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Experimental Investigation of Strengthening of RC Beam Using Ferro cement Laminates

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Abstract:

Ferro cement is a versatile construction material formed by using hydraulic cement mortar into closely spaced layers of a small sized wire mesh. The mesh may be of metallic or other materials. It has a high tensile strength to properties and predict flexural behaviour of Ferro cement laminates by replacing cement with industrial wastes to some extent. Portland cement weight ratio better cracking resistance behaviour when compared to reinforced concrete. The main aim of this research work is to increase the normal beam strength and also extend the old beam life span by using Ferro cement laminate with effective utilization of fly ash and silica fume are optimum weight of cement. The flexural characteristics of various specimens were obtained experimentally. The specimens are reinforced with different layer of chicken mesh, and formed by different replacement proportion

Keywords— **Chicken mesh, Epoxy resin, Fly ash, Ferro cement laminate, Flexural test, silica fume.**

I. INTRODUCTION

Ferro cement is a versatile construction material formed by filling hydraulic cement mortar into closely spaced layers of small sized wire meshes over a small thickness. The mesh may be of metallic or any other materials. It has a higher tensile strength to weight ratio and better cracking resistance behaviour when compared to reinforced concrete. It requires less skill and provides low cost serviceability without the loss of structural integrity. Ferro cement is identified as an eco-friendly technology. Ferro cement has proven to be less polluting technology that uses all resources in a more sustainable manner. It handles waste products in a more acceptable manner than other construction technologies. Ferro cement is truly sustainable and eco-friendly as it uses minimum natural resources, thus mitigating the effects of global warming. These potential advantages and the novelty of the concept make Ferro cement, an attractive material for construction purpose. Ferro cement originally started with boat building and presently it has got very wide applications, in the fields of agriculture, water supply, sanitation, housing rural energy, repair and rehabilitation of structures etc. The use of industrial by-products as partial replacement of cement in the mortar improves certain characteristics (Selcuk turkel & yigit altuntas 2009).

The maintenance, rehabilitation and upgrading of structural members are perhaps some of the most crucial problems in civil engineering applications. Moreover, a large number of structures constructed in the past using the earlier design codes in different parts of the world are sometimes structurally unsafe according to the current design standards. Since replacement of such deficient elements of structures incurs a huge amount of money and time, strengthening has become the acceptable way of improving their load carrying capacity and extending their service durability. Infrastructure decay caused by premature deterioration of buildings and structures has led to the investigation of several processes for repairing or strengthening purposes. One of the challenges in strengthening of concrete structures is the selection of a strengthening method that will enhance the strength and serviceability of the structure while addressing limitations such as constructability, building operations, and budget. Strengthening may be needed to allow the structure to resist loads that were not anticipated in the original design. This may be encountered when structural strengthening is required for loads resulting from wind and seismic forces or to improve resistance to blast loading. Thus a complete understanding of Ferro cement material behaviour would lead to an innovative technique for strengthening of reinforced concrete beams.

A. Need for Replacement

In Ferro cement the meshes serve as reinforcement and mortar serves as matrix resulting as an integral product. Engineers are continually pushing the limits to improve the performance of the mortar with the help of innovative chemical admixtures and supplementary cementitious materials. The development of new construction materials and technology can partly relieve pressures on the existing building material supply and help to arrest the spiraling rise in cost of these materials and also may reduce in-situ construction activities. The main benefits of fly ash and silica fume are their ability to replace certain amount of cement in the matrix and still able to display cementitious property. They reduce the cost of using Portland cement. The fast growth in industrialization has resulted in tones of by-product or waste materials such as fly ash and silica fume. The use of these by-products not only helps to utilize these waste materials but also enhances the properties of mortar in fresh and hydrated state (Kazim Turk et al 2013).

