IOSR Journal of Engineering (IOSRJEN)
ISSN: 2250-3021 Volume 2, Issue 7(July 2012), PP 01-10
www.iosrjen.org

"Performances of Chicken Mesh on Strength of Beams Retrofitted Using Ferrocement Jackets"

[1]Mr. Sandesh S Patil., [2]Prof. R A Ogale . [3]Prof. Arun Kr. Dwivedi
[1]B.E. Civil.Student of ME Civil (BS&T) Civil Engg. Dept SSVPS BSD College of Engg, Dhule-424002.
[2]B.E. Civil, M.Tech. Civil (Structure) HOD of Civil Engg.Dept.SSVPS BSD College of Engg, Dhule-424002 Maharashtra, India.
[3]B.E. Civil, M.Tech. Civil (WRE)Associate Professor in Civil Engg.Dept.SSVPS BSD College of Engg, Dhule-424002 Maharashtra, India.

ABSTRACT: *- Reinforced concrete structural components are found to exhibit distress, even before their service period is over due to several causes. Such unserviceable structures require immediate attention, enquiry into the cause of distress and suitable remedial measures, so as to bring the structures back to their functional use again. This strengthening and enhancement of the performance of such deficient structural elements in a structure or a structure as a whole is referred to as retrofitting. The all important issue to be addressed in retrofitting is life safety.*

What can be done to prevent collapse of the structure and prevent injury or death to occupants? Some retrofit requirements may try to address only the issue of life safety, while acknowledging that some structural damage may occur. Ferrocement sheets are most commonly used as retrofitting material these days due to their easy availability, economy, durability, and their property of being cast to any shape without needing significant formwork. Ferrocement as a retrofitting material can be pretty useful because it can be applied quickly to the surface of the damaged element without the requirement of any special bonding material and also it requires less skilled labour, as compared to other retrofitting solutions presently existing. The ferrocement construction has an edge over the conventional reinforced concrete material because of its lighter weight, ease of construction, low self weight, thinner section as compared to RCC & a high tensile strength which makes it a favourable material for prefabrication also. In the present thesis 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 is placed along the longitudinal axis of the beam. 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.

In the present paper 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 is placed along the longitudinal axis of the beam. 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.

Keywords*: ferrocement, retrofitting, jacket, wire mesh, orientation, beams.*

I. INTRODUCTION

Reinforced concrete is one of the most abundantly used construction material, not only in the developed world, but also in the remotest parts of the developing world. The RCC structures constructed in the developed world are often found to exhibit distress and suffer damage, even before their service period is over due to several causes such as improper design, faulty construction, change of usage of the building, change in codas provisions, overloading, earthquakes, explosion, corrosion, wear and tear, flood, fire etc. Such unserviceable structures require immediate attention, enquiry into the cause of distress and suitable remedial measures, so as to bring the structure into its functional use again. In the last few decades several attempts have been made in India and abroad to study these problems and to increase the life of the structures by suitable retrofitting and strengthening techniques. Of the various retrofitting techniques available, plate bonding is one of the most effective and convenient methods of retrofitting. Among the plate bonding techniques FRP plates are quite popular now-a-days. But it is observed that the use of FRP is restricted to developed countries or urban areas of the developing countries due to higher initial cost and requirement of skilled labour for their application. Thus, there is a need to develop an alternative technique, which is economical and can be executed at site with the help of semiskilled labour available at site. Ferrocement jacketing is found to be one such attractive technique due to its properties such as good tensile strength, lightweight, overall economy, water tightness, easy application and long life of the treatment. Many experimental studies have been conducted in recent years to strengthen flexural members by using various materials. [Andrew and Sharma (1998)] in an experimental study compared the flexural performance of reinforced concrete beams repaired with conventional method and ferrocement. They concluded that beams repaired by ferrocement showed superior performance both at the service and ultimate load. The flexural strength and ductility of beams repaired with ferrocement was reported to be greater than the corresponding original beams and the beams repaired by the conventional method.

Beams rehabilitated with ferrocement jackets show better performance in terms of ultimate strength, first crack load, crack width, ductility and rigidity of the section. It was observed that the cracking and ultimate strength increases by 10 percent and 40 percent in case of rehabilitated beams, whereas these increases were 10-30 percent and 40-50 percent in case of composite sections. The jacketing increases the rigidity of the beams and lead to 37 percent and 29 percent reduction in deflection. The crack width of the composite beams and rehabilitated beams decreases on an average by 42 percent and 36 percent respectively [Kaushik and Dubey (1994)].

