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EFFECT OF RC CYLINDRICAL COLUMN USING SELF COMPACTING CONCRETE AS A RETROFITTED MATERIAL

R.Deepan[1]&Dr T.S. Viswanathan[2]

[1.] *M.Tech structural engineering (final year), school of civil and chemical engineering VIT University, Vellore*

[2.] *Associate professor, school of civil and chemical engineering VIT University, Vellore*

ABSTRACT –

External confinement using jackets can suitably increase the strength and ductility of the reinforced concrete cylindrical columns. This paper encompasses an experimental investigation for studying the effectiveness and suitability of self compacting concrete (SCC) mixes as a retrofitting material and its use as jacket for cylindrical columns. The experimental programme included development of SCC mix and its use in retrofitting of cylindrical column specimens which were either intact or distressed earlier to certain level. The specimens are made up of M25 grade of concrete. Specimens are divided into two groups primary and control specimen. Size of the RC cylindrical column specimen 600mm length 150 mm diameter. The control specimen tested up to ultimate load carrying capacity of RC column. The primary specimen tested up to 80-85 % of ultimate load carrying capacity. After testing of the primary specimen were jacketed with welded wire mesh (WWM) of 25mm inner and outer cover. Based on EFNARC specification SCC mix were prepared by using fly ash and silica fume. All the distressed primary specimen were retrofitted with optimized SCC mix. The retrofitted specimens were tested after 28 days and 56 days curing. The test results revealed the effective use of SCC as retrofitting material. The SCC jacket with WWM as reinforcement increases the ultimate load carrying capacity of column specimen.

KEYWORDS - Self compacting concrete, retrofitting, jacketing, columns, cracks, deformation

1. INTRODUCTION

Technological advances, as well as growing population, have led to a radical change in the way of thinking. The civil engineering industry has revolutionized in order to meet sustainable development concepts by implementing fast execution technologies, finding new construction materials and modern methods of design. As a result, concrete in its various forms has evolved as the most widely used and fascinating construction material throughout the world.

Development of self-compacting concrete (SCC) is one of the most revolutionary advances in the history of development of concrete[1]. A very wide range of applications of SCC as structural concrete and architectural concrete in buildings, bridges and tunnels have been reported since its first use in the early 1990's [2]. Besides the use of SCC as a structural and architectural material, owing to its fresh state properties, SCC alsohas atremendous potentialtouseitas an optimal retrofitting material for jacketing applications of reinforced concrete columns. A variety of jacketing techniques with various materials such as conventionally vibrated concrete (CVC) [3], steel [4–6], fibre reinforced-polymers (FRP) [6–9], ferrocement[10], textile composites and textile-reinforced mortars(TRM)

Recently, the rehabilitation of flexural damaged reinforced concrete beams and columns using self-compacting concrete jackets has been investigated experimentally and reported [12]. The use of self-compacting concrete has inherent advantage over the use of normal concrete for retrofitting where thickness of jacket is invariably more even after application with modernized techniques. Various theoretical investigations on the retrofitted beams and columns have been reported. Lampropoulos in 2012, has reported a comprehensive numerical investigation using finite element models, at the interface between the old and the new concrete and jacket concrete shrinkage. In the study monolithic coefficient values for two different types of concrete jacket (four and three sided) have been determined in addition to, investigation on the effects of varying the normalized axial load, the thickness of the jacket, and the concrete strength

From the review of literature it is evident that in jacketing methods the degree of adhesion and interaction between the existing member and the jacket is an issue of critical importance. The jacketing in the present case was intended fully recover the strength of the columns, therefore only welded wire mesh (WWM) of mild steel was used in the jacket as reinforcement. From the review of literature it is evident that very scant literature is available on the retrofitting of RC columns using jacketing with SCC. Thus with an objective to study the effectiveness of the retrofit method i.e. use of SCC jacket for the rehabilitation of damaged RC columns the present investigation has been done.