Production of one ton of Portland cement releases 0.9 tons of CO2 into the atmosphere correspondingly, thereby impacting the environment. Portland cement is a highly energy intensive material. In India, about 100 million tons of fly ash is accumulated every year which is generated as waste from thermal plants. This is causing enough concern as its disposal involves design and installation of ash ponds covering large areas at each plant site. In spite of concerted efforts on a national scale, only a very small fraction (around 6%) of the fly ash is put to use in India, compared to its utilization to a greater extent in other countries (Md Emamul Haque 2013). Silica fume is also a waste by-product from the silicon metal and ferrosilicon alloy industries. An effort has been made to industrial byproducts as the substitutes for partial replacement of cement and to reduce waste pollution.

B. Research Significance

The wide application of admixtures with partial replacement of cement, reduction in embodied CO2 content and sustainability of the waste materials reuse have been the driving force for researchers to carry out extensive work in Ferro cement technology. Ferro cement is a cost effective and versatile material. Only certain types of materials locally available in bulk quantity can be used. There is a need for evaluating admixtures as replacement and simultaneously fulfilling advantages like low cost, abundance etc. for Ferrocement applications. There is also a demand for identifying and evaluating the admixture proportion of Ferrocement that should possess good ductility, less cracking and maximum strength. They should provide a sustainable technology to reuse industrial waste like fly ash, rice bran, wheat husk, silica fume along with cement paving the way for reducing CO2 emissions. The combined use of mineral admixtures and super plasticizers with cement resulted in synergistic effects. It led to modification enabled durable mortars to be used in a variety of conditions. The increased strength has to be thoroughly validated. So there is a need to study the flexural behaviour and impact resistance of Ferrocement laminates with material replacement. There has been a dearth of research work on studying flexure and the impact behaviour of Ferrocement laminates made from cement mortar, partially replaced with fly ash and silica fume at differing volume fraction of mesh. The reinforced concrete beams get strengthened with the use of the Ferrocement laminates. The research proposes an abundant, cost effective, strong and sustainable eco friendly construction material for the future through the use of Ferrocement technology.

C. Objectives and Scope Of Current Study

- To explore the salient features of many constituents for the composition of Ferrocement laminates and to select the suitable materials to be used in Ferrocement laminate preparation.
- To develop cementitious matrix containing a suitable combination of silica fume, fly ash, and superplasticizer, to be used in thin Ferro cement laminates that are applied for structural repair and strengthening applications.
- To study experimentally the flexural and impact characteristics for the different chicken mesh specimens of chosen size with different proportions of replacement.
- To formulate mathematical models that will compare the experimentally obtained ultimate moment capacity of Ferro cement laminates reinforced with chicken mesh..

The investigation shall be further extended experimentally to study flexural behaviour of reinforced concrete beams and to propose an analytical model to calculate the ultimate moment capacity in reinforced concrete beams, strengthened with Ferro cement laminates with partial replacement of cement by fly ash and silica fume.

II. REVIEW OF LITERATURE

1) Thomas et al (1999) studied the durability of concrete that contains ternary blends of Portland cement, fly ash and silica fume. It was concluded that the combination of 3% to 6% of silica fume and 20% to 30% of fly ash was effective in reducing expansion due to alkali silica reactivity. It also produced a high level of sulphate resistance. Concrete made with these proportions showed excellent fresh and hardened properties. The data indicated that the diffusivity of the concrete that contains ternary blends continues to decrease with age. The reductions are very significant and have a considerable effect on the predicted service life of reinforced concrete elements exposed to chloride environments.

2) Perumal & Sundararajan (2005) investigated the performance of M110 Grade of high performance concrete trial mixes having different replacement levels of cement with SF. The strength and durability characteristics of these mixes are compared with the mixes without SF. Compressive strength of 110 MPa and 54.65MPa at 28 days is obtained by using 10% and 0% replacement of cement with SF. The results showed that the SF concrete possesses superior durability properties.

