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Review of Behaviour of Ferrocement Panels

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Abstract – *Ferrocement is a thin member with small diameter wire mesh as reinforcement. It has the ability of micro crack formation when loaded which make it a versatile member in construction industry. From the review papers, it is seen that it could resist more crack propagation and widening of crack which leads to sudden failure conditions. It is also seen that the formation of micro cracks makes ferrocement more resistant to cyclic loading. In this paper, a summarized review of ferrocement structures subjected to various static and cyclic loading is presented which make us understand about the behaviour and uniqueness of ferrocement structures. The change in behaviour of ferrocement with varying proportion of reinforcement, thickness, volume fraction is also reviewed in the paper.*

***Key Words*:** **Ferrocement, matrix, welded mesh, hexagonal mesh, flexural behaviour, crack propagation.**

1.INTRODUCTION

Ferrocement is defined as structural members constructed with very thin width and reinforced with small diameter wire mesh in different layers as reinforcement. A The two main constituent of ferrocement are matrix and reinforcement. The main similarity with normal reinforced concrete is that, same principle of mechanics can be used to analyse the structure. The difference lies in the uniformity of the structure, more specific surface of reinforcement and more strength to weight ratio of ferrocement. Ferrocement can also cause reduction in construction cost as no specialized labour required. Ferrocement has very wide variety of application both in marine and terrestrial construction purpose. It can be used in water tanks, barges, storage tanks etc…There are different combinations of reinforcements to be used in ferrocement to study the behaviour of ferrocement. Different layers of mesh reinforcements can be provided. Sometimes different reinforcements in combinations can also be provided. The behaviour of ferrocement depends on change in volume fraction and specific surface of reinforcement. The uniformity in dispersion of reinforcement make it efficient for crack control.

2.REVIEW OF ANALYSIS OF FERROCEMENT PANELS

2.1. Linear Static Analysis

Ferrocement was known for its thin section and good crack control. So ferrocement has made as tension zone cover and flexural behaviour was studied. Simply supported slabs were tested with varied mesh layers and varied thickness to study the changing effects. It was observed that there was considerable reduction in the crack widening and also the number of cracks increased which shows narrow multiple racks. The crack width again reduced with the increment in percentage of reinforcement. But crack width was not influenced with the thickness of ferrocement cover. Slabs with ferrocement cover showed more stiffness than normal slab. (Al-Kubaisy and Zamin Jumaat, 2000).[2]

Ferrocement when used in sandwiched panels show better requirement for structure and thermal insulations. Twelve sandwiched ferrocement panel with different number of layers of wire mesh with and without skeletal steel was analysed. It was observed that the failure mode was in different stages. More cracks were concentrated at the middle portion of the panel and as the number of layers of reinforcement increased, the crack spacing got decreased and finer cracks be gin to appear. An increase in ductility and stiffness was observed with increase in number of layers. (Basunbul et al., 1991).[4]

Analysis of ferrocement roof slab panels were done. For the purpose of analysis, two different cross sectioned panels were taken. One with rectangular and other with channel cross section. The number of reinforcement layers were varied to understand the change in behaviour. Behaviour of ferrocement was again grouped as three stages. Pre cracking, multiple cracking and failure stage. At the early stages, mesh did not contribute much for strength but at ultimate loading condition, satisfactory deflection pattern was observed. There was no immediate or quick failure mode for slab with loading. For channel section, as ultimate condition approached, the strain at the top face of concrete changed to tension which is different from the normal phenomenon. More load was taken by slabs with channel section than that with rectangular section. (Hago et al., 2005).[7]

Ferrocement was used as a permanent formwork to understand its behaviour. Ferrocement panels were tested under flexure and the results were compared. In all the cases, the failure state only depicted cracking and release of load. No delamination or departure of wire mesh was observed. The flexural strength of ferrocement RC composite panels was slightly higher compared to ordinary RC beam. Although the flexural capacity improved, the first crack was seen near the second ferrocement panel, which was positioned at the bottom. After the elastic curve and the first crack formation, an opening developed in between the ferrocement panels. Though the flexural crack progressed and the width of the opening increased, it followed a clear ductile plateau with 10% increase in ultimate flexural capacity. After some particular loading, both ferrocement and conventional behave almost in similar manner. (Kumarasamy et al., 2017). [12]

