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Strengthening of corrosion damaged RC beams by ferrocement composite laminates

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ABSTRACT

This present paper reports the results of an experimental program designed to provide a more realistic assessment of the potential of using fibre-ferrocement polymer (FFP) materials in the repair and strengthening of reinforced concrete flexural members. The experimental program included eight RC flexural beams 125x250 mm in cross section and 3200 mm in length. Out of eight beams two are control specimens and tested for ultimate load with two point loading. The remaining six beams are damaged by accelerated corrosion technique. The rate of corrosion damage was induced (10% weight loss) in tensile reinforcement. Out of the six, two are control specimen for corrosion damage and the remaining four beams are rehabilitated by fibre-ferrocement polymer composite laminates with two different volume fractions. Then the corrosion control beams and strengthened beams are tested for ultimate load with two points loading. The experimental results are analysed in case of control, corrosion damaged, and rehabilitated beams for strength, deflection as well as moment-curvature characteristics and results from experimental data were compared with the results from nonlinear analysis by ANSYS. Tests in the present study show that it is necessary to consider the effects of corrosion induced damage on the load carrying and deflection capacities of externally reinforced flexural members. Furthermore, it is concluded that it is possible to achieve adequate corrosion repair with externally bonded FFP laminates. In particular, the current study shows that it is important to optimize FFP laminate by the addition of steel fibers in order to balance strength recovery with control of faulting and splitting which could in turn lead to premature member failure.

Keywords: accelerated corrosion; ferrocement; steel fiber; polymer; rehabilitation, ferrocement laminate, plate bonding.

1. INTRODUCTION

The reinforced concrete structures are one of the most abundantly used construction material not only in the developed world, but also in the remotest parts of the developing world. An increasing number of reinforced concrete structures have reached their end of service life, either due to deterioration of concrete or due to an increase in applied loads. These deteriorated structures may be structurally deficient or functionally absolute, and most are now in serious need of extensive rehabilitation or replacement. The need to increase the capacity of the existing structures has recently become one of the most active areas in structural engineering. In turn strengthening can be used as a cost-effective alternative to the replacement of these structures and is often the only feasible solution. In fact several strengthening methods have been used in the past with varying degrees of success such as providing additional beams, plate bonding, and external pre-stressing in order to strengthen a given structure. However each and every strengthening method has their own advantage or disadvantage over one another methods. As concern to steel plate bonding, results showed that even though improvements in performance could be achieved in terms of ultimate load, crack control, and stiffness, but the steel plate corroded significantly during exposure to adverse environment causing a loss in bond strength at the steel epoxy interface. Besides the problem of corrosion, steel plates possess certain intrinsic deficiencies such as difficulties in handling, cutting, splicing, and placements. Under such circumstances the fibre reinforced composite materials for structural rehabilitation shows great promise because of their immunity to corrosion, electro-magnetic neutrality, and efficiency of application. Moreover the composite plates can be glued to the existing structures in turn it's very difficult to make a satisfactory gluing of the strengthening plates on a construction site. In fact good gluing requires the preparation of the concrete and plate surfaces. Its also requires that a pressure be exerted on the plates during glue hardening. Therefore many investigators have highlighted the problem of premature failure due to shear peeling of the plates (1-3; 19-23). Even though FRP sheets can provide increases in strength and stiffness to existing concrete beams when bonded to the web and tension side (4). However a brittle failure may occur depending on the direction of FRP fibres relative to the direction of the existing cracks (5).

As a consequence, ferrocement is one such composite material having mortar as the matrix and fine wire mesh as the reinforcement which has many advantages over conventional reinforced concrete such as improvement in tensile and flexural strength, improvement in ductility, impact resistance, and crack arresting properties. Although the concept of ferrocement is almost as old as reinforced concrete and in turn the real development took place in recent years. From recent reports on tests on repaired simply supported reinforced concrete beams failing in flexure and shear, it was concluded that ferrocement can be effectively used for repairing beams failing in flexure, whereas repairs using steel fibres in combination with the conventional reinforcing bars can substantially improve the shear strength behavior of damaged beams (6). Actually Fibro-ferrocement has been essentially a New Zealand development (7) who has been able to combine the use of steel fibre with welded mesh to form a structural thin section material. The advantage of the technique relate to the ability to produce the accepted structural performance of ferrocement while considerably reducing the labour content normally associated with fitting overlaying sheets of fine mesh and hand forcing a cement plaster mix through the fine mesh. They concluded that, with this material combination like steel mesh and fibre produces a thin section capable of being used as a primary structural component. The potential application of fibrous ferrocement include like: tanks; reservoirs; power poles, plates, planks, and sheets; roofing; flooring; offshore structures; pontoons; buoys; farming applications; grass mats-grill flooring;cladding, culverts;fabrication of a barge; Bus-shelters; Fence post; Post and rail fence; Cattle stop; Gates. Thus in the present investigation, it has been planned to evaluate the Fibro-Ferrocement Polymer laminates which is to be applied at the tension side of the corrosion damaged reinforced concrete beams in turn to evaluate, the overall performance for flexural strength, stiffness, and load carrying capacities with different volume fractions of ferrocement composite material.

