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An Experimental Study on Behaviour of Strengthened Columns by RC Jacketing

K SENGOTTIAN[1] AND K JAGADEESAN[2]
[1]Anna University, Chennai, Tamil Nadu, India
[2]Department of Civil Engineering, Sona College Engineering, Salem, Tamil Nadu, India
Email: *ksengottian@rediffmail.com, jaganmoorthi24@gmail.com*

Abstract: In a multi storey building columns are very important structural elements The foundation has the transmission of entire loads. The load carrying capacity of the compression member has to be increased by confining the columns. There are a lot of confinement techniques that are used for strengthening of concrete structures. Ferrocement, glass fiber, aramid fiber, carbon fiber, etc. are some of the few materials that are used in the confinement of concrete columns. Reinforced concrete jacket around the existing structural member is one way of section enlargement. Enlargement is the placement of to achieve the desired sectional properties and performance. This experimental study aims at assessing the behavior of such reinforced concrete columns confined with external Reinforced Concrete jacketing technique. This would enable in arriving at the effectiveness of the confinement in concrete columns in seismic regions. Strengthened columns are tested under axial loading to study the behavior of RC Columns strengthened with RC Jacketing technique.

Keywords: *Section Enlargement, Confinement, Effectiveness, seismic retrofitting, Load carrying capacity*

1. Introduction

From a structural viewpoint, the dimensions of the column section is dictated by its height and the loads acting on it which, in turn, depend on the type of floor system, spacing of columns, number of storey, etc. Under gravity and lateral loads, the column is generally designed to resist axial compression combined with (biaxial) bending moments that are induced by ‘frame action’. The stresses induced in steel and concrete are in proportion to their modules of elasticity, Es and Ec, respectively just like any other composite section, when a column is subjected to an axial load within elastic limits.

The failure of the tied column occurs suddenly with the breaking down of concrete and the buckling of longitudinal bars between the ties in a pattern similar to that for a concrete cylinder in a compression test. On the other hand, a column reinforced with a spiral exhibits considerable deformation before complete failure on reaching the yield point, with the concrete shell outside the spiral spalling off. This reduces the load-carrying capacity because of the reduction of the concrete area, but the spiral prevents buckling of the longitudinal bars and confines the crushed concrete in the core.

Thus, the spiral may offset the loss sustained due to loss of cover by an increase in the load-carrying capacity of the concrete core. An optimum volume of spiral shall result in the value of the failure load to be equal to the load carried at the time of the spalling of the cover concrete. Thus, the spiral adds little to the strength of the column but provides considerable ductility until the spiral steel yields and undergoes large deformations.

2. Review of Literature

2.1 Seismic Deficiency of RC Column

Identification of detailing deficiencies is significant in selection of mitigation strategies because acceptable performance often may be achieved not by adding new lateral force- resisting elements but by local adjustment of detailing. The columns lacking ductile design and detailing suffer severe damage during earthquakes. Lack of confinement due to large tie spacing, insufficient development length, inadequate splicing of all column bars at the same section, hook configurations of reinforcements lack ductile detailing practices.

Longitudinal reinforcing bars compression in columns is prevented from buckling by Concrete which provides lateral restraint. Under cyclic loading, that does not involve alternating flexure; the compression steel in the columns does not ordinarily buckle out of concrete, even at high strains or in the absence of restraining stirrups and ties.

However when covering concrete subjected to high compressive stresses become unstable, the restraining effect is reduced and the bar buckles. Code limits are placed on the ratio of the distance between transverse reinforcement to the diameter of the longitudinal reinforcing bar. Figure 1 shows the buckling of column during earth quake.

Figure.1: *Failure of Column Due to Lateral Buckling of Longitudinal Reinforcement*

2.2 Seismic Retrofitting

Confinement of reinforced concrete columns significantly enhances the performance under axial load, bending and shear, because of the increase in concrete compressive strength, the increase in ductility, the increase in shear strength and the higher resistance against buckling of the steel reinforcement in compression. To retrofit existing structures by providing external confining stresses over the years, different methods have been used. The confinement of the columns is achieved by means of internal lateral reinforcement (hoop or closed stirrups) or by external reinforcement (steel or FRP jackets). The concept of jacketing has been investigated to provide the confining forces for the past few years. Externally applied jackets have been used as a reinforcement to contain concrete for different reasons. Traditional materials such as steel, wood and concrete used to confine and improve the structural behavior of concrete members.

