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Structural Response of Repaired RCC Beams in Flexure

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Abstract

Reinforced concrete structural elements are found to exhibit deformation, even before their life span. Due to heavy loads, corrosion and several effects. This strengthening and enhancement of the performance of such deformed and distressed structural elements in a structure is referred to as retrofitting. The immeasurably significant issue to be tended to in retrofitting is life safety.

Some retrofit necessities would address the issue of life security, while recognizing that some auxiliary harm may happen.. The Ferro cement has customary fortified lighter weight, simplicity of development, more slender segment when contrasted with RCC and a high elasticity which makes it an ideal material for construction moreover. In the present theory RC pillars are effected by a prefixed level of the sheltered burden are retrofitted utilizing. Ferro concrete to build the quality of beam in shear and flexure, the chicken mesh put along the longitudinal hub of the bar. From the investigation it is seen that the sheltered burden conveying limit of rectangular RC components retrofitted by Ferro concrete covers is altogether expanded with work utilized for retrofitting.

In this paper Reinforced concrete(RC) beams may stressed to a prefixed level of the protected burden are retrofitted utilizing Ferro cement (FC) to build the quality of beam in flexure, the chicken mesh is put along the major axis of the member. From the investigation it is seen that the safe load carrying capacity of rectangular Reinforced concrete(RC) members retrofitted by Ferro concrete covers is essentially expanded with chicken mesh utilized for retrofitting.

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I. INTRODUCTION

Reinforced concrete is one of the most bounteously utilized material, in the world, yet in addition in the remotest pieces of the creating scene. The RCC structures defective development, change of utilization of the structure, change in codas arrangements, over-burdening, seismic tremors, blast, consumption, mileage, flood, fire and so forth. Over the most recent couple of years a few endeavors have been made in India and abroad to think about these issues and to build the life of the structures by appropriate retrofitting and fortifying strategies.

To overcome difficult conditions of longitudinal beams we have to choose alternative technique, which is economical and easily executed at work place with the help of semiskilled labor available at site. Ferro concrete jacketing is seen as one such appealing system because of its properties, for example, great rigidity, lightweight, in general economy, water snugness, simple application and long existence of the

structures. Beams restored with Ferro concrete coats show better execution regarding extreme quality, ultimate strength, first crack load, Ultimate crack width, ductility and durability of the section. The

March - April 2020
ISSN: 0193-4120 Page No. 5225 - 5234

expansion of slim layer of Ferro cement to a solid beam upgrades its malleability and splitting quality. Composite bars reinforced with square mesh display better by and large execution contrasted with composite bars strengthened with hexagonal work. An expansion in the quantity of layers improves the splitting firmness of the composite pillars in the two cases.

From the test examination it was presumed that in the wake of fortifying the presentation of the shaft improved generously as far as quality, flexural rigidity nature and first split burden, given that satisfactory surface to get the overlay roughened to guarantee adequate bond quality for composite activity.

II. EXPERIMENTAL PROGRAMME

TEST PROGRAMME

The test program is so contrived in order to discover the properties of materials to be utilized, afterward the conduct of retrofitted bars. The test program consist of:

1. Determination of undamental properties of constituent materials in particular concrete, sand, coarse aggregate and steel bars according to important Indian standard details.

2. Casting of four real size beams (1200*100*200mm) using M 25 grade.

3. Calculation of the ultimate failure load of the beams and subsequently the safe load from deflection criteria.

4. The structural member stressed up to safe load and then retrofitted with Ferro cement laminates bonded with mortar and epoxy agent knitto bond @ 90^0 to the major axis of beam

MATERIALS:

CEMENT

PPC 53 grade cement physical Properties as determined from various laboratory tests are shown in Table 3.1. All the tests are carried out based on IS: 8112-1989.

Table 3.1 Properties of Cement

Specific Gravity	3.12
Normal Consistency	32%
Initial Setting Time	48mins
Final Setting Time	215mins

FINE AGGREGATES

Locally accessible material used.

COARSE AGGREGATES

Crushed stone aggregate (locally accessible) of 20mm and 10mm are utilized all through the trial study.

WATER

The water is generally liberated from natural issue, sediment, oil, sugar, chloride and acidic material according to necessities of Indian standard.