2. RESEARCH SIGNIFICANCE

This paper reports the results of a series of tests designed to study the effect of corrosion damage on the effectiveness of externally bonded FFP laminates in the flexural repair and strengthening of RC beams. Favorable findings from this series of tests would warrant further studies on the optimization of FFP layout due to addition of steel fibres. Similarly the following objectives of this research have been established such as: i) to study the flexural behavior of corrosion damaged RC beams retrofitted with ferrocement composite laminates; ii) To assess the effect of corrosion damage in terms of the perfect beams; iii) To study the effect of discontinuous fibres in the ferrocement laminates; iv) To study the theoretical and experimental moment-curvature relationship for control and strengthened beams; v) To study the load–deflection behavior by conducting monotonic static test; vi) To compare the experimental and analytical results.

3. LITERATURE REVIEW

The corrosion of steel reinforcement is the most common durability problem of reinforced concrete structures. Steel in concrete is normally protected from corrosion by a passive film of iron oxides on the steel surface resulting from the natural alkaline environment of the concrete. The passive film is chemically stable in the absence of carbonation and chloride ions (8). The ingress of chloride ions, Cl^-, to the level of the steel reinforcing bars destroys the passive film and initiates corrosion (9). The corrosion rate is a key element in determining the time from corrosion initiation to corrosion cracking, which is usually used to predict the functional service life of a corroded RC structure (10). After corrosion initiation, the corrosion rate depends mainly on the availability of oxygen and moisture at the cathode and on the concrete resistivity, which is mainly affected by the internal moisture content and concrete porosity (11). Corrosion of the steel reinforcement in reinforced concrete RC structures affects both the steel and the concrete. The strength of a corroding steel reinforcing bar is reduced because of a reduction in the cross-sectional area of the steel bar. Pitting corrosion may also reduce the ductility of the steel bar by introducing notches on the surface of the steel bars that leads to a premature necking (12).

From previous decades, it was (13) inferred that an astronomical increase in the cost of construction has forced the engineers to look for economical and better methods for the repairs of damaged or distresses structures. Its now well established that ferrocement as when used for infrastructure rehabilitation has inherent and unique advantages. Investigation carried out by (14) provided additional data on the performance of reinforced concrete beams strengthened and repaired with ferrocement laminate. The results show that all the strengthened beams exhibited higher ultimate flexural capacity and greater stiffness. A decreased in the volume fraction of reinforcement of the ferrocement laminates from 3.55% - 2.36% resulted in a reduction in strength. The presence of the ferrocement laminate has an inhibiting effect on the tensile crack, crack spacing and crack width were reduced after strengthening. Actually in previous decades by investigator (15), some theories had been developed for ferrocement in order to give crack spacing in terms of transverse steel which may obscure the basic cracking mechanism. This is demonstrated in crack behaviour of the newer form of ferrocement in which high tensile wire reinforcement used in conjunction with wire fibres in which transverse steel may be omitted. Nevertheless characteristic crack spacing comparable with that induced in much finer wire mesh reinforced ferrocement occurs. Alexander (16) reports a series of experiments with mono-layered high tensile steel mesh encased in a fibrous (steel) cement mortar matrix. In which, the outcome is a high strength material for which flexural properties can be designed and predicted with acceptable accuracy. Also from the experimental results, it's confirmed that the material has a superior cracking mechanism, offers improved energy absorption and impact resistance. El-Kholy (17) inferred that, the presence of steel fibres in addition to meshes in turn further increases the load at which a specified crack width forms. However, when larger numbers of mesh layers are used, the influence of fibres appears to be comparatively smaller. Also the number of cracks formed on ferrocement specimens with higher percentage of fibres are less than those formed on ferrocement specimens without fibres. Thus researchers like Alcheson and Alexander (18) inferred that for the case of marine applications in turn a high tensile wire reinforced fibrous ferrocement was developed in order to provide ultimate flexural strength comparable and exceeding that of mild steel plate on a weight for weight basis to enhance impact resistance, and to fully used the permissible crack serviceability range.

4. EXPERIMENTAL WORK

The dimensions (125 mmx250 mmx3200mm) of the eight RC beams with an effective span of 3000 mm were cast using 2-12mm ϕ bars (yield strength of 415 N/mm^2) as tension reinforcement, 2-8 mm ϕ bars as compression reinforcement, and 22 numbers of 6 mm ϕ at 125 mm c/c stirrups. The mean strength of concrete used for control beam is 35.21N/mm^2. The concrete mix used was 1:1.53: 3.2 by weight with a water-cement ratio of 0.49. For in case of ferrocement laminates, the mean strength of plain mortar and plain mortar with steel fibre used was 30.75 N/mm^2 and 46.50 N/mm^2 with water/cement ratio of about 0.40 having workability in terms of slump not exceeding 50 mm as specified in Ferrocement Modal Code-2001(FMC). In which two types of meshes (square weld and square woven mesh) were used. For the purpose of rehabilitation, four fibro-ferrocement laminates were cast with different volume fraction of reinforcement (5.94 % & 7.41 %) having a size of 125mm x 20 mm x 3000 mm. The first two beams (PB-1 & PB-2) were perfect beams and the remaining six beams were damaged under accelerated corrosion by constant current source (Dc = 10% rebar mass loss). Out of six beams (CB-1 & CB-2) were considered as control beams for corrosion damaged condition and remaing four beams (CR-1- CR-4) were repaired and rehabilitated by fibro-ferrocement laminates with different volume fraction of reinforcement. The details of tested beams with their designation are given in Table 1. Similarilly the reinforcement detail as well as arrangement of retrofiited fibro-ferrocement laminate for beams were shown in Fig.1 and Fig.2.