The addition of thin layer of ferrocement to a concrete beam enhances its ductility and cracking strength. Composite beams reinforced with square mesh exhibit better overall performance compared to composite beams reinforced with hexagonal mesh. An increase in the number of layers improves the cracking stiffness of the composite beams in both cases. [Nassif (1998), Vidivelli (2001), Nasif (2004)].

A ferrocement shell improves the flexural behaviour of RCC beams, although there is no increase in the moment carrying capacity of under reinforced beams. However, the moment carrying capacity increased by 9 per cent and 15 per cent for balanced and over reinforced sections respectively [Seshu (2000)].

The ultimate strength of the reinforced concrete beams, which failed due to overloading and were repaired using ferrocement laminate, is affected by the level of damage sustained prior to repairing. However, ultimate strength ductility ratio and energy absorption have been reported to improve after the repair in all cases. The steel ratio used in the repair layer has a great influence on the amount of gain in the resisting moment, ductility ratio and energy absorption. The higher the steel ratio the higher the gain in resisting moment and energy absorption; conversely, the ductility ratio was found to be decreased with increase in steel ratio [Fahmy and Ezzat(1997)].

The flexural behaviour of reinforced concrete T-beams strengthened with thin ferrocement laminate attached to the tension face using L-shaped mild steel round bars as shear connectors. From the experimental investigation it was concluded that after strengthening the performance of the beam improved substantially in terms of strength, flexural rigidity and first crack load, provided the connectors are adequately spaced and the surface to receive the laminate roughened to ensure sufficient bond strength for composite action. [Paramasivam (1994]). Thus, ferrocement is a viable alternative material for repair and strengthening of reinforced concrete structures. It has been accepted by the local building authority in Singapore for use in upgrading and rehabilitation of structures. The National Disaster Mitigation Agency (NDMA), Government of India, also accepted the use of ferrocement for this purpose. The behaviour of ferrocement in flexure depends upon various parameters such as mortar, type of wire mesh, orientation of wire mesh etc.; hence the behaviour of ferrocement jackets. In the present paper the effect of chicken mesh on the strength, toughness and ductility of the retrofitted beams is presented.

II. EXPERIMENTAL PROGRAMME:-

To carry out the investigation, six prototype beams of size 140mm x 220mm x 1550mm reinforced with three bars of 8 mm diameter in tension and two bars of 8mm diameter in compression were cast using the proportioned mix as shown in Fig.1 Out of these six beams, two were used as control beams are tested to failure to find out the safe load carrying capacity corresponding to the allowable deflection as per *IS:456-2000* i.e. span /250. The other four beams were stressed to 60 & 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 as shown in Fig. 2 The jacket was reinforced with doubled layer of 10mm x 10mm Hexagonal chicken mesh. The set of beams (two each) were divided into three categories depending upon the stressed level. Control beams were designated as Type-A, whereas, beams retrofitted with chicken mesh stressed with 60% were designated as Type – B beams. Retrofitted beams having chicken mesh stressed with 80% were designated as Type – C respectively.

3. Materials

The properties of various materials used in the experimental study are reported in Tables 1 to7

Table 1 Physical properties of cement used

Sr. No.	Characteristics	Value obtained Experimentally	Value Specified by BIS:8112-1989
1	Standard consistency	30.34%	-
2	Fineness of cement as retained by 90 micron no. sieve	3	< 10%
3	Setting time 1. Initial 2.Final	 52 min. 290 min.	 >30 min. <10 hours
4	Specific gravity	3.07	-
5	Compressive Strength (N/mm^2) 1. 7days 2. 28days	 27.5 37.35	 33 43
6	Soundness (mm) (By Le-Chatelier's method)	2.5	<10(Fresh cement) < 5(old cement)

Table 2 Physical properties of fine Aggregates

Sr. No.	Characteristics	Value
1	Specific gravity	2.46
2	Bulk density loose (Kg/lt)	1.58
3	Fineness Modulus	3.83
4	Water Absorption	1%
5	Grading Zone	Zone I

Table 3 Physical properties of course Aggregates

Total Weight Taken= 3Kg.