REINFORCING STEEL

Fe-415 of 12mm, and 10mm dia were used as longitudinal steel in tension and compression zone. 8mm (mils steel) dia bars are utilized as shear stirrups.

STEEL MESH

MS welded steel wire work of 0.53mm distance across with square networks was utilized in Ferro concrete coat. The matrix size of work was 40X40 mm. The yield quality of the wire work is more prominent than the yield quality of the tensile reinforcement. Yield quality of tensile reinforcement is 415 Mpa while the yield quality of the Ferro work is 483Mpa.

Table 3.5 Ferro Mesh description

Test type	Tension-0.2KN
Sample type	Flat

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Length in mm	33.299999237060
Diameter in mm	0.53
Sample area in sq mm	0.22

Table 3.6 Properties of Ferro Mesh

Peak Load(kN)	12.6
Peak Stress(N/Sqmm)	57272.73
Displacement at Peak Load (mm)	48.39
Strain at Peak Stress (%)	145.315

CONCRETE MIX

M25 grade as per IS design procedure using the properties of materials, the W/C ratio 0.45.

Cement	fine aggregate	fine aggregate	water
450kgs	653.66 kgs	1077 kgs	208kgs
1	1.45	2.4	0.45

The mix proportion of concrete comes out to be 1:1.45:2.4 (cement: sand: aggregate) and compressive strength of concrete cubes after 7 day is 23.6Mpa .

Table 3.7 Trial mix compressive strength of concrete cubes

Concrete cubes(15*15*15cm)	Compressive strength(Mpa)
1	24.9
2	20.56
3	25.31

III. TESTING ARRANGEMENT

All the four beams are tested under simply supported end conditions. Out of 1200mm length of beam 10cms, each of 5cm is left to support conditions and 10cms at middle of beam is analyzed as flexure zone and load is applied at that position using two point loading. Load is applied gradually till 90% of safe load is reached and value of ultimate load is noted. The load at which crack is initiated is noted and width of the crack is measured. Three dial gauges are arranged at a distance of L/4, L/2 and 3L/4 and readings are noted to calculate deflection at respective lengths of the virgin beam.

Damec gauges are used to calculate the strains near the flexure region to calculate moment and curvature (phi) at corresponding loads. from moment and curvature curve, we obtain ductility ratio.

$$\text{Ductility} = \frac{\text{phi at 85\% of ultimate strength}}{\text{Phi of Yield strength}}$$

From the above results we get the ductility, and crack initiation load and width of crack.

Figure 2.1 Beam testing before retrofitting with Ferro mesh

Figure 2.2 Calculation of strain at compression and tension face using damec gauges.

The below figure shows the failure of unretrofitted beam at flexural portion. Most of the cracks in the flexural portion are observed to start from tension side and progressed towards compression face. There are no cracks or distress of beam at end portion.

TEST Engineering & Management

March - April 2020
ISSN: 0193-4120 Page No. 5225 - 5234

Figure 2.3 Flexural failure of a beam

IV. RETROFITTING OF BEAMS

The pillars are worried up to a predetermined point of confinement as above and afterward retrofitted by applying steel wire work at a direction of 90 degrees as appeared in fig no 3.4 and afterward putting it with concrete mortar up to the thickness of 20mm for every one of the four bars. Hence last cross area of pillar with Ferro concrete cover will become 1200*100*200 mm.An cover of 3 creeps at the spot of joint between wire work is presented.

Process of Retrofitting

The distressed beam with cracks in the flexure zone is chipped off up to cover portion without any damage to the core concrete. Chipped off beams are then cleaned and Ferro wire mesh of desired properties is U wrapped leaving the compression face. Wire mesh is bonded to the beam with the help of bonding material called knitto bond which has the ability to bond very quickly and strongly. After applying the knitto bond to the beam, wire mesh is wrapped and mortar is applied of 1:2 proportion with water ratio of 0.5.This retrofitted beam is cured for 28 days in curing tank and then tested.

Figure 2.4 Beam with cover chipped off at flexural portion

V. NITTO BOND:

Nitto Bond is a strong adhesive material which has the ability to join or adhere two composite surfaces very ultimately and perfectly.it consists of two phase material namely hardener and base.two components are mixed thoroughly in required or prescribed proportion and the surface to be applied is cleaned neatly. Then after ,with the help of brush ,apply this epoxy on the desired surface.