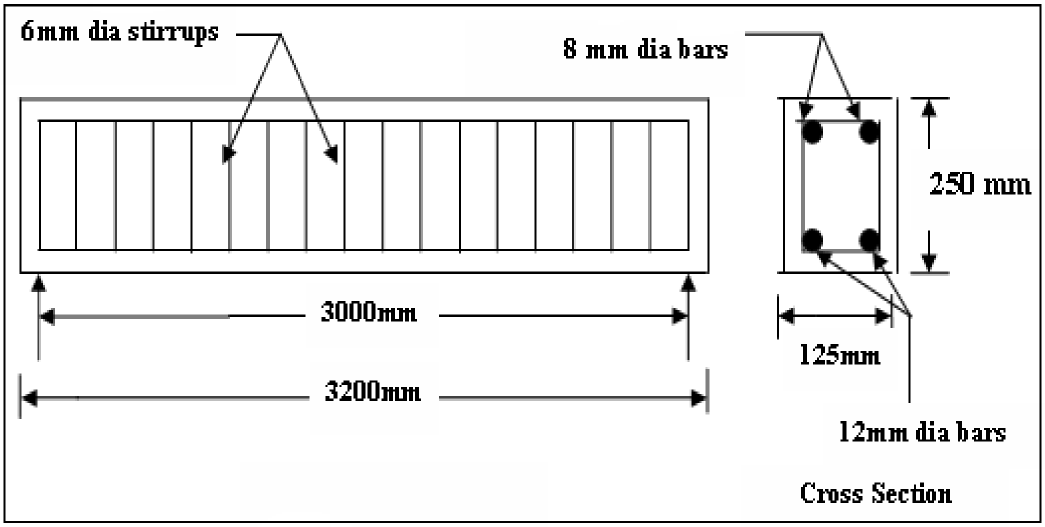


Figure 1 Reinforcement details of beam

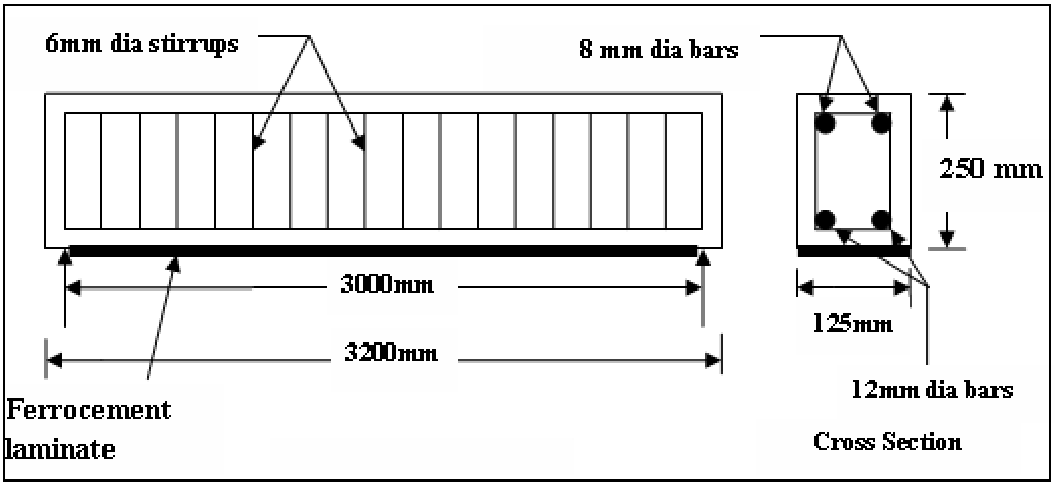


Figure 2 Details of rehabilitated beam

Table 1 Designation of beams

Designation of beams	Details
PB-1	Perfect beams
PB-2	
CB-1	Control beams for 10% corrosion
CB-2	
CR-1	Retrofitted beam (Vr = 5.94%)
CR-2	
CR-3	Retrofitted beam (Vr = 7.41%)
CR-4	

4.1. Accelerated Corrosion process:

The reinforced concrete beams were subjected to an accelerated corrosion process in an electrolytic cell by means of a direct current supply. An electric current was passed through the main longitudinal bottom reinforcing bars of about maximum 5000 mA. The beams were placed on the stainless steel plate SS316 grade acting as a cathode (Non-corrosive plate) and this set up was placed in the 3.5% NaCl solution, which acted as an electrolyte and the solution level in the tank was adjusted to slightly exceed the concrete cover plus rebar diameter in order to ensure adequate submission of longitudinal reinforcement. The layout of corrosion monitoring setup is shown in the Fig.3 It is possible to convert the current flow to metal loss by Faraday's second law. According to Faraday's law, the time for accelerated corrosion was calculated as 95.96 hours for 10% mass loss (corrosion) of tension steel.

