Bending Behaviour of Ferrocement Confined Concrete Specimens With Different Sizes

A Review

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Abstract :
The need of the construction industry to look for a reliable component for reinforced concrete structure has led to the usage of ferrocement which proves to be a effective solution and gives better output.
This describes the structural short-term behavior of a beam strengthened with ferrocement laminate and identifies its advantages.
In all Previous researches on structural behaviour of ferrocement structures is compared to a normal reinforcement structures and from the experiment carried out, beam strengthened with ferrocemnt proves to have a higher cracking load, ultimate load as well as having a lower deflection in compression to a normal beam.
It is necessary to design and calculate tensile reinforcement channels with various spans used in different structures. However all researches are done by different persons that we can see in literature reviews, on tensile strength of ferrocement structures but we are going to work on the bending strength of ferrocement.
We will cast the models of ferrocement of different size (length, width and span) and will check the behaviour of the structure on the basis of bending strength and analysis the deflection of ferrocement structures and correspondingly compairing the results given by individual specimens.
IndexTerms - cracking load, lower deflection , bending strength

I. INTRODUCTION

Concrete is a widely used construction material all over the world. However, it often suffers deterioration due to various environmental (like earthquake, flood) and structural (like overloading) factors. A variety of materials and methods have been tried by the engineers to increase the strength and ductility of unsafe or deteriorated concrete structures. The materials and techniques applied for such strengthening activities should be structurally effective; and also cost effective as cost effectiveness is another major concern for developing countries.

Fiber reinforced polymer (FRP) is widely used nowadays as a confining/strengthening material for upgrading the strength of concrete members. However, FRP is very expensive, and its installation also requires highly skilled labor. Installation of FRP in hot and humid weather is very difficult and need special measures during its installation. On the other hand, ferrocement is very cost effective technology in developing countries as its raw materials are easily available in these countries. Ferrocement is a form of RC using closely spaced single or multiple layers of mesh and/or small-diameter skeletal rods completely infiltrated with, or encapsulated, in mortar. Although, ferrocement is an old technology, it is extensively used as a construction material with advanced technology in both developed and developing countries due to its ease of fabrication. It could be one of the promising materials for confining the concrete elements due to its improved structural properties.

Below listed are some of the advantages of using ferrocement:

Ferrocement, also called reinforced concrete, is obtained by mixing cement with sand mortar and applying the mixture over some layers of woven or welded steel mesh with small diameter holes/openings. It is widely used in shipbuilding, water and food storage tanks, water transport tubing ,silos, roofs , urban and rural houses , and structure repair. Ferrocement is especially popular because its raw materials are easily and widely available, it is easy to prepare and shape, and it is fire resistant. It is also known to promote the seismic resistance of masonry structures. Research has indicated the use of additives such as fibers, silica, fly ash, and resin to increase the strength of mortar in ferrocement.

Ferrocement, also written as ferrociment, ferrocemento, ferrocimento, and ferrozement, literally mean much steel rather than much concrete. The Committee 549 of the American Institute for Concrete submitted the following definition of the ferrocement subsequently adopted by the majority of the specialists:" The ferrocement is a type of reinforced concrete in thin elements currently constituted by micro concrete of hydraulic cement reinforced with thick layers of continuous netting, in wire with a relatively small diameter/opening. The net may be metallic or in other materials."A.E. Naaman defines ferrocement as reinforced concrete in guise of thin elements with very high performance as regards the resistance to extension, the ductility, the resistance to impact. The same author enhances the possibility of using this material for executing several constructions with thin walls, with superior physic-mechanical characteristics.

Although discontinuously used on the market, ferrocement is a contemporary material of reinforced concrete. According to Shah's published works, the Lambot was the first small boat made of ferrocement in 1849. Incredibly, this boat was still a floating 1949, that is to say a hundred years after it was constructed. Since then, it has been exhibited in the Brignoles Museum. Pier Luigi Nervi, who considered ferrocement as a boatbuilding material, started using it in Italy during the last century. He also built ships, due to the flexibility and exceptional resistance of this material. One of these ships called "Irene", had 165 ton of displacement and her hull had 1.38 inch (35 mm) of thickness. According to Nervi , the ship was 5% lighter and 40% cheaper than a similar hull made of wood. Nervi also builds a shed with a span of 321.64 feet (98m) for the Turin Exhibition in 1949. This shed had 1.58inch (40 mm) thickness ferrocement prefabricated ribbed assembled shells.