Figure 2.5Testing of beam retrofitted with Ferro mesh

Figure 2.6 Failure of retrofitted beam after testing

III RESULTS AND DISCUSSIONS

TESTING METHODOLOGY

Firstly control beams are tested to failure and the data corresponding to it is noted. The data noted includes dial gauge reading which gives us deflections at a distance of L/4, L/2 and 3L/4.Damec gauge is used to note down the strains in tension and compression face which ultimately gives the curvature of the beam.

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March - April 2020
ISSN: 0193-4120 Page No. 5225 - 5234

$$\text{Curvature} = \frac{\text{strain in compression face} + \text{strain in tension face}}{\text{Distance between the two faces (h)}}$$

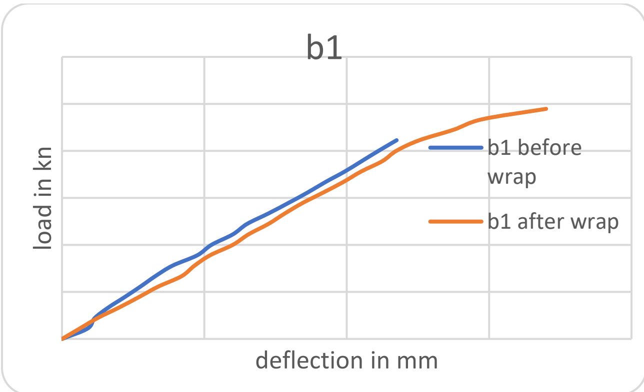
Similarly moment is calculated at different loads and a graph is drawn correspondingly between moment and curvature. From moment and curvature graph we calculate the ductility factor of the desired beam.

COMPARISON OF EXPERIMENTAL DEFLECTION CHARACTERISTIC OF RETROFITTED BEAMS TO NORMAL CONCRETE BEAM 1.

Table 4.1 and Table 4.2 shows the load deflection values of the normal concrete beam1 before retrofitting and after retrofitting.

Before wrapping		After wrapping	
Load(kN)	Deflection at L/2	Load (kN)	Deflection at l/2
0	0	0	0
4.449816	0.36	4.449816	0.25
8.899632	0.46	8.899632	0.5
13.34945	0.65	13.34945	0.8
17.79926	0.88	17.79926	1.08
22.24908	1.1	22.24908	1.35
26.6989	1.31	26.6989	1.68
31.14871	1.55	31.14871	1.86
35.59853	1.9	35.59853	2.08
40.04834	2.1	40.04834	2.4
44.49816	2.4	44.49816	2.62
48.94798	2.6	48.94798	2.9
53.39779	2.9	53.39779	3.13
57.84761	3.18	57.84761	3.38
62.29742	3.45	62.29742	3.67
66.74724	3.7	66.74724	3.95
71.19706	3.97	71.19706	4.2
75.64687	4.21	75.64687	4.5
80.09669	4.45	80.09669	4.7
84.5465	4.7	84.5465	5.02
		88.99632	5.5
		93.44614	5.9
		97.89595	6.8

Figure 4.1 Load v/s Deflection graph at a distance of L/2 of beam 1



COMPARISON OF EXPERIMENTAL DEFLECTION CHARACTERISTIC OF RETROFITTED BEAMS TO NORMAL CONCRETE BEAM 2.

Table 4.3 and Table 4.4 shows the load deflection values of the normal concrete beam2 before retrofitting and after retrofitting.

Before wrapping		After wrapping	
Load(kN)	Deflection at L/2	Load (kN)	Deflection at l/2
0	0	0	0
4.449816	0.15	4.449816	0.24
8.899632	0.36	8.899632	0.5

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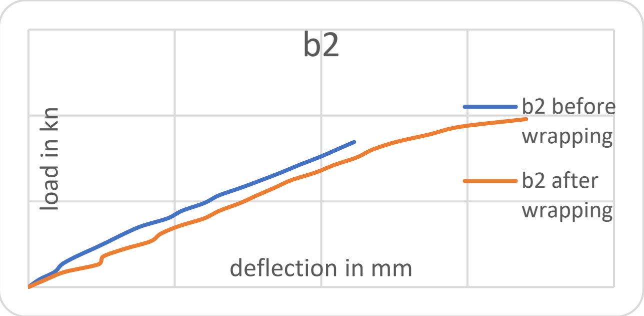
March - April 2020
ISSN: 0193-4120 Page No. 5225 - 5234

