# STUDY ON STRENGTHENING OF CORROSION DAMAGED RCC BEAM BY FERROCEMENT

**Mithun. K[1], Akshay. J[2], Inchara. K.P[3]**

[1]*Assistant Professor, Dept. of Civil Engineering, KIT, Karnataka, India*
[1]*Assistant Professor, Dept. of Civil Engineering, KIT, Karnataka, India*
[1]*Assistant Professor, Dept. of Civil Engineering, KIT, Karnataka, India*

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**Abstract -** *Reinforced concrete structures are important elements of infrastructure and buildings, now many buildings are found to be distressed or damaged. Replacement of such deteriorated structure takes plenty of money and time, strengthening by ferrocement has become an acceptable way of improving the performance of the structures and extending their service with less cost and time.*

*In this experimental study, ferrocement (with connectors) were used to externally strengthen reinforced concrete beam. This work present result of 10 beams strengthened with using ferrocement. The result of this experimental work pointed out a general improvement in terms of load carrying capacity and deflection for the strengthened beam.*

*From the study it is seen that increasing volume fraction contributes to strengthening in increasing order and also the beam retrofitted by 2 layer mesh at orientation of 45 degree with connectors reinforced ferrocement are the most efficient than 1 layer and 2 layer mesh at orientation of 45 degree with connectors reinforced ferrocement. Therefore we can strengthen the corrosion damaged RCC beam in terms of its cracking load and failure load as well as cracking deflection and failure deflection.*

***Key Words***: *Control beam with normal steel (CB- NS), Control beam with corrosion steel(CB- CS), Ordinary Portland Cement(OPC), High Performance Ferrocement Laminate(HPFL), Reinforced Cement Concrete(RCC).*

## 1. INTRODUCTION

Reinforced concrete structures are important elements of infrastructure and buildings. Now a day's building are found to be distressed or damaged. Such a building requires immediate attention and need of strengthening, retrofitting to bring them back to their functional use again. Today deteriorations of RC structures are one of the major problems in civil industry as large number of building are constructed according to older design course. Since replacement of such deteriorated structure takes plenty of money and time, strengthening has become an acceptable way of improving the performance of the structures and extending their service. Many modern techniques are involved in proper effective strengthening and retrofitting methods. In this project we have studied on strengthening of corrosion damaged RCC beam by "FERROCEMENT".

### 1.1 Ferrocement

Ferrocement is a composite material consisting of rich cement mortar matrix uniformly reinforced with one or more layers of very thin wire mesh with or without supporting skeletal steel.

The thickness of ferrocement elements normally ranges from 10mm to 40mm whereas in reinforced concrete elements the minimum thickness used for shell or plate element is around 75mm. Low self-weight and high tensile strength make ferrocement a favourable material for fabrication.

## 2. MATERIALS AND METHODOLOGY

### 2.1 Materials

**Cement -** OPC 53 grade cement from a single lot is used for the study.
**Water -** Fresh and clean water is used for casting and curing the specimens. The water is relatively free from organic matter, silt, oil, sugar, chloride and acidic material as per requirements of Indian standard.
**Fine aggregate -** Locally available sand is used as fine aggregate in the concrete mix and cement mortar.
**Coarse aggregate -** Crushed stone aggregate of 20mm nominal size.
**Steel -** TMT steel of grade Fe-500 of 10mm diameter was used as main reinforcement and nominal reinforcement, 8mm bars are used as stirrups.
**Mesh -** Welded steel wire mesh of 1.286mm diameter with square grids was used in ferrocement jacket. The grid size of mesh was 16mm x 16mm.
**Connector -** Connectors made by binding wire in two threads, binding wire of 20 gauge annealed wire conforming to IS 280. It shall be free from rust, oil, paint, grease, loose mill scale or any type. It shall be free from corrosion and abrasion.

### 2.2 Methodology

#### 2.2.1 Casting of composite beams

The casting of beams is done in a single stage. The beams are casted in a mould of size 100 x 150 x 700mm. First of all the entire beam mould is oiled. Spacers of size 35 mm are used to provide uniform cover to the reinforcement. When the bars have been placed in position as per the design, concrete mix is poured in the mould and compactions are given with the help of tamping rod. The compaction is done until the mould is completely filled and there is no gap left. The beams are then removed from the mould after 24 hours. After demoulding the beams are cured for 28 days using curing tank.

