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PERFORMANCE EVALUATION OF DISTRESSED RC BEAMS REPAIRED WITH MICRO CONCRETE

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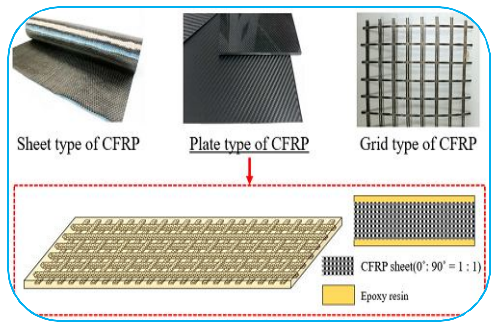
ABSTRACT

This study presents an experimental investigation into the flexural behaviour of reinforced concrete (RC) beams, including both control and retrofitted specimens. Four RC beams with dimensions of 150 mm × 230 mm and a span of 2.43 m were cast and tested. Two beams were loaded to failure and classified as distressed. These distressed beams were subsequently repaired using micro-concrete and retested alongside two control beams under two-point loading conditions. Deflections were measured at the mid-span and at one-third spans using dial gauges, while crack development, propagation, and crack width were closely monitored throughout the loading process. The comparative analysis between control and repaired beams revealed insights into the effectiveness of micro-concrete retrofitting in restoring flexural capacity and stiffness. The study highlights the potential of micro-concrete as a viable material for structural rehabilitation of distressed RC elements.



KEYWORDS: *Reinforced Concrete Beams, Flexural Behavior, Micro-Concrete Retrofitting Deflection Measurement.*

1. INTRODUCTION

Reinforced concrete (RC) structures are widely used in civil engineering due to their durability and load-bearing capacity. However, over time, these structures may experience distress or failure due to various factors such as overloading, earthquake-induced stresses, environmental degradation, and other natural calamities. Such failures can compromise the safety and serviceability of structures, necessitating timely and effective retrofitting measures to restore or enhance their performance.

Retrofitting is a crucial technique in structural engineering that involves strengthening or rehabilitating existing structures to meet current safety standards or to extend their service life. Among the various retrofitting methods available, the use of micro-concrete has gained prominence due to its superior flowability, shrinkage resistance, and ability to bond well with existing concrete surfaces. Micro-concrete is a pre-packed, flowable, non-shrink material that can be applied without the need for vibration, making it ideal for repairing inaccessible or congested areas.

In practical applications, micro-concrete has been successfully used in the rehabilitation of distressed beams, columns, and slabs, especially in seismic zones and aging infrastructure. Its ease of application and compatibility with reinforcement make it a preferred choice for restoring structural integrity without extensive demolition or reconstruction.

This paper presents an experimental investigation into the flexural behaviour of RC beams repaired using micro-concrete. The study involves a comparative analysis between control beams and distressed beams that were retrofitted and tested under two-point loading. Key parameters such as deflection, crack development, and load-carrying capacity were monitored to evaluate the effectiveness of micro-concrete retrofitting. The findings aim to contribute to the understanding of micro-concrete as a viable solution for structural rehabilitation in real-world scenarios.

2. METHODOLOGY:

2.1 Methodology

The objective of the present investigation is to study the effect of micro concreting on distressed beams. About FOUR concrete beams were casted and out of which TWO beams were considered as control beams and the other TWO beams are stressed and made to fail by applying the loads. These two distressed beams were repaired with micro concrete and finally all the four beams were tested and a comparative study is made to study the structural behavior of control beams and micro concreted beams.

2.2 Materials Testing

2.2.1 Cement

In the present investigation work Zuari cement of 53 Grade was used and the cement sample was tested as per IS 4031 and following properties were recorded,

TABLE 2-0-1 PROPERTIES OF CEMENT

Physical Properties	Study Results
Specific gravity	3.00
Standard consistency	30%
Initial setting time	30 minute
Final setting time	245 minutes
Compressive strength of cement mortar cubes at 7 days.	35.32 MPa

2.2.2 Fine aggregates

The river sand which was locally available was used in the experimental work. Various tests were conducted and the following results are the properties of fine aggregates.