3) Ramakrishna & Sundarajan (2005) presented the experimental investigations of the resistance to impact loading of cement mortar slabs (1:3, size: 300 mm X 300 mm X 20 mm) reinforced with four natural fibers, coir, sisal, jute, hibiscus cannebinus and subjected to impact loading using a simple projectile test. Four different fiber contents (0.5%, 1.0%, 1.5% and 2.5%—by weight of cement) and three fiber lengths (20 mm, 30 mm and 40 mm) were considered. The results obtained have shown that the addition of the above natural fibers increased the impact resistance by 3–18 times more than that of the plain mortar slab. Of the four fibers, coir fiber reinforced mortar slab specimens have shown the best performance based on the set of chosen indicators, i.e. the impact resistance, residual impact strength ratio, impact crack-resistance ratio and the condition of fibre at ultimate failure.

4) Selcukturkel & Yigitaltuntas (2009) compared the effect of limestone powder (LP) on the properties of Supplementary Cementitious Replacing Materials (SCRM) with other mineral additives such as silica fume (SF) and fly ash (FA) and their combination effects. Fresh properties, flexural and compressive strengths and water absorption properties of mortars were determined. The use of SF in mortars significantly increased the dosage of super plasticizer (SP). At the same constant SP dosage (0·8%) and mineral additives content (30%), LP can better improve the workability than that of control and FA

mixtures by 19% and 27%. However, the results of this study suggested that certain FA, SF and LP combinations can improve the workability of SCRMs, more than FA, SF and LP alone. LP can have a positive influence on the mechanical performance at early strength development while SF improved aggregate-matrix bond resulting from the formation of a less porous transition zone in mortar. SF can better reduce the effect on total water absorption while FA and LP would not have the same effect, at 28 days.

5) Kazim Turk et al (2013) scrutinized the effect of ASTM C 618 Class F Fly ash (FA) at 25%, 30%, 35% and 40% and Silica fume (SF) at 5%, 10%, 15% and 20% replacement of Portland Cement in SCC was used to evaluate the effect of the types and quantity of powder additions on compressive strength and permeations properties of SCC. To this end, eight types of SCC were designed, in comparison with Vibrated Traditional Concrete (VTC). The results indicated that SCC specimens with SF15 had the highest compressive strength with 73.87 MPa for 130 days. The sorptivity values of SCC specimens with FA and SF were lower than those of VTC specimens regardless of the type and quantity of powder additions. On the other hand, the carbonation resistance of VTC was higher than that of SCC specimens containing both SF and FA for all accelerated carbonation periods. Consequently, it can be said that the type and quantity of powder additions had an important effect on the correlation among the compressive strength and permeation properties of SCC.

III. METHODOLOGY

The methodology of present study is explained by the properties of cement, fly ash, silica fume, fine aggregate, chicken mesh are studied. The compressive strength of mortar was studied at 1:2 by weight and with water binder ratios of 0.35. At water binder ratio, partial replacement of cement with fly ash content was varied from 10%, 15%, 20%, 25% and 30% together with a constant 5% silica fume by weight of cement. Ferrocement laminates of sizes 100 mm x 25 mm x 500 mm, 1:2 mix ratio, 0.35 water binder ratio, partial replacement of cement with fly ash content varying from 10%, 15%, 20%, 25% and 30% together with a constant 5% silica fume by weight of cement were prepared The flexure test was conducted with the load applied at one two point.

The reinforced concrete beams with simply supported span lengths of 1.22 m, and a cross-section of 150 x 100 mm were cast with M25 grade concrete of mix ratio 1:1.5:3 by weight and the water cement ratio of 0.45. The beam was reinforced with two steel bars of 10 mm diameter with two-legged stirrups of 6 mm diameter at 75 mm c/c. Ferrocement laminates were used to strengthen the beams. The ferrocement laminates were sized 1220 mm x 100 mm x 25 mm with the mortar mix of cement sand ratio of 1:2 and a water binder ratio of 0.35.

IV. MATERIAL INVESTIGATION

A. Cement

In this investigation cement which is of the ordinary Portland cement 53 grade was used.

