International Journal of Research in Advent Technology (E-ISSN: 2321-9637) Special Issue
International Conference on Technological Advancements in Structures and Construction
"TASC- 15", 10-11 June 2015

Comparative Study of Columns Strengthened by Steel Angles and Ferrocement Jacketing

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Abstract- Various strengthening techniques are used in construction industry to improve the capacity of structural members. Jacketing technique is considered as the best method for strengthening of columns, beams etc. In strengthening of structural members, different materials like CFRP, GFRP, ferrocement, steel angles, steel plates etc are bonded to the surface of structural member to increase its strength. In the present work, two methods for strengthening of columns are compared by experimental investigation. The two methods are ferrocement jacketing and jacketing by means of steel angle and strips. The columns were cast and jacketed using steel angles and ferrocement jacketing. The obtained results were compared to suggest the best method among the two.

Index Terms-Strengthening; Steel Angles; Ferrocement Jacketing,

1. 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. The three most commonly used materials for column jacketing are ferrocement, steel, or fibre-reinforced polymers

Ferrocement is one such material which could afford to offer answer to such a situation and hence the part of the present study is a program to explore the potentials of ferrocement for its utilization in improving performance of a structural member. 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 and steel strips spaced at a rational spacing are welded to the angles to form a steel cage. 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. 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 which needs a special protection from fire hazards. 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.

2. RESEARCH SIGNIFICANCE

The main purpose of this study was to evaluate theeffectiveness of two methods used for strengthening of columns. This was achieved by comparing the behaviour of columns strengthened by steel angles and strips with that of ferrocement jacketing. 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.

3. EXPERIMENTAL INVESTIGATION

3.1. *Materials*

3.1.1. Cement

Thecement should be fresh, of uniform consistency and free of lumps and foreign matter. It should be stored under dry conditions and for as short duration as possible.

3.1.2 Fine Aggregate

M-Sand was used as fine aggregate in this experimental investigation. The specific gravity of fine aggregate used in this study was 2.50 and it belongs to Zone II. IS 383: 1970

3.1.3 Coarse Aggregate

Coarse aggregate conforming to IS 2386-1963(I, II, III) was used in this study.

3.1.4 Super plasticizer

CONPLAST SP-430 in the form of sulphonated naphthalene polymer conforming to IS: 9103-1999 and ASTM 494 Type F was used in this study to improve the workability of the concrete mix.

3.1.5 Reinforcing Mesh

Welded wire mesh with an opening size of 15mm was used. The diameter of the wire mesh used was 1mm.

3.2. *Mix Proportion*

The mix was designed as per IS: 10262-1982 to have a characteristic compressive strength of 25 N/mm^2. According to the mix design the cement content was found to be 340kg/m^3. The water cement ratio was taken as 0.50. Super plasticizer was added by 0.30% by weight of cement in the concrete mix.

Table 1. Mix Proportion

Item	Mix Proportion	By Weight (kg/m^3)
Cement	1	340
Fine Aggregate	2	680
Coarse Aggregate	3.67	1248
Water (litre)	0.50	186

3.3. *Specimen Preparation*

Concrete columns were cast satisfying the condition for short column, i.e.l/b<12. The cross sectional dimensions of the columns are 200mm X 200mm and the height of the column was 550m. 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 byweight. The concrete was mixed by concrete mixer. The workability of the concrete was tested with the slumpcone test. The prototype column is shown in Fig 1.

3.4. *Strengthening of Columns*

In this study two strengthening methods were used; ferrocement jacketing and steel jacketing.

3.4.1 Ferrocement Jacketing

Ferrocement is a thin-wall composite material normally with isotropic behavior in two principal directions. In this study jacketing done using welded wire mesh of 1mm diameter and with an opening size of 15mm.Final size of the jacketed specimen was 224mm including 12mm ferrocement jacket. Wire mesh was kept at the middle of the jacket layer with a 6mm cover on both interior and exterior layers. The cement:sand proportion of the mortar used for jacketing work was 1:2.5. A gap of 5mm was kept at the top and bottom of the specimen so that direct compression on the ferrocement jacket can be avoided. All strengthened columns were cured in water for 14 days before testing.Fig2 shows the column strengthened by ferrocement jacketing.