Sr. No.	Characteristics	Value	
		20mm	12mm
1	Types	Crushed	Crushed
2	Specific gravity	2.555	2.404
3	Water Absorption	0.5%	0.55%
4	Fineness Modulus	2.43	2.52

Table 4 Physical Properties of steel bars & chicken mesh

Sr. No	Diameter of bars/ chicken Mesh	Yield-Strength (N/mm^2)	Ultimate Strength (N/mm^2)	Elongation (%)
1.	8mm	621.64	716.13	27.5
2.	6mm	442.42	612.7	32.9
3.	0.78mm	430	551.36	2.42

Table 5 Physical Properties of chicken mesh.

Sr. No	Properties of chicken mesh	Values
1	Gauge no.	21
2	Wire diameter (mm)	0.78
3	Opening(mm)	19.0
4	Weight Per unit area of mesh (Kg/m^2)	0.535
5	Volume per unit area of mesh (*10^{-5} m^3/m^2)	6.82
6	Surface area per unit area of mesh (m^2)	0.339

Table 6 Different Types of Wire Meshes and Their Characteristics

Type of Mesh	Wt. of one layer per unit area($kg/m^{2)}$	Mesh thickness (mm)	Steel content (kg/m^2)	Steel surface per unit Vol. (mm^2/mm^3)
Hexagonal wire mesh 0.78mm * 21 gauge	0.55	1.45	415	0.265
Square welded mesh12 mm *19 gauge	1.10	2	545	0.251
Expanded metal T.C.G.269	1.20	2.55	495	0.248
Woven mesh	3.50	5.55	655	0.240

Table 7 Web Reinforcement Description And Volume Fraction.

Type	Opening size	Designation	Volume fraction V_f (%)
Diamond	Large	DL	1.15
Square	Large	SL	0.38
Square	Small	SS	0.38
Diamond	Small	DS	0.25
Chicken	N/A	C	0.15

III. TESTING ARRANGEMENT

All the six beams are tested under simply supported end conditions. Two points loading is adopted for testing & the testing of beams is done with the help of hydraulic operated jack connected to load cell. The load is applied to the beam with the help of hydraulic jack and the loading data is recorded at pressure gauge is attached at pressure pump, which is attached with the load cell and one dial gauge is placed at the centre (L/2). The value of deflection is obtained from this dial gauge. Out of these six beams two are control beam, which are tested after 28 days of curing to find out the ultimate load carrying capacity after find out ultimate load carrying capacity of beams and subsequently remaining four beams two of each seat are stressed up to the 60%, & 80%, average of safe load carrying capacity of control beams and then retrofitted with 15mm thick ferrocement laminate. And all the beams where tested in house on the loading frame at structure laboratory of S.S.V.P.S.B.S.Deore. College of engineering. Dhule. Flexural test was performed and the final results were analyzed. The experiential set up is shown in fig.3.

3.1. LOADING DEVICES (INSTRUMENTATION)

The most important part of instrumentation is the loading frame. The vertical load is produced with the help of a hydraulic jack and the pumping unit, where as the load is to be measured with the help of dial gauge attached to the pumping assembly and loading frame as shown in Plate.1 The deflection caused due to the load is measured with the help of dial gauge which are kept below the beam at Central position. The vertical load is measured in KN and the deflection is measured in mm from the dial gauge. The load is applied almost at a uniform rate; load and deflection were recorded at regular intervals for each test setup. The load intervals are 0, 20, 40, and 80 KN. whereas corresponding values of deflection is recorded with respect to load intervals in mm. This continues till the ultimate load and final failure of the test specimen.

3.2. OBSERVATIONS DURING TESTING PROGRAMME

The following observations were observed during the conduct of test up to collapse.

i) Initial adjustment & initial reading - Before starting the experiment, bolts were fully tightened ensuring full fixity at load points and supports. The dial gauge was checked for proper functioning before it was mounted in position. The dial gauges contact between the tip and bottom surface of beam was ensured. The jack centerline was aligned along the beam axis. The important load points were marked with red pen. The gauge was adjusted to show zero initial reading. The initial reading for the dial gauge was also recorded.

3.3. RETROFITTING OF BEAMS

The beams are stressed up to a specified limit as above and then retrofitted by applying steel chicken mesh and then plastering it with cement mortar up to the thickness of 15mm for all six beams. Therefore final cross-section of beam with ferrocement laminate will become 170 x 235 x 1550 mm. Effect of two different stress levels of 60%,and 80% has been studied to see their effect on the strength of retrofitted beams with chicken mesh placing it over the free surfaces of beam. An overlap of 3 inches at the place of joint between wire mesh is introduced.