Results on Ferrocement specimens showed that the tensile strength depends on both matrix strength and wire mesh ratio. Tensile strain at which plastic stage of stress-strain response was found to depend on tensile strain of matrix, tensile strength of matrix and ultimate tensile stress of Ferrocement(Mohammed, n.d.).[14]

Lightweight aggregate when used in concrete of ferrocement could affect its strength and performance. The results show that lightweight aggregates can be used in ferrocement applications without any significant difference in their bending strength (aldağ and eker, 2018). [1]

The ferrocement slabs with expanded wire and welded wire mesh reinforcements were analysed with one and two number of layers. Ultimate load was more for expanded wire mesh reinforced slab than the other. It is inferred that the expanded wire mesh has increased volume fraction which improved the load carrying capacity. The ultimate deflection has decreased with increase in mesh layer but one with expanded mesh showed less ultimate deflection.(Hago et al., 2005)[8]

Flexural and punching shear resistance has studied for ferrocement. Expanded metal wire mesh was used in this study. One-layer mesh was given at mid depth of the slab and analysed. Then two and three layers were also given to understand the influence of the number of layers. As number of layers increased, the crack width reduced. It was observed that irrespective of the number of mesh layers, as the thickness increased, the flexural behaviour decreased. Ultimate punching load increase with thickness of slab irrespective of the reinforcement layers. But as number of mesh layers increased, it shows further increase.(Rahman & Khan, 2007)[16]

The flexural behaviour of ferrocement slab with self-compacting concrete reinforced with steel fibre was studied. The number of reinforcement mesh has been changed and the percentage of steel fibers reinforced also differ to understand the behaviour. The crack pattern with static loading was studied. The load carrying capacity and ultimate load of self-compacting concrete ferrocement with steel fiber was more. As the number of layer increased, stiffness improved. Better performance observed when the percentage of steel fibers improved. SCC ferrocement slab with high percentage of steel fibers embedded in it could show more crack propagation resistance.(Ashraf & Halhalli, 2013)[3]

2.2. Dynamic Analysis

Reinforced frames with and without ferrocement infill was modelled to study the application of ferrocement in frames. Different volume fraction of ferrocement reinforcement was used to understand the change in the behaviour when loaded with lateral reverse cyclic loading. The strengthening of frame was identical for the comparison purpose. Different volume fraction was chosen. The model was scaled down by four times and analysed. For each cycle of lateral cyclic load, it comprised of two half cycles and direction was interchanged after each half cycle. It was seen that the lateral direction displacement and the lateral load capacity has reduced with ferrocement infills than that of bare frames with the same reinforcement detailing. The cracking pattern was observed for the bare frames and infilled frames. It was seen that for bare frames the cracks originated and widened at the vicinity of the beam column joint and finally failure occurred. But for infilled frames no crack initiation was observed at the ferrocement infills and the crack propagation was reduced and become more uniform along the entire length of the column. The first crack load was increased by 2 to 2.5 times as that of bare frames. The ductility, energy dissipation capacity and stiffness also has shown significant improvement with ferrocement infills. (Ganesan et al., 2017).[7]

It contributes to a better analysis that the ruling design criterion for most usages of ferrocement is not the crack width, which cannot be constantly modelled, but the steel stress. Six layers of weld mesh were used as reinforcement for a percentage of reinforcement of about 1 %. No usage of skeletal steel. fatigue and static specimens were tested. They concluded that there were micro cracks in specimens failing by fatigue with a stress level lower than in those failing under static loads. For control of crack width and propagation, crack spacing plays an important role. The crack-spacing is generally small under cyclic loading, the cracks in ferrocement should have an insignificant influence on the corrosion of steel (Xiong, 1994).[19]

Precast ferrocement walls has been analysed for cyclic loading to understand its use in seismic prone areas. Two types of precast walls were used for the analysis purpose The structure was made with precast ferrocement constituents like mortar, and reinforcement as hexagonal and steel wire mesh. Two precast walls differ in the arrangement and type of reinforcements. One contain rebars surrounded by different layers of hexagonal mesh and other contains one steel wire mesh surrounded by eight layers of hexagonal wire mesh and both were loaded with cyclic loads. The first wall experienced secant stiffness degradation, moderate pinching and strength loss after manty cycles but the other wall experienced more pinching effect. Moderate degrading stiffness and severe cyclic load strength loss. Second wall has more energy dissipation than the other. The result also showed that ferrocement precast walls can be approved to use in two storey or even more. (Herrera et al., 2020).[9]