**Fig – 1:** Casting of composite beam

### 2.2.2 Retrofitting (jacketing) of beams

The beams were casted with corrosion steel and then retrofitted by applying steel wire mesh at an orientation of 45 degree with connectors as shown in fig.2 to fig.4. and then plastering it with cement mortar up to the thickness of 15-20mm for all six beams. Effect of 1, 2, and 3 layer mesh at an orientation of 45 degree reinforced ferrocement with connectors has been studied to see their effect on the strength of retrofitted beams, placing it over the three surfaces of beam.

**Fig – 2:** Beam with connectors

**Fig - 3:** Application of mesh at 45 degree orientation with connectors for jacketing

**Fig – 4:** Application of mortar for jacketing

### 2.2.3 Flexural test on beam

All beam specimens were instrumented and loaded simply supported as shown in fig.4.8. The load was applied through UTM machine. All beams were tested under two point loading. They were statically tested to failure at equal 2.5 KN increment of load. During loading deflection at 284 mm from two supports was measured by using dial gauge (0.01mm), distance between two supports is 600mm. Beam edge to support distance is 50mm. First crack load and deflection were also recorded for each stage.

**Fig – 5:** Universal Testing Machine with flexural test setup

## 3. RESULTS AND DISCUSSION

### 3.1 Control beam with normal steel

**Table -1:** Control beam with normal steel

| LOAD (KN) | DEFLECTION (mm) | LOAD (KN) | DEFLECTION (mm) |
|---|---|---|---|
| 2.5 | 0.02 | 27.5 | 0.35 |
| 5 | 0.04 | 30 | 0.49 |
| 7.5 | 0.06 | 32.5 | 0.63 |
| 10 | 0.08 | 35 | 0.71 |
| 12.5 | 0.10 | 37.5 | 0.82 |
| 15 | 0.12 | 40 | 0.98 |
| 17.5 | 0.14 | 42.5 | 1.29 |
| 20 | 0.16 | 44.5 | 1.54 |
| 22.5 | 0.18 | 44.5 | 12.00 |
| 25 | 0.20 | | |

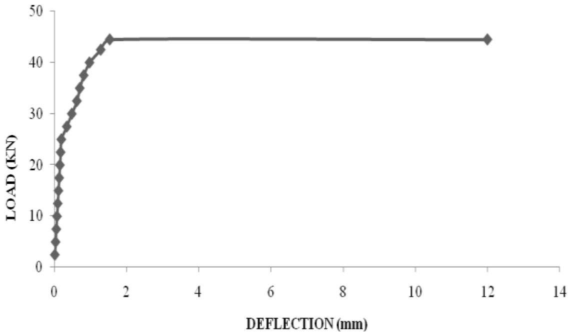


**Chart -1**: Load v/s Deflection curve for Control beam with normal steel

**Fig -6**: Cracking pattern of Control beam with normal steel

### 3.2 Control beam with corrosion steel

**Table -2:** Control beam with corrosion steel

| LOAD (KN) | DEFLECTION (mm) | LOAD (KN) | DEFLECTION (mm) |
|---|---|---|---|
| 2.5 | 0.21 | 22.5 | 1.42 |
| 5 | 0.38 | 25 | 1.64 |
| 7.5 | 0.56 | 27.5 | 1.88 |
| 10 | 0.77 | 30 | 2.50 |
| 12.5 | 0.90 | 32.5 | 2.76 |
| 15 | 1.08 | 35 | 3.02 |
| 17.5 | 1.22 | 37 | 3.23 |
| 20 | 1.33 | 37 | 12 |

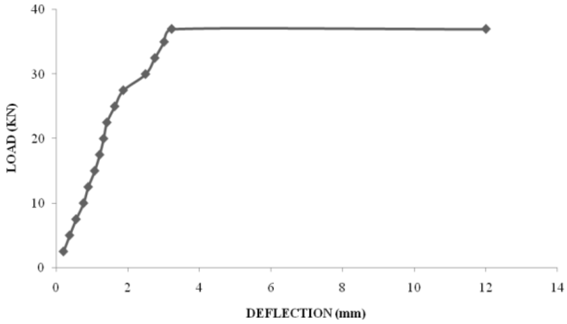


**Chart -2**: Load v/s Deflection curve for Control beam with corrosion steel

**Fig -7**: Cracking pattern of Control beam with corrosion steel

### 3.3 Jacketed beam by 1 layer mesh at orientation of 45 degree ferrocement with connectors

**Table -3:** Jacketed beam by 1 layer mesh at orientation of 45 degree reinforced ferrocement with connectors

| LOAD (KN) | DEFLECTION (mm) | LOAD (KN) | DEFLECTION (mm) |
|---|---|---|---|
| 2.5 | 0.7 | 37.5 | 3.45 |
| 5 | 0.94 | 40 | 3.45 |
| 7.5 | 1.09 | 42.5 | 3.75 |
| 10 | 1.20 | 45 | 3.9 |
| 12.5 | 1.30 | 47.5 | 4.03 |