Figure 3 View of corrosion monitoring

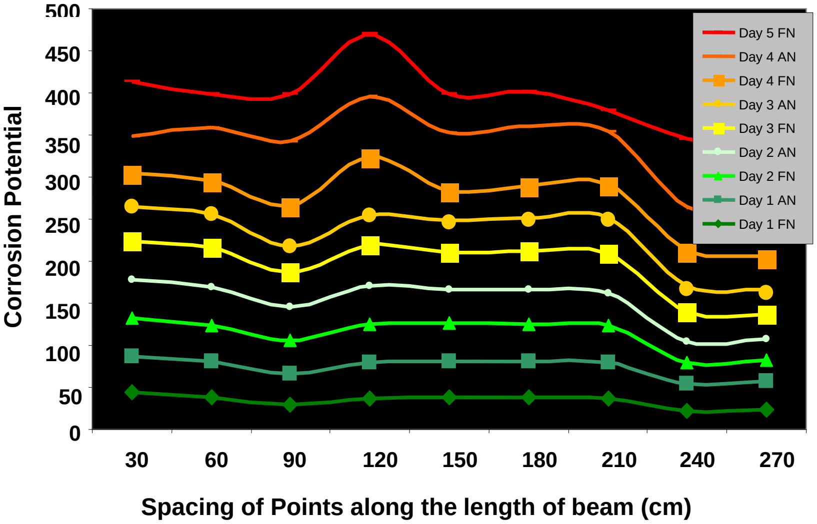


Figure 4 Corrosion potential Vs Time

4.2. Monitoring of Corrosion:

The corrosion process causes electrical potential to be generated, where as the half-cell provides method of detecting these electrical potentials. The half cells consist of an electrode of a metal contained in an electrolyte consisting of a saturated solution of one of its own salts. Copper in copper sulphate and silver in silver chloride are commonly used. A porous plug in the end of the cell allows the electrolyte to make contact with concrete surface. The half-cell provides a reference against which corrosion potentials of steel in concrete can be measured. Corrosion activity on the reinforcement will cause a change in the potential generated by the copper cell. The half cell is moved to different locations on the concrete surface, usually in a grid pattern and the potential in milli-volts at each location is noted. Using the half cell potential setup, potential readings were taken along the length of the beam at a uniform distant to monitor the progress of corrosion process. The potential readings were taken two times per day and plotted a graph of corrosion potential value versus time as shown in Fig.4. After the accelerated corrosion process the beam specimens were taken for rehabilitation.

4.3. Casting of Ferrocement Laminates:

The woven mesh and weld meshes were used to cast the ferrocement laminates. The mesh strips were placed in to the mould. Total four numbers of laminates were cast in two different volume fractions. Then the laminates were allowed for curing of about 28 days.

4.3.1. Bonding of Ferrocement Laminates:

The damaged beams were arranged with its tension side facing upwards for surface preparation, corrosion repair and for bonding work as shown in Fig.5. Prior to bonding of laminates, tension side of the beams was grinded to remove the surface laitance and to expose the rough surface. After surface preparation, the cracks were filled by a low viscous resin grouting. Then the adhesive components were mixed thoroughly and applied to the surfaces using trowel and then ferrocement laminates were placed in position. After bonding of laminates, the test specimens were kept for atmosphere curing for 7 days. During this period the specimens should not be disturbed and the environment should be free from moisture.

Figure 5 Surface preparation

4.3.2. Testing procedure

The beams were tested for static test under two point loading. For this purpose the beams were loaded with simply supported boundary condition subjected to two equal point loads, each at the one-third span as this gives constant BM and shear force between loads. The beams were kept on the loading frame. The beams were instrumented with a Linear Variable Differential Transducer (LVDT) at midspan (LVDT range 0-100 mm) to monitor deflection on right and left using range of LVDT 0-75 mm on either side to monitor deflection. The load was applied using a 50 tones capacity hydraulic jack and it was measured using 50 tones proving ring with L.C of 0.002, 0.2 mm. Demec gauge pellets were pasted at the topmost compression fiber and axis of steel i.e., tension zone where the middle third zone of beam. Demec gauge pellets were pasted at the shear span of 1/3rd zone of beam. The load was given as a increments of 0.25T at each stage of loading the deflection were measured using LVDT, crack width were measured using crack detection microscope and strains were measured using strain indicator and were recorded. The following are the measurements were taken while the testing of beam specimens for each load increments: Initial cracking load; Ultimate load; Deflection; Crack width; Strain measurements using Demec gauge.

4.3.3. Overall performance of corrosion damaged and rehabilitated beams

The cracking patterns of the perfect and retrofitted beams after testing are shown in the following Fig.6. Similarly load-deflection and moment-curvature curve for control, corrosion control, and retrofitted beams were shown in the following (Fig.7-12). Also typical characteristics of the beam response to loading are summarized in Table 2.

