International Journal of Emerging Technology in Computer Science & Electronics (IJETCSE)
ISSN: 0976-1353 Volume 20 Issue 3 – MARCH 2016.

STRENGTHENING OF RC SQUARE COLUMN USING STEEL ANGLES

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Abstract- **The purpose of this project is to study the behavior and efficiency of reinforced concrete square column strengthened by steel angle. An experimental program was conducted on axially loaded column specimen till failure. There are many ways to increase the axial load capacity and available ductility of concrete column. Adding new concrete jacket with additional reinforcement using external steel angle. Strengthening of reinforced concrete column using steel angle is fairly easiest available technique. This strengthening method requires a limited space around the column section when compared with concrete jackets. It also requires less fire protection than wrapping with FRP. This strengthening method is very efficient and a gain in the axial load capacity of the strengthened column was obtained. Structural retrofitting is becoming more and more frequent to maintain, repair or improve the load-bearing capacity of a structure. Columns are the elements that support building structures; thus failures in column behaviour may lead to collapse of the whole structure. Column strengthening is therefore a very important aspect in a building structure. There are different strengthening techniques for reinforced concrete (RC) columns; the more widely used being concrete jacketing, composite-based strengthening systems (FRP) and the use of steel jacketing. Steel jacketing is one of the most common strengthening techniques.**

Index Terms— **RC columns, strengthening, steel angles.**

I. INTRODUCTION

Reinforced concrete in one of the most abundantly used construction material not only in the developed world, but also in the remotest parts. Column is one of the most important structural elements, which is designed to support mainly the compressive load. Lateral confinement by means of lateral individual ties or continuous spiral in RC column enhances the performance of the same against axial as well as lateral loads. Strengthening or retrofitting of existing reinforced concrete structures is required for a variety of reasons. Sometimes it may be change in use causing higher loads, or deterioration due to factors like environmental factors, or for withstanding lateral loads. Column is an important component of any structure. The strengthening is carried out to increase compressive strength and ductility of the column. The method of providing confinement to concrete enhances both the ultimate compressive strength and the ultimate compressive strain of the concrete. Strengthening of reinforced concrete columns using steel angles connected by horizontal strips is one of the cheapest and fairly easiest available techniques. In this technique, four steel angles are fixed at the corners of the concrete columns. A small gap left between the steel cage and the surface of the concrete column is then grouted using cement or epoxy grout to ensure full contact between the two of them. The methodology should be simple in execution; offer better performance even when handled by less experienced workers, must involve materials which are readily available, durable, strong and economical.

A. Research Significance

The main purpose of this study was to evaluate the effectiveness of one methods used for strengthening of columns. This was achieved by comparing the behaviour of columns strengthened by steel angles and strips. The parameters involved in this study are load-carrying capacity, deflection and ductility of columns. The proposed jacketing technique could be considered as a competitive alternative to enhance the performance of concrete columns especially in developing countries.

B. Scope and Objective

An experimental investigation was conducted to study the strengthening of rc column using steel angles. This deals with the scope and objective of the study. The scope of this project is to study experimentally the behavior of rc column with steel angle. To overcome the buckling of column the steel angles have been added and improving the properties of rc column.
To study the efficiency of this strengthening technique in the case of relatively high strength concrete. To study the behavior of rc column using steel angle under axial loading. To define the expected failure modes. To compare the available load carrying equations in the literature with the obtained results from the experiments. To arrive the important conclusion.

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. Column Specimen

The experimental work consisted of a total of two square column. Concrete columns were cast satisfying the condition for short column,(l/b<12).All column were of the same size 200mm x 200 mm x 1000 mm, this were designed as per IS 456 -2000.The columns consist of 4nos of 12mm diameter longitudinal bars which were tied using 6mm bars at a spacing of 180mm. The quantities of cement, fine aggregate and coarse aggregate was determined by weight. The concrete was mixed by concrete mixer. The workability of the concrete was tested with the slump cone test.

B. Steel Angle

The columns were strengthened by four steel angles and if need steel strips which were welded to the longitudinal angles at equal intervals. The gap left between the steel angles and strips was filled with cement grout. The angles used were 50mm equal angles and having thickness of 5mm.

C. Strengthening of RC columns

Strengthening of reinforced concrete columns is needed when:

1. The load carried by the column is increased due to either increasing the number of floors or due to mistakes in the design.
2. The compressive strength of the concrete or the percent and type of reinforcement are not according to the codes requirements.
3. The inclination of the column is more than the allowable.
4. The settlement in the foundation is more than the allowable.