2. MATERIALS

- ***Cement***

Cement used as a binder material in concrete. The main characteristics of cement in the concrete mix design is developing the compressive strength within period. In this study 53 grade of ordinary Portland cement properties are confirming to code IS:12269-1987 [**Error! Reference source not found.**]. The specific gravity of cement found in the laboratory is 3.13.

- ***Aggregate***

Aggregate which passes through the 12.6 mm sieve is used as the coarse aggregate. Mainly aggregate occupy 70% in concrete, the coarse aggregate will satisfies the requirement specified in the code. The fine aggregate which having the fineness value of 2.6 confirming to Zone-II is used and the properties of fine aggregate is confirming to the requirement specified in IS:383-1970 [**Error! Reference source not found.**]. The specific gravity of the coarse aggregate is find out as 2.74

- ***. Fly-ash***

Fly ash is a byproduct material which is generated during the combustion of coal. The fly- ash used in this study is to confirm to IS:3812-2003 [**Error! Reference source not found.**]has a specific gravity of 2.17. Fly-ash used in this study is obtained from Ennore Thermal Power Plant, Chennai.

- ***Silica fume***

Silica fume is an industrial product in the form of very fine powder, with a SiO2 content of over 90 and 3% in loss on ignition.

3. EXPERIMENTAL WORK

The experimental investigation was divided in two distinct phases. First phase of the experimental program, included development of SCC mixes based on EFNARC [1] specifications & SCC mix design method. The second phase comprised of experimental study relating to efficiency and suitability of SCC mixes as a retrofitting material. In the first part of the study , the SCC mixes were developed on the basis of different trial mixes after examining fresh state properties of self-compacting abilities. The coarse and fine aggregates were varied in each trial mix but ratio of fine aggregate to coarse aggregate were kept constant. Also w/p, superplasticizer dosages and powder content were kept constant for all the trial mixes. Two SCC mixes as per mix proportions satisfied all the fresh properties as per EFNARC[1], were selected for further optimization of SP dosages and fly ash content. The fly ash content in these selected mixes was optimized by comparing the water and SP dosage required to achieve self compacting properties by partially replacing Portland cement with fly ash content by 30% and silica fume by 5% 10% 15% 20% 25% by mass of powder content in paste and mortar. The water to powder ratio by volume just sufficient to initiate the flow in paste at different replacement levels of fly ash and silica fume has been determined with mini slump cone. The minimum SP dosage required to achieve self-compacting properties at different replacement levels in mortar has been investigated with mini slump cone test and mini V-funnel test as per recommendations of EFNARC [1]. Finally, the performance of optimized contents was verified for fresh state properties and compressive strength in SCC mixes itself.

TABLE 1 : MIX DESIGN

CEMENT (Kg/m*3)	FINE AGGREGATE (Kg/m*3)	COARSE AGGREGATE (kg/m*3)	WATER (kg/m*3)	W/C RATIO
392	981.65	868.40	176.40	0.45

The second phase of experimental investigation comprised of tests on sixteen columns of diameter 150 mm and height 600 mm, cast with M25 grade of conventionally vibrated concrete. All the column specimens were reinforced longitudinally with six bars each of 12 mm diameter. The transverse reinforcement consisted of 4 bars each of 8 mm diameter. The transverse reinforcement was provided in the form of circular ties around the longitudinal bars. Both longitudinal as well as transverse reinforcement were of high yield strength deformed (HYSD) steel conforming to IS: 1786-2008. Further the dimensions of column specimens were restricted to horizontal and vertical clearance of the testing machine. Clear concrete cover of 25 mm was provided for all the specimens.