The structural response of ferrocement–reinforced concrete composite slab with high calcium wood ash (HCWA) high strength mortar used as the compression zone was done to understand its behaviour. The slab system consisted of conventional reinforced concrete slab with a layer of high strength ferrocement composite containing various contents of HCWA by total weight of binder at the top. The main parameters of the study are serviceability moment, ultimate moment capacity, flexural stiffness and conditions after occurrence of crack, crack width development, crack spacing and failure mode. When HCWA contained ferrocement composite used in the normal slab, effect on the crack spacing of the composite slab at ultimate failure (Cheah & Ramli, 2013. [4]

As the ferrocement is of more thin section, stronger and due to the easiness in installation, it was used in unreinforced masonry walls. The walls with and without openings in window were used in the experiments. Retrofitting with ferrocement was done with different configuration. The cyclic loading was applied from time to time and the wall was subjected to shaking. The different configuration of ferrocement belt was given with and without opening. Ferrocement was given in horizontal direction, vertical direction, both horizontal and vertically and diagonally. The loading pattern resembles the actual earthquake behaviour for analysis. For walls without opening cracks began to appear at level of foundation and when open space was given, cracks generated at the interface of opening and then propagated to mortar layer. For horizontal belt, crack at top portion was completely arrested from propagation. No significant diagonal crack appeared but for vertical belt diagonal cracks were generated. Ductility of retrofitted walls shown improvement. Ductility behaviour improved from two to three times with ferrocement retrofitting.(De Silva and Abeygunawardana, 2020). [6]

Seismic analysis of ferrocement shell structured building need to be carried out. The ferrocement thin roof slabs and wall panel allows more restraining effect to the lateral load on the structure. The circular shaped ferrocement structure has created the similar effect as ordinary shear wall in intense seismic zone. Under dynamic loads, ferrocement showed better crack resistivity, reduced shrinkage, improved stress capacity and good fatigue strength. A full scale ferrocement building when constructed could reduce the construction cost by seventy percent.(Jazaei et al., 2018)[10]

Four different reinforcements were used in ferrocement slabs to study its effect on fatigue behaviour of ferrocement. Squared welded wire mesh and chicken wire mesh was used. Sinusoidal wave of 10 Hz frequency given to the sample with different percentage of maximum stress. The failure criteria adopted was either first fracture load on outermost layer or deflection of 20mm. Only very little difference in fracture surface with static and dynamic loading. Static loading caused necked surface for wire and fatigue caused brittle failure. It is interpreted that the weaker wires break in cyclic loading and then only less number of wire present to resist further loading. Sudden failure occurs in welded mesh than that of chicken mesh. This may due to the fact that the stress concentration occurs at the welded interface. It was also seen that the fatigue strength increased with number of layers of mesh with increased probability.(Singh et al., 1973)[18]

3. CONCLUSIONS

Ferrocement become unique with its uniformity in the distribution of the reinforcement mesh which make the reinforcement to distribute in the entire area of concrete matrix, thereby giving very less tension to concrete. Tis makes the concrete more crack resistant and the structure undergo only ductile failure. There are many factors which affect the behaviour of ferrocement to different loading conditions. Main aspect is with volume fraction of reinforcement in the matrix. Volume fraction is expressed with the number of layers of mesh reinforcement, types of reinforcement, diameter of reinforcements, spacing between reinforcement etc. There are many configurations and patterns of reinforcements to analyse ferrocement structures. The ferrocement structures are analysed with static loading conditions and dynamic loading conditions. In any case ferrocement structures show three main stages: pre cracking stage, multiple cracking and failure stage. Review suggested that as the number of layers of reinforcement increased, the response of ferrocement structure to loading also improved. It could resist the crack propagation and crack widening which make the structure safer. It could also withstand cyclic loading in considerable amount. There are many applications of ferrocement. All the configurations of ferrocement structures is to studied with different combination of loading conditions to give it a space in the common market and for the better sustainable use of ferrocement.

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