TABLE 2-0-2 PROPERTIES OF FINE AGGREGATES

Properties of fine aggregates	Values
Specific gravity of sand	2.18
Fineness modulus	2.72
Bulk density of sand	15 kN/m^3
Gradation	Zone II

2.2.3 Coarse aggregates

For the present experimental work locally available crushed stone aggregates of 20mm and down size was used. The coarse aggregates were tested as per IS 2386 to study their physical properties and the results are tabulated below

TABLE 2-0-3 PROPERTIES OF COARSE AGGREGATES

Properties of Coarse aggregates	Values
Specific Gravity	2.63
Bulk density	17.10 kN/m^3
Flakiness Index	24.76%
Grain size distribution	Well graded

2.2.4 Reinforcing steel bars

To cast the reinforce concrete beams, HYSD bars of 10 mm diameter was used and test were carried out to study the properties of steel and the results are tabulated as below.

TABLE 2-0-4 PROPERTIES OF STEEL

Properties of steel	Experimental Values
Percentage of elongation	21.60%
Percentage of reduction of area	33.33%
Young's Modulus of steel	1.9825 x 10 ^{5} N/mm^2
Average Yield stress	490 N/mm^2

2.2.5 Water

Potable drinking water free from chlorides and having a PH value of 7.8 was used.

2.3 Concrete Mix Design

Indian Standard (IS) method was used to design the concrete mix to get a target mean strength of 25.94 N/mm^2. The mix proportion is as given in the table.

TABLE 2-0-5 CONCRETE MIX PROPORTION

Mix	Cement	Fine aggregates	Coarse aggregates	Water
M20	1	1.645	3.2	0.5

2.4 Structural Design details of beams

Theoretical calculations were made as per IS 456-2000, using limit state method and the following parameters were finalized for the present investigation work

Structural design details of the beam;

Effective length of beam= 2200 mm
Clear span of the beam= 2000 mm
Width of the beam= 150 mm
Overall depth of beam= 230mm
Effective depth of the beam= 200 mm
Clear cover to the reinforcement=25 mm
Area of tensile steel = 3 bars of 10 mm diameter
Area of steel provided= 235.60 mm^2
Anchor bars= 2 bars of 6 mm diameter
Shear reinforcement= 2 legged vertical stirrups of 6 mm diameter at 150 mm c/c
Grade of concrete = M20

The reinforcement details of the beam is as shown in the figure below

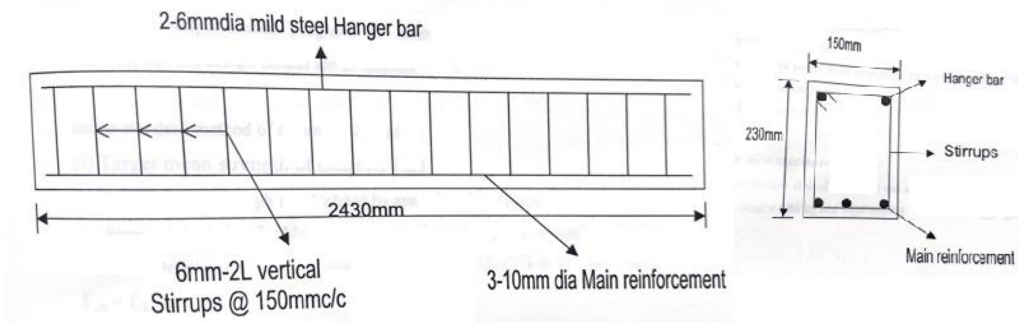


FIGURE 2-0-1 DETAILS OF THE BEAM

2.5 Casting of beams

Four reinforced concrete beams of cross section 150 mm x 230 mm and span of 2430 mm were casted.

Number of specimens:

Control beams = 2
Distressed and strengthened by micro concrete =2

Type of member:

Simply supported singly reinforced beams.