Out of these sixteen column specimens, four were designated as control specimens and remaining 12 were designated as primary specimens. The four control specimens were tested under monotonic concentric compression at uniform slow rate with stress-controlled universal testing machine from zero to failure i.e. up to their ultimate load. The primary specimens were also tested under monotonic concentric compression at uniform slow rate with stress-controlled universal testing machine but loading was discontinued when the axial load was reached up to 80–85% of their theoretical ultimate load carrying capacity. Afterwards the primary columns were divided into four groups designated as Group 1 to Group 4. Group 1, 2 was retrofitted with jacket of SCC mix SCC1 and Group 3,4 was retrofitted with jacket of SCC mix SCC2. The thickness of jacket for all the groups was kept 50 mm. The jacket of both the groups was also reinforced with welded wire mesh (WWM) of mild steel. The size of grid in WWM was 5mm. The retrofitted columns were tested under monotonic concentric compression after 28, 56 days of curing.

Data for loads, stress and deformation for control, and primary as well as retrofitted specimens were acquired in universal testing machine

4. CASTING AND CURING OF CONTROL & PRIMARY SPECIMES

Control and primary specimen were casted and it is cured under 28 and 56 days of curing .cubes were also casted to find out the compressive strength of concrete

5. TESTING OF CONTROL AND PRIMARY SPECIMENS

Testing of all the control and primary specimens was done after the curing was stopped. Prior to testing, precautions were taken to prevent any accidental eccentricity in the axial load application by precise alignment of the test set-up. The position of the specimen was adjusted until its centre-line matched the line of action of axial load. This preload also ensured the elimination of abnormality in loading or non-uniformity in the pressure. In case of unequal readings, the specimen was again unloaded and readjusted to remove the load eccentricity. The procedure was repeated until the initial loading was approximately concentric. After removal of eccentricity and initializing all the readings, the specimens were loaded under a monotonic uni-axial compression load at uniform slow rate. The control specimens were first tested up to failure i.e. up to their ultimate load carrying capacity. For primary specimens the loading was discontinued when the axial load reached 80–85% of the theoretical ultimate load carrying capacity. Significant data points corresponding to first crack load, failure load, stress due to failure and deformation were also recorded during testing along-with axial load and axial stress.

Table 2 : Experimental results for control specimen

Control specimen	First crack load (KN)	Corresponding axial stress (MPa)	Ultimate load (KN)	Corresponding axial stress (MPa)	Deformation (mm)
1	260	14.71	550	31.12	3.7
2	275	15.56	570	32.25	4.3
3	245	13.86	555	30.95	3.5
4	270	15.27	545	30.84	4

6. REPAIR AND RETROFITTING OF DISTRESSED SPECIMENS

All the primary specimens were damaged reasonably during the testing. All the loose concrete including cover of primary specimen was first chipped off and the surface of the columns was cleaned. While filling the cracks, care was taken to obtain a levelled and smooth surface after repairing. The welded wire mesh (WWM) reinforcement, were then carefully placed around the repaired specimens followed by the placement of mould for retrofitted specimen. Steel collars were also provided at top and bottom along the circumference of the retrofitted specimen to prevent end failure during testing. Group 1, 2 were retrofitted with SCC mix SCC1 and group 3,4 were retrofitted with SCC mix OSCC2. The control cubes were also cast and cured simultaneously for investigating the quality of concrete used in the preparation of specimens. Jacket reinforcement is usually placed practically on the surface of the existing element with dowels to enhance connectivity and force transfer at the interface between old and new concrete. In this case while distressing the primary specimen most of the concrete cover spall doff and had to be chipped off before the retrofitting. The thickness of concrete therefore placed for retrofitting was 50 mm, with 25 mm inside the WWM cage and 25 mm outside the cage.