3. Methods and Methodologies

3.1. Confinement Techniques

Jacketing is one the most frequently used techniques to strengthen reinforced concrete columns. This method increases axial strength, bonding strength, and stiffness of the original column are increased. It is well known that the success of this procedure is dependent on the monolithic behavior of the composite element. The treatment of the interface must be carefully Chosen to achieve this purpose. The common practice consists of increasing the roughness of the interface surface normally an Variable passive confinement is dependent on the level and stiffness of confinement provided.

3.2. Research Significance

It is necessary to arrive at an efficient method of retrofitting the damaged RC columns. A detailed experimental study has been carried out various parameters such as load deflection behavior.

3.3. Experimental Program

For experimental study, totally eighteen number of columns is used. Figure 2 shows the details of the specimen.

For experimental model, the dimension of column was 150mm diameter with helical reinforcement has been used. Height of the Column was kept as 1200mm. The main reinforcement used for the specimen was 6 numbers of 6 mm diameter bar. The lateral helical reinforcement was 6mm dia spaced at 100mm c/c.

Figure.2: *Spiral Reinforcement Details of the Specimen*

Design mix of M 20 grade concrete water cement ratio of 0.45 was used for casting the column specimens.

3.4. Properties of Companion Specimens

To find the properties of hardened concrete, the following tests are carried out

- Compressive strength test for cubes
- Flexural strength test.

The test results of the companion specimens are shown in Table.1

Table 1: *Test Results of Companion Specimens*

Sl. No	Properties of the companion specimens	Average Strength value in N/mm²
1	Cube Compressive Strength	24
2	Flexural strength	3.15

3.4.1. Test Setup

Each specimen was tested by means of 50 tones capacity hydraulic jack in the structural Laboratory. In the loading platform, the columns were placed for testing. . The column was centered accurately using plumb bob to avoid eccentricity. The bottom end was placed in the frictionless surface. It's used for applying axial load for column and also avoids the movement of column. To avoid local failure, the top and bottom side of the column steel cap were used. Two Dial gauges were used to measure the lateral displacements in the column at mid height of the column. Electrical strain gauge was used to measure the strain in concrete details of the specimens are shown Figure4. Six numbers and 2 numbers of 6mm diameters were used for main reinforcement of column and 6mm diameter helix with 100mm c/c spacing was adopted for both the types of specimens.

Figure.3: *Test Setup*

A strain gauge which is fixed to the side face of the specimen is connected to the electronic strain indicator. By means of the hydraulic jack thed axial load is applied gradually. The testing is done to a specified percentage of the calculated theoretical ultimate load. The specimens were grouped based on the percentage of ultimate load applied namely 50%, 60%, 70% (121KN, 145KN, 170KN). Figure.3 shows the test setup.

Figure 4 *Core specimen*

Figure.4a: *Before Retrofitting of Specimen*

Figure.4b: *Detailing of Retrofitting Specimen*

Figure.4c: *After Retrofitting Specimen*

3.4.2. Testing of Retrofitted Specimens

The retrofitted specimens were shown in the Figure.5. The retrofitted specimens were tested in the same manner as that of the conventional specimens. Axial loading was applied gradually till the failure of the specimen. The corresponding load or stress readings are plotted against axial strains and lateral deflections.

Table 5.1 *Details of loading and reinforcement of the test specimens*

Sl. No	**Name of the specimen Group**	**% of ultimate load applied (kN)**	**Number of longitudinal reinforcement (6mm dia)**
1	RC1	50	6
2	RC2	60	6
3	RC3	70	6

Table 6.1 *Comparison of Load carrying of 1zretrofitted specimens*

Sl. No	**Specimen**	**Cracking Load (kn)**	**Ultimate load (kn)**	**Theoretical ultimate load(kn) Indian code**	**Theoretical ultimate load(kn) aci code**
1	CC	180	242	198	276
2	RC1	383	470	410	576
3	RC2	373	450	410	576
4	RC3	360	440	410	576