Table – 1: Properties of cement

Sl. No	Test Conducted	Result Obtained	Requirement As per 1s 4031
1.	Normal Consistency	32%	Not specified
2.	Initial setting time	42min	Shall not be less than 30 min
3.	Final setting time	320 min	Shall not be more than 600 min.
4.	Compressive Strength	62 MPa	Shall not be less than 53Mpa
5.	Specific gravity	3.15	3.16
6.	Soundness	6.1mm	Shall not be more than 100mm

Fig 1- OPC

B. Fine and Coarse Aggregate

For all the experimental investigations locally available river sand of good quality, passing through a 2.36 mm sieve was used. The grading of sand used conforms to Zone-II of IS: 383-1970, ACI 549 1R-93 and Ferro cement Model Code (FMC).The coarse aggregates is passing through a 20 mm & above sieve was used.

Fig 2- Fine And Coarse Aggregate

C. Water

Water is an important ingredient of concrete and mortar as it is actively participates in the chemical reaction with cement. Since it helps to form strength, giving cement gel, the quantity and quality of water is to be looked very carefully.

D. Fly Ash

Ash produced in small dark flecks by the burning of powdered coal or other materials and carried into the air.

Table - 2 Properties of fly ash

Description of test	Result obtained	Requirement As per 1s 3812
Specific surface area (m^2/kg)	312 m^2/kg	320 m^2/kg
Soundness	0.65	0.8

Fig – 3 Fly Ash

E. Silica Fume

Silica fume is a byproduct of producing silicon metal or ferrosilicon alloys. One of the most beneficial uses for silica fume is in concrete. Because of its chemical and physical properties, it is a very reactive pozzolan. Concrete containing silica fume can have very high strength and can be very durable.

Table – 3 Properties of silica fume

Description of test	Result obtained	Requirement As per 1s 3812
Bulk density (m^2/kg)	546 m^2/kg	480-720 m^2/kg
Specific surface area (m^2/g)	19	>15

F. Wire Meshes

Hexagonal chicken wire mesh locally available were used as the reinforcement in ferrocement laminate.

Table – 4 Properties of wire mesh

Description	Chicken mesh
Raw meterial	Steel
Width(m)	1
Mesh opening size (mm)	15X10
Thickness(mm)	1.5
Diameter (mm)	0.5
Mesh shape	Hexagonal
Density (kg/m^3)	7850
Yield strength (N/mm^2)	310

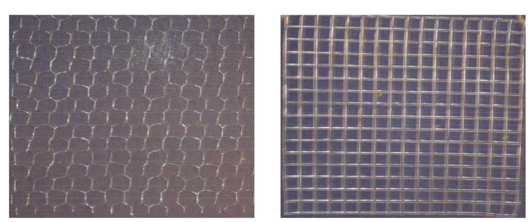


Fig – 5 Wire Mesh

G.Epoxy Resin

The epoxy resin is a two part epoxy system consisting of a resin and a hardener. It has a mix ratio of 1: 2 by weight with a long work life of 40-50 minutes. It can be cured at room temperature. Epoxy resin exhibits low shrinkage during curing. The cured epoxy has high chemical, corrosion resistance but good mechanical and chemical properties.

Table – 5 Properties of Epoxy resin

Description	Strength (N/mm^2)
Compressive strength (ASTM D 695)	75
Tensile strength at 7 days (ASTM D 638)	38
Pull out Adhesion at 3 days	2.91
Pull out Adhesion strength at 7 days	15.4

H. Reinforcement Of Beam

The longitudinal reinforcement for beams were two steel bars of 10 diameter and yield strength of 500 N/mm^2 in tension. The two-legged stirrups were of 6 mm diameter at 75 mm c/c.

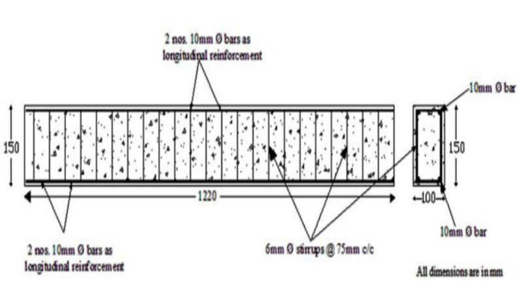


Fig – 6 Reinforcement of Beam

V. EXPERIMENT RESULTS

In this chapter, the results based on the experimental investigations which were carried out on optimized mortar matrix are discussed. The flexural characteristics of ferrocement laminates, with different proportion of fly ash and silica fume together with cement, reinforced with chicken mesh of single, double, three and four are presented. The results are compared with conventional mortar specimens of ferrocement laminates. The experimental investigation on strengthened reinforced concrete beams with ferrocement laminates of conventional mortar and optimized mortar containing silica fume, fly ash and cement reinforced with chicken mesh of four layer also presented. The experimental results in flexural capacity of ferrocement laminates and strengthening of reinforced concrete beams are compared.