Table 2 Test results

Beam code	Initial load (KN)	Ultimate load (KN)	Initial central deflection (mm)	Ultimate central deflection (mm)	Initial crack width (mm)	Ultimate crack width (mm)
PB-1	12.50	47.50	0.17	35.00	0.04	0.40
PB-2	20.00	50.00	0.28	36.00	0.06	0.50
CB-1	10.00	42.50	0.40	57.00	0.10	0.60
CB-2	15.00	40.00	0.85	60.00	0.08	0.80
CR-1	32.50	65.00	0.20	18.95	0.02	0.30
CR-2	36.00	70.00	0.42	19.95	0.04	0.42
CR-3	38.50	72.50	0.10	17.25	0.02	0.20
CR-4	40.00	75.00	0.21	19.55	0.02	0.22

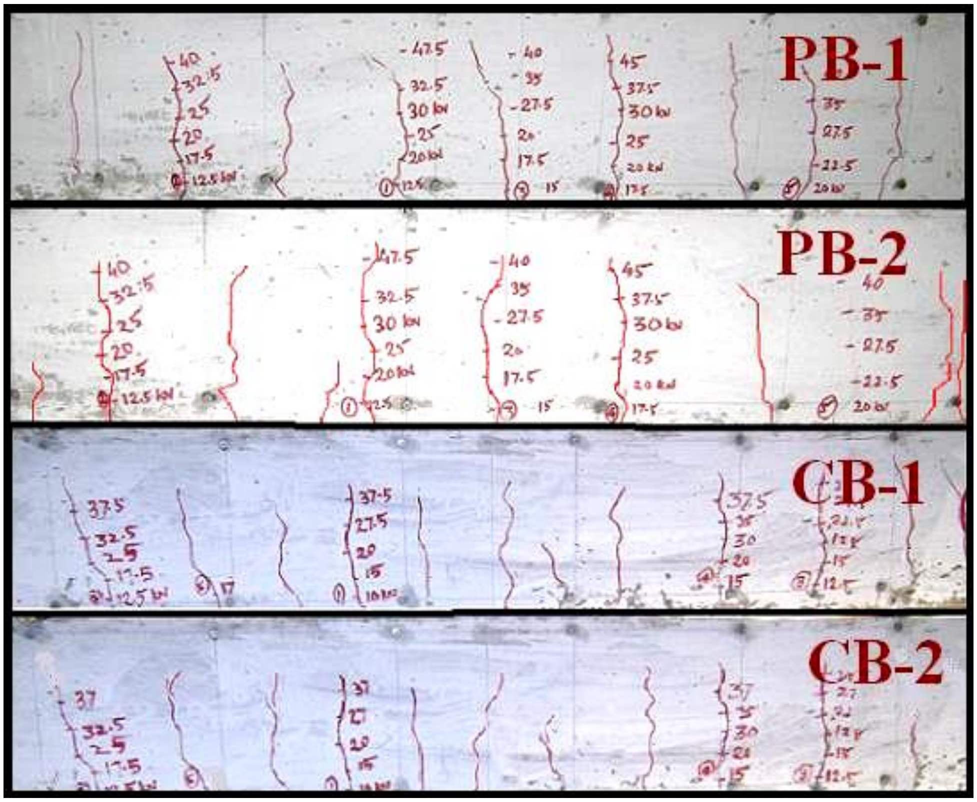
It was confirmed from test results (Table 2) that, there were to be an increase of initial load (37.50%) as well as ultimate load (5%) carrying capacity, initial central deflection (39.28%), ultimate central deflection (2.78%), initial crack width (33.33%), and ultimate crack width (20%) in case of perfect beam(PB-2) as when compared to that of perfect beam (PB-1). As a consequence of accelerated corrosion in case of corrosion control beams (CB-1& CB-2), it was revealed that there were to be an increase in initial load (33.33%) as well as little bit decrease in ultimate load (5.88%) carrying capacity, but more pronounced initial central deflection (52.94%) with not too much variation in ultimate central deflection (5%) as well as decrease in initial crack width (80%), and more predominant increase in ultimate crack width (25%) for the case of corrosion control beam(CB-2) as when compared to that of corrosion control beam (CB-1). Also with reference to corrosion (2 layer) rehabilitated beams (CR-1 & CR-2), it was observed from pilot program that there were to be an increase of initial load (9.72%) as well as ultimate load (7.14%) carrying capacity, initial central deflection (52.38%), ultimate central deflection (5.01%), initial crack width (50%), and ultimate crack width (28.57%) in case of corrosion rehabilitated beam(CR-2) as when compared to that of corrosion rehabilitated beam (CR-1). Similarly in case of corrosion (3 layer) rehabilitated beams (CR-3 & CR-4), it was inferred that there were to be an increase of initial load (3.75%) as well as ultimate load (3.33%) carrying capacity, initial central deflection (52.38%), ultimate central deflection (11.76%), initial crack width (0%), and ultimate crack width (9.10%) in case of corrosion rehabilitated beam(CR-4) as when compared to that of corrosion rehabilitated beam (CR-3). Also for the assessment of variation in various parameters such as initial load and ultimate load carrying capacity, initial central deflection, ultimate deflection, initial crack width, and ultimate crack width was analyzed by comparing sets of beams such as (CR-3-4-CR-1-2), (CR-3-4-CB-1-2), (CR-3-4-PB-1-2), (CR-1-2-CB-1-2), (CR-1-2-PB-1-2), and (PB-1-2-CB-1-2). Thus the over all interpreted test results are given in Table 3.

