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Retrofitting of Reinforced Concrete Column by External Jacketing

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ABSTRACT

The main reason of the project is to gain the fundamental and technical knowledge of seismic resistant buildings. Because now a day the construction of seismic resistance buildings are increased. Since the future expansions are viable, a framed structure has been selected in consideration with the increased loading. In this project an attempt has been made to design square column strengthened by steel angle and strips (steel cage) by using diagonal steel plate in stainless steel material. Size of the steel angle, strip spacing, grout material between column side and angle, and the connection between the steel cage to the specimen head, were the main studied parameters in this paper.

It was concluded that using this strengthening method will be very efficient and a gain in the axial load capacity of the strengthened columns was obtained. This gain was due to the confinement effect of the external steel cage, and the ability of the steel angle to resist an extensive part of the applied axial load. The failure in most of the strengthened specimens was due to the buckling of the steel angle followed by crushing of the original columns.

I. INTRODUCTION

There are many way to increase the axial load capacity and available ductility of concrete columns. Adding new concrete jacket with additional reinforcement, using external stainless steel angles and horizontal strips and wrapping the original column section with normal reinforcement, NR, are the most popular method of strengthening and retrofitting concrete columns.

Strengthening of reinforced concrete columns using stainless steel angle connected by horizontal strips is one of the cheapest and fairly easiest available techniques. In this technique four steel angle are fixed at the corner of the concrete columns and steel strips; spaced at a rational spacing; are welded to the angle 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. Many researchers conducted experiments on square columns strengthened by steel cage to study the performance and the ultimate capacity.

II. EXPERIMENTAL INVESTIGATION

2.1. Materials

Portland cement (often referred to as OPC 53 grade, from ordinary Portland Cement) is the most common type of cement in general use around the world because it is a basic ingredient of concrete, mortar and most non –specialty grout it usually originates from limestone. it is a fine powder produced by grinding Portland cement clinker (more than 90%), a limited amount of calcium sulfate (which control the set time) and up to 5% minor constituents as allowed by various standards such as the European standard EN197-1

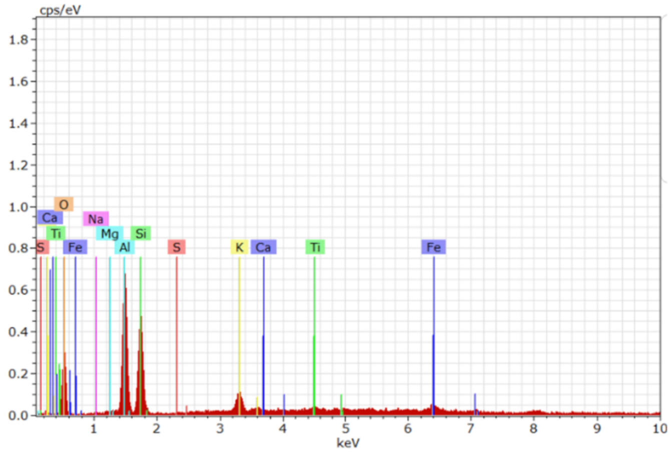


Fig. 1Chemical composition of Cement

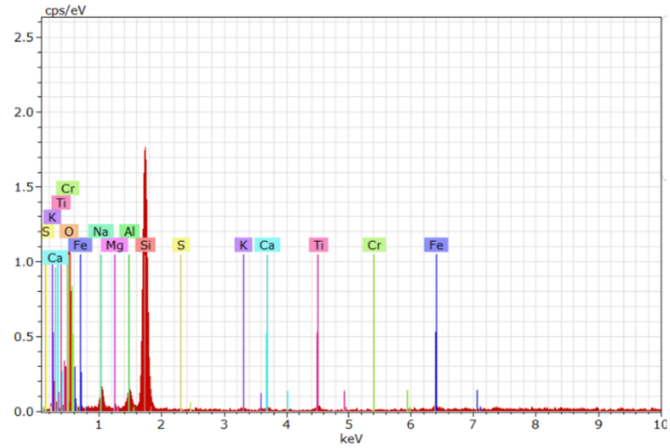


Fig. 2 Chemical composition of steel plate

2.2. Mix Proportion

BIS: 10262-2019 was used to build the concrete mix. With a water cement ratio of 0.5, the concrete mix proportions were 1 part cement, 1.65 part fine aggregates, and 2.87 part coarse aggregates. Both concrete mixtures were rendered with a constant water-to-cement ratio of 0.5. Table 1shows the proportions of the mixture.