13.34945	0.46		13.34945	0.96
17.79926	0.65		17.79926	1.02
22.24908	0.88		22.24908	1.31
26.6989	1.1		26.6989	1.67
31.14871	1.31		31.14871	1.81
35.59853	1.55		35.59853	2.06
40.04834	1.9		40.04834	2.4
44.49816	2.1		44.49816	2.61
48.94798	2.4		48.94798	2.89
53.39779	2.6		53.39779	3.12
57.84761	2.9		57.84761	3.36
62.29742	3.18		62.29742	3.59
66.74724	3.45		66.74724	3.92
71.19706	3.7		71.19706	4.18
75.64687	3.97		75.64687	4.49
80.09669	4.21		80.09669	4.7
87.66138	4.45		84.5465	5.02
			88.99632	5.48
			93.44614	5.9
			97.89595	6.8

Figure 4.2 Load v/s Deflection graph at a distance of L/2 of beam 2



COMPARISON OF EXPERIMENTAL DEFLECTION CHARACTERISTIC OF RETROFITTED BEAMS TO NORMAL CONCRETE BEAM 3.

Table 4.5 and Table 4.6 shows the load deflection values of the normal concrete beam3 before retrofitting and after retrofitting.

Before wrapping			After wrapping	
Load(kN)	Deflection at L/2		Load (kN)	Deflection at l/2
0	0		0	0
4.449816	0.15		4.449816	0.45
8.899632	0.3		8.899632	0.82
13.34945	0.71		13.34945	1.15
17.79926	1		17.79926	1.52
22.24908	1.26		22.24908	1.98
26.6989	1.52		26.6989	2.35
31.14871	1.75		31.14871	2.7
35.59853	2.01		35.59853	3.03
40.04834	2.25		40.04834	3.4
44.49816	2.52		44.49816	3.76
48.94798	2.76		48.94798	4.08
53.39779	3.01		53.39779	4.4
57.84761	3.33		57.84761	4.75
62.29742	3.6		62.29742	5.15
66.74724	3.85		66.74724	5.55
71.19706	4.07		71.19706	6.02
75.64687	4.42		75.64687	6.65
80.09669	5.2		80.09669	7.25
	4.45		84.5465	8.5

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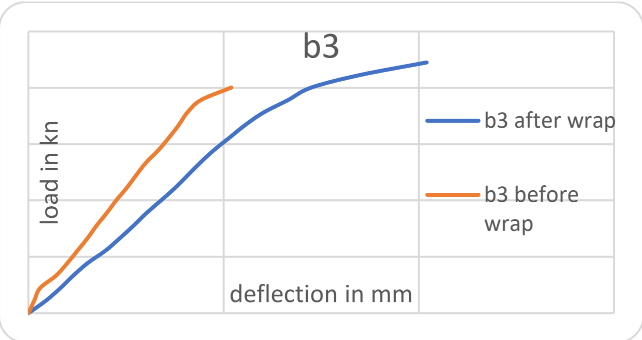
			88.99632	10.2
			93.44614	5.9
			97.89595	6.8

Figure 4.3 Load v/s Deflection graph at a distance of L/2 of beam 3



COMPARISON OF EXPERIMENTAL DEFLECTION CHARACTERISTIC OF RETROFITTED BEAMS TO NORMAL CONCRETE BEAM 4.

Table 4.7 and Table 4.8 shows the load deflection values of the normal concrete beam3 before retrofitting and after retrofitting.

