the room, thus keeping a cooler atmosphere within the building.

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