THOMSON REUTERS ENDNOTE
[Rajkumar* *et al.*, 5.(6): June, 2016] ISSN: 2277-9655
IC™ Value: 3.00 Impact Factor: 4.116

IJESRT
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

RETROFITTING OF CONCRETE CIRCULAR COLUMNS USING CFRP

Dr. R. Rajkumar*, Akkineni Surya Teja
* Associate Professor in Civil Engineering SSN College of Engineering, Kalavakkam, Chennai – 603110, Tamilnadu, India
UG Student in Civil Engineering SSN College of Engineering, Kalavakkam, Chennai – 603110, Tamilnadu, India

DOI:

ABSTRACT

Structures of architectural importance present a number of challenges in restoration and retrofit, which limit the application of modern codes and building standards. Recommendations are desirable and necessary to ensure rational methods of analysis and repair methods appropriate to the cultural context. Retrofit specifically aims to enhance the structural capacities (strength, stiffness, ductility, stability and integrity) of a building that is found to be deficient or vulnerable. In the specific context of enhancing the resistance of a vulnerable building to earthquakes, the term seismic retrofit is used. The building need not be deteriorated or damaged. The retrofit is intended to mitigate the effect of a future earthquake.

This paper is an attempt to show how retrofitting increases the strength of concrete columns. It is essential to identify the deficiencies in a building before undertaking retrofitting measures. Identification of the deficiencies is also expected to create awareness for future construction. For experimental purpose, the sizes of the testing specimens are scaled down to one-fourth the size of a standard reinforced concrete column.

Nine concrete specimens of the scaled dimension are cast and cured. The specimens are cast in PVC moulds (cut longitudinally for convenience during removal of specimens). Post curing, retrofitting is carried out using epoxy primer. Three concrete specimens are retrofitted at their centers, three at their ends and the other three are not retrofitted. The retrofitted specimens are dried for a day. Initially, these retrofitted concrete specimens are subjected to non-destructive testing i.e., rebound hammer test and their values are observed. Subsequently, these specimens are tested for their ultimate strength using a universal testing machine and the values for the corresponding cases are observed. The cracking patterns are observed and the variation in ultimate strengths due to retrofitting are studied and reported.

KEYWORDS: Retrofit, PVC mould, Epoxy primer, Rebound hammer.

INTRODUCTION

Retrofit specifically aims to enhance the structural capacities (strength, stiffness, ductility, stability and integrity) of a building that is found to be deficient or vulnerable. Retrofit can effectively raise the performance of a building against earthquakes to a desired level. To what extent the retrofit has to be carried out is an important decision that also has cost implications. In the case of old buildings, it is generally not necessary to raise the structural capacities to the level expected of a new building as per the current code of practice.

It is essential to identify the deficiencies in a building before undertaking retrofit. Identification of the deficiencies is also expected to create awareness for future construction.

GENERAL BUILDING DEFICIENCIES

The typical problems that are frequently encountered due to the deterioration of existing masonry buildings are cracking, spalling, staining, moisture ingress , deterioration of mortar and loose components, corrosion, differential settlement of the foundation, blistering of coating, design and construction defects. Most of these defects are due to improper construction, lack of quality control during construction, over-emphasis on reducing cost at the expense of durability and safety, and lack of maintenance. Many of the problems listed above occur even in relatively new buildings, which require repair within 5 years after construction.

Cracking

Cracking is the most common visually detectable distress encountered in a building, needing repair or retrofit. The cracking may be minor such as those due to restraint to shrinkage. Else, the cracking may be major due to a) Over-loading b) Differential settlement of the foundation c) Thermal movement d) Load transfer from beams and columns in a framed building e) Vibration f) Corrosion of reinforcing bars in a reinforced masonry building.

Spalling

The delamination of surface of brick or mortar or plaster is called spalling. Spalling can occur due to internal stresses or due to external actions. Spalling also occurs due to concentrated eccentric load, freeze-thaw effect of entrapped water, chemical effect, efflorescence and repeated wetting and drying in coastal areas. Observation of the location of spall gives an indication of the cause.

Staining

Staining of masonry walls is caused by absorption of water containing salts and subsequent efflorescence. Efflorescence is defined as the deposition of water-soluble salts on the surface after evaporation of the water. The efflorescence can disrupt the wall because of internal crystallization of salts.