Before wrapping			After wrapping	
Load(kN)	Deflection at L/2		Load (kN)	Deflection at l/2
0	0		0	0
4.449816	0.15		4.449816	0.45
8.899632	0.3		8.899632	0.82
13.34945	0.71		13.34945	1.15
17.79926	1		17.79926	1.52
22.24908	1.26		22.24908	1.98
26.6989	1.52		26.6989	2.35
31.14871	1.75		31.14871	2.7
35.59853	2.01		35.59853	3.03
40.04834	2.25		40.04834	3.4
44.49816	2.52		44.49816	3.76
48.94798	2.76		48.94798	4.08
53.39779	3.01		53.39779	4.4
57.84761	3.33		57.84761	4.75
62.29742	3.6		62.29742	5.15
66.74724	3.85		66.74724	5.55
71.19706	4.07		71.19706	6.02
75.64687	4.42		75.64687	6.65
80.09669	5.2		80.09669	7.25
84.5465	6.7		84.5465	8.5
			88.99632	10.2

Figure 4.4 Load v/s Deflection graph at a distance of L/2 of beam 4

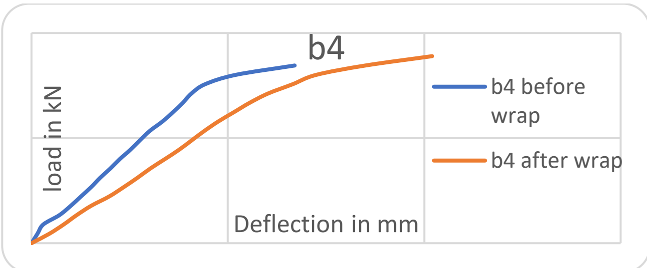


Table 4.9: Variation in Load carrying capacity of beams before and after wrapping

Beam	Before Wrapping(kN)	After Wrapping(kN)
1	84.5465	97.89595
2	87.66138	97.89595
3	80.09669	88.99632
4	84.5465	88.99632

Variation in Load carrying capacity of Beams before and after wrapping:

From Table 4.9 for Beam 1, it is seen that retrofitting leads to increment in the ultimate load carrying capacity of beam in flexure from 84.54 kN (before wrapping) to 97.89 kN (after wrapping) which indicates an increase of 15.79% after wrapping.

For Beam 2, it is seen that retrofitting leads to increment in the ultimate load carrying capacity of beam in flexure from 87.66138 kN to 97.89 kN which indicates an increase of 11.73% after wrapping.

For Beam 3, it is seen that retrofitting leads to increment in the ultimate load carrying capacity of beam in flexure from 80.09669 kN to 88.9 kN which indicates an increase of 11.11% after wrapping.

For Beam 4, it is seen that retrofitting leads to increment in the ultimate load carrying capacity of beam in flexure from 84.54 kN to 88.99 kN which indicates an increase of 5.26% after wrapping.

Figure 4.5 Variation of load carrying capacity of all beams before and after wrapping

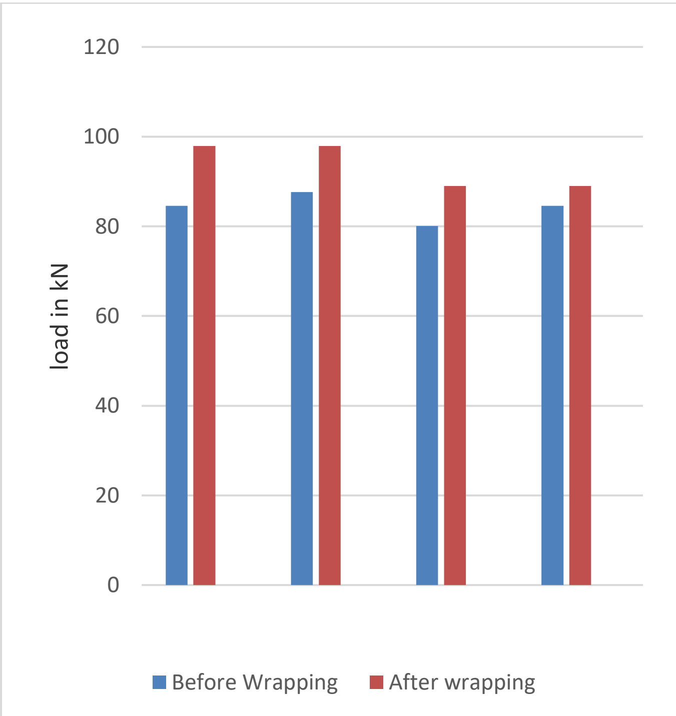


Figure 4.6 Variation of maximum deflection of all beams before and after wrapping