The engineering properties of ferrocement structure are equivalent to normal concrete, and in some applications it performs better. The tensile strength of ferrocement is a result of the volume of reinforcement used in the structure. Apart from the volume of reinforcement, the direction of its use in line with the force direction and tensile stress direction is also important. The tensile performance of the ferrocement concrete or structure can be grouped into three, namely, the pre cracking phase, post cracking phase, and finally the post yielding phase. A ferrocement member subjected to upwards tensile stress behaves something like linear elastic material until the first crack appears. Beyond this, the member will enter the multiple cracking and eventually continuing to a point where the mesh starts to experience yielding. Once at this stage the number of cracks will continue to grow with the increase in the tensile force or stress. The specific surface area of ferrocement member or element has been found to influence the first crack in tension, as well as the width of the cracks. The maximum stress at first crack for ferrocement matrix increases in proportion to the specific area of the element. The behavior of ferrocement element under compression mainly depended on mix design properties. The well distributed and aligned reinforcement has made the ferrocement to behave like steel plates. Ferrocement is also has other outstanding properties besides its engineering properties compared to normal concrete. Ferrocement exhibits a very easy mold-ability characteristic, that it can be used to produce any desired shape of structure. Besides that due to superior tensile behavior and water tightness, the material is widely used for lightweight construction and water tight structure as well as for potable structure. Some of the successful application of ferrocement includes boat, sampan, pipes, shell roofs, wind tunnel, modular housing, sandwich pools, permanent form of concrete structure etc.

Ferrocement is a type of building materials made up of a relatively thin layer of cement mortar reinforced with layers of continuous uniformly distributed wire mesh. The ACI Committee 549 defined ferrocement as “A type of thin wall reinforced concrete commonly constructed of hydraulic cement mortar reinforced with closely spaced layers of continuous and relatively small diameter wire mesh”. The cementing mix consists of cement and sand mortar while the reinforcement steel wire mesh has openings large enough for adequate bonding of the mixture. The uniform dispersion of the steel wire mesh and the close distribution of its opening transform the usually weak and brittle mortar mixture into a high performance building material distinctly different from normal reinforced concrete. This steel wire mesh is also responsible for ferrocement structures to have greater tensile strength and flexibility which is not found in ordinary concrete structures. It possesses higher tensile strength to weight ratio and a degree of toughness, ductility, durability and cracking resistance considerably greater than those found in other conventional cement based materials. Since ferrocement is made of the same cementitious materials as reinforced concrete structure (RC), it is ideally used as an alternative strengthening component for rehabilitation work on any RC structures.

The most widely used construction materials in today’s world would be concrete and steel combined to make reinforced concrete as can be seen in most building construction. However, the first known example of the usage of reinforced concrete started with the construction of boats when Joseph Lambot of France began to put metal reinforcing inside concrete in 1840s. That was the birth of reinforced concrete and from there subsequent developments followed. The technology at that period could not accommodate the time and effort needed to produce meshes of thousands of wires. Instead, large rods were used to make what is now called standard reinforced concrete.

II. PROBLEM STATEMENT:

Ferrocement is widely used construction material so it is mandatory to find out the capacity for the members of frame work such as beams and columns so by checking the behavior of such specimens we come to know when, where and how this technique is useful. The comparison of different specimens also gives the proper requirement at proper places and also the effectiveness according to the sizes of specimens so that its applications can be made in the structure.

Ferrocement can be used effectively in structures of different shapes and sizes such as dome shaped structure etc. so it can turn out to be effective as well as ecominical method/technique.

2.1Advantages

I. Greater Tensile strength
II. Provide better resistance to fire, earthquake, and corrosion than traditional materials, such as wood, adobe and stone masonry in residential construction.
III. The materials are relatively inexpensive, and can usually be obtained locally.
IV. Only a few simple hand tools are needed to build.
V. Repairs are usually easy and inexpensive.
VI. Structure can take any shape & size.