7. TESTING OF RETROFITTED SPECIMENS

The retrofitted specimens were carefully centred beneath the loading frame of universal testing machine, for applying preload of 20% of the total ultimate load of the specimen to check the instrumentation, data acquisition system and to ensure the concentric loading in a similar manner as done for primary specimens. The specimens were then loaded under a monotonic uni-axial compression load at uniform slow rate with stress-controlled universal testing machine. The testing was terminated when the retrofitted specimen was unable to sustain the loading i.e. when the ultimate load carrying capacity of retrofitted specimen was reached. Significant data points such as first crack load and ultimate load, stresses and deformation were also recorded. Therefore, in this case the load was applied on the entire cross section including the existing column and jacket. Since the load was applied over the entire cross section of retrofitted column the deformation characteristics of core and the jacket are expected to be the same, as long as bonding between the jacket and core is intact. If the load is applied on core only, it would render early de-bonding of jacket from core and different behavior of core and jacket would be expected.

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Table 3 : Experimental results for primary specimen

y specimen (80-85% of ultimate load)	ed load (kN)	ding axial stress (MPa)	crack load(kN)	ding axial stress (MPa)	tion (mm)
GROUP1	440	24.89	248	14.03	3.5
	450	25.46	256	14.48	3.2
	467	26.43	245	13.86	3.8
GROUP2	456	25.80	260	14.71	3.6
	467	26.43	275	15.56	3.4
	484	27.38	270	15.27	4
GROUP3	445	25.18	265	14.99	3.6
	448	25.35	285	16.12	3.8
	465	26.31	250	14.14	3.3
GROUP 4	436	24.67	260	14.71	3.8
	447	25.29	245	13.86	3.6
	463	26.20	275	15.56	3.5

8. RESULTS AND DISCUSSION:

8.1. Behavior of control and primary column specimens

The results of tests on the control specimens are presented. The average values for all 4 specimens D1–D4 corresponding to appearance of first crack and corresponding stress, ultimate load and corresponding axial stress. It is observed that the ultimate load for control specimens was in the range of 545 to 570 kN with ultimate compressive stress varying of 30-32 MPa. The average compressive load for these control specimens was 565 kN with corresponding average stress of 30 MPa. It was also observed that the first crack appeared in the specimens corresponding to an average stress of 14.22 MPa, which is around 43% of the ultimate stress induced in the control specimens at the time of failure. The control specimens were tested to determine the ultimate load whereas primary specimens were distressed up to 80–85% of their theoretical ultimate load carrying capacity. The theoretical load carrying capacities were also calculated with an aim to establish the effectiveness of the retrofitting technique and assess the amount of confinement. This cracking may be attributed to development of hoop strains in the concrete cover. With further increase in the loads, these cracks widened and eventually led to the spalling of concrete cover, which was marked by the separation of large pieces of cover from core concrete. This lead to the exposure of longitudinal steel bars and lateral ties confining the core of concrete. The loading was stopped for primary specimens at this stage, which was almost 80–85% of the theoretical ultimate load carrying capacity. The control specimens were loaded till failure leading which even lead to bending of the longitudinal reinforcing bars in some of the specimens. The buckling of longitudinal reinforcing bars progressed and the crushing of concrete could be noticed which coincided with the ultimate load. The average ultimate stress for control specimens was found to be 32.82 MPa and therefore the primary specimens were distressed to a stress level varying from 27.77 MPa to 28.18 MPa.. In retrofitted specimens, yielding can be considered when strength reduces to 85% of the ultimate strength due to deformation in the post peak zone.

TABLE 4 : COMPRESSIVE STRENGTH FOR SELF COMPACTING CONCRETE

MIX ID	COMPRESSIVE STRENGTH (MPa)		
	7 DAYS	14 DAYS	28 DAYS
MIX-1 Flyash(30%)+silica fume(5%)	22	28	32
MIX-2 Flyash(30%)+Silica fume(10%)	24.50	29	36.5
MIX-3 Flyash(30%)+silica fume(15%)	19.40	23	27
MIX-4 Flyash(30%)+silica fume(20%)	18.50	22	25
MIX-5 Flyash(30%+silica fume(25%)	16	17.5	19

