Behaviour of Strengthened RC Beams in Shear

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Abstract

Since last few years, the demand of strengthening is going on increasing due to variety of reasons. The various reasons for deterioration of structural members include change in loading condition, improper design or execution, change of functionality of building etc. Construction of new structure post demolishing old one will not only be uneconomical but also it might have adverse effect on the adjoining structures. Thus, it is not advisable. Rather it is better to enhance the load bearing capacity of the present deteriorating structure. Beams are the most important members of any structure. They are designed for flexure and checked for shear. However, the flexural failure of beam is preferred against the shear failure which leads to catastrophic failure. Various materials are now available in the market for strengthening of RC Beams. A study has been carried out wherein 5 beams were casted of 2000 mm length, 200 mm width & 270 mm depth followed by testing after strengthening. In the current experiment, materials used for strengthening are weaved mesh and welded mesh, using mechanism of Ferro-cement & Micro-Concrete. Further loads and deflections were measured and the results show improvement in load carrying capacity of strengthened beam as compared to non-strengthened beam.

Introduction:

The main aim of the designing of any structure is that it should serve for the period it has been designed to serve. But before the design period is over the structure needs maintenance due to reasons like change in loading conditions, functional change, damages due to earthquakes etc. The structure constructed during ancient time and which are still existing demand more repair. However, some of the new structures also show the sign of deterioration. Various mechanism are available in the market for strengthening of RC beams like Ferro Cement, Micro-Concrete, external plate bonding, shotcreting, sprayed concrete etc.

Method of sprayed concrete can be used where the dimension increment is not a problem. Also, it is not cost effective and consumes more time. Strengthening using steel plate with epoxy is also a better alternative but not in common practice due to problem of corrosion and being uneconomic. Jacketing is used widely but the main disadvantage of this method is that it increases the original dimensions and thus weight of the structure.

Ferro cement was 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 mesh"[1]. Literature shows that lots of research has been done to study the effect of ferrocement technique on different structural members. Ferrocement technique improves the load barring capacity of concrete and can also use as jacket in reinforced concrete columns [2–4]. Nassif[5] conclude that by adding a thin layer of ferrocement to a concrete it enhances its ductility as well as its cracking strength. All these studies showed that ferrocement technique provide strengthen and crack resistance concrete which is better than other concrete construction [6]. Further to expand the use of ferrocement, the present study was carried out to investigate the behavior of the reinforced concrete beam strengthened with ferrocement technique using waved and welded wire mesh.

Micro-Concrete is ready to use single componentdry powder cementitious material. It is supplied as a preblended polymer modified dry powder the addition ofrecommended water at the site to produce a non-shrinkfree flowing high strength micro concrete. This isspecially designed for repair to damaged reinforcedconcrete. It is suitable for use in wide range of repairs,pavements, ramps etc.It is mainly recommended for the repair of damagedconcrete structures: columns beams, slabs etc. it is alsorecommended for grouting of large gaps. [7]

Problem Formulation

The experimental programme carried out for this research work consist of total five reinforced concrete beams with a size of 2000 x 200 x 270 mm. Nomenclature of all the tested beam is describe in Table 1. Beam section (2000 x 200 x 270 mm) was design such that it fails in shear only. It comprised of 5 bars of 12 mm diameter Fe-415 as tension steel and 2 anchor bars of 10 mm diameter. 6 mm 2-legged MS stirrups (150 mm x 220 mm out to out) at a spacing of 300 mm center to center distance were used as shear reinforcement. All the beams were casted in mould of size 2000 mm x 200 mm x 270 mm (in to in Dimensions). The moulds were fabricated from MS sheets of 4 mm thickness.

Table 1Nomenclature of Beams

Sr. No.	Name of Specimen	Nomenclature
1.	Non-Strengthened Beam	NSB
2.	Ferrocement with welded wire mesh	SFC-Weld
3.	Ferrocement with weaved wire mesh	SFC-Weave
4.	Micro-Concrete with welded wire mesh	SMC-Weld
5.	Micro-Concrete with weaved wire mesh	SMC-Weave

Experimental Setup

A. Material Used

1. Cement

Ordinary Portland Cement of 53 Grade was used in the current experimental work. The test properties of Ordinary Portland Cement are given in Table 2.

Table 2 Properties of Cement

Sr. No.	Name of Test	Test Results
1	Standard Consistency of Cement	37.5 %
2	Initial Setting Time	28 minutes
3	Final Setting Time	47 minutes
4	Compressive strength of cement (Tested with 1:3 cement mortar with Standard Ennore Sand)	54.7 N/mm^2

2. Fine & Coarse Aggregate

For the experimental study carried out here, angular crushed coarse aggregates were used. The size of aggregate should not more than 20 mm. Crushed stone aggregate of size 20 mm and 10 mm were used as per the requirement of Indian Standards 380:1970. Properties of Coarse and fine are given in Table 3 below.