A. Optimization Of Mortar Mix

When cement sand ratio was varied from 1:2 compressive strength of mix at 28 days increased to a maximum value with cement sand ratio of 1:2 which can be observed graphically from

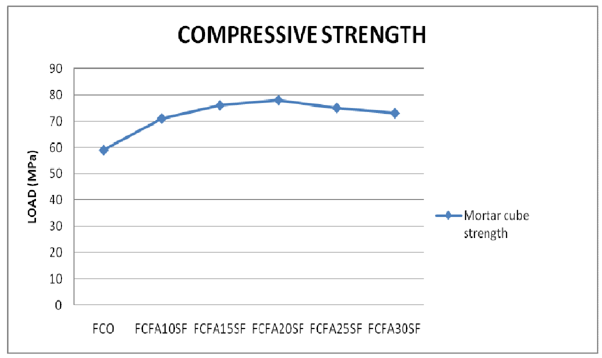


Chart -1

B. Flexural Behavior Of Ferrocement Laminates

The results and discussions presented are based on the experimental investigations carried out on ferrocement specimens of size 100 mm x 25 mm x 500 mm

Fig – 7 Flexural Test Setup for Laminates

Table – 6 First Crack Load(KN)

	I LAYER	II LAYER	III LAYER	IV LAYER
FCO	0.8	1	1.2	1.4

FCFA10SF	1.1	1.2	1.4	1.5
FCFA15SF	1.15	1.3	1.45	1.6
FCFA20SF	1	1.4	1.45	1.63
FCFA25SF	1.1	1.3	1.3	1.45
FCFA30SF	0.95	1.1	1.25	1.4

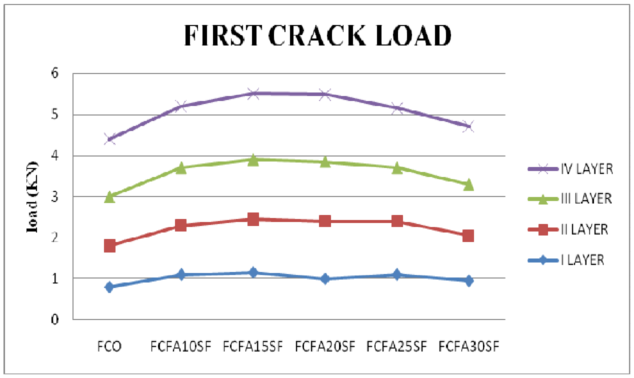


Chart - 2

Table – 7 Ultimate Load

	I LAYER	II LAYER	III LAYER	IV LAYER
FCO	1.15	1.65	2.3	3
FCFA10SF	1.25	1.75	2.4	3.2
FCFA15SF	1.5	1.8	2.5	3.4
FCFA20SF	1.55	2.2	2.6	3.5
FCFA25SF	1.2	2	2.3	2.9
FCFA30SF	1	1.5	2.1	2.7