Table 3 Interpretation of test results

Beam code	Initial load, (KN) % increase	Ultimate load, (KN) % increase	Initial central deflection, (mm) % decrease	Ultimate central deflection, (mm) % decrease	Initial crack width, (mm) % decrease	Ultimate crack width, (mm) % decrease
(CR-3-4) (CR-1-2)	12.73	08.47	51.61	94.60	66.67	58.33
(CR-3-4) (CB-1-2)	68.15	44.06	36.50	31.45	22.22	53.84
(CR-3-4) (PB-1-2)	58.59	33.89	66.67	51.83	40.00	46.67
(CR-1-2) (CB-1-2)	63.50	38.89	49.20	33.24	33.33	51.42

(CR-1-2) (PB-1-2)	52.55	27.78	30.80	54.79	60.00	80.00
(PB-1-2) (CB-1-2)	23.07	15.38	36.50	60.68	55.55	64.28

Thus it was confirmed from interpreted test results (Table 3) that, there were to be an increase of initial load (12.73%, 68.15%, & 58.59%), ultimate load (08.47%, 44.06%, & 33.89%) with a reduction in initial central defection (51.61%, 36.50%, & 66.67%), ultimate central deflection (94.60%, 31.45%, & 51.83%), initial crack width (66.67%, 22.22%, & 40%), and ultimate crack width (58.33%, 53.84%, & 46.67%) for in case of beams(CR-3-4) as when compared to that of beams (CR-1-2), (CB-1-2), and (PB-1-2). Similarly there were to be an increase of initial load (63.50%, & 52.55%), ultimate load (38.89%, & 27.78%) with a reduction in initial central defection (49.20%, & 30.80%), ultimate central deflection (33.24%, & 54.79%), initial crack width (33.33%, & 60%), and ultimate crack width (51.42%, & 80%) for in case of beams (CR-1-2) as when compared to that of beams (CB-1-2), and (PB-1-2). Also there were to be an increase of initial load (23.07%), ultimate load (15.38%), and with a reduction in initial central defection (36.50%), ultimate central deflection (60.68%), initial crack width (55.55%) as well as ultimate crack width (64.28%) for in case of beams (PB-1-2) as when compared to that of beams (CB-1-2). Also tests conducted in the current study demonstrated that corrosion induced damage affect the ultimate load carrying capacity (44.06%), central deflection (31.45%), and crack width (53.84%) of fibro-ferrocement laminate externally reinforced flexural members for in case of beams (CR-3-4-CB-1-2) as when compared to that of beams (CR-1-2-CB-1-2). This may be due to extent of corrosion damage. Which in turn once a beam is loaded, the concrete cover starts to play an important role in transferring stresses from the RC member to the fibro-ferrocement laminate. The efficiency of this stress transfer depends on the integrity of the concrete cover. Since corrosion of the steel reinforcement results in deterioration of the concrete cover, it is expected that the efficiency of fibro-ferrocement laminate external reinforcement of corrosion damaged RC member would depend on the extent of corrosion damage with proper maintenance of voltage. In addition to that the observed failure mechanisms suggest the efficiency of fibro-ferrocement laminate external reinforcement can be improved in the following three ways such as first by suppressing the opening of faulting cracks; second, by delaying the opening and propagation of splitting cracks; third by stabilizing the propagation of debonding cracks between the fibro-ferrocement laminate and concrete.



