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EXPERIMENTAL STUDY ON CONCRETE BEAM BY PARTIAL REPLACEMENT FLY ASH FOR CEMENT, RETROFITTED WITH SIMCON AND FERRO CEMENT LAMINATES

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ABSTRACT - *The cost of civil infrastructure constitutes amajor portion of the national wealth. Its rapid deterioration has thus created an urgent need for the development of novel, long - lasting and cost - effective methods for repair and retrofit. In the present days life extension of structures through strengthening is becoming an essential activity. As the number of civil infrastructure systems increases worldwide, the number of deteriorated buildings and structures also increases. Complete replacement is likely to be an increasing financial burden and might certainly be waste of natural resources if upgrading or strengthening is a viable alternative. Hence, the flexural strengthening of RC beams using externally bonded High Performance Fiber Reinforced Cementitious Composites (HPFRCCs) called Slurry Infiltrated Mat Concrete (SIMCON) and Ferro cement Laminates are preferred. In this project, M40 grade concrete is casted in which cement is to be replaced by optimum percentage (20%) of Fly Ash and conventional beam is to be casted. The four beams of size 150mm*150mm*1000mm are then decided to be retrofitted with the SIMCON and Ferro cement Laminates (welded wire mesh & Galvanized expanded metal mesh) alone and together. In this concrete, strength properties such as compressive strength, tensile strength and flexural strength had been evaluated and compared with the conventional beams.*

Key Words: M40 grade, Fly Ash, retrofitted, SIMCON,Ferro cement laminates, compression test, Split tensile test, Flexural test.

1. INTRODUCTION

Concrete is strong in compression, as the aggregate efficiently carries the compression load. Normally, the tensile strength of concrete is about 10% to 15% of its compressive strength. However, it is weak in tension as the cement holding the aggregate in place can crack, allowing the structure to fail. Reinforced concrete adds either steel reinforcing bars, steel fibers, or other materials to carry tensile loads. So that the compressive bending stress is carried by concrete and tensile bending stress is carried entirely by steel reinforcing bars.

As the number of civil infrastructure systems increases worldwide, the number of deteriorated buildings and structures also increases. Complete replacement is likely to be an increasing financial burden and might certainly be waste of natural resources if upgrading or strengthening is a viable alternative. Many reinforced concrete buildings and structures need repair or strengthening to increase their load carrying capacities or enhance ductility under seismic loading. Much of our current infrastructure is constructed of concrete. As time passes, deterioration and change of use requirements facilitate the need for new structures. Demolition of existing and construction of new structures is a costly, time consuming and resource intensive operation.

If existing structures could be reinforced to meet new requirements then the associated operating costs of our infrastructure would be reduced. In recent years repair and retrofitting of existing structures such as buildings, bridges, etc., have been amongst the most important challenges in Civil Engineering. The main reason for strengthening of RC structures is to upgrade the resistance of the structure to withstand underestimated loads and increase the load carrying capacity for loads such as seismic loads. The maintenance and rehabilitation of structural members, is perhaps one of the most crucial problems in civil engineering applications. Conventional methods that is already available. They are High Performance Fibre Reinforced Cementitious Concretes (HPRCCs) such as SIMCON, SIFCON, Ferro cement, etc.. Here, we are using SIMCON and Ferro cement Laminates.

1.1 OBJECTIVES OF STUDY

This study is conducted to achieve the following objectives:

1. To find the replacement percentage of cement with fly ash which gives the optimum result.
2. To study the strength properties like cube compressive strength, split tensile strength, flexural strength.
3. To obtain optimum mix proportion to cast the test specimens.
4. To study the properties of Ferro cement.
5. To study the properties of SIMCON Laminates.

6. To identify the specific advantages of fly ash based on the results and experimental investigation.
7. To study the load deflection behaviour of structural elements.
8. To compare the result of conventional concrete beams with Retrofitting of ferrocement beams and SIMCON Laminated Beams.
9. To arrive the important conclusion.

