# Behaviour of Reinforced and Unreinforced Circular Concrete Columns Retrofitted By Microconcrete & CFRP Confinement

Vikram Jadhav[1], Dr. Rosalin Sahoo[2]

[1] *Research Scholar, Structural Engineering Dept. Sardar Patel College of Engg. Andheri (W) Mumbai*

[2] *Asst. Professor Structural Engineering Dept. Sardar Patel College of Engg. