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RETROFITTING OF RC BEAM USING SIMCON LAMINATE

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***Abstract*- This paper presents the results of experimental and analytical studies concerning the flexural strengthening of RC beams using externally bonded High Performance Fiber Reinforced Cementitious Composites (HPFRCCs) called Slurry Infiltrated Mat Concrete (SIMCON). A total of three reinforced concrete beams were cast and tested in the laboratory over an effective span of 1200 mm. three beams were strengthened with bonded SIMCON laminates. Static responses of all the beams were evaluated in terms of strength, stiffness, ductility ratio, energy absorption capacity factor, compositeness between laminate and concrete, and the associated failure modes. Comparison was made between experimental results SIMCON. The results show that the strengthened beams exhibit increased flexural strength, enhanced flexural stiffness, and composite action until failure. To overcome this, new ideas emerged and such a one kind is retrofitting. Retrofitting means the further modification of anything after it has been manufactured. Retrofitting can be achieved by using composite materials. By effectively doing retrofitting process, we can improve the strength of existing structures against seismic activity.**

***Index Terms*— High Performance Fiber Reinforced Cementitious Composites (HPFRCCs), Slurry Infiltrated Mat Concrete (SIMCON), retrofitting, seismic activity.**

I. INTRODUCTION

The cost of civil infrastructure constitutes a major 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. A host of strengthening systems has to be devised and adopted over the years. The choice of the strengthening system depends on the specific performance requirements. 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 are already available. Slurry Infiltrated Mat (SIM) are been extensively used as external wraps for the structural strengthening and rehabilitations of buildings. In particular its application is been in the area of masonry and concrete structures. Strengthening and retrofitting activity by using synthetic fibres such as glass/carbon/aramid is becoming popular all over the world. Extensive research across the world during some years are so as led to better understanding of the properties and behaviour of SIMCON under different conditions, and more extensive use of SIMs is likely to seen in the coming years. Synthetic fibres are non-made fibres resulting from research and development in the petrochemical and textile industries. The various synthetic fibres include - acrylic, aramid, carbon, glass, etc.., but using these synthetic fibres is as costlier and chances for applicability in rural areas are remote.

But for the last three decades there has been a growing awareness amongst civil engineers of the importance of the unique mechanical and in-service properties of these materials together with their customized fabrication techniques. In fact, this class of materials presents an immense potential for use in Civil Engineering, both for rehabilitation of existing structures and for the construction of new facilities A structure is designed for a specific period and depending on the nature of the structure, its design life varies. For a domestic building, this design life could be as low as twenty-five years, whereas for a public building, it could be fifty years. Deterioration in concrete structures is a major challenge faced by the infrastructure and bridge industries worldwide. The deterioration can be mainly due to environmental effects, which includes corrosion of steel, gradual loss of strength with ageing, repeated high intensity loading, variation in temperature, freeze-thaw cycles, contact with chemicals and saline water and exposure to ultra-violet radiations. As complete replacement or reconstruction of the structure will be cost effective, strengthening or retrofitting is an effective way to strengthen the same. In this experimental work SIMCON was used as a retrofitting material. SIMCON made using a non - woven “steel fibre mats” that are infiltrated with concrete slurry. Steel fibres produced directly from molten metal using a chilled wheel concept are interwoven into a 0.5 to 2 inches thick mat. Although the fibres and resins used in SIMON systems are relatively expensive compared to steel and concrete, the labor and equipment cost to install

SIMCON systems is much lower and these systems can be utilized in areas with limited access and where traditional strengthening techniques are impractical. The techniques used to strength existing reinforced concrete members involves external bonding of FRP sheets by means of epoxy adhesives. By this way it is possible to improve the performance of a structural member. The wide use of this method for various structures, include buildings and bridges, have demonstrated its efficiency and convenient.

A. Problem Definition

A promising new way of resolving this problem is to selectively use advanced composites such as High Performance Fibre Reinforced Cementitious Composites (HPFRCCs). With such materials novel repair, retrofit and new construction approaches can be developed andthat would lead to substantially higher strengths, seismic resistance, ductility, durability while also being faster and more cost - effective to construct than conventional methods. Normally two types of HPFRCCs available in the market namely,

1. SIFCON (*Slurry infiltrated fibre concrete)*
2. SIMCON (*Slurry infiltrated mat concrete)*

And here we are going to use a SIMCON (*Slurry infiltrated mat concrete).*

B. Objective and Need

To study the flexural behaviour of RC beam by wrapping the SIMCON laminates at various sides. To compare the flexural strength of normal RC beams and RC beams by wrapping with SIMCON laminates. To study the effect of SIMCON strengthening and failure pattern of reinforced concrete beams. Among the various fibers, simcon fiber reinforced composite is of particular interest as these composites have high impact strength besides having moderate tensile and flexural properties compared to other fibers. Since SIMCON is eco friendly it can be used for strengthening of RC beams. To improve the load carrying capacity of the RC beams. To reduce the cost of rehabilitation since the sheet is economical. Hence encouragement will be given for the use of simcon fibers.

II. Literature Review

DhanuM.N(2014) carried out an investigation on the ductility of concrete column-to-beam Due to new innovations the plain cement concrete was introduced with steel members and it gives quite satisfactory results but the problem is that the aggressive steel member introduced in the plain cement concrete may get corroded if its affected by moisture content. To overcome this, new ideas emerged and such a one kind is retrofitting. Retrofitting can be applied on old structures, and structures in seismic zone to resist their structural collapse. Retrofitting means the further modification of anything after it has been manufactured. Retrofitting can be achieved by using composite materials. By effectively doing retrofitting process, we can improve the strength of existing structures against seismic activity. Then the boundary conditions are applied. Boundary conditions are selected from the load and support. The load can be applied either as force, torque, weight etc. and the support can be given as simply supported or as fixed. Here weight is applied as load and support is assumed to be fixed. The permissible load from the numerical study is applied as load and stresses are calculated.

Balamuralikrishnan R (2013)made experiments to find 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 beams using 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.

Maariappan G &Singaravadivelan R (2013) The investigation was mainly directed towards the Studies on Behaviour of RCC Beam-Column Joint Retrofitted with Basalt fibre Reinforced Polymer Sheet under static and reverse loading .Totally nine RC beam-column joint specimens were cast and tested to failure Among the nine specimens, three specimens were with reinforcement detailing as per code IS 456:2000 and the other three specimens with reinforcement detailing as per code IS 13920:1993. Retrofitting with Basalt FRP was done on another three specimens which has reinforcement detailed as per code IS 456:2000Parameters Investigated:M30 grade concrete with the longitudinal reinforcement in the column portion in all the specimens consisted of 4 no. 12mm Ø (HYSD) bars. The tension reinforcement in the beam portion consisted of 2 no 16mm Ø bars and the beam compression reinforcement consisted of 2 no 16mm Ø bars. The anchorage length of the tension and the compression reinforcement of the beam is extended into the column as per codal provision. the size of the mould is The inner dimensions of the mould are 1500 x

200x 200 mm in the column portion and 600 x 200 x 200 mm in the beam portion. The specimen were tested by push-pull jack. In the case of specimens having reinforcement details as per code IS 456:2000, there is an increase of 14.4% in load carrying capacity and18.87% in energy absorption capacity, when the axial load on column was increased from 15% to30%.In the case of specimens having reinforcement details as per code IS 13920:1993, there is an increase of 16.71% in load carrying capacity and 21.06% in energy absorption capacity, when the axial load on column was increased from 15% to 30%.In the case of specimens retrofitted by Basalt FRP wrapping, there is an increase of 31.89% in load carrying capacity and 33.07% in energy absorption capacity, when the axial load on column was increased from 15% to 30%.

Reddy et al (2009) presents the paper Retrofitting of RC 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 an experimental 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.