1.2 SCOPE OF STUDY

1. The scope of this project is to study the strength properties of Ferrocement strengthened beam and SIMCON Laminated Beam under point loading.
2. The performance of beams retrofitted with Ferrocement and SIMCON Laminates to be studied from experimental tests.
3. Based on the experimental results, a comparative study on the performance of conventional beam and retrofitted beams going to be carried out.

2. LITERATURE REVIEW

The present investigation deals with studies on utilisation of fibre in SIMCON & Ferrocement laminates and its application in flexural strengthening of RC beams, an attempt has been made to review briefly the available literature on the following topics.

- Strengthening of RC beams
- Effect of fibres

For this investigation, some of the important literatures were reviewed and presented briefly.

2.1. FERRO CEMENT

Ganapathy and sakthieswaran (2015) studied theflexural behavior of reinforced cement concrete beam by using fibrous ferrocement laminates. The Properties of fibrous Ferrocement laminates and Load - Deflection behaviour for control specimen was compared with Polymer modified fibrous Ferro cement composite beams. Wire meshes were used for ferrocement laminates with mortar mix of 1:2 and water- cement ratio of 0.4. Six beams were casted and tested under two point loading. All beams were tested to ascertain the load deflection behaviour and maximum ultimate load. Five beams were cracked under overloading by applying 70% ultimate load, and one beam was used for control beam. Then the cracked beams were strengthened by polymer modified fibrous Ferro cement composites with two different volume fractions (4.94%, 7.41%). Comparing the flexure strength of control beam with respect to the beam rehabilitated with modified fibrous Ferro cement laminate. The reinforced cement concrete beam using fibrous Ferro cement laminate increased the flexural strength of the beam.

Khan et al. (2013) investigated the serviceabilityperformance of reinforced concrete beams strengthened through two ferrocement strengthening techniques, cast in situ and precast ferrocement laminates. Eight RC beams was tested under two-point loading up to service load. Then, those beams were strengthened by cast in situ wire-mesh layers and by precast ferrocement laminates. Wire-mesh was anchored to the soffit of the beam through nails. The laminate connectors were placed over the exposed stirrups and mortar was used to fix the laminate connectors with stirrup. After hardening of mortar, precast laminate was attached by passing bolts through the holes and nuts were used to tighten the laminates. The experimental results in terms of stiffness were compared within and across the groups to assess the effect of variation of development length and number of wire-mesh layers. Performance of RC beams strengthened by three layers of wire-mesh using both techniques has been found better in terms of maximum increase in stiffness.

Patil et al. (2012) studied the performance ofchicken mesh on strengthening of beams retrofitted using ferrocement jackets. RC beams initially stressed to a prefixed percentage of the safe load are retrofitted using ferrocement to increase the strength of beam in both shear and flexure, the chicken mesh was placed along the longitudinal axis of the beam. To carry out the investigation, six prototype beams were cast using the proportioned mix. Out of the six beams, two were used as control beams are tested to failure to find out the safe load carrying capacity. The other four beams were stressed to 60 and 80 percent of the safe load obtained from the testing of the control beams and were then retrofitted with 15 mm thick ferrocement jackets made with 1:2 cement sand mortar and w/c ratio 0.40. The jacket was reinforced with doubled layer of 10mm x 10mm hexagonal chicken mesh. From the study it is seen that the safe load carrying capacity of rectangular RC elements retrofitted by ferrocement laminates is significantly increased with chicken mesh used for retrofitting.

Paramasivam and Ong (2009) reviewed themethods of repair and strengthening of the reinforced concrete beams using ferrocement laminates attached on to the surface of the beams. The transfer of forces across the ferrocement interface, the effect of level of damage sustained by the original beam prior to repair, and the results of repeated loading on the performance of the strengthened beams were discussed. The results showed that ferrocement is a viable alternative as a strengthening material for the rehabilitation of reinforced concrete structures.