In reinforced masonry walls, rust staining may occur due to absorption of water. Because of increase in volume due to the formation of rust, spalling and cracking occur. If unattended, it can lead to faster corrosion of the steel bars and deterioration of the wall. Thus, to check corrosion and efflorescence staining, the problem of absorption of water has to be addressed.

Moisture ingress

The moisture ingress depends on several factors such as the porosity of the bricks, the mortar joints, the pointing, cracks in the wall and the plastering. Water seepage causes wetness and encourages the growth of mould, fungi and vegetation. It can degrade the quality of the wall. Penetration of rainwater and its pathways can be detected through visual observation of wet areas and patches following rainy days.

Differential settlement of the foundation

If parts of the ground are made of fill or are susceptible to consolidation or swelling, differential settlement of the wall foundation can cause cracks. The cracks tend to widen with time.

Construction defects

The construction defects are primarily due to use of poor quality bricks, use of poor construction procedure such as not soaking the bricks before construction, defective bond and flashing, incorrect wall thickness, out-of-plumb wall, defective and misaligned joints of walls, lack of movement joints for expansion and contraction and plugged weep holes.

Local deficiencies

Local deficiencies arise due to improper design, faulty detailing, poor construction and poor quality of materials. These lead to the failure of individual members of the building such as flexural and shear failures of beams, columns and shear walls, crushing or diagonal cracking of masonry walls and failure of beam-column joints or slab-beam or slab-column connections.

OBJECTIVES FOR RETROFITTING

- To increase the lateral strength and stiffness of the building.
- To increase the ductility in the behavior of the building. This aims to avoid the brittle modes of failure.
- To increase the integral action and continuity of the members in a building.
- To eliminate or reduce the effects of irregularities.
- To enhance redundancy in the lateral load resisting system.
- This aims to eliminate the possibility of progressive collapse.
- To ensure adequate stability against overturning and sliding.

Local retrofit strategies

Local retrofit strategies pertain to retrofitting of columns, beams, joints, slabs, walls and foundations. The local retrofit strategies are categorised according to the retrofitted elements. The analysis of a building with a trial local retrofit strategy should incorporate the modeling of the retrofitted elements.

The local retrofit strategies fall under three different types: concrete jacketing; steel jacketing (or use of steel plates) and fiber-reinforced polymer (FRP) sheet wrapping.

Column retrofitting

The retrofitting of deficient columns is essential to avoid collapse of storeys. Hence, it is more important than the retrofitting of beams. The columns are retrofitted to increase their flexural and shear strengths, to increase the deformation capacity near the beam-column joints and to strengthen the regions of faulty splicing of longitudinal bars. The columns in an open ground storeys or next to openings should be prioritized for retrofitting. The retrofitting strategy is based on the "strong column weak beam" principle of design. During retrofitting, it is preferred to relieve the columns of the existing gravity loads as much as possible, by propping the supported beams.

MATERIALSCARBON FIBRE REINFORCED POLYMER SHEET (CFRP)

Carbon-fiber-reinforced polymers are composite materials consists of two parts: a matrix and a reinforcement. The reinforcement is carbon fiber, which provides the strength. The matrix is usually a polymer resin, such as epoxy, to bind the reinforcements together.

Nitowrapep (cf)

NitowrapEP(CF) is a carbon fibre composite system for strengthening columns and beams and slabs of load bearing structures particularly where improvement to shear strength and deformation characteristics is required.

Primer

A substance used as a preparatory coat on wood, concrete, metal, or canvas, especially to prevent the absorption of subsequent layers of paint or the development of rust.

Nitowrap 30

The mixed material of Nitowrap 30 epoxy primer is applied over the prepared and cleaned surface. The application shall be carried out using a brush and allowed for drying for about 24 hours before application of saturant.

Saturant

Substance added to water to create a solution and wets out carbon fiber easily and efficiently.

Nitowrap 410

The mixed material of Nitowrap 410 saturant is applied over the tack free primer. The wet film thickness shall be maintained @ 250 microns.

Uv resistant top coat

UV protection additive that protects binder integrity.

Nitowrap 512

If UV resistance is required then two additional coats of two component aliphatic polyurethane coating Nitowrap 512 shall be applied as topcoat. The WFT shall be 100 micron.