Table 1

Concrete mix proportions

Mix Designation	**CC**	**A**	**B**	**B1**
Cement (kg/m3)	394.32	354.8	315.46	276.02
Fine Aggregate (kg/m3)	649.25	454.475	454.475	454.475
Coarse Aggregate (kg/m3)	1130.77	1130.77	1130.77	1130.77
Slump Value (mm)	90	92	90	91

2.3. For Arriving Optimum Percentage

Table 2 shows the four concrete mixes that were prepared for compressive strength, from which an optimum percentage was determined at 7 days for certain mechanical properties, as well as micro structural analysis. Table 2 shows the different mix proportions for concrete with compressive power.

Table 2

Concrete different mix proportion with compressive strength

Mix Ratio	**Compressive Strength N/mm2**
Conventional Concrete (CC)	25.52
Group A (M_1)	27.85
Group B (M_2)	25.06
Group B1(M_3)	16.56

The compressive strength of M_2can be used to achieve higher concrete strength for various mixes.

2.4. Specimen Preparation and Casting

BIS: 1199-1959 [8] was used to prepare all of the specimens. Test specimens were held in the casting room for 24 hours after casting, at a temperature of around 27 1 _C. After 24 hours, they were remould and placed in a water-curing chamber before testing. For each property, three specimens were cast and examined, and the average value was taken.

2.5. Fresh Concrete Properties

The properties of fresh concrete, such as slump flow, are calculated using the Indian standard specification IS: 1199 – 1959[8]. Furthermore, when preparing concrete for various mixes, the workability of the concrete is unaffected by the substitution of CK and UFS for cement and fine aggregate, respectively.

2.6. Hardened Concrete Properties

2.6.1. Compressive Strength Test

Column and Cube specimens of size 150 mm x 150 mm x 150 mm and 120mm x 120mmx 850mmwere taken out from the curing tank at the ages of 7 and 28 days in compliance with Indian Standard Specifications BIS: 516-1959 [7]and tested immediately on removal from the water (while they were still in the wet condition). Surface water was wiped off, the specimens were tested shown in Fig. 3.

Fig. 3 Compressive Strength Test

Fig. 4 Buckling of column

2.6.2. Splitting Tensile Strength Test

The split tensile strength of concrete is determined by casting cylinders of size 150 mm x 300 mmin compliance with Indian Standard Specifications BIS: 516-1959 [7]. The cylinders were tested by placing them uniformly. Specimens were taken out from curing tank at age of 28 days of moist curing and tested shown in Fig. 5 after surface water dipped down from specimens. This test was performed on compression Testing Machine.

Fig. 5 Splitting Tensile Strength Test

2.6.3. Flexural Strength Test

The flexural strength of concrete is determined by casting beam of size 100 mm x100 mm x500mmin compliance with Indian Standard Specifications BIS: 516-1959 [7]. The beams were tested by placing them uniformly. Specimens were taken out from curing tank at age of 28 days of moist curing and tested shown in Fig. 6 after surface water dipped down from specimens. This test was performed on compression Testing Machine on beam attachment.