2.2 SIMCON LAMINATE

Balamuralikrishnan R (2013)made experiments tofind the strengthening of Beams with the simcon laminates The advantage of using steel fiber mats over a large volume of discrete fibers is that the mat configuration provides inherent strength and utilizes the fibers contained in it with very much higher aspect ratios. The fiber volume can, hence, be substantially less than that required for making of SIMCON, still achieving identical flexural strength and energy absorbing toughness. Providing the fibers as a mat which is then infiltrated by high strength slurry, a new type of HPFRCC, called Slurry Infiltrated Mat Concrete (SIMCON) can be produced. The Beams were tested in third - point loading (ASTM C78) the maximum stress is present over the center 1/3 portion of the beam under static monotonic loading. centroidal axis of steel (tension zone) at the middle third zone of beam. At any given load level, the deflections are reduced significantly thereby increasing the stiffness for the strengthened beams. At ultimate load level of the control specimens.

SandeepkumarL.S (2013) retrofitting of RC beamsusing natural FRP wrapping(NSFRP) the beams are in the length of 1.8m and width of 100mm and depth of 160mm with longitudinal bars at top 2 nos of 8mm dia each longitudinal bars at bottom 2 nos of 10mm dia stirrups 8mm dia at 100mmc/c.First three beams are control mix beams and two beams are wrapped with NSFRP at tension zone and another two beams are wrapped with NSFRP at flexural zone by experimental results of nine beams strengthening by silk fibre composite at tension zone beams have carried more ultimate load by about 39.77% compared to that of control beam specimen. Strengthening by silk fibre composite at flexure zone beams have carried more ultimate load by about 36.82% compared to that of control beam specimens. The ultimate load carrying capacity was found to be high for beams retrofitted with NSFRP composites as compared to control beams.

Reddy et al (2009) presents the paper Retrofitting ofRC piles using GFRP composites using finite element analysis result comparison to study about the behaviour nature of retrofitted RC piles that are strengthened with the help of glass fibre reinforced polymer (GFRP) composites. The analysis was carried out using commercial software ANSYS. In order to study the behaviour under various loadings, there were totally eight RC pile specimens casted with same reinforcement details. Four specimen were used as control specimens and the remaining specimens were made to retrofit with glass fibre reinforced polymer. The loading effect was made and the corresponding deflection and the strain are obtained and compared with experimental plots. The conclusion were made from the result from finite element modelling 43% of increase in axial compression is obtained for the retrofitted specimen. Lateral load capacity of the retrofitted specimens is found to be relatively higher than that control piles.

Alexander G. Tsonos (2008) carried out anexperimental investigation to evaluate the retrofitting methods to address the particular weaknesses that are often found in reinforced concrete structures, especially older structures, namely the lack of sufficient flexural and shear reinforcement within the columns and the lack of adequate shear reinforcement within the joints. Thus, the use of a reinforced concrete jacket and a high-strength fiber jacket for cases of post-earthquake and pre-earthquake retrofitting of columns and beam–column joints was investigated experimentally and analytically. The effectiveness of jacket styles was also compared. The results indicated that the beam-column joint specimens strengthened with carbon-epoxy jacketing were effective in transforming the brittle joint failure mode of specimens into a ductile failure mode with the development of flexural hinges into the beams.

2.3 LITERATURE SUMMARY

From all the above literature reviews, it was evident that SIMCON and Ferro cement Laminates can be used as retrofitting material in a beam.

But there was no literature available on the utilization of both the laminates and optimum % replacement of Fly Ash for cement in the above mentioned replacement in the same concrete mix.

Hence it is planned to use Fly Ash as cement replacement, and beams are retrofitted with SIMCON, Ferro cement Laminates(G.I. Expanded Metal Mesh & welded wire mesh) alone and together for strengthening of the concrete beam.

3. MATERIAL USED

The materials used for the project is collected and made sun dried before as initial testing and for further usage. The amount of material to be used should be noted in advance based on the preparation of mix design. From the results of mix design the quantity of each component such as cement, FA, CA and water will be finalized, then the collection of materials to be done and to be stored in a specified place free from impurities. Based on the availability of the materials and its condition the following tests were performed.