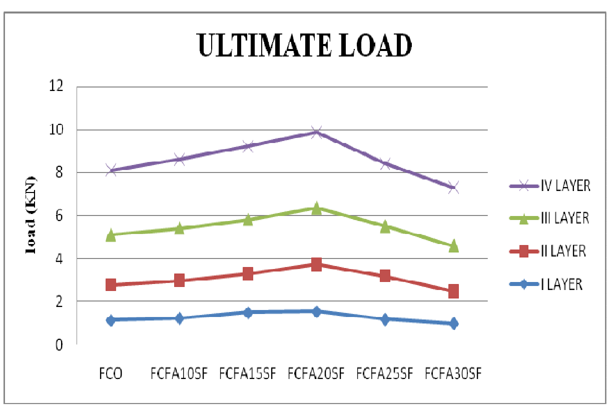
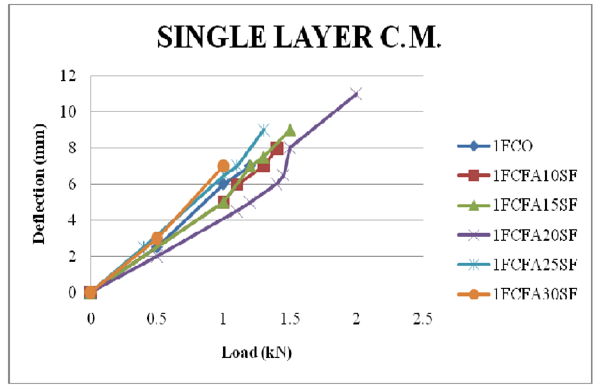


Chart - 3

C. Load Deflection Characteristics

Load deflection curves for Ferro cement panels tested under flexure for different layers of chicken mesh are shown in Figures.



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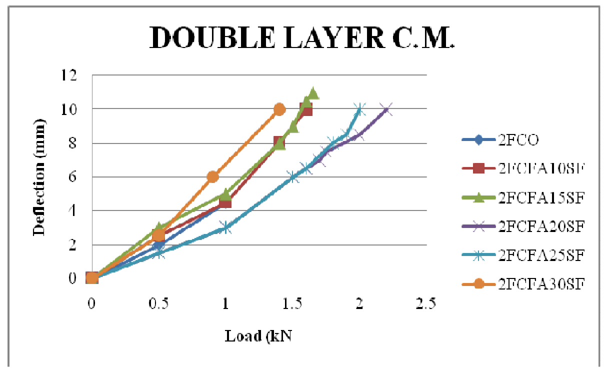

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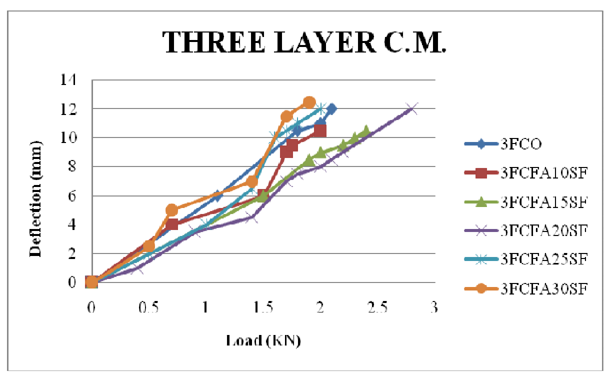

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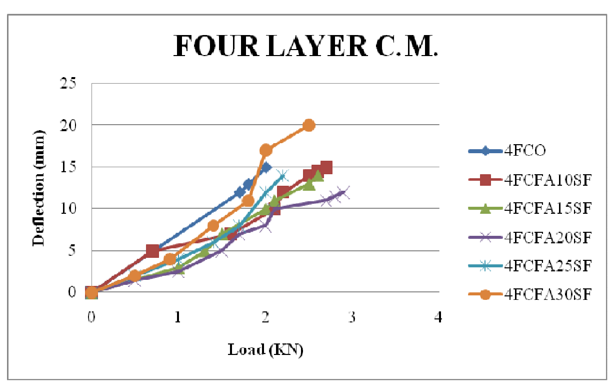