| | | | |
|---|---|---|---|
| 15 | 1.41 | 50 | 4.17 |
| 17.5 | 1.49 | 52.5 | 4.30 |
| 20 | 1.55 | 55 | 4.43 |
| 22.5 | 1.74 | 57.5 | 4.86 |
| 25 | 2.26 | 60 | 5.37 |
| 27.5 | 2.77 | 62.5 | 5.87 |
| 30 | 3.12 | 65 | 6.38 |
| 32.5 | 3.23 | 65 | 6.38 |
| 35 | 3.33 | | |

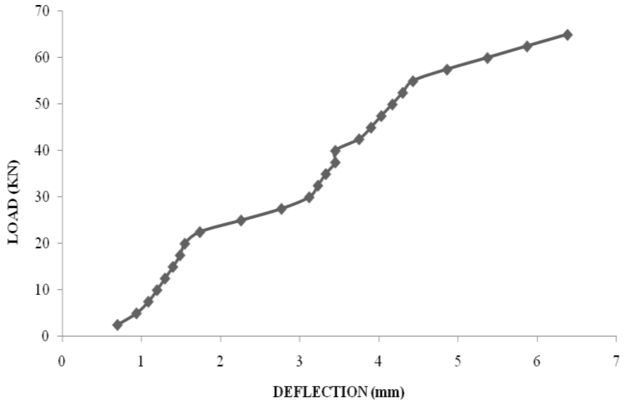


**Chart -3**: Load v/s Deflection curve for jacketed beam by 1 layer mesh at orientation of 45 degree reinforced ferrocement with connectors

**Fig -8**: Cracking pattern of jacketed beam by 1 layer mesh at orientation of 45 degree reinforced ferrocement with connectors

### 3.4 Jacketed beam by 2 layer mesh at orientation of 45 degree reinforced ferrocement with connectors

**Table -4:** Jacketed beam by 2 layer mesh at orientation of 45 degree reinforced ferrocement with connectors

| LOAD (KN) | DEFLECTION (mm) | LOAD (KN) | DEFLECTION (mm) | LOAD (KN) | DEFLECTION (mm) |
|---|---|---|---|---|---|
| 2.5 | 0.47 | 32.5 | 2.02 | 62.5 | 3.40 |
| 5 | 0.70 | 35 | 2.17 | 65 | 3.95 |
| 7.5 | 0.92 | 37.5 | 2.28 | 67.5 | 4.11 |
| 10 | 1.04 | 40 | 2.44 | 70 | 4.25 |
| 12.5 | 1.14 | 42.5 | 2.55 | 72.5 | 4.46 |
| 15 | 1.27 | 45 | 2.66 | 75 | 4.60 |
| 17.5 | 1.37 | 47.5 | 2.78 | 77.5 | 5.15 |
| 20 | 1.46 | 50 | 2.9 | 80 | 5.37 |
| 22.5 | 1.56 | 52.5 | 3.02 | 82.5 | 5.71 |
| 25 | 1.67 | 55 | 3.13 | 85 | 6.26 |
| 27.5 | 1.77 | 57.5 | 3.23 | 87.5 | 7.15 |
| 30 | 1.88 | 60 | 3.32 | | |

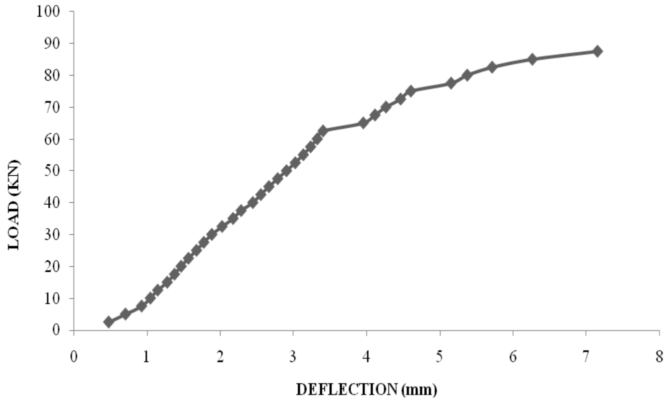


**Chart -4**: Load v/s Deflection curve for jacketed beam by 2 layer mesh at orientation of 45 degree reinforced ferrocement with connectors