3.1 CEMENT

Portland pozzolana 53 grade cement from a single lot is used for the study. Pozzolana is a natural or artificial material containing silica in a reactive form. It may be further discussed as siliceous and aluminous material which is itself possesses little or no cementitious properties, but is chemically react with calcium hydroxide at ordinary temperature to form compounds possessing cementitious properties. The physical properties of cement as obtained from various tests are listed in Table 3.1. All the tests are carried out in accordance with procedure laid down in IS: 8112-1989.

Table 3.1.: Physical Properties of Cement used

S.NO.	CHARACTERISTICS	VALUE
1 2	Standard consistency Fineness of cement	34 0.5
3	Initial setting time	35 mins
4	Final Setting time	5 hours
5	Specific gravity	3.07

3.2 FINE AGGREGATE

The sand from river due to natural process attrition tends to possess smoother surface texture and better shape. It also carries moisture that is trapped in between the particles. These characters make concrete workability better. The properties of fine aggregate are given in table 3.2.

Table 3.2 Properties of fine aggregate

PROPERTY	VALUE
Sp ecific gravity Water absorption	2.68 % 1.0 %
Free moisture content	2 %
Fine modulus	2.89 %

3.3 COARSE AGGREGATE

Graded crushed hard blue granite jelly available in local area was used. Aggregate shall comply the requirements of IS 383. As far as possible preference shall be given to natural aggregates. The nominal size of coarse aggregate should be large as possible within the limits specified but in no case greater than one- fourth of the minimum thickness of the member. However for most of the work 20 mm and 10 mm sizes in the combination of 60% : 40% respectively were selected as coarse aggregate because this particular combination had minimum voids. The properties of coarse aggregate used are given in table 3.3.

Table 3.3 Properties of Coarse aggregate

PROPERTY	VALUE
Specific gravity	2.68
Water absorption	1.0 %
Free moisture content	0.2 %
Fine modulus	6.89

3.4 FLY ASH

Fly ash obtained from thermal power station was used in this investigation. This fly ash is classified as class F low calcium fly ash. The physical and chemical properties of fly ash are given below.

FIG 3.1 Class F Fly Ash

Table 3.4 Properties of Fly Ash

S.NO	CHARACTERISTICS	REQUIREMENT GRADE OF FLY ASH	
		I	II
1	Fineness–specific surface in m^2/kg	320min	320min
2	Compressive strength at 28 days in N/mm^2	4.5 min	3.0 min
3	Compressive strength at 28 days in N/mm^2	Not less than 80% of the strength of corresponding plain cement mortar cube	
4	Soundness	0.8 max	0.8max

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3.5 SIMCON LAMINATES

SIMCON can also be considered a pre - placed fibre concrete. The fibres are placed in a "mat form" rather than as discrete fibres. Steel fibres produced directly from molten metal using a chilled wheel concept are interwoven into a 0.5 to 2 inches thick mat. The advantage of using steel fibre mats over a large volume of discrete fibres is that the mat configuration provides inherent strength and utilizes the fibres contained in it with very much higher aspect ratios. The fibre volume can, hence, be substantially less than that required for making of SIFCON, still achieving identical flexural strength and energy absorbing toughness. The SIMCON Laminates are bought from Online.

FIG 3.2 SIMCON LAMINATES

MECHANICAL PROPERTIES OF SIMCON LAMINATES

The different combination of SIMCON volume fraction say 4.0 to 6.0 percent within cement of 0.5 percent and three different aspect ratio l/d = 300, l/d = 400 and l/d = 300 &400 cocktail fibers were used to find optimum volume fraction and aspect ratio. Similar basic tests were conducted. From the basic test (compression, tension and flexure) results, the laminate with optimum volume fraction Vf =5.5 percent and aspect ratio l/d = 300 performed well in all respects.