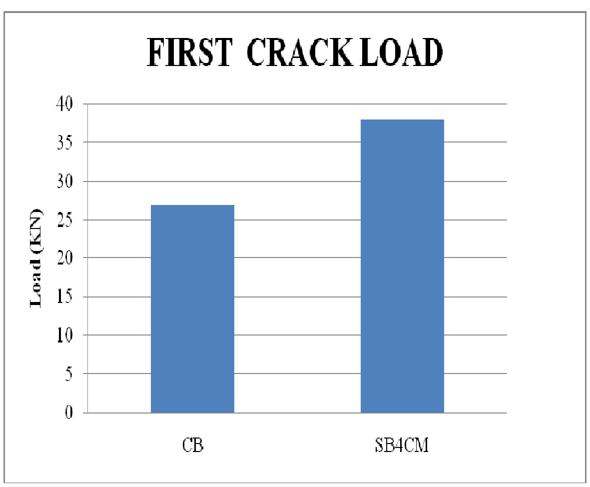
Chart - 7

D. Flexural Strengthening Of R.C Beam With Ferro cement Laminates And Load Deflection Characteristics

The experimental results of control beam and strengthened beam with Ferro cement laminates are discussed. The Ferro cement laminates are four layer chicken mesh partially replacement of 20% fly ash and 5% silica fume by weight of cement, because 4FCFA20SF giving result is excellent compared to other specimens.

Fig – 8 Flexural Test Setup For Strengthening Beam

Fig – 9 Crack Pattern Of Control Beam And Strengthened Beam



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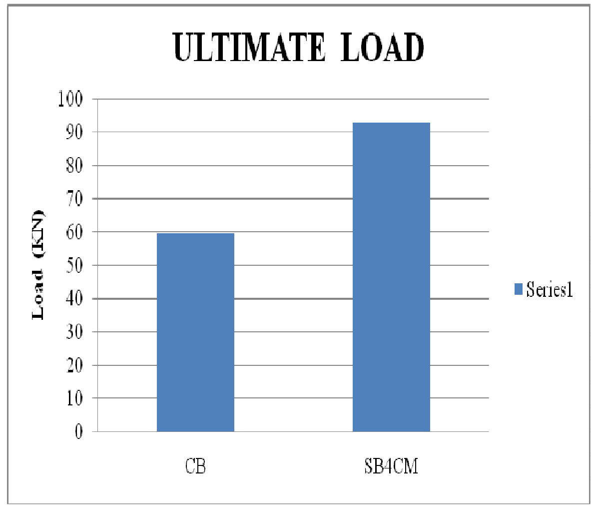

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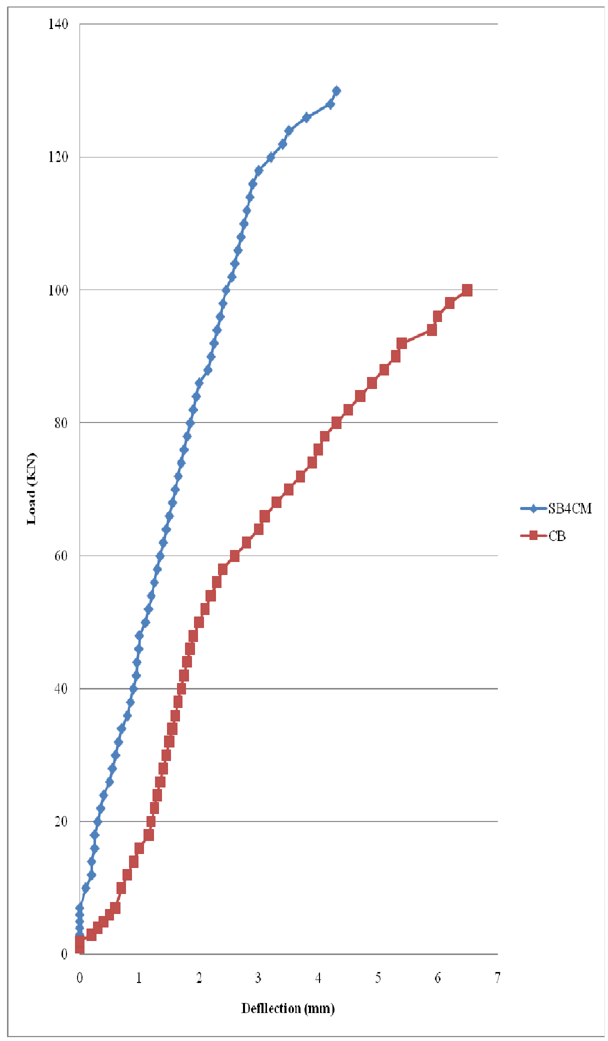

Chart – 10 Strengthening beam

E. Software analysis

The strengthening of R.C beam with ferrocement laminates analysis to use the stadd.pro software.