8.2. Behaviour of retrofitted column specimens

The retrofitted specimens of Group 1 and 2 were cured under normal conditions for 28 days, Group 3 and 4 were cured for 56 days . The first crack load, ultimate load and corresponding to ultimate stress. The retrofitted specimens initially behaved in similar manner as that of primary specimens. Damage of the specimen initiated with fine hair cracks developing in the longitudinal direction in the upper as well as lower half portion of the specimen, as a result of circumferential strains in the cover concrete. These cracks further widened up with the increase in loading. These widened cracks marked on the specimen can be seen. On further increasing the load, the spalling of concrete took place and deformation of WWM reinforcement was clearly noticeable. The retrofitted specimens tested could develop an average stress of 35 MPa at 28 days, 38 MPa at an age of 56 days in comparison to an average ultimate stress of 32 MPa in the control specimens. Further, increase in load led to the crushing of concrete and separation of large pieces of concrete from jacket. Primary column behaviour, encased in the concrete jacket, could not be observed during testing of the retrofitted specimens until large pieces of cover from jacket were removed. With the progressive increase in the compressive load, increase in deformation of WWM and buckling of longitudinal reinforcement of the primary column was noticed. The buckling of longitudinal reinforcing bars progressed and the crushing of concrete could be noticed at this stage. The transverse ties opened up at the location where longitudinal reinforcing bars buckled. Significant deformation in

8.3. Effectiveness of retrofitting technique

Effectiveness in terms availability, applicability and economics, of retrofitting technique for existing structures is a concern. Concrete jacketing using SCC is an economical and viable option where concrete core is confined by steel rebar. The addition of a new retrofitting material, such as reinforced concrete jacket, fibre reinforced polymer wraps or steel plates provides another layer of confinement. Conventional design methods analyse jacketed columns as a composite of old and new concrete along with the longitudinal steel present therein. Such analysis typically underestimates the actual strength gain and the increased post-peak ductility of the jacketed columns . Even though research has been carried out on the axial capacity, flexural strength and seismic resistance The various concrete confinement models available in the literature were reviewed with respect to their suitability for predicting the response of reinforced concrete columns retrofitted with self-compacting concrete jacket. Accordingly, the experimental results were compared with results obtained from three concrete confinement models which are Mander et al. model, Saatcioglu et al. model ,Legeron et al. model and with conventional approach without confining effect to assess the behavior of retrofitted specimen in the specimens was observed at this stage and structural integrity of the specimens was drastically decreased. At this stage, the specimens deformed excessively and loading had to be stopped. The average value of ultimate load, average value of axial and lateral strain at ultimate load, average value of first crack load for group 1–4 of retrofitted column specimens were recorded. The average values are derived on basis of four column specimens in a group.

Table 5 : Experimental results for retrofitted specimen

MIX ID	ultimate load (kN)	Corresponding axial stress (MPa)	First crack load (kN)	Corresponding axial stress (MPa)	Deformation (mm)
GROUP1 (28 days) Flyash(30%)+silica fume(5%)	645	36.50	260	14.71	4.5
	630	35.65	275	15.56	4.2
	635	35.90	265	15.20	4.6
GROUP2 (56 days) Flyash(30%)+Silica fume(5%)	655	37.20	280	15.84	3.8
	675	38.19	295	16.70	4.2
	670	37.91	290	16.41	4
GROUP3 (28 days) Flyash(30%)+silica fume(10%)	660	37.34	280	17.50	4.3
	665	37.63	275	17.10	4.1
	650	36.78	285	17.76	4.4
GROUP4 (56 days) Flyash(30%)+Silica fume(10%)	680	38.48	295	18.10	4.2
	675	38.19	300	18.16	4.6
	670	37.91	290	17.95	4.3

terms of the load carrying capacity, strains and stress-strain response .

9. CONCLUSIONS

To evaluate the effectiveness of the retrofitting of circular columns using self-compacting concrete jacket tests were conducted on control, primary and retrofitted specimens grouped in 4 groups. The comparison of the ultimate loads, stresses, and deformation for the control and the retrofitted specimens are made.