2.2Objectives

Following are the objectives of our project to be carried out:
1. Behaviour of the beam specimen with ferrocement jackets.
2. To compare the behavior of different beam specimens
i,e. Ferrocement confined and unconfined concrete/ mortar specimen.
3. To show the increase in flexural behavior of specimens by using ferrocement.

2.3 Scope of the project work:

One of the greatest assets of ferrocement is its relatively low unit cost of materials but in countries which demand higher cost of labor, the usage of ferrocement is not economical. For countries where unskilled, low-cost labor is available and can be trained, and as long as a standard type of construction is adhered to, the efficiency of labor will improve considerably, resulting in a reduced unit cost. With these conditions, ferrocement proves to be a more favorable option than other materials used in construction, all of which have a higher unit material cost and require greater inputs of skilled labor. The primary worldwide applications of ferrocement construction to date have been for tanks, roofs, silos and mostly boats. In this paper, the flexural behavior of beam strengthened with ferrocement mesh will be investigated. The result from the testing of ferrocement strengthen beam will be compared to a control beam to have a clearer insight into the advantages of using ferrocement. The cracking behavior and ultimate load carrying capacity will be highlighted in this paper.

III. LITERATURE REVIEW

Balaguru has investigated the axial load behavior of wire mesh composite plain concrete cylinder and observed an enhanced strength and ductility of the confined concrete.Singh and Kaushik studied the effectiveness of ferrocement confinement for repairing both circular and square short concrete columns and achieved an enhanced strength and ductility of the jacketed specimens.Walliudin and Raffeeqi studied the order of casting of ferrocement for confining the plain concrete.

The methods of confinement studied were:(i) mesh layer cast integrally, (ii) mesh layers in precast shell, (iii) wrapped mesh layer on precast.They have observed that the confinement is 100% effective when the ferrocement jacket cast integrally with the concrete core.Ramesh studied the confinement behavior of ferrocement in confining steel fiber reinforced concrete. The study achieved an improved ultimate strength by about 10%, but 200% ultimate strain compared with the similar ferrocement confinement of normal core concrete.Mourad investigated the behavior of externally confined plain concrete with welded wire mesh ferrocement. He studied the effect of different attaching methods of wire mesh around the concrete specimens.Kondraivendhan and Pradhan have investigated the behavior of ferrocement confined cylindrical concrete specimens of different grade and observed that the strength enhancement varies with the grade of concrete.

Xiong et al. investigated the strength and ductility of plain concrete encased with ferrocement including skeletal steel bars and compared with FRP confined concrete. They concluded that the ferrocement confined concrete is more ductile under axial load than that of FRP confined concrete.Kaish et al. proposed some improved square ferrocement jacketing to strengthen square RC columns. The performance of those improved square ferrocement jacketed square RC columns under concentric compressive load was verified later by Kaish et al. Kaish et al. have also investigated the behavior of ferrocement encased square RC columns under eccentric load. Paramasivam, Lin and Ong: The strengthening of reinforced concrete beams using ferrocement laminates attached onto the surface of the beams has been carried out by Paramasivam, Lim and Ong. In the research, they have come to the conclusions that the addition of ferrocement laminates to the soffit(tension face) of the beams tested statistically substantially delayed the first crack load, restrained cracks from further widening and increased the flexural stiffness and load capacities of the strengthened beam. The improvements in mid-span deflection and load capacities are lower in beams where the composite action was lost between the original beam and the strengthening ferrocement laminates. Thus, it is suggested that the surface of the beam to receive the ferrocement laminate to be roughened and provided with closely spaced shear connectors in order to ensure full composite action.