METHODOLOGY

Application instructions

Surface preparation

Concrete surfaces to be treated shall be free from oil residues, demoulding agents, curing compounds, grout holes and protrusions. Incase of distressed structures, the concrete surface to be wrapped, shall be structurally repaired prior to treatment. Corrosion induced damages shall be repaired with Renderoc range of mortars and Galvashield XP shall be installed wherever necessary. Structural damages shall be repaired by using epoxy grouting/appropriate mortar from the Renderoc range. All depressions, imperfections etc., shall be repaired by using Nitocote VF/ Nitomortar FC, epoxy putty.

Mixing

Before mixing, the contents of each can should be thoroughly stirred to disperse any settlement, which may have taken place during storage. The base and hardener are emptied into a suitable container and the material is thoroughly mixed for at least 3 minutes. Mechanical mixing using a heavy-duty slow speed (300 - 500 rpm), drill, fitted with a mixing paddle is recommended.

Primer

The mixed material of Nitowrap 30 epoxy primer is applied over the prepared and cleaned surface. The application shall be carried out using a brush and allowed for drying for about 24 hours before application of saturant.

Saturant

The mixed material of Nitowrap 410 saturant is applied over the tack free primer. The wet film thickness shall be maintained at 250 microns.

Nitowrapcf

The Nitowrap CF fabric shall be cut to required size and then pressed first by gloved hand on to the saturant applied area and then with a stiff spatula or a surface roller to remove air bubbles. One more coat of Nitowrap 410 saturant is applied over the carbon fabric at 250 microns WFT after a minimum time lapse of 30 minutes. The same procedure shall be followed for multiple layer fibre strengthening.

Top protective coat

If UV resistance is required then two additional coats of two component aliphatic polyurethane coating Nitowrap 512 shall be applied as topcoat. The WFT shall be 100 microns per coat.

Curing

The coatings will become tack free in approximately 4 - 6 hours and be fully cured in 7 days.

Cleaning

Tools and equipments should be cleaned with Nitoflor Sol, solvent immediately after use. Hands and skin shall be washed with soap, or an industrial hand cleaner.

Casting of the scaled model of concrete column moulds

A standard size of a circular column is taken to be our model, which has a height of 2.8 m and a diameter of 400 mm with 6 Nos. of 16 mm dia bars as reinforcements. It is scaled down by 1:4.

Nine cylindrical concrete specimens of M20 Grade mix, 100 mm diameter and 700 mm height were cast and cured. Among the nine specimens, three were not retrofitted after curing, three were retrofitted at either ends and three were retrofitted at their centres. Post retrofitting, the specimens were left to dry. After the drying period, they were subjected to two tests namely - Rebound hammer test and Ultimate strength test.

In the rebound hammer test, 10 readings were taken for each case for each specimen and the mean values were tabulated.

MIX DESIGN

Step 1: Design Stipulations

1. Characteristic Compressive Strengthrequired at 28 days - 20Mpa
2. Maximum size of aggregate -20mm (Angular)
3. Degree of quality control - Good
4. Type of exposure - Mild

Step 2: Test data for materials

1. Specific gravity of cement - 3.15
2. Compressive strength of cement at 7 days - Satisfies the requirementsof IS: 269-1989
3. Specific Gravity of course aggregates - 2.8
4. Specific Gravity of fine aggregates - 2.7
5. Water absorption of Course aggregate - 0.5%
6. Water absorption of Fine Aggregate - 1%

Step 3: Target mean strength of concrete

The target mean strength for specified characteristic cube strength is
20 + 1.65 x 5 = 28.25 Mpa

Step 4: Selection of water-cement ratio

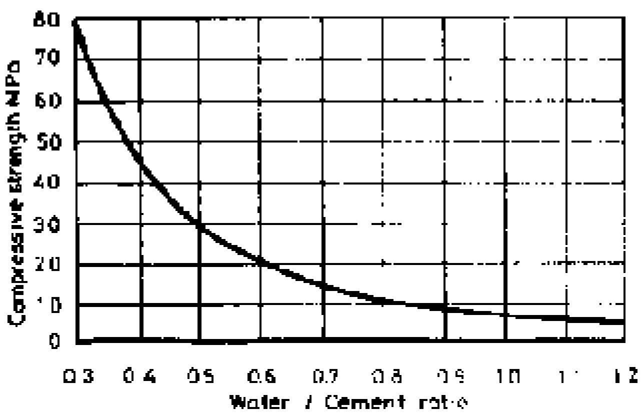

Fig.1: Compressive Strength to Water cement ratio

From figure 1, the water cement ratio required for the target mean strength of 28.25 MPa is 0.50. This is lower than the maximum value of 0.55 prescribed for 'Mild' exposure. Thus we adopt W/C ratio of 0.50.