3.4 PROCESS OF RETROFITTING

First of all surface of beam is cleaned and after cleaning of the surface, doubled layers of chicken mesh stretched and raped to three faces on beam with nail & visor for bonding between beam and mesh. As shown in Plate.1 after that 15 mm plaster in the form of 1:2 cement mortar (w/c=0.4) is applied on three faces of beams. After this the beam is cured for 28 days. Then with the same procedure as of control beam, testing of beams is done under two points loading in order to calculate ultimate load and corresponding deflections & then observations of the experimental programme along with the results and their discussion.

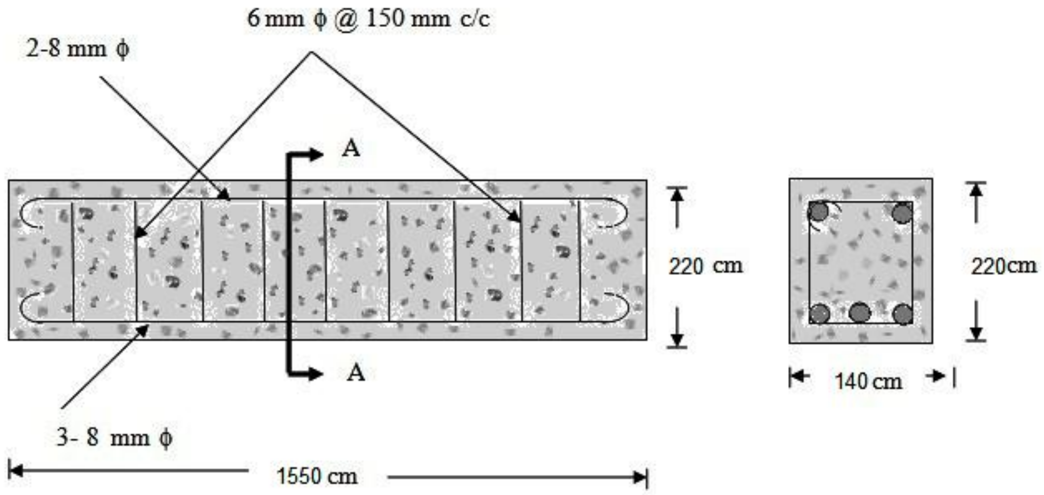


Fig.1 Longitudinal and Cross Section (A-A)

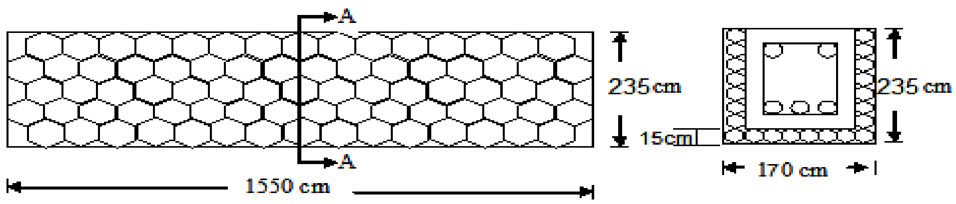


Fig. No.2 Longitudinal & Cross section A-A of Retrofitted beam with chicken mesh.