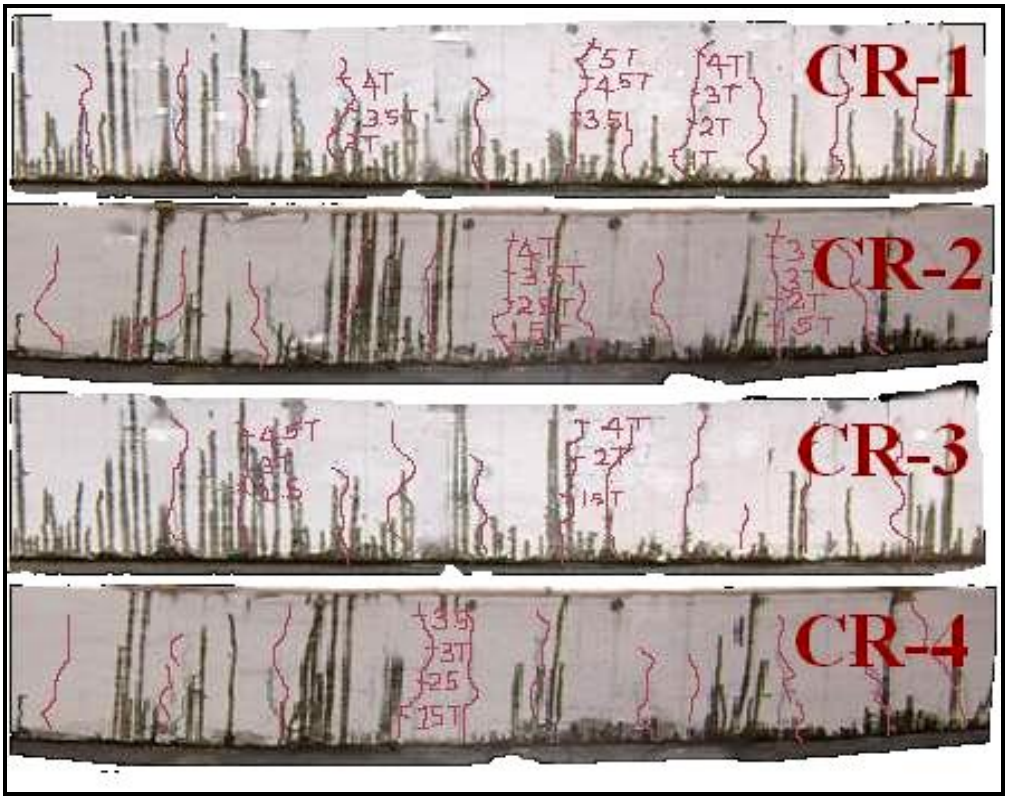


Figure 6 Crack pattern of perfect and corrosion control beams

Also as seen from the moment-curvature graph (Fig.8), it's confirmed that there were to be an increasing trend in moment-curvature value in case of rehabilitated beam (CR-1-2 or CR-3-4) with about 32.42% and 50% as when compared to reference (PB-1-2) as well as corrosion control beam (CB-1-2). But when compared to beam (CR-1-2), there were to be slight incremental tendency in moment-curvature value (7.42%) in case of beam (CR-3-4). Thus the performance of ferrocement laminated beams was excellently impressive even in the ultimate stages with an increase in the ultimate load up to maximum value over the reference, corrosion control beam (Fig.7). In turn among all the ferrocement laminated beams (CR-1-2 or CR-3-4), the performance of beam (CR-3-4) which was strengthened for flexure was excellent. Also ultimate crack width and central deflection in the constant bending moment zone were reduced after strengthening beams with ferrocement laminates on tension side as when compared to that of reference beam PB-1-2). Also the predictions which were made through finite element modeling technique (ANSYS) had shown (Fig.9-12) a good correlation with the actual experimental results as in case of reference (PB-1-2), corrosion control (CB-1-2), and rehabilitated beam (CR-1-2 or CR-3-4).