AzadehParvin and Shanhong Wu(2008) used a numerical method to investigate the effect of ply angle on the improvement of shear capacity and ductility of beam-column connections strengthened with carbon fiber reinforced polymer wraps under combined axial and cyclic loads. Three-dimensional nonlinear finite element models for the beam–column connections were developed and simulated using finite element analysis. It indicated that the behaviour of three beam–column connections strengthened with the CFRP wrapping with various combination of angles such as 0, 45 and 90 degrees. The results indicated that four layers of wrapping placed successively at 45 degree ply angle with respect to the horizontal axis is the most suitable upgrade scheme for improving shear capacity and ductility of beam–column connections under combined axial and cyclic loads.

Lakshmi G.A et al (2008) carried a detailed investigation on strengthening of beam column joints under cyclic excitation using FRP composites. Three typical modes of failure namely flexural failure of beam, shear failure of beam and shear failure of column were discussed. Comparison was made in the terms of load carrying capacity. Three exterior beam column joint sub assemblages were cast and tested under cyclic loading. All three specimens were retrofitted using FRP materials and the results were compared with controlled specimens. Finite element analysis has been carried out using ANSYS to numerically simulate each of these cases. They concluded that the shear failure was very brittle and hence retrofitting should be done in such a manner that the failure occurs in the beam in flexure.

Tarek H. Almusallam and Yousef A. Al-Salloum(2007) presented a procedure for analytical prediction of joint shear strength of interior beam-column joints, strengthened with externally bonded fiber-reinforced polymer sheets. To implement the available formulation for shear capacity prediction, a program was developed. Using this program, shear capacity of the joint and joint shear stress variation at various stages of loading were predicted and compared with experimental observations. It was observed that even a low quantity of FRP can enhance shear capacity of the joint significantly.

Athur V.K(2006) presented an overview of building materials from local resources with a particular attention on natural fibers based composites. Natural fibers have low-cost, locally available in abundance and obtained from renewable resources. At the Central Building Research Institute, Roorkee, the potential of sisal and jute fibers as reinforcements were systematically investigated to overcome their well defined problems of moisture absorption. The performance of polymer composites made from these natural fibers and unsaturated polyester/epoxy resin was evaluated under various humidity, hygrothermal and weathering conditions. Consequent to this composite product such as laminate have been prepared and the suitability to these product is assessed as an alternate material.

JianChen(2005) investigated the detailed structural behaviour of confined concrete members using CFRP fabric jackets by both analytical and experimental approaches. A series of CFRP wrapped concrete cylinder tests were conducted to study the compressive stress-strain behaviour for CFRP confined concrete members. He concluded that the CFRP fabrics can increase the splitting tensile strength of normal concrete. The more layers applied to the specimens, the more increase in tensile strength can be attained. However when compared to the greater strength increase in compression, the strengthening effect on tension is still lacking. It is concluded that the tensile strength of the fabric-confined concrete can be ignored in design.

Abhijit Mukherjee and Mangesh Joshi(2005) carried out an investigation on the performance of reinforced concrete beam-column joints under cyclic loading. Joints were cast with adequate and deficient bond of reinforcements at the beam-column joint. FRP sheets and strips have been applied on the joints in different configurations. The columns were subjected to an axial force while the beams were subjected to a cyclic load with controlled displacement. The

amplitude of displacement is increased monotonically using a dynamic actuator. The hysteretic curves of the specimens were plotted. The energy dissipation capacity of various FRP configurations was compared. In addition, the control specimens were reused after testing as damaged specimens that are candidates for rehabilitation. The rehabilitation was carried out using FRP and their performance was compared with that of the undamaged specimens.

RamakrishnanV et al(2003) researched and find out the basalt fibre may use in concrete. After investigations, the basalt fibre used in concrete for the first time in world. And also they are find out the beams reinforced with plain basalt bars failed in flexure due to inadequate bond between the rod and concrete. All the actual ultimate moments were much less than the calculated ultimate moments to the bar pullout failure. The beam with fibres exhibited a primary failure in flexure and shear followed by a secondary failure on splitting and also ductile, micro cracks resist bond between all the modified basalt rebar and concrete was extremely good. Ultimate moment good compare with normal concrete. In general the basalt fibres are suitable for use in reinforced concrete section.