Step 5: Selection of water and sand content

From table 1, for 20mm maximum size aggregate, sand conforming to grading Zone II, water content per cubic meter concrete = 186 kg which has a slump of 50 mm.
But for a slump of 125 mm, we need to increase the water content.
For every 25mm change in slump value, there should an increase of water cement ratio by 3%. Thus, our correction is 9%. So, Water content = 186 + 9/100 x 186 = 202.74 kg

Table 1: Approximate sand & Water content

Maximum Size of Aggregate (mm)	Water content including surface water, per cubic meter of concrete (kg)	Sand as percent of total Aggregate by Absolute volume
10	200	40
20	186	35
40	165	30

Step 6: Determination of Cement content

1. Water cement ratio - 0.50
2. Water - 202.74 liter
3. Thus, Cement - 202.74/0.5 = 405.48 kg/m^3

This cement content is adequate for 'mild' exposure conditions.

Step 7: Determination of course and fine aggregate content

Volume of course aggregate is 0.62 of the total volume of aggregate And, 2% is taken as air voids of the whole volume. Thus, taking the total content of aggregates as '**x**', the equation is formed as

$$1 - (2/100)\ m^3 = 202.74 / 1000 + 405.48 / 3150 + x$$

After equating, the value of **x,** i.e., the total volume of course aggregates comes to 0.648 m^3

Thus,

The volume of course aggregate = 0.648x0.62x2800

= 1124.92 kg

The volume of fine aggregate = 0.648x0.38x2700

= 625.44 kg

Step 8: Actual quantities required for the mix

For 1m^3 of volume, the mix is:

Water content - 202.74 liters

Cement - 405.48 kg

Fine aggregate - 625.45 kg

Course aggregate - 1124.92 kg

Arranging these values in ratio we get,

202.74 : 405.48 : 625.45 : 1124.92

Dividing the whole by 405.48, we get,

0.5 : 1 : 1.52 : 2.75

Finally the Design mix ratio is **1 : 1.52 : 2.75** with a w/c ratio as **0.5**

Table 2: Test results on Validating Design Mix

Type of mould	Specimen No.	Ultimate load (KN)	Strength (N/mm^2)
Cube	1	410	18.23
	2	520	23.12
	3	470	20.88
Cylinder	1	460	26.04
	2	460	26.04

NON DESTRUCTIVE TEST

Rebound hammer test

Rebound hammer test is done to find out the compressive strength of concrete by using rebound hammer as per IS: 13311 (Part 2) – 1992.

The test hammer will hit the concrete at a defined energy. Its rebound is dependent on the hardness of the concrete and is measured by the test equipment. By reference to the conversion chart, the rebound value can be used to determine the compressive strength.

Prior to testing, the Schmidt hammer should be calibrated using a calibration test anvil supplied by the manufacturer for that purpose. 10 readings are taken, dropping the highest and lowest, and then take the average of the ten remaining. Using this method of testing is classed as indirect as it does not give a direct measurement of the strength of the material. It simply gives an indication based on surface properties.
The rebound value is read from a graduated scale and is designated as the rebound number or rebound index. The compressive strength can be read directly from the graph provided on the body of the hammer.

RESULTS AND DISCUSSION

Rebound hammer test

The results for the rebound hammer of retrofitted specimens at the center and ends are as shown in table 3 and 4 respectively.