Fig. 6 Flexural Strength Test

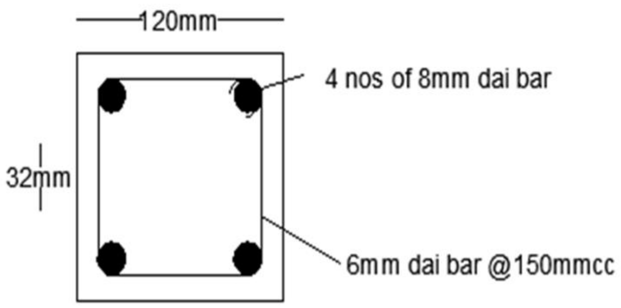
2.6.4. Modulus of Elasticity Test

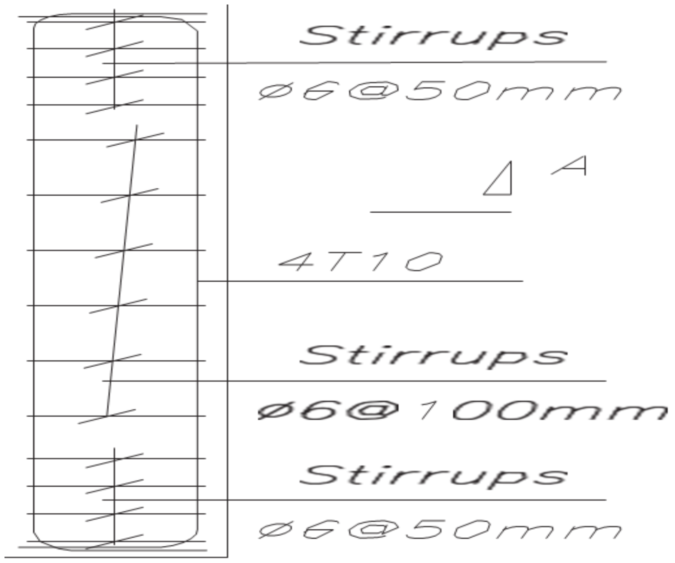
The modulus of elasticity of concrete is determined by casting cylinders of size 150 mm x 300 mmin compliance with Indian Standard Specifications BIS: 516-1959 [7]. Specimens were taken out from curing tank at age of 28 days of moist curing and tested shown in Fig. 8 after surface water dipped down from specimens. The cylinders were tested with dial guage to get the readings for stress-strain curve to plot the graph.

III. RESULT AND DISCUSSION

3.1 RETROFITTING

Fig. 8 RETROFITTING OF CUBE





Eight square columns 120 mm x 120 mm and 135mm x 135mm were prepared and casted with two different cube strength values and the total height of the specimens was 850mm. All the tested columns were reinforced with the same longitudinal 4 bars of diameter 8 mm and tied with 6 mm steel square stirrups spaced at 150 mm along the column height and 50 mm at both ends of the column as demonstrated in Fig. 6.1.

Both the ends of the specimens were protected using 8 mm steel heads where the gap between the end of columns and the steel head was filled vertically with a flowable cementitious grout material.

Two reference columns were kept un-strengthened; one in each main group. The other six columns' specimens were strengthened using four longitudinal steel angles and horizontal strips of width equal to 50 mm which were welded to the longitudinal angles at specific spacing.

The spacing between horizontal strips was reduced to 50 mm at both ends close to the steel head to avoid the risk of local failure at these ends and to enforce failure to occur at the middle of the column as shown in Fig. 6.2.

The left gap between the steel angles and strip was vertically filled with grout to fill the 10 mm gap. Table 1 shows the details of the test specimens. The properties of the used grout mortars are given in Table 2 as provided by the manufacturing company.

Also the mechanical properties of the steel angles, steel strips, and steel reinforcement are presented in Table 3. The tested columns were divided into two main groups; group 1 was strengthened using four angle 50 x 50 x4.5 mm while in Group 2, columns were strengthened using four vertical angles 30 x 30 x 3 mm.

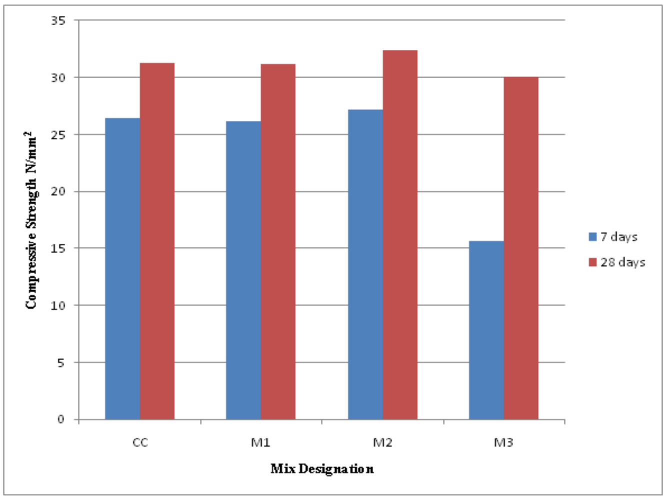


Fig. 9 Compressive Strength in N/mm2

3.2 FAILURE MODES

For reference columns, N1 and N2 the behavior was similar. The axial shortening increased in a linear manner till failure. A sudden failure occurred when parts of the concrete cover spelled-off and buckling of the longitudinal reinforcement bars was observed as shown in Fig 10.

During failure of column N2, the lock of one stirrup started to open outside the section during failure stage. In the case of the strengthened columns, the relation between load and axial shortening was almost linear till about 75% of the failure load followed by some nonlinear increase in the axial shortening.

The failure in these specimens started with the buckling of the one or more of the vertical angles followed by the buckling of the reinforcement steel bars and eventually a crushing of concrete section near these bars as shown in fig 10.