Table 3.5 Mechanical Properties of SIMCON Laminates

Density of SIMCON mat	7695.97 kg/m^3
Density of SIMCON laminates	1800 kg/m^3
Mean Compressive Strength of SIMCON laminates, f	88 N/mm^2
Mean Tensile Strength of SIMCON laminates, f	17 N/mm^2
Modulus of Elasticity of SIMCON laminates, E	2.70×104 N/mm^2

3.6 FERROCEMENT LAMINATES

Ferro cement 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.

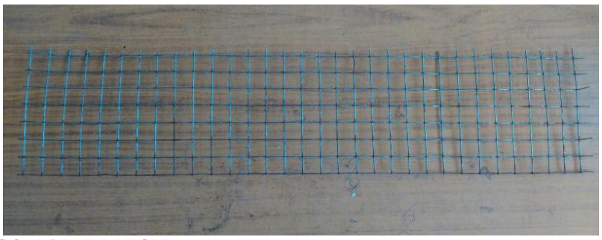

FIG 3.3 SQUARE MESH

FIG 3.3 SQUARE MESH

FIG 3.4 EXPANDED METAL MESH

Table 3.6 Different Types of Wire Meshes and their Characteristics

TYPES OF MESH	WT OF ONE LAYER PER UNITAREA (Kg/m^2)	MESH THICKNESS (mm)	STEEL CONTENT (Kg/m^2)	STEEL SURFACE PER UNIT VOL (mm^2/mm^3)
Hexagonal wire mesh 12mm * 22 gauge	0.58	1.4	410	0.275
Square welded mesh 12 mm * 12 mm * 19 gauge	1.08	2	540	0.248
Expanded metal Mesh T.C.G.269	1.22	2.5	490	0.245
Wastsan mesh	3.55	5.5	650	0.236

In this project, Welded Wire Mesh and Galvanized Expanded Metal Mesh are used for retrofitting the Beams. The Meshes are bought from the Steel Stores in Paris, Chennai

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4. METHODOLOGY

The following procedure is adopted to cast the specimen:

1. M40 grade concrete of mix ratio 1:1.35:2.41 is used for casting the specimens of w/c ratio 0.4.
2. The cement is replaced by optimum percentage of Fly Ash (20%).
3. Five Beams (A1, A2, A3, A4, A5) of mould size 150mm*150mm and span length of 1000mm are taken.
4. After filling the moulds with wet concrete, level the surface.
5. Demould the specimen after 24 hours.Keep all specimen for curing of 28 days.
6. After curing for 28 days remove all specimen from curing tank then start retrofitting work.
7. Before retrofitting chipping should be done.
8. Then rough layer of mortar of 1:2 ratio of 20mm is applied on the surface of beam.
9. Take slurry infiltrate mat concrete and cover to full beam then mortar will be applied to full beam (A2).
10. The same procedure is used for retrofitting Ferrocement Laminate (Welded Square Mesh) in beam A3, FC Laminate (Expanded Metal Mesh) in beam A4, SIMCON, Welded Square Mesh and Expanded Metal Mesh together in beam A5.
11. After retrofitting, beams are then cured for 28 days again.
12. Then the beams are tested under loading frame to find the flexural strength of the beams.

5. EXPERIMENTAL INVESTIGATION

Experimental Investigation comprises of test on cement, Fine aggregate and Coarse aggregate, concrete with partial replacement of Cement with Fly Ash(20%, 25%,30%).

The cubes and cylinder specimens are casted and tested to find the Compressive Strength and Split Tensile Strength at 7, 14 and 28 days respectively.

5.1 BEAM SPECIFICATION:

The experimental work consisted of a total of five rectangular beams under reinforced concrete. All beams were of the same size 150 mm x 150 mm x 1000 mm, 2 -12MMdiameter bars were used for flexural reinforcement at the bottom of each beam, 2-10 mm at the top of each beam and 8 mm diameter stirrups spaced 150 mm center-to-center for shear reinforcement and this were designed as per IS 456 -2000. The casting of beams was made as per IS code specification using M40 grade concrete with 20 mm maximum size of coarse aggregate, locally available sand and53 grade ordinary Portland cement in which cement replaced by 20% of class F Fly Ash.