Fig 1.RC Column

3.4.2 Steel Jacketing

The columns were strengthened by four steel angles and steel strips of width equal to 32mm and 5mm thickness 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 as shown in Fig 3.

Fig 2.Column strengthened by ferrocement jacketing

Fig 3.Column strengthened by steel angles and strips

3.5. ***Testing Methods***

A total of 9 RC column specimens were cast in this study;3 reference columns, 3 columns strengthened by ferrocement jacketing and 3 columns 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 at every load increment of 50KN. 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 of the curing tank and the surface water was wiped off. Three specimens were tested as a representation of a batch.

4. RESULTS AND DISCUSSIONS

4.1 ***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/mm^2. This value was above the target strength for M25 mix as per IS: 10262-1982. Hence the mix design was ok.

4.2 ***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/mm^2. The test was carried out under Universal Testing Machine.

4.3 ***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/mm^2.

4.4 *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%.

4.5 *Marine Attack*

100mm cubes were cast to study the behaviour of concrete mix in marine environment. The specimens were kept in marine water for 56days after 28 days of curing in water. After this period the specimens were taken out and weighed. This weight was compared with that of specimens kept in water. The average loss of weight was found to be 5.16%.

4.6 *Acid Attack*

To study the behaviour of concrete mix towards acid, 100mm cubes were cast. The specimens were cast and kept in H_2SO_4 for 56 days after 28 days of curing in water. After 56 days the specimens were taken out and weighed. This weight was compared with that of specimens kept in water. The average loss of weight was found to be 13.14%.

4.6 *Strength of Columns*

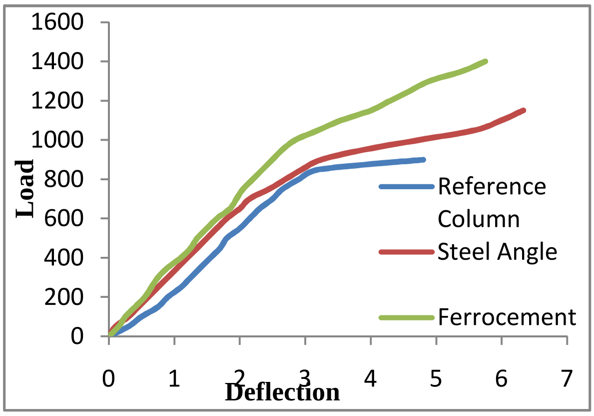
In this study, a total of nine columns were cast and tested. The nine columns can be classified into three groups; three reference columns, three columns strengthened by ferrocement jacketing and three columns strengthened by steel angle and strips.In the case of reference columns the ultimate load obtained was 890KN. The deflection corresponding to the ultimate load was 3.70mm, but in the case of columns strengthened by steel angles and strips the ultimate load was 1246KN and the corresponding deflection was 6.33mm. For columns strengthened by ferrocement jacketing the ultimate load was obtained as 1470KN and the deflection corresponding to that load was 5.60mm. The load deflection curve corresponding to the ultimate loads of reference column and the two types of strengthened columns is shown in fig 4.

5. CONCLUSION

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

- Ferrocement jacketing and 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 ultimate load carrying capacity of column strengthened by ferrocement jacketing was found to be increased by 65%.
- The ferrocement jacketed columns show less deflection at higher ultimate loads when compared with that of the reference columns and column strengthenedby steel angles and strips.
- The initial portion of the load-deflection curve of the conventional column is almost same for jacketed columns. The later portion of the load-deflection curve of thestrengthened columns clearly shows theeffect of confinement.

Fig 4. Load-Deflection Curve



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