In some specimens, it was noted that the weld between the horizontal strip and vertical angle was broken, most probably after the occurrence of buckling of the vertical angles as it is obvious from the buckling shape of the angles as demonstrated in fig 10

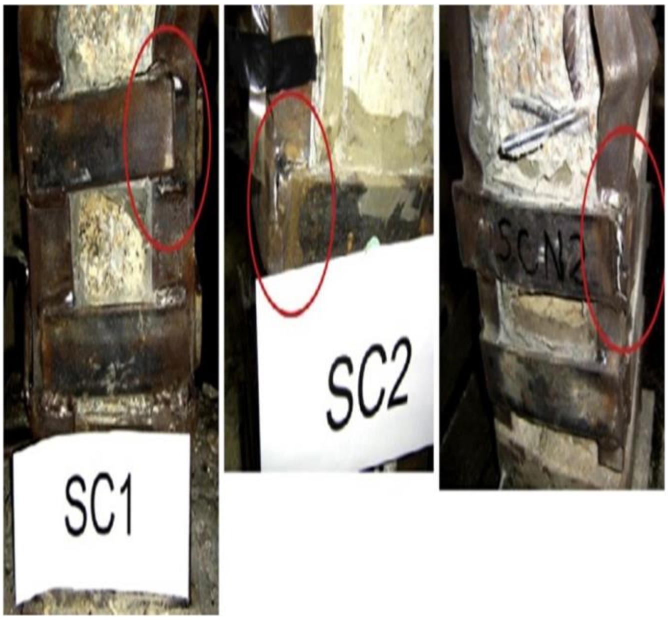
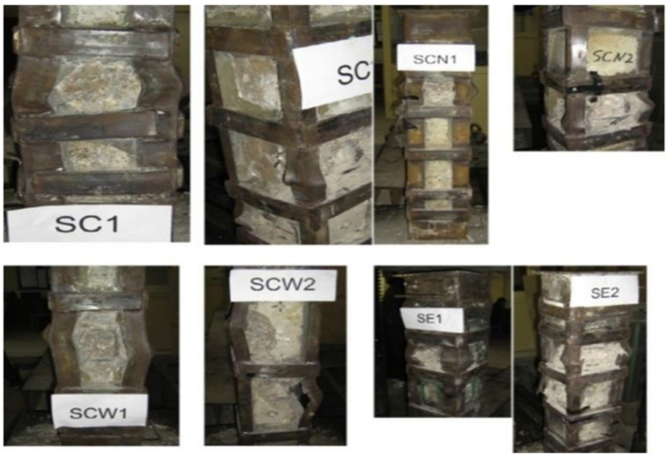


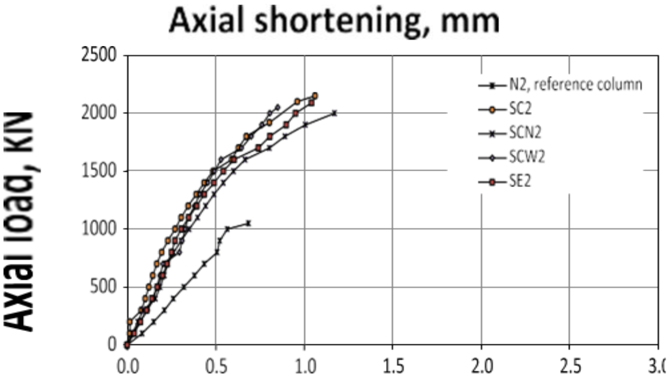
Fig 10 Fracture of weld in HS and VS



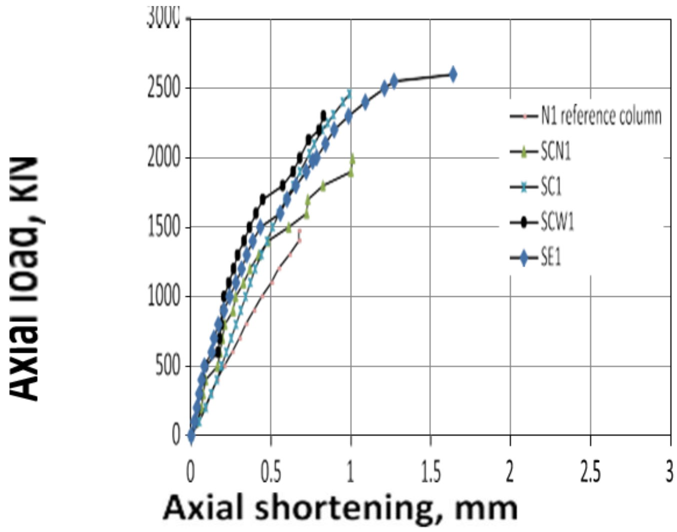
3.3 LOAD AXIAL SHORTENING BEHAVIOUR

The relationships between applied axial load and column axial shortening of the tested specimens are presented.