Al- Kubaisy and Jumaat: The flexural behavior of reinforced concrete slabs with ferrocement tension zone cover had been investigated by Al- Kubaisy and Jumaat. Their research proves that reinforced concrete slabs with ferrocement tension zone cover are superior in crack control, stiffness and first crack moment compared to similar slabs with normal concrete cover. Deflection near serviceability limit was significantly reduced in specimens with ferrocement cover. Research has shown that ferrocement is effective for strengthening purposes for various types of reinforced concrete members such as beams, columns and slabs in terms of increasing the flexural strength, crack control as well as deflection. Columns reinforced with ferrocement jacket also had increased shear strength and higher ductility. Construction costs will be slightly higher with ferrocement cover but this is greatly offset by the money spent on repairing damaged structures caused by cracking or spalling of normal concrete cover. In addition to that, ferrocement allows the existing conventional concrete material and practices to be used and thus, is more practical as a strengthening material compared to others. The usages of ferrocement and its advantages compared to a normally reinforced beam is an interesting topic for further investigation. The short-term behavior, cracking load as well as cracking behavior could be analyzed further to gain more understanding of the advantages of ferrocement.Sandowich and Grabowski have studied both axial and eccentric load behavior of circular composite columns made of ferrocement pipes filled concrete column and reported a ductile behavior of such columns.Nassif and Najm: Although the need for experimental research to provide the basis for design equations continues but by applying the FEM, can reduce the time and cost of otherwise expensive experimental tests, and may better simulate the loading and support conditions of the actual structure. So to this end the FEM is used by Nassif and Najm to investigate the behavior of ferrocement composite beams under a two-point loading system. They used a smeared crack model, which can be applied the constitutive equations independently at each integration point of the model to determine failure in concrete and as a result they found that the ferrocement composite beams have better ductility, cracking strength, and ultimate capacity compared to reinforced concrete beams.

Qasim Mohammad: Likewise Qasim Mohammad studied the FEM to analyze the ferrocement slabs. Modeling of concrete compression and tensile cracking has been done by a plasticity model and smeared cracking approach respectively.

Aboul-Anenet al.: Moreover, to study the composite action between the ferrocement slabs and steel sheeting, Aboul-Anenet al. applied ANSYS software with Eight-node solid isoparametric elements.

Shaheen et al. : This finite element software was also used by Shaheen et al. to find the modal parameters of the healthy and damage tank.

Ho et al .have proposed a strengthening method for circular RC columns using high-performance ferrocement (HPF) composites.Baker (1956) to Chien - Hung Lin et al (2001): The extensive review of literature on confined concrete starting from Baker (1956) to Chien -Hung Lin et al (2001) on different aspects revealed that the confinement improves the strength of concrete as well as the failure strain. However, the later increases to a greater degree. Consequently, the depth of neutral axis in a confined cross section at ultimate is less than an exact similar unconfined section. The two factors namely the increased value of failure strain and decreased depth of neutral axis produce a larger value of ultimate curvature and improve the post ultimate behavior of a reinforced concrete section.A few investigations Ganesan (1990), Alsayed (1992), A.H. Al - Shaikh (1992), Mansur et al (1997) and Foster et al (2001) reported the use of fiber for confinement of concrete. These investigations qualitatively indicated considerable increase in the ductility of concrete.A few investigations Ganesan (1993), Waliuddin (1994), Seshu (1998) and Rajeshkumar (2001) reported the use of ferrocement shell for confinement of concrete. The results published, reported the effectiveness of tie confined fiber reinforced concrete and ferrocement confined reinforced concrete individually. However, there is no sufficient reported literature on the combined use of ferrocement and fiber reinforced concrete. This investigation proposes a detailed experimental and analytical investigation on the study of Engineered Ferro Fiber Concrete (EFFC).

Ganesan and Anil, and Wang stated that the jacketing with rounded corner gives certain degrees of confinement by reducing stress concentration at corners. This justifies the development of innovative rehabilitation and strengthening method by ferro-cement jacket for CFS (Cold-formed steel) structures which extend the life expectancy of many steel structures. Limited studies were reported for the similar work in case of ferro-cement strengthened cold-formed column. Stud connectors are subjected to the flexural and axial forces in resisting the interface forces by means of dowel action. Hence the force which transfers in composite structures depends on the strength and stiffness of their components including the composite beam and the shear connectors. Therefore, it is necessary to determine the design parameters namely, shear strength and stiffness for stud connector prior to their use in the construction. This is mostly accomplished by conducting experiments on push-out specimens.

Al-Salloum.Ollgaard et al. and Hawkins: Several types of push-out specimens have been studied in past decades and reported in the literature. For example, behavior of stud shear connectors in light weight and normal weight concrete was studied by Al-Salloum. Ollgaard et al. investigated the strength of push-out specimens. Recommendations of various empirical equations about the effect of variation in material strength, and on the strength of shear connectors have been highlighted by Hawkins.