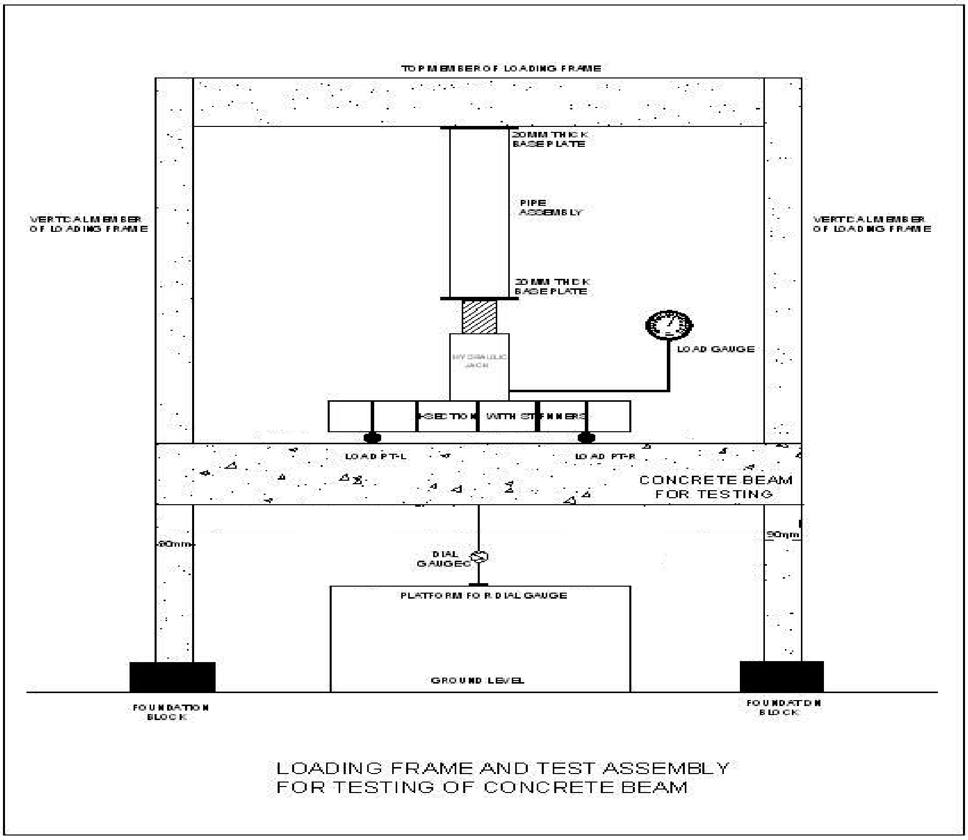
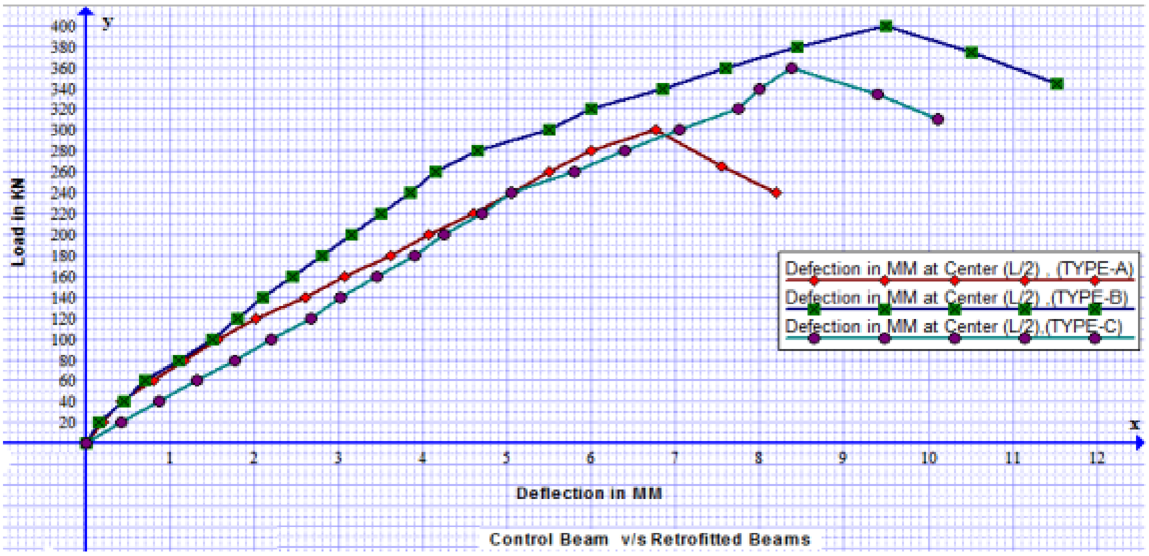