Chris P. Pantelides et al (2004)performed tests to differentiate between the usage of CFRP and GFRP jackets. GFRP jackets are found to be more effective in circular columns with usual concrete. The study implies on the importance of using at least two layers of FRP composites in retrofitting. It was proved that the circular columns possess more effectiveness for FRP jacketing than that of square columns. FRP jacketing improves the ductility, strength and column axial behaviour.

Houssamtoutanji et al (2002) in his paper " Strength and Durability performance of Concrete Axially loaded members Confined with AFRP Composite sheets" clearly depicts about the performance of concrete columns externally wrapped with aramid fibre reinforced polymer(AFRP) sheets. Loading in uniaxial compression were made on the control specimens (Both Confined and unconfined). Measurement of axial load and axial and hoop strains were made in order to evaluate the various properties of the wrapped specimens. The main evaluation done in this paper is by presenting the performance of the wrapped concrete specimens in extreme environmental conditions. The specimens were exposed to wetting cycles of about 300 nos. and drying is made using salt water. Based upon the results obtained with the specimens wrapped with aramid fibres, it is so clear that there is no reduction in strength due to wet/dry exposure. But, there is reduction due to freeze/thaw action of about 7.9%.

Mahmoud T. El-Mihilyn et al(2000) via the analysis of reinforced concrete beams and strengthened with FRP laminates showed about the strengthening of existing smaller bridges in north America. These strengthening were based upon the use of reliable and cost effective method of repair and strengthening. This paper mainly focuses on the use of external bonding fibre reinforced polymer(FRP) laminates for the strengthening process. Analytical procedure for finding the flexural capacity of the FRP laminates were made in the simple manner. This procedure was found to be reliable and efficient for both the singly and doubly reinforced concrete sections and also for the flanged sections like T section I sections etc. graphs were made to facilitate the usage of the simplified procedure for the analysis of FRP laminates. Ductile property of the beams were examined to find the upper and lower limits of FRP laminates that are effectively used. Finally the results were related with the experimental results and found to have greater correlation.

Ahmed Khalifa and Antonio Nanni(2000) carried out an investigation on the shear performance of reinforced concrete beams with T-section. Different configurations of externally bonded carbon fiber-reinforced polymer sheets were used to strengthen the 9 specimens in shear. The experimental program consisted of six full-scale, simply supported beams. One beam was used as a bench mark and five beams were strengthened using different configurations of CFRP. The experimental results indicated that externally bonded CFRP can increase the shear capacity of the beam significantly.

PrvinA and GranataP(2000) carried out an investigation on the application of fiber-reinforced polymer composite laminates to exterior beam-column joints to increase their moment carrying capacity. Three beam-column joint models with various fiber composite laminates and wraps with various thicknesses made out of epoxy and fibers such as glass, carbon, and kevlar were examined. One beam-column joint model without FRP reinforcement was used as a control specimen for comparison. The other two beam-column joint models used for the investigation included laminates bonded to the tensile faces with and without wraps. The wraps were provided to prevent the peeling of the laminates. The results of the finite element analysis indicated that the choice of the fiber composite materials, the laminate, arrangement of wraps and thickness affected the enhancement of the structural joint performance significantly. Furthermore, an increase in the moment capacity of up to 37% was observed when the joints were reinforced with FRP laminates compared to the control specimen.

Jianchun Li et al(1999) reported the results of tests on prototype reinforced concrete frame specimens which were designed to represent the column-beam connections in plane frames. The tests were devised to investigate the influence of fiber reinforcement applied to the external surfaces adjacent to the beam-column connection on the behaviour of the test specimens under static loading to find the influence of reinforcement on the strength and stiffness. The hybrid FRP composites of glass and carbon with a vinyl-ester resin were designed to externally reinforce the joint of the concrete frame. The results indicated that retrofitting the critical sections of concrete frames with FRP reinforcement can provide strengthening and stiffening to concrete frames and improve their behaviour.