SPECIMEN IDENTIFICATION	RETROFITTING TECHNIQUES
A_1	Conventional Beam
A_2	Beam retrofitted with SIMCON Laminate
A_3	Beam retrofitted with FC Laminate (Welded Square Mesh)
A_4	Beam retrofitted with FC Laminate (Expanded Metal Mesh)
A_5	Beam retrofitted with Sandwich of 3 Laminates (SIMCON, Welded Square Mesh & Expanded Metal Mesh together)

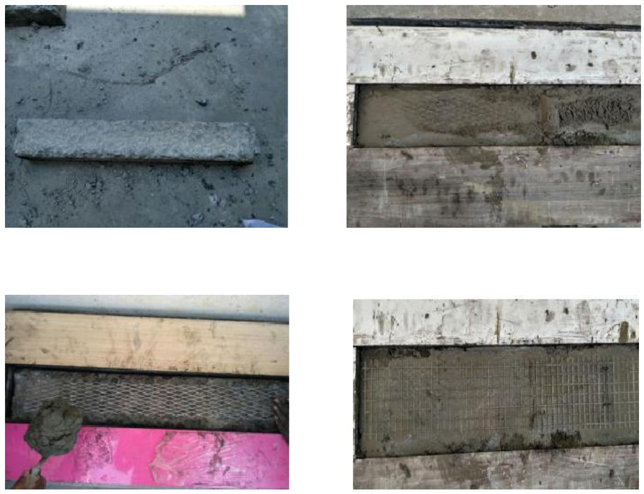

Fig 5.1 Retrofitted Beams: A) Chipped Beam B) SIMCON Laminate C) Expanded Metal Mesh D) Square Metal Mesh

5.1 TESTING

Compressive Strength: 150 mm × 150 mm × 150 mmcubes were casted for carrying out compression strength test. 7 day, 14 day and 28 day strength of the specimens were measured. The specimens were tested on a compression testing machine with capacity of 2000 kN.

To determine the compressive strength, we casted cubes with different percentage of Fly ash replaced for cement in the concrete. After casting and curing, the specimens are tested at 7, 14 and 28 days at compression testing machine (CTM) as per I.S. 516-1959.

Table 5.1: Compressive Strength Result

From the above results, Fly Ash of 20% shows the higher compressive strength. As % of Fly Ash Increases, the compressive strength decreases

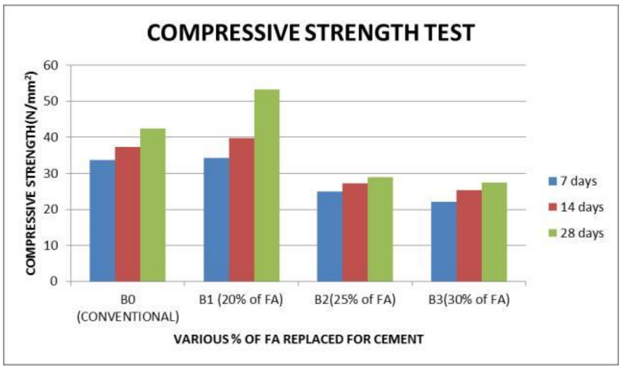

Chart 1 Compressive Strength of Different % of FA replaced cubes

Fig 5.2 Compression testing

Split Tensile Strength: The split tension test wereconducted on cylinder specimen of 150mm diameter and300mm length. The cylinders are casted with different % of FA replaced for cement in concrete. The specimens are cured and tested by placing the cylinder horizontally in Compression testing machine. The split tensile strength is determined at 7, 14 and 28 days.