Also, the ratio of the ultimate load of each column to that of the reference column of the same group generally, the ultimate axial load and the maximum vertical deformations are higher in Group 1 than those of Group 2 due to the higher concrete compressive strength.



Axial load Group 2.



Group 1

Mechanical properties

Grout material	**Compressive strength**	**Flexural strength(N/MM2)**
Cement mortar	18 -20	6.95
Epoxy grout	100	40

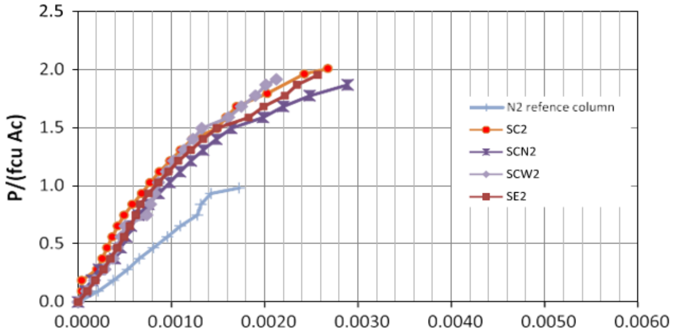
Main result of the tested columns group 1

SP	GROUP	fcu (mpa)	P failure kn	Max axial	Strain	P ¼ P/fck.Ac	P failure/p reference
N1	1	57	1475	0.67	0.0017	1.13	1.00
SC1	1	57	2570	0.99	0.0025	1.98	1.74
SCN1	1	57	1990	1.0	0.0025	1.46	1.35
SCW1	1	57	2310	0.83	0.0021	1.77	1.57
SE1	1	57	2600	1.64	0.0041	2.00	1.76
SE	0	0	0	0.1	0	-	-
SE	0	0	0	0.1	0	-	-

Main result of the tested columns in group 2

SP	GROUP	fcu (mpa)	P failure kn	Max axial	Strain	P ¼ P/fck. Ac	P failure/p reference
N2	2	47	1075	0.67	0.0017	1.13	1.00
SC2	2	47	2770	0.99	0.0025	1.98	2.80
SCN2	2	47	1890	1.0	0.0025	1.46	1.90
SCW2	2	47	2310	0.83	0.0021	1.77	1.95
SE2	2	47	2600	1.64	0.0041	2.00	1.96
SE	0	0	0	0.1	0	-	-
SE	0	0	0	0.1	0	-	-

Fig 7.4 axial concrete strain group 2



IV.CONCLUSION

In this study, an experimental program was conducted on Eight axially loaded column's specimens till failure. The main objectives of this paper were to study the behavior and the efficiency of reinforced concrete square columns strengthened by steel angles and strips (steel cage).

Size of the steel angle, strip spacing, grout material between column sides and steel angles, and the connection between the steel cage to the specimen head, were the main studied parameters in this paper. The behavior of the tested columns, axial deformation, axial strain of vertical angles and horizontal strips were obtained and analyzed.

Also, an analytical model was developed in this study using the simple mechanics and strain compatibility to obtain the ultimate loads of the strengthened columns. The effect of the confining stress due to the steel cage and forces in the vertical angles were calculated considering both directly and indirectly connected angles.

CONCLUSIONS FROM THE EXPERIMENTAL INVESTIGATION

Based on the experimental investigations, the following conclusions are made

This gain is due to the confinement effect of the external steel cage, and the ability of the steel angle to resist a part of the applied axial load even in the case of indirectly connected angles. The failure in most of the strengthened specimens was due to the buckling of the steel angle followed by crushing of the concrete columns. Also, it was noticed that axial ductility of the strengthened column increased by 50% in most cases comparing to that of the un strengthened columns.

1. In all tested strengthened columns, failure was initiated by the buckling of the vertical angles after their yielding in most cases. No yielding of the horizontal strip was observed. This is due to the relatively large size of the horizontal strips with respect to the vertical angles.
2. Using epoxy grout instead of cement grout slightly enhanced the behavior of the strengthened column.
3. Therefore, it may be economical to use cement grout to fill the gap between the steel cage and concrete column due the higher cost of epoxy grout comparing with that of cement grout.
4. Directly connected vertical angles to the head of the column enables to transfer load directly to the angle. All angles connected in this manner showed yielding before failure of the strengthened column. On the other hand, load was transferred to indirectly connected angles by friction, and the angles did not reach yielding in this case.

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