Based on this study, the following conclusions were made:

1. To evaluate the effectiveness of the retrofitting of circular columns using self-compacting concrete jacket tests were conducted on control, primary and retrofitted specimens grouped in 4 groups.
2. The comparison of the ultimate loads, first crack load, deformation and stresses for the control and the retrofitted specimens are made.
3. Damaged primary column specimens of group 1 and group 2 retrofitted with SCC1(30% flyash and 5% silica fume) cured under water for 28 and 56 days. Results indicate that using SCC jacket with welded wire mesh 9% to 12% increases the load carrying capacity of the column
4. Damaged primary column specimens of group 3 and group 4 retrofitted with SCC2(30% flyash and 10% silica fume) cured under water for 28 and 56 days. Results indicate that using SCC jacket with welded wire mesh 10% to 12% increases the load carrying capacity of the column
5. The axial load carrying capacity of the retrofitted columns improves, after retrofitting of column specimen
6. The present investigation reveals that the effective use of SCC as retrofitting material.It has been observed that SCC jacket with welded wire mesh as reinforcement increases the ultimate load carrying capacity of column specimen

10. REFERENCES:

References

[1] EFNARC. Specifications and guidelines for self-consolidating concrete. European Federation of Suppliers of Specialist Construction Chemicals (EFNARC). Surrey, UK. 2002. <http://www.efnarc.org>.

[2] H. Okamura, M. Ouchi, Self-compacting concrete, J. Adv. Concr. Technol. 1 (1) (2003) 5–15.

[3] S.Z. Yuce, Y. Ercan, B. Yilmaz, T. Kivanc, F.H. Karadogan, Local thin jacketing for the retrofitting of reinforced concrete columns, Struct. Eng. Mech. 27 (5) (2007) 589–607.

[4] L. Sarno, A.S. Di, D.A. Elnahai, Seismic retrofitting of framed structures with stainless steel, J. Constr. Steel Res. 62 (2006) 93–104.

[5] J.M. Adam, Structural behavior of RC columns strengthened by steel jacketing, Research report, Code 1940/66, Technical University of Valencia, 2007.

[6] D.A. Bournas, T.C. Triantafillou, Flexural strengthening of reinforced concrete columns with near-surface-mounted FRP or stainless steel, ACI Struct. J. 106 (4) (2009) 495–505.

[7] S.K. Bhattacharyya, A. Deb, R. Dandapat, Localised failure in fibre-reinforcedpolymer

TRM jackets, in: 4th Colloquium on Textile Reinforced Structures (CTRS4), 2008

wrapped cylindrical concrete columns, J. ACI, Struct. Eng. 109 (4) (2012) 445–456.

[8] I. Bazaa, M. Missihoun, P. Labossieve, Strengthening of reinforced concrete beams with CFRP sheets, in: Proceedings of the 1st International Conference on Composites in Infrastructures (ICC'96): Fibre Composites in Infrastructure, Tucson, Arizona, USA, 1996, pp. 746–759.

[9] C.E. Chalioris, Torsional strengthening of rectangular and flanged beams using carbon fibre-reinforced-polymers—experimental study, Constr. Build. Mater. 22 (1) (2008) 21–29.

[10] A.B.M.A. Kaish, M.R. Alam, M. Jamil, M.F.M. Zain, M.A. Wahed, Improved ferrocement jacketing for re-strengthening of square RC short column, Constr. Build. Mater. 36 (2012) 228–237.

[11] T.C. Triantfillou, Innovative textile-based composites for strengthening and seismic retrofitting of concrete and masonry structures, in: Proceedings of the 5th International Conference on FRP Composites in Civil Engineering
(CICE'10), Beijing, China, 2010.

[12] D. Bournas, T. Triantafillou, C. Papanicolau, Retrofit of seismically deficient RC columns with