Table 5.2: Split Tensile Strength Result

CYLINDER SPECIMEN	Split Tensile Strength (N/mm^2)		
	7 days	14 days	28 days
C_0	1.55	1.82	2.01
C_1	1.78	1.83	2.23
C_2	1.69	1.8	1.96
C_3	1.55	1.76	1.85

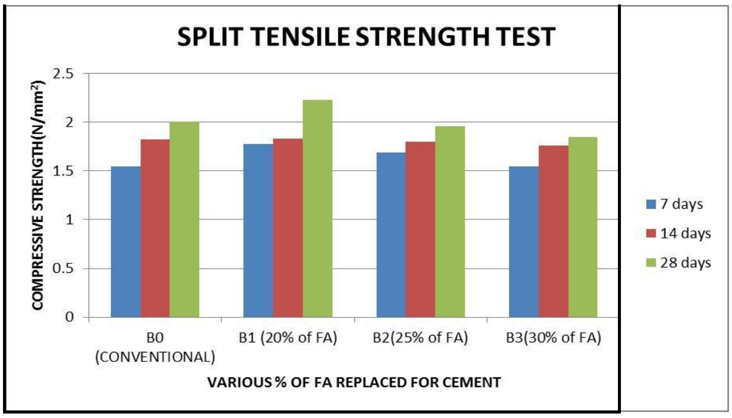

Chart 2 Split Tensile Strength of Different % of FA replaced cylinders

Fig 5.3 Split Tensile Test

Flexure strength test: The following procedure is adopted to conduct the flexural strength test. The capacity of the Loading frame used is 50 Ton

1. Brush the beam clean. Turn the beam on its side, with respect to its position as molded, and place it in the breaking machine. The size of the beam specimen is 150 x 150 x 1000 mm.

2. Set the bearing plates square with the beam and adjust for distance by means of the guide plates furnished with the machine.

3. Place a strip of leather or similar material under the upper bearing plate to assist in distributing the load.

4. Bring the plunger of the jack into contact with the ball on the bearing bar by turning the screw in the end of the plunger.

5. After contact is made and when only firm finger pressure has been applied, adjust the needle on the dial gauge to "0".

6. Here we are applying two point loading on the beam specimen, apply load till it breaks and note that as failure load Computation of the flexural strength was as follows. Flexural strength = $/^2$ X 1000

Where, P = Load in Kn
L = Effective length of beam = 900 mm b = Width of the beam = 150 mm
d = Depth of the beam = 150 mm.

Table 5.3 Flexure Strength Result

SPECIMEN	FAILURE LOAD (KN)	FLEXURE STRENGTH (MPa)	DEFLECTION (mm)
A_1	19	4	3.85
A_2	25	4.8	3.77
A_3	32	8.53	5.54
A_4	36	9.6	9.3
A_5	48	12.8	4.6

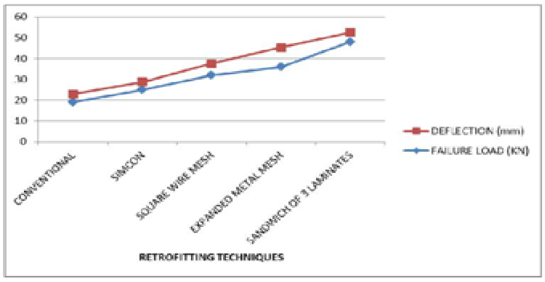

Chart 3 Failure Load & Deflection of all Beams

Fig 5.4 Testing of retrofitted beam under Loading Frame

6. CONCLUSIONS

Based on the results obtained from experiment, the following conclusions are drawn:

1. Thus it can be concluded that the concrete beam retrofitted with SIMCON & Ferrocement Laminates yields higher flexural strength than beams retrofitted with single laminates and conventional Beams.

2. The compression test and split tensile test results shows that the strength can be increased by replacement of optimum % of Fly Ash (20%) for Cement.

3. None of the beams attain Brittle Failure.

4. A Laminate retrofitted with cement mortar will ensure that the bond line does not break before failure and participate fully in the structural resistance of the strengthened beams.