Parameters and scope of investigation:

(i) Load deflection characteristics
(ii) Cracking characteristics
(iii) Cracking and ultimate loads
(iv) Comparison and performance behavior of strengthened specimens over the control.

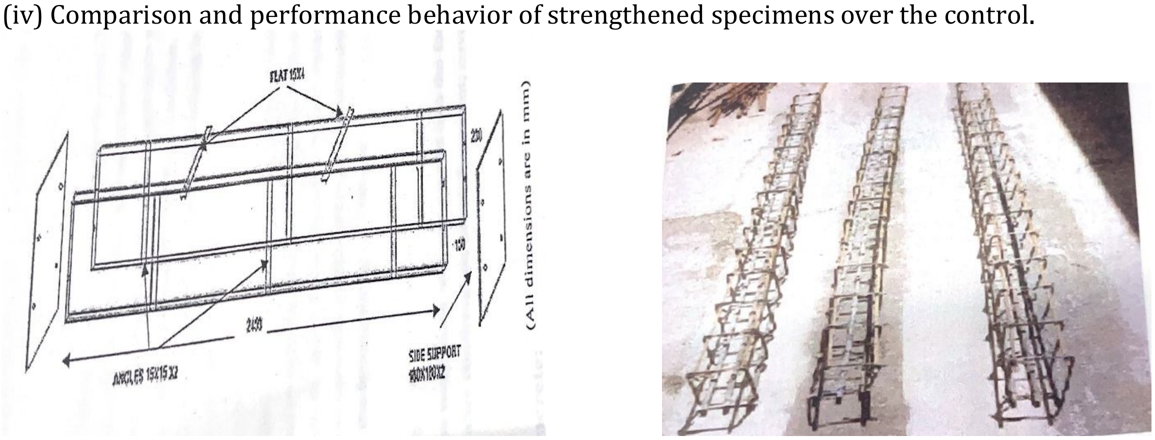


FIGURE 2-0-2 FORM WORK AND FABRICATION OF REINFORCEMENTS.

FIGURE 2-0-3 FINISHED BEAMS READY FOR TESTING

3. TEST SET-UP AND TESTING PROCEDURE

3.1 Preparation of beams prior to Testing.

The beams cast for testing are prepared through the following steps:

1. **Surface preparation** – Clean and smoothen the beam surface to remove dust, laitance, and irregularities.
2. **Filling blow holes and imperfections** – Inspect and repair defects using suitable mortar or epoxy to ensure uniformity.
3. **Coating with white primer** – Apply a thin, even coat to improve visibility of markings and provide a consistent finish.
4. **Load support points** – Mark and fix the designated points for load application to ensure accurate and uniform testing.

3.2 Test Set-up

The following figure shows the loading frame and loading system

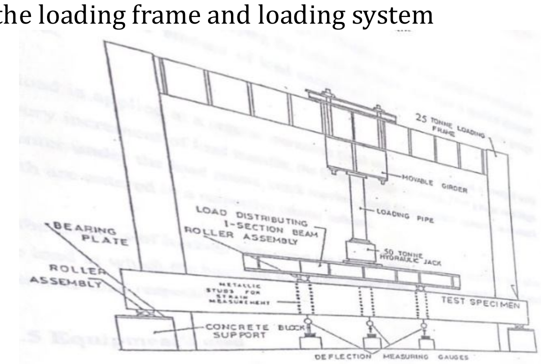


FIGURE 2-4 LOADING FRAME

3.3 Testing procedure

After the test set up, the initial readings of Demec gauge and dial readings are entered in the tabular column before applying load on the beam. The load is applied gradually through hydraulic jack, the amount of load applied can be read directly on the gauge. The load is applied slowly at a regular increment of 1 ton. At every increment of load, the Demec gauge readings and dial gauge readings at the center, left and right points are noted down. Observations are made to check the development of cracks in the beam and consequently, the position of crack, width of the crack and progress of the crack are marked on the beam and noted down.

Out of the four beams, two beams are stressed and made to fail. The failed beams are retrofitted with micro concreting. Cracks in reinforced concrete (RC) beams are repaired with micro-concreting by removing damaged material, cleaning the reinforcement, and applying a high-strength, free-flowing micro-concrete mix to restore the section and bond.