Grace et al (1999) investigated the behaviour of RC beams strengthened with CFRP and GFRP sheets and laminates. They studied the influence of the number of layers, epoxy types, and strengthening pattern on the response of the beams. It is observed that all beams experienced brittle failure, with appreciable enhancement in strength, thus requiring a higher factor of safety in design. Experimental investigations, theoretical calculations and numerical simulations showed that strengthening the reinforced concrete beams with externally bonded CFRP sheets in the tension zone

considerably increased the strength at bending, reduced deflections as well as cracks width.

III. Specimen Details

A. SIMCON

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.

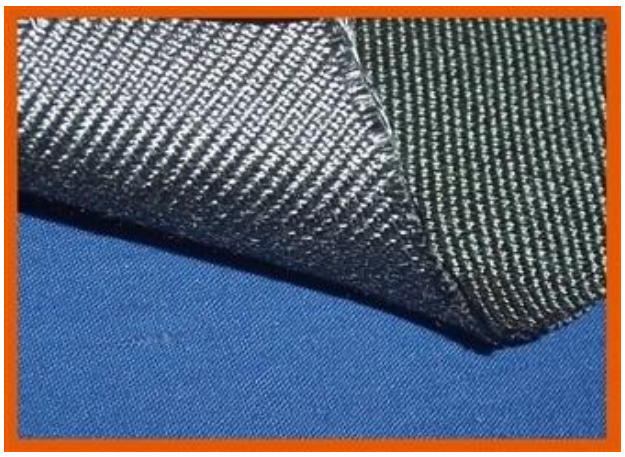
i. Uses

As recommended by ACI Committee 544, when used in structural applications, steel fibre should only be used in a supplementary role to inhibit cracking, to improve resistance to impact or dynamic loading, and to resist material disintegration. In structural members where flexural or tensile loads will occurthe reinforcing steel must be capable of supporting the total tensile load. Thus, while there are a number of techniques for predicting the strength of beams reinforced only with steel fibres, since these would be expected to contain conventional reinforcing bars as well. An extensive guide to design considerations for SIMCON has recently been published by the American Concrete Institute.

ii. Manufacturing of Silicon Laminates

Providing the fibres as a mat which is then infiltrated by high strength slurry, a new typeof HPFRCC, called Slurry Infiltrated Mat CONCRETE (SIMCON) can be produced. SIMCON is made using a non - woven "steel fibre mats" that are infiltrated with concrete slurry. Steel fibres produced directly from molten metal using a chilled wheel concept are interwoven into a 0.5 to 2 inches thick mat. This mat is then rolled and coiled into weights and sizes convenient to a customer's application (normally up to 120 cm wide and weighing around 200 kg per meter). By having the steel fibres in the form of a mat, placement and handling on a construction site are considerably easier. SIMCON is similar to that of SIFCON in that both use slurry infiltration methods. SIMCON laminates have shown great promise to upgrade structural systems. The present study has been taken up for evaluating the effects of strengthening Reinforced Concrete (RC) beams with externally bonded SIMCON laminates.

Steel Fiber



Steel Fiber Simcon Mat

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.

iii. Mechanical Properties

- Density of SIMCON mat = 7695.97 kg/m3
- Density of SIMCON laminates = 1800 kg/m3
- Mean Compressive Strength of SIMCON laminates, fcm = 88 N/mm2
- Mean Tensile Strength of SIMCON laminates, fct = 17 N/mm2
- Modulus of Elasticity of SIMCON laminates, Er = 2.70×104 N/mm2

IV. Mix Design

The concrete mixes for the present study comprises of a Portland cement concrete and 4 diverse concrete mixes with constant water-cement ratio. Grade 20 concrete is aimed for the design.