Oehlers and Johnson: Effect of transverse reinforcement on the shear strength of stud shear connectors have been investigated by Oehlers and Johnson using push-out tests. They reported that the shear strength was affected by stiffness of transverse reinforcement and not by its strength.Lloyd and Wright: Static push-out tests have been conducted by Lloyd and Wright to determine the ultimate slip and strength of profiled steel sheets and headed shear connectors. They found that ultimate connection strengths for the majority of the tests fell below current code-design values.Oehlers and Park reported that transverse reinforcement provides confinement to the concrete in the vicinity of studs rather than contribution to the strength of stud connectors. They also studied the behavior of stud connectors in high strength and normal strength concrete. Studs in normal strength concrete exhibited ductile behavior as the descending branch was gradual and longer when compared to the studs in high strength concrete.

Li and Cederwall, and BrO and Westberg has also cited a comprehensive compilation of experimental studies on push-out specimens.Ferrocement is an established material for rendering external confinement for axially loaded concrete members. However, the available research on ferrocement as a confining material is not much compared to the research carried out on other strengthening materials and techniques. Although ferrocement is a very old material, but still there is a big gap in scientific knowledge to use it as a confining material for concrete structures. The size effect of concrete specimens on the confinement action of ferrocement jacket is still not investigated. This gives the necessity of investigating the effect of specimen size on the effectiveness of ferrocement confinement. Moreover, there are only three confinement models available in the literature for ferrocement confined plain concrete, two of those were proposed for woven mesh ferrocement jacket and the rest was for welded mesh including steel bars. However, most of these models are very complicated to use practically for design purpose. Additionally, skeletal steel bars are not used in the ferrocement jacket all times. Thus, a simple strength model is also required for concrete confined with welded mesh ferrocement jacket that have no skeletal steel bars. This study is intended to further the understanding of the confinement mechanism of ferrocement (made of welded wire mesh) jacketing for concrete members.

a. Since the wire mesh (reinforcement) is much stronger in tension compared to the matrix (mortar), the role of the matrix is to properly hold the mesh in place, to give a proper protection and to transfer stresses by means of adequate bond.

b. Compression strength of this composite is generally a function of the matrix (mortar) compressive strength, while the tensile strength is a function of the mesh content and its properties.

c. It follows from (b) above that the stress-strain relationship of ferrocement in tension may show either a complete elastic behavior (up to fracture of reinforcing mesh) or some inelasticity depending upon the yielding properties of the mesh.

d. Since the properties of this composite are very much a function of orientation of the reinforcement, the material is generally anisotropic and may be treated as such in the theoretical analysis.

IV. Discussion :

The ultimate axial deflection capacities of the tested specimens. It is observed that the flexural deflections atboth yield and ultimate load and the ultimate axial deflection ofjacketed specimens are higher than the non-jacketed concrete specimens. Theultimateflexural deflections of single layer mesh ferrocementjacketed specimens are 1.74, 1.73 and 1.87 times the ultimate flexural deflections of non-jacketed specimens for type LS,MS and SS specimens, respectively. For double layer mesh ferrocementjacketed specimens, the ultimate axial deflections are 2.18, 2.08 and 2.23 times the ultimate axial deflections of non-jacketed specimens for type LS, MS and SS specimens, respectively. The higher deflection capacity may be due to the ductile nature of ferrocementjacket that permits the jacketed specimens bulge slowly under higher flexural load.

V. Conclusion:

Ultimate load capacity and flexural strength will be more for jacketed specimens.Ferrocement jacketing technique could be used effectively, if proper jacketing scheme have been adopted/introduced.From the crack pattern it can be said, that the ferrocement technique is more effective for small size specimen.Increasing the strength of mortar in ferrocement is a vital factor for achieving higher strength, larger ductility, better energy dissipation, and higher stiffness and this enhancement is prominent in small size jacketed specimens The small size jacketed specimen have higher strength carrying capacity.

It can be concluded that, this method is effective and economical in small size storage tanks, some types of roof shell construction, boats and ships, architectural monuments, sculptures and wherever the ease of forming complicated shapes and lighter weight of ferrocement can be easily exploited. The failure pattern and stress–strain behavior indicates thatsingle layer mesh ferrocement jacket cannot provide significantexternal confinement. However, double layer mesh ferrocementjacket can provide sufficient confinement to enhance the behaviour of confined concrete.

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