Finally the two control beams and the two stressed and strengthened beams with micro concreting are tested in the above procedure and the test results are tablulated.

4. PRESENTATION OF TEST RESULTS

The beams were tested under two-point loading. The following features were measured at every load increment.

a. Load deflection characteristics
b. Ultimate load
c. Cracking load
d. Crack widths
e. Crack spacing
f. Crack pattern and modes of failure

4.1 Test results

The overall performance of the beams under loadings and the representative samples are presented in the following tables

TABLE 4-0-1 LOAD CHARACTERISTICS

Sl. No	Beam	F_{ck} N/mm²	F_{cr} N/mm²	S_{hr} N/mm²	P_{cr} N/mm²	P_u N/mm²
1	Control-1	36.00	6.57	27.703	60	82.5
2	Control-2	35.80	6.57	27.52	60	82.5
3	Micro concrete beam -1	35.60	6.76	22.75	59	82
4	Micro concrete beam -2	34.87	6.76	23.15	59	82

TABLE 4-0-2 LOAD DEFLECTION CHARACTERISTICS AT THE CENTER OF THE BEAM

Sl.No	Beam	Cenral deflection in mm @								
		10 kN	20 kN	30 kN	40 kN	50 kN	60 kN	70 kN	80 kN	90 kN
1	Control-1	0.3	3.5	6.00	7.13	8.23	10.0	11.42	12.45	--
2	Control-2	1.07	2.8	5.6	6.88	7.81	9.50	10.91	12.33	--
3	Micro concrete beam -1	0.49	2.00	3.86	5.08	7.10	7.78	9.54	11.00	17.05
4	Micro concrete beam - 2	0.5	2.08	3.90	5.94	6.95	8.79	10.29	12.29	----

TABLE 4-0-3 LOAD DEFLECTION CHARACTERISTICS AT LEFT THIRD POINT

Sl.No	Beam	Left deflection in mm @								
		10 kN	20 kN	30 kN	40 kN	50 kN	60 kN	70 kN	80 kN	90 kN
1	Control-1	0.42	1.80	3.25	4.53	5.60	6.76	8.10	10.68	--
2	Control-2	0.44	1.74	3.55	4.62	6.10	7.05	9.23	11.54	---
3	Micro concrete beam -1	0.38	1.64	3.11	4.15	5.18	6.38	8.85	9.90	15.6
4	Micro concrete beam - 2	0.43	1.74	3.22	4.60	5.63	7.05	8.18	10.05	----

TABLE4-0-4 LOAD DEFLECTION CHARACTERISTICS AT RIGHT THIRD POINT

Sl.No	Beam	Right deflection in mm @								
		10 kN	20 kN	30 kN	40 kN	50 kN	60 kN	70 kN	80 kN	90 kN
1	Control-1	0.99	2.15	3.02	4.27	5.98	7.62	9.39	10.5	--
2	Control-2	1.13	3.23	4.23	5.52	6.74	8.13	9.86	11.0	---
3	Micro concrete beam -1	0.48	1.80	3.38	4.46	6.15	6.74	8.24	9.44	15.66
ximj	Micro concrete beam - 2	0.35	a	3.31	4.95	6.14	7.69	9.09	10.9	----

TABLE 4-0-5 MAXIMUM CRACK WIDTH AT DIFFERENT LOADS.

Sl. No	Beam	Maximum crack width in mm at load							
		30kN	40 kN	50 kN	60 kN	70 kN	80 kN	90 kN	100 kN
1	Control-1	0.06	0.1	0.22	0.30	0.40	0.48	--	--
2	Control-2	0.04	0.12	0.14	0.4	0.46	0.5.--	--	--
3	Micro concrete beam -1	0.1	0.24	0.36	0.40	0.42	0.44	0.50	1.60
4	Micro concrete beam - 2	0.1	0.14	0.3	0.4	0.6	0.66	1.8.	---