There are two major techniques for strengthening reinforced concrete columns:

i. Reinforced Concrete Jacket

The size of the jacket and the number and diameter of the steel bars used in the jacketing process depend on the structural analysis that was made to the column. In some cases, before this technique is carried out, we need to reduce or even eliminate temporarily the loads applied to the column; this is done by the following steps:

- Putting mechanical jacks between floors.
- Putting additional props between floors.

Moreover, in some cases, where corrosion in the reinforcement steel bars was found, the following steps should be carried out:

- Remove the concrete cover.
- Clean the steel bars using a wire brush or sand compressor.
- Coat the steel bars with an epoxy material that would prevent corrosion.

- If there was no need for the previous steps, the jacketing process could start by the following steps:
  - Adding steel connectors into the existing column in order to fasten the new stirrups of the jacket in both the vertical and horizontal directions at spaces not more than 50cm.Those connectors are added into the column by making holes 3-4mm larger than the diameter of the used steel connectors and 10-15cm depth.
  - Filling the holes with an appropriate epoxy material then inserting the connectors into the holes.
  - Adding vertical steel connectors to fasten the vertical steel bars of the jacket following the same procedure in step 1 and 2.
  - Installing the new vertical steel bars and stirrups of the jacket according to the designed dimensions and diameters.
  - Coating the existing column with an appropriate epoxy material that would guarantee the bond between the old and new concrete.
  - Pouring the concrete of the jacket before the epoxy material dries. The concrete used should be of low shrinkage and consists of small aggregates, sand, cement and additional materials to prevent shrinkage.

ii. Steel Jacket

This technique is chosen when the loads applied to the column will be increased, and at the same time, increasing the cross sectional area of the column is not permitted. This technique is implemented by the following steps.

- Removing the concrete cover.
- Cleaning the reinforcement steel bars using a wire brush or a sand compressor.
- Coating the steel bars with an epoxy material that would prevent corrosion.
- Installing the steel jacket with the required size and thickness, according to the design, and making openings to pour through them the epoxy material that would guarantee the needed bond between the concrete column and the steel jacket.
- Filling the space between the concrete column and the steel jacket with an appropriate epoxy material.

In some cases, where the column is needed to carry bending moment and transfer it successfully through the floors, one should install a steel collar at the neck of the column by means of bolts or a suitable bonding material.

D. Testing Methods

A total of 2 RC column specimens were cast in this study one reference columns, and one column strengthened by steel angles and strips. The tests were conducted using compression testing machine with a capacity of 5000KN. A dial gauge was fixed to the loading setup to measure the deflection of the columns. The loading was done vertically and the reading was noted from the dial gauge. The loading was done until the ultimate failure of column occurs. Therefore the ultimate load and corresponding deflection were noted for each specimen. A series of tests were carried out to study different properties of the concrete mix also. They include split tensile strength, flexural strength, compressive strength, water absorption test, and durability tests. Durability tests include marine attack and acid attack. For all the tests, concrete specimens were cast in respective steel moulds and compacted in a table vibrator to ensure complete compaction. After 24 hours the specimen were demoulded and allowed for curing till the date of testing. After 28-days curing the concrete specimens were taken out and tested.

i. Compressive strength

Cubical moulds of 150mm side were used for casting specimens for this test. After 28 days of curing, the specimens were tested under compression testing machine. The average 28 day compressive strength was obtained as 33.50 N/mm2. This value was above the target strength for M25 mix as per IS: 10262-1982. Hence the mix design was ok.

ii. Flexural Strength

For this test beam moulds with cross sectional dimensions of 100mm X 100mm and a length of 500mm was used. The average flexural strength was obtained as 4.90 N/mm2. The test was carried out under Universal Testing Machine.

iii. Split Tensile Strength

Standard cylindrical moulds of 150mm diameter and 300mm height were cast for this test. The test was carried out under Compression Testing Machine. The average split tensile strength obtained for the concrete mix was 2.77 N/mm2.

iv. Water Absorption test

This test was carried out on 150mm standard size cubes. The average value of water absorption for the concrete mix was found to be 1.77%.

RC Coloumn

RC Column & Column strengthened by steel angle and strips

IV. CONCLUSION

From the experimental investigation carried out on the columns strengthened using steel angles, the following concluding remarks could be made.

- Steel angle jacketing improves the load carrying capacity appreciably as compared to the reference columns.
- The ultimate load carrying capacity of columns strengthened by steel angles and strips were found to be increased by 40%.
- The initial portion of the load-deflection curve of the conventional column is almost same for all columns.

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