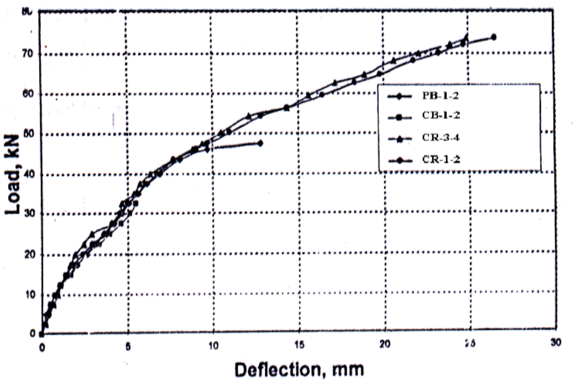


Fig.7 Comparison of load – deflection curve

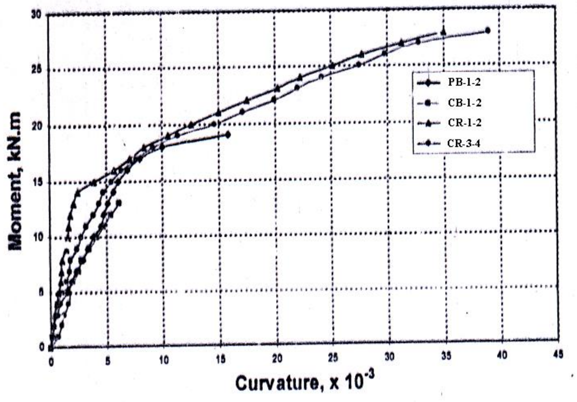


Fig.8 Comparison of Moment - curvature curve

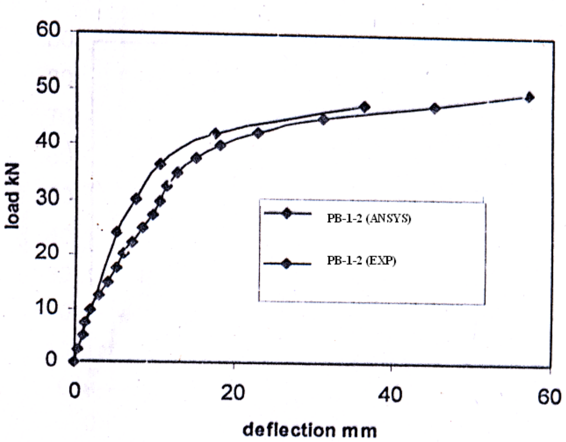


Fig.9 Comparison of ANSYS & Experimental Load – deflection curve

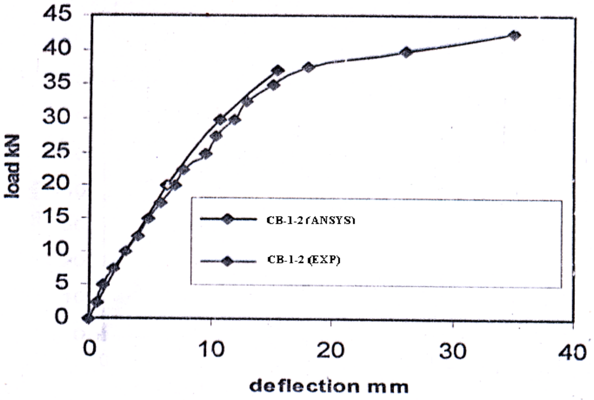


Fig.10 Comparison of ANSYS & Experimental Load – deflection curve

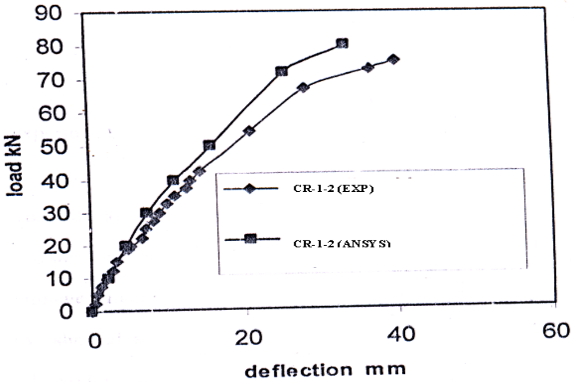


Fig.11 Comparison of ANSYS & Experimental Load– deflection curve

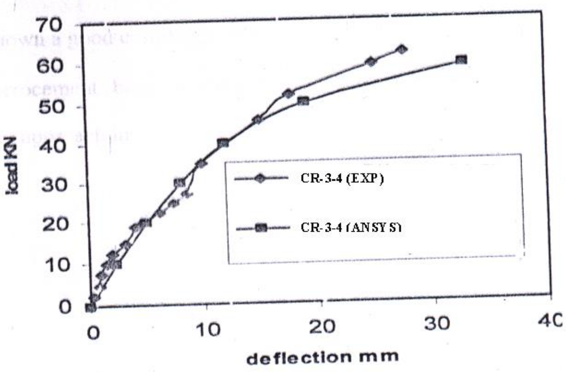


Fig.12 Comparison of ANSYS & Experimental Load– deflection curve

5. REQUIRED RESEARCH

The analysis of the research studies performed on strengthening for flexural with externally applied Fibro-ferrrocement laminate revealed numerous gaps that need to be addressed. Following are the most salient ones:

1) The experimental and analytical investigations are required to link the flexural contribution of fibro-ferrocement laminate with the load condition by considering both the longitudinal steel reinforcement ratio and the concrete strength as parameters.
2) The flexural strengthening effectiveness of fibro-ferrocement laminate has to be addressed in cases of short and very short shear spans in which arch action controls failure.
3) The interaction between the contribution of external fibro-ferrocement laminate and internal steel shear reinforcement has to be investigated.
4) To optimize design algorithms, additional specimens need to be tested with different volume fraction of reinforcement for fibro-ferrocement laminate configurations in order to create a large database of information.
5) The research into durability related aspects of fibro-ferrocement laminate strengthening and repair is a relatively new field, and the information currently available is consequently rather limited. There is thus clear need for more data on the effects of various environments such as (wet-dry, marine, freeze-thaw, UV), temperature, and loading conditions on both the properties of fibro-ferrocement laminate material systems used in infrastructure rehabilitation as well as on the differences in behaviour due to changes in resin, and fibre type with their percentage replacement amount is required.
6) Another topic to be further investigated is the effects of the state of damage and degree of damage in a structure at the time of fibro-ferrocement laminate repair on the long term performance of the retrofit.

6. CONCLUSION

1) Thus it was confirmed from interpreted test results that, there were to be an increase of initial load (12.73%, 68.15%, & 58.59%), ultimate load (08.47%, 44.06%, & 33.89%) with a reduction in initial central defection (51.61%, 36.50%, & 66.67%), ultimate central deflection (94.60%, 31.45%, & 51.83%), initial crack width (66.67%, 22.22%, & 40%), and ultimate crack width (58.33%, 53.84%, & 46.67%) for in case of beams(CR-3-4) as when compared to that of beams (CR-1-2), (CB-1-2), and (PB-1-2).
2) Similarly there were to be an increase of initial load (63.50%, & 52.55%), ultimate load (38.89%, & 27.78%) with a reduction in initial central defection (49.20%, & 30.80%), ultimate central deflection (33.24%, & 54.79%), initial crack width (33.33%, & 60%), and ultimate crack width (51.42%, & 80%) for in case of beams (CR-1-2) as when compared to that of beams (CB-1-2), and (PB-1-2).
3) There were to be an increase of initial load (23.07%), ultimate load (15.38%) with a reduction in initial central defection (36.50%), ultimate central deflection (60.68%), initial crack width (55.55%) as well as ultimate crack width (64.28%) for in case of beams (PB-1-2) as when compared to that of beams (CB-1-2).
4) Also tests conducted in the current study demonstrated that corrosion induced damage affect the ultimate load carrying capacity (44.06%), central deflection (31.45%), and crack width (53.84%) of fibro-ferrocement laminate externally reinforced flexural members for in case of beams (CR-3-4-CB-1-2) as when compared to that of beams (CR-1-2-CB-1-2) with a ultimate load of (38.89%), central deflection (33.24%), and ultimate crack width (51.42%) which in turn this may be due to extent of corrosion damage.
5) In addition to that from the moment-curvature analyses, it's confirmed that there were to be an increasing trend in moment-curvature value in case of rehabilitated beam (CR-1-2 or CR-3-4) with about 32.42% and 50% as when compared to reference (PB-1-2) as well as corrosion control beam (CB-1-2). But when compared to beam (CR-1-2), there were to be slight incremental tendency in moment-curvature value (7.42%) in case of beam (CR-3-4).
6) The tensile strength of the ferrocement laminates increases which in turn able to achieve increased ultimate load carrying capacity of beams with reduction in ultimate deflection capacity as well as reduced crack width due to addition of steel fibres.
7) The predictions made through finite element modeling (ANSYS) technique have shown a good correlation with the experimental results.
8) The ferrocement base rehabilitation technique has proved to be a most efficient approach in terms of cost and performance.

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