TABLE 4-6 ULTIMATE LOADS AND FAILURE PATTERN OF BEAMS

Sl.No.	Beam	Fck in N/mm²	$P_{u\,exp}$	Mode of failure
1	Control-1	36.00	80	Flexural
2	Control-2	35.80	80	Flexural
3	Micro concrete beam -1	35.60	90	Shear diagonal tension
4	Micro concrete beam - 2	34.87	80	Shear diagonal tension

4.2 Comparison of crack pattern at failure

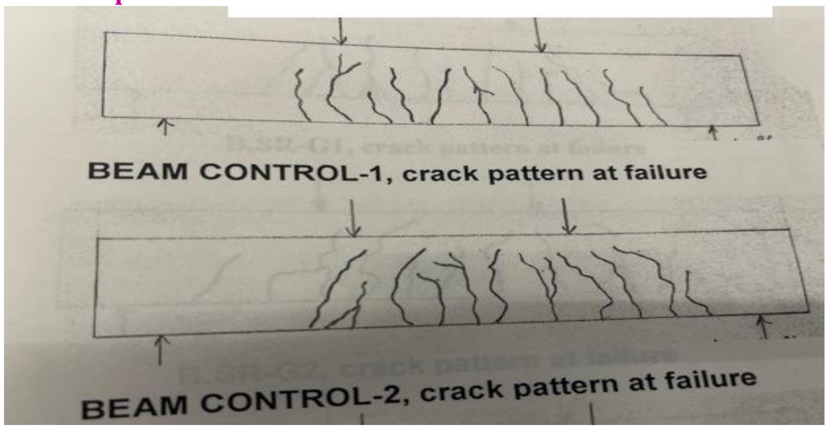


FIGURE 4-0-1 CRACK PATTERN IN CONTROL BEAMS

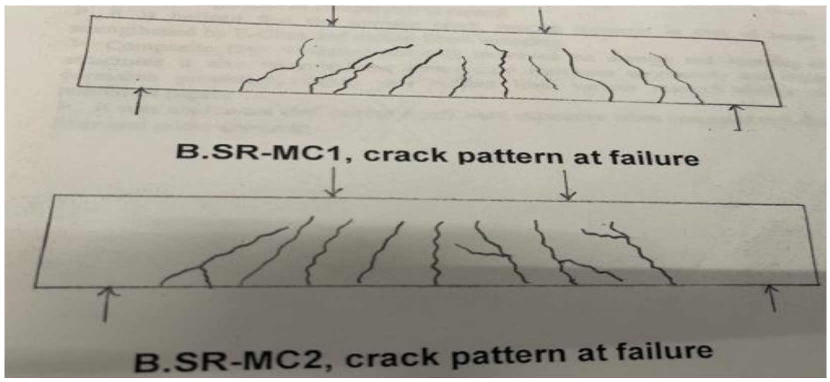


FIGURE 4-2 CRACK PATTERN IN MICRO CONCRETE STRENGTHENED BEAMS

5. CONCLUSIONS AND INFERENCES

5.1 Conclusions

The different behavioral aspects are investigated from test observations.

1.Ultimate Load Capacity: Despite the characteristic strength and modulus of rupture of concrete and reinforcement being the same in both control and strengthened beams, the strengthened beams successfully regained their ultimate load-carrying capacity. In certain cases, they even exhibited higher capacity than the control beams.

2.Failure Mode: The control beams predominantly failed in flexure, whereas the strengthened beams exhibited shear failure in the form of diagonal tension. This indicates that strengthening enhanced the flexural performance, shifting the governing failure mode.

3.Crack Pattern: The crack development in both control and strengthened beams was broadly similar, suggesting that strengthening did not significantly alter the crack initiation and propagation behavior.

4.Deflection Behavior: Strengthened beams showed a marginal improvement in maximum deflection compared to control beams, reflecting slightly enhanced serviceability performance.

5.2 Overall Observation

The strengthened beams performed on par with the original control beams and, in some cases, demonstrated superior load-carrying capacity and structural behavior. This confirms the effectiveness of the strengthening technique in restoring and improving beam performance.

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