Fig.3. EXPRIMENTAL SETUP

IV. RESULTS AND DISCUSSION

Firstly control beams are tested up to failure and the data corresponding to it is recorded. Then out of four, two in each seat of beams was stressed up to 60% and 80% of the safe loads of control beams. The safe load is calculated from the average of load data for allowable deflection of 6mm at the load is 280KN and the corresponding loads at 60%, 80%, stress level are 168KN , 224KN respectively. Then the retrofitting of the beams is done with cement mortar of thickness 15mm along with doubled layers chicken wire mesh bonded on three sides for all four beams. After 28 days of curing the beams are tested again with the same method as the control beam was tested initially and the corresponding results are recorded are shown in Table No 8 and Plate No.(2&3). These retrofitted beams were then loaded to failure and the data was recorded in the form of load and deflection. The Table No. 8 Also presents this data for the control beams and beams retrofitted using specified chicken mesh. And Graph.1 shows the load deflection behaviour at the mid span points of the control as well as beams retrofitted with chicken mesh. It is observed from the curves that with an increase in load there is a considerable increase in deflection for all the beams. It was also noted that the average Ultimate load carrying capacity of 60% was 400kN compare with control beams, for which it was 300kN.at 6.77mm deflection. The deflection increased to 9.50 mm in 60% stressed beams. This shows that the distribution of stress with chicken mesh in 60% stressed beams is better. It is also observed that corresponding to the serviceability requirement of 6mm deflection, the load increased from 280 KN for the control beam to 320 KN, and 282.35 KN, for type B and C retrofitted beams, respectively. It is also observed from the curves that the deflection at the centre at maximum load is maximum in the case of beams retrofitted with chicken mesh in 60%stressed level which is 9.50mm as compared to those with chicken mesh with 80% stressed level for which it is 8.37mm. The load deflection curves were idealized as quadric-linear curves. Using the idealized curves the ductility ratio i.e. ratio of deflection at ultimate load to yield load, are calculated and presented in Table 9. It is observed that the average ductility ratio increases by 1.40 and 1.23 for Type-B, and Type-C beams respectively as compared to the control beams Type-A. The results indicate that the beams retrofitted with chicken mesh at 60% stressed as reinforcement in the ferrocement jacket is best among all specimens with regards to enhanced maximum load carrying capacity followed by 80% stressed beams respectively. However, the ductility ratio and load carrying capacity is highest in case of beams retrofitted chicken mesh at 60% stressed level. The increase in ductility ratio of beams retrofitted using ferrocement jacket having chicken mesh at different stressed level as reinforcement are makes the retrofitted beams suitable for dynamic load applications.



Graph 1.Load and Deflection Curve between Control specimen and Retrofitted Specimen

Plate 1 Loading Frame Arrangement & Application of Chicken Mesh on Beam Surfaces

Plate 2 Testing Arrangements of control Beam

Plate 3 Testing of Retrofitted Beams

Table 8 Compare between Control specimen and Retrofitted Specimen

TYPE-A Average of Control beams without Retrofitting {(C1+C2)/2} =say "CB"			**TYPE-B Average of beams with Retrofitting {(RR1+RR3)/2} =say "R60%"**			**TYPE-C Average of beams with Retrofitting {(RR2+RR4)/2} =say "R80%"**		
Sr. No	Force in KN	Defection in MM	Sr. No	Force in KN	Defection in MM	Sr. No	Force in KN	Defection in MM
		Center (L/2)			Center (L/2)			Center (L/2)
1	0	0	1	0	0	1	0	0
2	20	0.20	2	20	0.15	2	20	0.42
3	40	0.42	3	40	0.45	3	40	0.87
4	60	0.80	4	60	0.70	4	60	1.32
5	80	1.17	5	80	1.10	5	80	1.77
6	100	1.57	6	100	1.50	6	100	2.20
7	120	2.02	7	120	1.80	7	120	2.67
8	140	2.60	8	140	2.10	8	140	3.02
9	160	3.07	9	160	2.45	9	160	3.45
10	180	3.62	10	180	2.80	10	180	3.90
11	200	4.07	11	200	3.15	11	200	4.25
12	220	4.60	12	220	3.50	12	220	4.70
13	240	5.07	13	240	3.85	13	240	5.05
14	260	5.50	14	260	4.15	14	260	5.80
15	280	6.00	15	280	4.65	15	280	6.40
16	300	6.77	16	300	5.50	16	300	7.05
17	265	7.55	17	320	6.00	17	320	7.75
18	240	8.20	18	340	6.85	18	340	8.00
			19	360	7.60	19	360	8.37
			20	380	8.45	20	335	9.40
			21	400	9.50	21	310	10.10
			22	375	10.50			
			23	345	11.52			

V. COST ANALYSIS

A comparative cost analysis for three types of beams is presented in Table 10.It is noted that beams retrofitted with chicken mesh stressed with 60% are the most efficient than 80% stressed level as its cost to strength ratio is the equal to the control specimens.