Table 3 Properties of Fine and Coarse Aggregate

Sr. No.	Name of Test	Coarse Aggregate	Fine Aggregate
1	Specific Gravity	2.87	2.604

2	Water Absorption	0.96 %	0.8 %
3	Free moisture content	0.38 %	0.4 %

3. Water

Tap water was used for experimentation as well as for curing purpose. Care has been taken for water used for mixing and curing, as it is to be clean and free from oils, salts , sugar , organic materials or other substances that may be deleterious to concrete or steel.

4. Steel

High Yield Deformed Steel Bars of 12 mm diameter of grade Fe-415were used in the all the samples of R.Cbeam as tension reinforcement, also two anchor bars of 10 mm diameter (again Fe-415 grade) were provided. 6 mm plain steel bars of grade Fe250 were used as shear reinforcementin the form of two legged closed stirrups in all the specimens at a spacing of200 mm center to center. These reinforcement barsare be tied together with the help of binding wires.

5. Ferro-Cement

The proportion for ferrocement mortar used for the current study was 1:2. Water cement ratio used for ferrocement mortar was 0.4.

6. Micro Concrete

Micro concrete consists of ratio of 1:3 Cement mortar wherein 1 part of cement is divided in to two portions (50 % Cement and 50 % Ground Granulated Blast Furnace Slag (GGBS). The remaining 3 portions of sand consists of Silica Sand (1.4 to 1 mm size). Following composition is adopted for preparing one time mix of micro-concrete M-50 Grade. Mix proportion for micro concrete is shown in Table 4.

Table 4 Mix proportion of Micro Concrete

Cement (kg)	GGBS (kg)	Silica Sand (kg)	Grit (kg)	Water (lit)
6.25	6.25	37.5	25	9 Lit

7. Wire Mesh

In the current research work welded and weaved wire mesh were used for strengthening of reinforced concrete beam for ferrocement technique as well as for micro concrete. Figure 1 shows welded and weaved Wire meshes used.

Figure 1 Welded & Weaved Wire Meshes

8. Bonding Agent

MYK MultiCrete is the acrylic emulsion based, used as a cement modifier when applied, provides good bond with masonry/ cement and thus improves the tensile and flexural strength properties of the mortar.

9. Mix proportion of concrete

Mix design of M 25 grade of concrete has been carried out as per the Indian Standard 10262:2009. Based on the results of ingredients, mix design of concrete was carried out. Water cement ratio adopted for mix design was 0.42. Mix proportion for M25 concrete used for the current study is shown in Table 5.

Table 5 Mix proportion of M25 Concrete

Cement (kg)	FA (Sand) (kg)	CA (20 mm) (kg)	CA (10 mm) (kg)	Water (kg)
340.2	962.0	692	446	167.7

10. Strengthening of Reinforced Concrete Beams

Out of five beams cast one beam was selected as Non Strengthened beam (NSB). Strengthening of the four beams were carried by using ferrocement and micro-concrete with welded and weaved wire meshes. Shear span of the beams were chipped and cleaned by washing with water. Than after shear span of beam allowed to dry before application of bonding agent as shown in Figure 2. MYK MultiCrete (a bonding agent imparting strength to bond between old and new concrete surfaces) was prepared and applied on the cleaned surface using a brush for perfect bonding with strengthening material. After this strengthening of beam was done with the help of welded/weaved wire mesh and 30 mm thick ferrocement/micro-concrete layer was applied on the soffit of the beam.Then the beams were allowed to cure for the period of 28 days.

Figure 2 Shear Span Applied with MultiCrete Layer

B. Testing of Beams

All the beams strengthened as well as non-strengthened tested in this research work were tested under two point loading system as shown in Figure 3. The effective span of beam was 1.8 m and distance between two point loads was 60 cm. The Linear Variable Differential Transformer (LVDT) with capacity of 100 mm was used to measure the deflection at the center of the beam. A 400 kN capacity double acting loading jack was used to test the all the beams. Testing of all the five beams was carried out to measure the load at first crack, ultimate load and corresponding deflections.

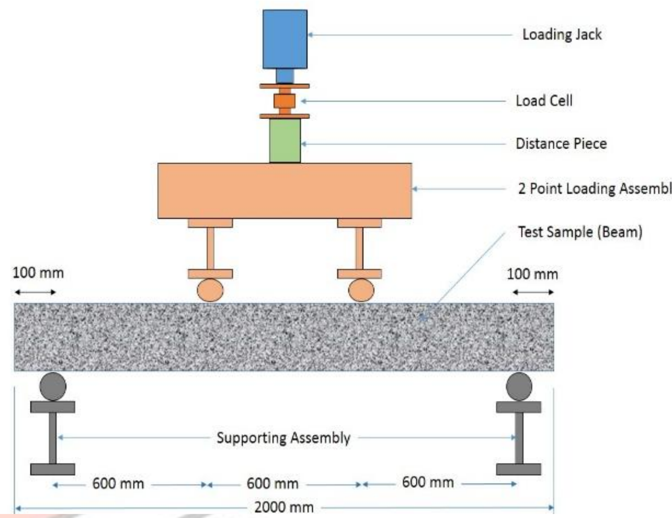

Figure 3Diagrammatic Representation ofTest Setup Assembly

Results and Discussion

All the five beam were tested under two point loading systemand load at first crack, ultimate load and their corresponding deflection was recorded.