7. REFERENCES:

[1] ACI Committee 549, "Guide for the Design, Construction and Repair of Ferrocement". ACI Structural journal, May - June 1988.

[2] Ahmed Khalifa and Antonio Nanni , "Improving Shear Capacity of Existing RC T – Section Beams Using CFRP Composites", Cement and Concrete Composite. Vol 22 , No 2, july 2000.

[3] Ahmed Khalifa ; Antonio Nanni; Abdel Aziz .M.I; William.J .Gold.," Contribution of Externally Bonded FRP to Shear Capacity of RC Flexural Members". Journal of Composites for Constructions / Nov 1998.

[4] AL- Sulaimani , G.J . and Basinbol ,F.A., " Behaviour of ferrocement material under direct shear" , Journal of ferrocement , vol 21,no 2 , April 1991.

[5] Alexander , D., " What is ferrocement", Journal of ferrocement , vol 22 , no1,January 1992 .

[6] Al- Sulaimani , G.J. , Brundel R. and Mousselhy, E., "Shear behaviour of ferrocement box beams", J. Cement and Concrete,1977.

[7] ACI Committee 549 (1982), "State of the art report on ferrocement", Concrete International 4.

[8] American society for Testing and Material (1980), "Annual book of ASTM standards",1980 , part 14.

[9] American Concrete Institute (1979), "Ferrocement Materials and Applications", pub SP-61.

[10] Application of ferrocement in Developing countries (1973)," National Academy of Sciences, 90.

[11] Chemboi.A. and Nimityongskol.P.(1969),"A bamboo reinforced cement water tank ", Journal of Ferrocement,19 (1).

[12] Desai Prakash ; Nandkumar N . and El-Kholy , A..Sayyed, "Shear strength of ferrocement trough section elements" , Journal of ferrocement , vol .24 , no 4 oct 1984.

[13] Desai .P; and Nandkumar.N ;"A quasi – empirical approach to shear strength of ferrocement trough section elements ", Journal of ferrocement , vol 25, no 4, oct 1995.

[14] E.L. Hackmen, M.B. Farrel and O.O. Dunham, "Simcon in filtrated mat concrete (SIMCON)", Concr. Int., vol. 14(12), pp.53-56,November 1992.

[15] IS 456, Code of practice for reinforced concrete design, New Delhi:Bureau of Indian Standards, 2000.

[16] Kaushik.S.K and Gupta.V.K "Proceedings of Second Asia Pacific Symposium on Ferrocement , Roorkee, India,25-27 February 1994".

[17] Kaushik .S.K ; Gupta.V.K. and Rahman .M.k. " Efficiency of mesh overlays of ferrocement elements" ,Journal of ferrocement 17(4). 1987

[18] L. C. Hollaway and M. B. Leeming, "Strengthening of reinforced concrete structures using externally- bonded FRP composites instructural and civil engineering". England: CRC Press, 1999

[19] M.A.Al-Kubaisy and P.J. Nedwell, "Behaviour and Strength of Ferrocement Rectangular Beams in Shear", Journal of ferrocement Vol .29. No 1 Jan 1999

[20] Mansur.M.A. and Ong.K.C.G ., "Shear strength of ferrocement beams" , ACI Journal 84 (1), 1987

[21] N. Krstulovic-Opara, E. Dogan, C.-M.Uang and A. R. Haghayeghi, "Flexural behaviour of composite RC-slurry infiltrated mat concrete(SIMCON) members", ACI Mater. J., vol. 94(5), pp. 502-512, September-October 1997

[22] Paul. B.K; and Pama. R.P., "Ferrocement Bangkok", Ferrocement Information Centre, Bangkok, Thailand, 1978

[23] Rafeeqi.S. F.A;Lodi. S.H;Wadalawala.Z.R. "Behaviour of Reinforced Concrete Beams Strengthened in Shear" Prof and Co Chairman, Dept Civil, NED Univ of Engg and Tech , Karachi(Pakistan)

[24] Raj .V. "Utilisation of lime for improving durability of Ferrocement"