A. Mix Proportion

Mix design is done as per IS10262-2009 and it is given below
Grade of concrete = M20
Type of cement = opc (53 grade)
Characteristic strength required = 20N/mm^2
Size of aggregate = 20mm
Shape of coarse aggregate = Angular
Degree of exposure = moderate
Sand confirming to = zone III
Specific gravity of coarse aggregate =2.51
Specific gravity of fine aggregate = 2.085

B. Mix Design

Step :1
fck = fck + 1.65s
fck = Target average compressive strength
s = Standard deviation
fck = characteristic strength
for M20 s=4
from table IS 10262 2009
fck' = 20+ (1.65×4)
= 26.6 Mpa

Step :2

Selection of water cement ratio

Water cement ratio = 0.5

Step :3

from table 2 of IS10262 max water content for 20mm aggregate = 186 litre

Step :4

Calculation of cement content

Water cement ratio = 0.5

Cement content = 186/0.5

Volume of coarse aggregate = $0.6m^3$

Volume of fine aggregate = 1-0.6

= 0.4

Step :5 Mix Calculation

The mix calculation per unit volume of concrete shall be as follows

Volume of concrete = $1m^3$

Volume of cement = (Mass of cement/specific gravity)×(1/1000)

$$\frac{372}{3.15} \times \frac{1}{1000} = 0.118m^3$$

Volume of water = $\frac{186}{1} \times \frac{1}{1000}$

$= 0.118m^3$

Volume of aggregate = [1-(volume of cement + volume of water)]

= 1-0.118-0.186

$= 0.696m^3$

Mass of coarse aggregate = [volume of all aggregate × volume of coarse aggregate × specific gravity of coarse aggregate]

Specific gravity of coarse aggregate = 2.51

Mass of coarse aggregate = 0.696×0.6×2.51×1000

= 1048.2kg

Mass of fine aggregate = [volume of fine aggregate × volume of fine aggregate× Specific gravity of fine aggregate]

Specific gravity of fine aggregate = 2.085

Mass of fine aggregate = 0.696×0.4×2.085×1000

= 584.64kg

Hence

Cement = $372kg/m^3$

Water = $186\ kg/m^3$

Fine aggregate = 584.64 kg

Coarse aggregate = 1048.2kg

Water cement ratio = 0.5

Finally the ratio of concrete is obtained

Grade	Cement : FA : CA	w/c ratio
M20	**1 : 1.57:2.89**	**0.50**

Volume of beam mould= 150×230×1200

$=0.0414m^3$

Therefore quantity of concrete required for one batch is

Weight of cement =18.19kg

Weight of fine aggregate= 28.57kg

Weight of coarse aggregate= 52.59kg

V. Beam Specification

The experimental work consisted of a total of four rectangular beams under reinfor-ced concrete. All beams were of the same size 150 mm x 230 mm x 1200 mm, 2 -12 mm diameter bars were used for flexural reinforcement at the bottom of each beam, 2-12 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 M20 grade concrete with 20 mm maximum size of coarse aggregate, locally available sand and 53 grade ordinary Portland cement.

VI. Conclusion

Based on the results obtained from experiments, analytical and theoretical analyses, the following conclusions are drawn:

- **SIMCON** laminates properly bonded to the tension face of RC beams can enhance the flexural strength substantially. The strengthened beams exhibit an increase in flexural strength of 45.45 percent for laminates having volume fraction 5.5 percent and aspect ratio 300 and 400, 89.09 percent for volume fraction 5.5 and aspect ratio 400, and 100 percent for volume fraction 5.5 percent and aspect ratio 300.
- 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, the strengthened beams exhibit a decrease of deflection up to 87 percent.
- All the beams strengthened with **SIMCON** laminates with optimum volume fraction 5.5 percent and aspect ratio 300, 400, and 400 and 300 experience flexural failures. None of the beams exhibit premature brittle failure.
- A flexible epoxy system will ensure that the bond line does not break before failure and participate fully in the structural resistance of the strengthened beams.
- Among the three different volume fraction and aspect ratio of bonded **SIMCON** laminates, the strengthened beam RB1 of volume fraction 5.5 percent and aspect ratio 300 exhibit 100 percent increase in flexural strength when

compared to the control specimen and has close agreement with the experimental, theoretical calculations (section analysis) and numerical (ANSYS) results.

- The ultimate loads from the finite element analysis are lower than the ultimate loads from the experimental results by 3.10 percent to 5.80 percent. The ultimate loads from the theoretical calculations (section analysis) are lower than the ultimate loads from the experimental results by 0.50 percent to 2.90 percent.

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