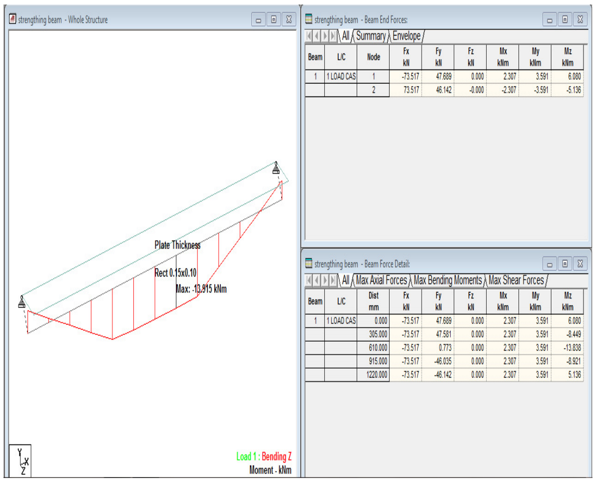

Fig – 7 Bending Moment

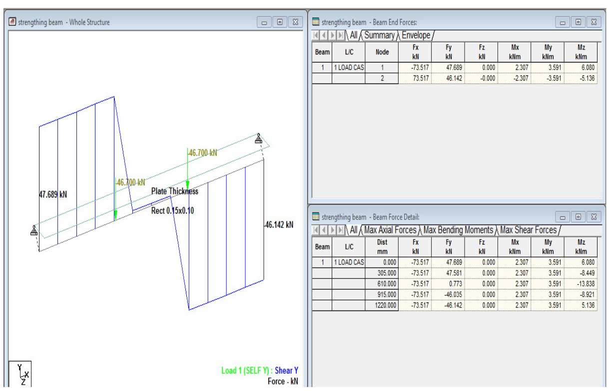

Fig -8 Shear Force

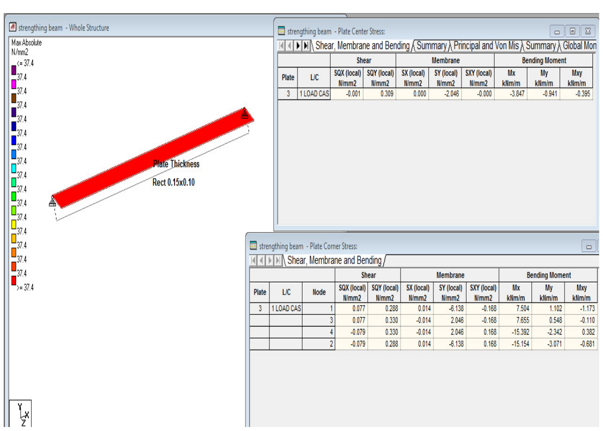

Fig – 9 Stress

VI. CONCLUSION

Based on the experimental investigations on flexural strength behaviour of Ferro cement laminates cast by partial replacement of cement with fly ash content varying from 10%, 15%, 20%, 25% and 30% together with a constant 5% silica fume by weight of cement and reinforced with chicken mesh.

- The mortar mix was found to have a composition of 1:2 mortar mix, 0.35 water binder ratio with partial replacement of cement with fly ash 20% together with a 5% silica fume is gives the good results, so it is suitable for casting Ferro cement elements.
- The first crack load of 4 layer chicken mesh specimen is 60.6% greater than single layer specimen. The 4 layer chicken mesh specimen ultimate load is 44% of greater then single layer chicken mesh specimen.
- The first crack load of strengthening beam is 75% of greater than conventional beam. The ultimate load of strengthening beam is 64% of greater than conventional beam.
- The Ferro cement laminate use to increase the beam strength and lifespan of beam.
- This method is also suitable for old buildings repair techniques.

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