Table 9.Cost Analysis of Beams Retrofitted Using Ferrocement Jacket With Chicken Mesh

Material	**Quantity Per Beam**	**Rate (Rs)**	**Cost required for Per Beam type (Rs)**		
			Type –A	Type-B	Type-C
Concrete Ingredients					
Cement (Kg)	3 bags	280/- (Rs)	840/-	840/-	840/-
Steel 3-8mm. dia. 2-8mm. dia. 9-6mm.dia.	 2.38 Kg 1.40Kg 1.45Kg	55/-(Rs) Per Kg	265.65/-	265.65/-	265.65/-
Coarse Aggregates (cft)	0.32 m^3	800 (Rs) per. m^3	255/-	255/-	255/-
Fine aggregates (cft)	0.16 m^3	1000 (Rs) per. m^3	160/-	160/-	160/-
Labour for control beams	2 No.	250 Per day	500/-	500/-	500/-
Cost of Ingredients			**2,020/-**	**2,020/-**	**2,020/-**
Retrofitting Material					
Chicken Mesh.	10'feet	15/- per feet.	----	150/-	150/-
Additional material like cement, Fine aggregates, screws etc.	0.5 bags 0.03m^3 & 10no.	280/-per. Bags, 1000/- (Rs) per.m^3 & 1/- Rs	----	180/-	180/-
Labour	1 No.	250/-	-----	250/-	250/-
Cost of Retrofitting Material			-----	580/-	580/-
Total Cost			**2020/-**	**2600/-**	**2600/-**
Cost ratio			1.00	1.30	1.30
Strength Ratio			1.00	1.34	1.20
Cost/Strength Ratio			1.00	0.97	1.08

Table 10 Comparison of Experimental Ultimate Loads, Deflection Characteristics and Ductility Ratio of Beams

Beam Designation	Observed Ultimate loads in KN	%increase in Ultimate Load carrying capacity after retrofitting	Experimental Deflection of midspan at Ultimate Load	% Increase in deflection Corresponding to Ultimate load deflection	Safe Load Corresponding to (L/250) i.e. 6mm Deflection	% increase in safe load for 6mm Deflection as per BIS	Ductility Ratio*
Control Beam	300	---------	6.77	--------	280.00	---------	--------
RR1	400	33.34	9.65	42.54	314.50	12.32	1.42
RR2	360	20.00	8.65	27.76	282.50	1.00	1.27
RR3	400	33.34	9.35	38.10	325.50	16.25	1.38
RR4	360	20.00	8.10	1.19	282.35	1.00	1.19

Ductility ratio is defined as ratio of deflections of retrofitted and un-retrofitted beam Ultimate load

VI. CONCLUSIONS

Based upon the test results of the experimental study undertaken, the following conclusions may be drawn:

1. The beams retrofitted with chicken mesh are increasing Ultimate load carrying capacity when loaded to failure.
2. The failure of the composite is characterized by development of flexural cracks over the tension zone. The spacing of cracks is reduced for retrofitted beams indicating better distribution of stress.
3. Chicken mesh stressed with 60% after retrofitting the stressed beams has the highest load carrying capacity as compared to control beam as well as the other beams retrofitted with different stressed level
4. After retrofitting, all the test specimens showed large deflection at the ultimate load, and also a significant increase in the ductility ratio. As well, making the components better equipped to resist dynamic loads.
5. Beams retrofitted with chicken mesh with 60% stressed level were the most efficient as their cost to strength ratio is near about equal to control beam.

VII. FUTURE SCOPE AND LIMITATIONS OF WORK: -

From the observation of result and application of ferrocement suggests that the use of chicken mesh in ferrocement laminates offer better distribution of load because chicken mesh has high modulus of elasticity. The ferrocement jacketing is applied only where the structural strength of an otherwise healthy. The experimental program is sophisticated and requires extreme care during testing work. There are several limitations related with laboratory testing work like capacity of loading frame and jack, size of beams, workmanship etc. This method is relevantly new and more information is awaited for ascertaining the long-term behavior of structures repaired by this method. Now-a-day there is limited experience in this methodology and not much more information is available on the behaviour of chicken mesh used for retrofitting work therefore, there is a future scope to undertake more studies about the behaviour of ferrocement jacketing for strengthening and other application purpose.

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