**Fig -9**: Cracking pattern of jacketed beam by 2 layer mesh at orientation of 45 degree reinforced ferrocement with connectors

### 3.5 Jacketed beam by 3 layer mesh at orientation of 45 degree reinforced ferrocement with connectors

**Table -5:** Jacketed beam by 3 layer mesh at orientation of 45 degree reinforced ferrocement with connectors

| LOAD (KN) | DEFLECTION (mm) | LOAD (KN) | DEFLECTION (mm) | LOAD (KN) | DEFLECTION (mm) |
|---|---|---|---|---|---|
| 2.5 | 0.44 | 35 | 2.42 | 67.5 | 4.03 |
| 5 | 0.81 | 37.5 | 2.58 | 70 | 4.21 |
| 7.5 | 0.94 | 40 | 2.68 | 72.5 | 4.36 |
| 10 | 1.08 | 42.5 | 2.79 | 75 | 4.56 |
| 12.5 | 1.22 | 45 | 2.91 | 77.5 | 4.85 |
| 15 | 1.42 | 47.5 | 3.06 | 80 | 5.13 |
| 17.5 | 1.54 | 50 | 3.17 | 82.5 | 5.83 |
| 20 | 1.67 | 52.5 | 3.31 | 85 | 6.00 |
| 22.5 | 1.75 | 55 | 3.40 | 87.5 | 6.21 |
| 25 | 1.91 | 57.5 | 3.57 | 90 | 6.54 |
| 27.5 | 2.05 | 60 | 3.69 | 92.5 | 7.82 |
| 30 | 2.15 | 62.5 | 3.80 | 92.5 | 12 |
| 32.5 | 2.31 | 65 | 3.90 | 32.5 | 2.31 |

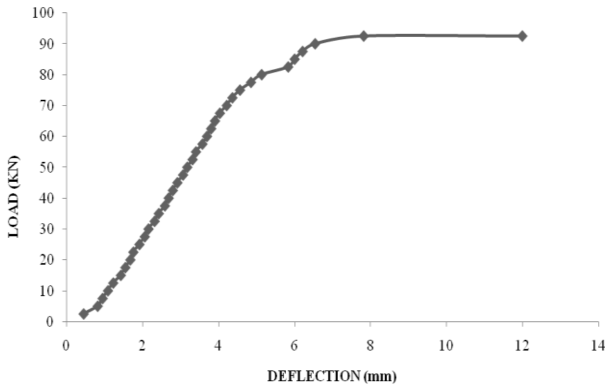


**Chart -5**: Load v/s Deflection curve for jacketed beam by 3 layer mesh at orientation of 45 degree reinforced ferrocement with connectors

**Fig -10**: Cracking pattern of jacketed beam by 3 layer mesh at orientation of 45 degree reinforced ferrocement with connectors

## 4. CONCLUSIONS

- The failure of composite beam is characterized by development of cracks over the tension zone. The spacing of cracks is reduced for beams retrofitted by ferrocement with wire mesh at $45^0$ orientations(with connectors) for different volume fraction increases in increasing order indicating better distribution of stress.
- Retrofitted beam corresponding to 3 layer mesh reinforcement has the highest cracking load and failure load as compared to other specimen with 1 or 2 layer mesh reinforcement depicting that increasing volume fraction contributes to strengthening in increasing order.
- The beam retrofitted by 2 layer mesh reinforced ferrocement are the most efficient than others as its strength to cost ratio is the highest i.e. 1.1 as compared to the other two retrofitted beam for which the value is 0.65 and 1.04 for 1 layer mesh reinforced ferrocement and 3 layer mesh reinforced ferrocement, respectively.
- Volume fraction of mesh in ferrocement for jacketing depends on the amount of strength and stiffness reduced due to corrosion and also stage (Position) of corrosion in RC beam.
- Ferrocement can strengthen the corrosion damaged RCC beam in terms of its cracking load and failure load as well as cracking deflection and failure deflection.
- This method is simple to understand and apply, and therefore, may be utilized in non-engineered rural construction and could achieve maximum results.

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