Retro-fitting Case	Specimen No.	Trial No.	Strength (KN/m)	Mean Strength
200mm Retrofitted at center	1	1	29.6	30.6
		2	36.0	
		3	20.7	
		4	36	
		5	36	
		6	29.6	
		7	27.4	
		8	37.2	
		9	11.6	
		10	42.5	
	2	1	34.1	29.75
		2	32.6	
		3	35.8	
		4	29.1	
		5	25.8	
		6	28	
		7	31	
		8	26	
		9	24.1	
		10	31	
	3	1	39.1	32.3
		2	32.6	
		3	40.8	
		4	27.4	
		5	27.8	
		6	29.6	
		7	39.1	
		8	37.4	
		9	22.5	
		10	27.4	

Table 3: Rebound Hammer on Specimens Retrofitted at center

Retro-fitting Case	Specimen No.	Trial No.	Strength (KN/m)	Mean Strength
200mm Retrofitted at Ends	1	1	39	30.08
		2	24.2	
		3	32.5	
		4	29	
		5	34.1	
		6	36	
		7	23	
		8	26.5	
		9	27.3	
		10	29.2	
	2	1	32.8	29.5
		2	29.1	
		3	36.0	
		4	29.1	
		5	20.8	
		6	34.1	
		7	32.6	
		8	24.1	
		9	32.4	
		10	24.2	
	3	1	34.1	26.97
		2	20.8	
		3	24.1	
		4	37.4	
		5	20.8	
		6	32.6	
		7	27.4	
		8	27.4	
		9	21.0	
		10	24.1	

Table 4: Rebound Hammer on Specimens Retrofitted at Ends

Compression strength test

The test results for ultimate compression strengths on specimens are as shown in table 5.

Retrofitting Case	Specimen No.	Ultimate load (KN)	Strength (N/mm^2)
Without Retrofitting	1	134	17.07
	2	145	18.47
	3	160	20.38
200mm Retrofitted at Center	1	150	19.1
	2	171	21.78
	3	180	22.92
200mm Retrofitted at Ends	1	220	28.02
	2	225	28.66
	3	210	26.75

Table 5: Test Results for Compression Strengths on Specimens

Fig 2. Compression Test on Specimen (Retrofitted at Center)

Fig 3. Compression Test on Specimen (Retrofitted at Ends)

CONCLUSIONS

The specimens were subjected to compression and the load at which failure took place was noted and the pattern of failure of retrofitted specimens was studied and compared with that of the non-retrofitted specimens and the results are tabulated as shown in the table 6.

Table 6: Mean values of the Results

Type of test	Type of Retrofitting	Mean Strength
Rebound hammer Test	200mm Retrofitted at Center	28.85
	200mm Retrofitted at Ends	30.88
Compression Test	Not Retrofitted	18.64
	200mm Retrofitted at Center	21.27
	200mm Retrofitted at Ends	27.81

ISSN: 2277-9655
Impact Factor: 4.116

From the results the following conclusions could be drawn.

1. The compressive strength of specimen retrofitted at the centre had a compressive strength of 14.10 % more than that of conventional concrete specimen.
2. The compressive strength of specimen retrofitted at the ends had a compressive strength 49.19 % more than that of conventional concrete specimen.
3. The specimen retrofitted at the centre showed an increase of 54.77 % in rebound hammer test than that of conventional concrete specimen.
4. The specimen retrofitted at the ends showed an increase of 65.66 % in rebound hammer test than that of conventional concrete specimen.

REFERENCES

[1] S.Eshghi and V.Zanjanizadeh 'Retrofit of slender square reinforced concrete columns with glass fibre reinforced Polymer for seismic resistance', 2008
[2] V.C. Li, 'Repair and retrofit with engineered cementitious composites', 2000
[3] Gaur P Johnson and Ian N Robertson 'Retrofit of slab-column connections using CFRP', 2004
[4] Simon Foo 'Rectangular concrete columns retrofitted by external prestressing for seismic shear resistance', 2004
[5] M C Griffith and A V Pinto ' Seismic Retrofit of reinforced concrete buildings' 2000
[6] ChinthaPerera 'Structural strengthening for optimizing floor space during retrofitting of high-rise office buildings',2006
[7] M. Tavakkolizadeh 'Repair of Damaged Steel-Concrete Composite Girders using Carbon Fibre-Reinforced Polymer Sheets', 2003
[8] Michel Bruneau 'Seismic Retrofit of Steel Structures'.
[9] K. Olivova and J Bilcik 'Strengthening of Concrete Columns using CFRP', 2008
[10] Handbook on Seismic Retrofit of Buildings 'Retrofit of Reinforced Concrete Buildings', pp. 9.1-9.42, 2007
[11] T.JeffGuh and ArashAltoontash 'Seismic Retrofit of Historic Building Structures,'2006