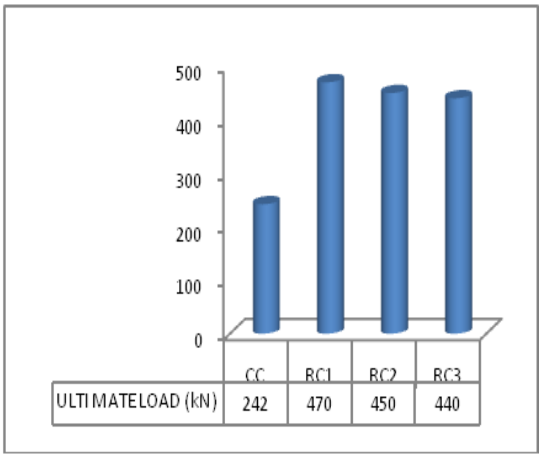

Figure 5.1 *Comparison of load carrying capacity*

Table 6.2 *Test results for retrofitted specimens (Axial load vs lateral deflection)*

Sl. No	Load (kN)	Deflection (mm)			
		CC	RC1	RC2	RC3
1	000	0.00	0.00	0.00	0.00
2	050	0.53	0.28	0.09	0.35
3	100	0.84	0.46	0.18	0.65
4	150	1.28	0.62	0.36	0.99
5	200	1.65	0.75	0.53	1.4
6	250	1.92	1.02	0.83	1.9
7	300	-	1.3	1.07	2.43
8	350	-	1.7	1.32	3.04
9	400	-	2.1	1.68	3.7

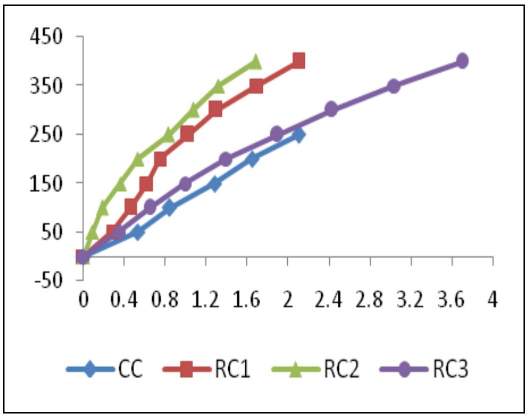

Figure 5.2: *Comparison of load deflection behavior of all columns*

Table 6.3 *Test result for retrofitted specimens (axial stress vs axial strain)*

Sl. No	Load (kN)	Stress (N/mm2)	Strain (µs)			
			CC	RC1	RC2	RC3
1	000	0.00	00	00	00	000
2	050	1.20	06	05	06	025
3	100	2.41	14	11	12	045
4	150	3.61	21	17	19	073
5	200	4.81	34	26	28	098
6	250	6.02	42	34	37	123
7	300	7.22		42	50	149

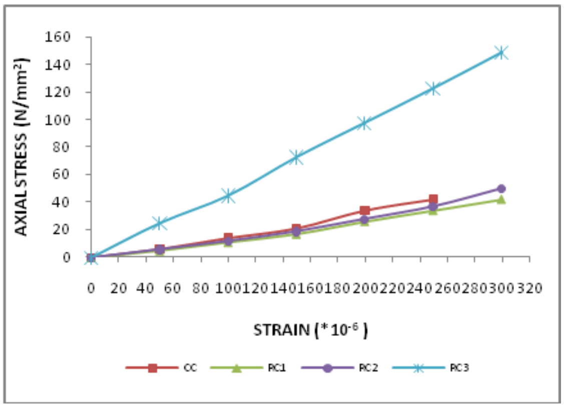

Figure 5.3: *Axial stress Vs axial strain in concrete respective of all retrofitted specimens*

4. Conclusions

Conclusions based on the results of experimental study.

The ultimate load carrying capacity of the retrofitted column is 1.9 times more than that of conventional column.

The cracking load of the retrofitted column is about 2 times to that of conventional column.

The mode of failure of the entire column occurs due to vertical cracking and spalling of concrete.

The ultimate load carrying capacity is increased in retrofitted R.C. jacketing with 6 Nos. of longitudinal bars.

When the damage due to load was increased from 50% to 70% the load carrying capacity of retrofitted column decreased marginally.

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