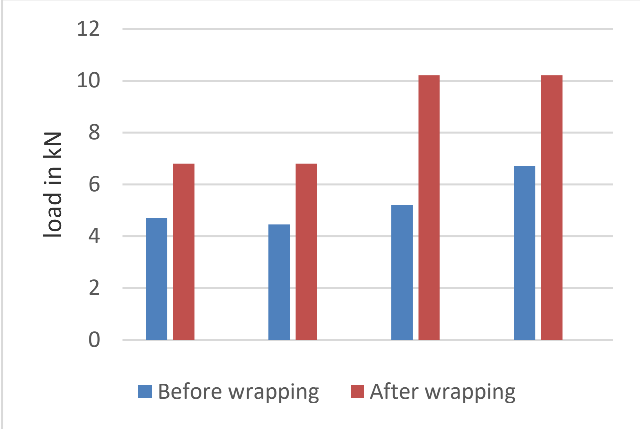


Table 4.10: Variation in maximum deflection of beams before and after wrapping.

Beam	Before Wrapping(mm)	After Wrapping(mm)
1	4.7	6.8
2	4.45	6.8
3	5.2	10.2
4	6.7	10.2

Variation in maximum deflection of Beams before and after wrapping:

From Table 4.10 for Beam 1, it is observed that retrofitting leads to increase in the maximum deflection of beam in flexure from 4.7mm (before wrapping) to 6.8mm (after wrapping) which indicates an increase of 44.68% after wrapping.

For Beam 2, it is observed that retrofitting leads to increase in the maximum deflection of beam in flexure from 4.45mm to 6.8mm which indicates an increase of 52.80% after wrapping.

For Beam 3, it is observed that retrofitting leads to increase in the maximum deflection of beam in flexure from 5.2mm to 10.2mm which indicates an increase of 200% after wrapping.

For Beam 4, it is observed that retrofitting leads to increase in the maximum deflection of beam in flexure from 6.7mm to 10.2 mm which indicates an increase of 52.2% after wrapping.

From the experimental data observation, the initiation of crack in all beams after wrapping is delayed around 10% when compared to crack initiation load before wrapping. This obviously shows an increase in the load bearing capacity of beam after wrapping with Ferro mesh.

VI. CONCLUSIONS

From the above experimental data observation, the following conclusions are drawn. They are as follows:

- Repairing the RCC members with Ferro cement wrapping can be done without sacrificing the load bearing capacity of the basic structure.
- The load carrying capacity of the RC beams retrofitted with Ferro cement wrapping in the present investigation is nearly 15 percent excess over the basic RC beam.
- The initiation of crack is greatly delayed in case of RC beam retrofitted with Ferro cement wrapping, which obviously shows the increase in serviceability of the retrofitted beam.

The maximum deflection at ultimate load are found to increase about 50 percent which ultimately indicates that beams retrofitted with mesh have more ductility than those of un retrofitted beams

REFERENCES

[1]. K C Ong, K., et.al (1992), “Flexural strengthening of reinforced concrete beams using Ferro cement laminates”. Journal of Ferro cement, vol.22.

[2]. Waliuddin, A. et.al (1994) .Study of the behavior of plain concrete confined with Ferro cement. Journal of Ferro cement, volume 24.

[3]. Seshu.D. et.al (2001).Flexural strength assessment of Ferro cement confined reinforced concrete FCRC beams.

[4]. Bansal, P.P, et.al (2008).Effect of wire mesh orientation on strength of beams retrofitted using Ferro cement jackets. Volume 2.

[5]. Onet, T et.al . (1992).Aspects concerning the behavior of Ferro cement in flexure.

[6]. Fahmy, et.al (1997).Repairing reinforced concrete beams using Ferro cement, volume 27.

[7]. B.Sivagurunathan,, et.al (2000) Experimental investigation on flexural behavior of concrete beams strengthened by Ferro cement laminates

[8]. ACI 549, "Guide for the Design, Construction and Repair of Ferrocement," Michigan: American Concrete Institute; 1988

[9]. A. E. Naaman, "Ferrocement and Laminate Cementitious Composites," USA: Techno Press 3000; 2000

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