A. <u>Ultimate Load carrying capacity</u>

The ultimate load carrying capacity of SFC-Weave and SFC-weld increases by 1.6% and 3.03% respectively as compared to Non-

Strengthened beam. In case of Micro-concrete maximum load carrying capacity of beam SMC-Weave and SMC-Weld increases by 4.62% and 14.69% respectively compared to Non-Strengthened beam. The graphical representation of the comparison is shown in the following figure.

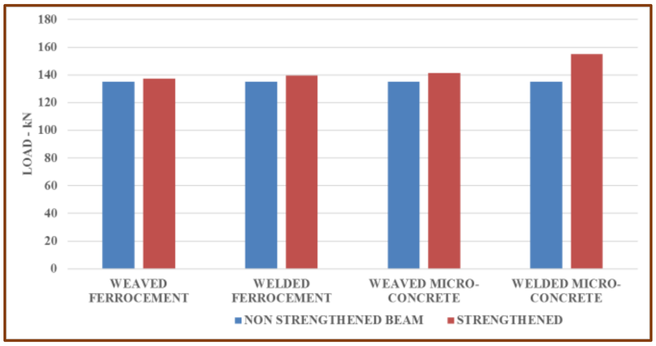

Figure 4 Comparison of Non-Strengthened Beam with Strengthened at Ultimate Load

B. First Crack Load v/s Deflection

In this current research work load at first crack and deflection at this corresponding load was also observed as shown in Figure 5.

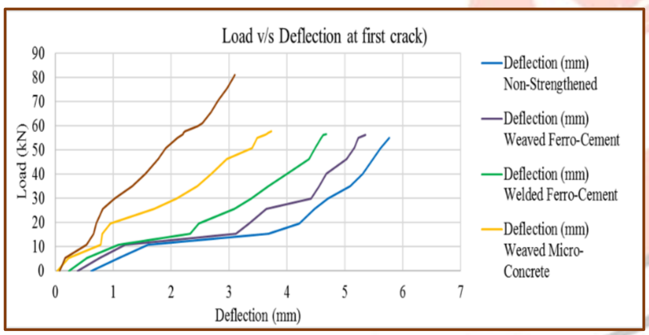

Figure 5 Load v/s Deflection at First crack

In the load v/s deflection curve for the Strengthened (SFC-Weave, SFC-Weld, SMC-Weave, SMC-Weld) beam was higher than the Non-Strengthened Beam (NSB). Load at first crack in non-strengthened beam was 55.07 kN. At this load the deflection in SFC-Weave, SFC-Weld, SMC-Weave and SMC-Weld were 5.23 mm, 4.59 mm, 3.62 mm and 2.19 mm respectively, which is less than the deflection in NSB (5.77 mm).

C. Ultimate Load v/s Deflection

In the present manuscript load v/s deflection at ultimate load was also measured as shown in Figure 6. NSB was failed at the load of 135.21 kN and deflection at ultimate load was 15.12 mm. But at this ultimate load deflection in SFC-Weave, SFC-Weld, SMC-Weave and SMC-Weld were 14.44 mm, 14.83 mm, 12.87 mm and 9.24 mm respectively. It is clearly observed that the strengthened beam give the least deflection compared to non-strengthened beam. SMC-Weld was give the least deflection of 5.88 mm compared to non-strengthened beam (15.12 mm).

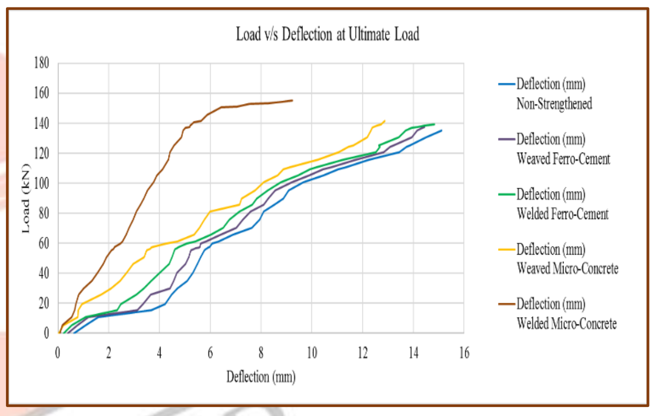

Figure 6 Load v/s Deflection at Ultimate Load

D. Failure Pattern

The non-Strengthened Beam (NSB) was failed in shear because it was designed to fail in shear only.

Figure 7 Failure Pattern of Beam

Conclusions

1. All the four mechanism adopted in the study shall be recommended since all the strengthened beams failed in flexure instead of shear.
2. The de-bonding of the strengthened part took place.
3. Strengthening of beam carried with welded wire mesh and Micro-Concrete shows the least deflection even at first crack and at ultimate load.
4. The maximum increase in the ultimate load carrying capacity of beam strengthened with Welded Mesh and Micro-concrete is found to be 14.69 %.
5. The deflection of beam strengthened with Welded Mesh and Micro-Concrete was reduced to about 38.88 % at the ultimate loading.

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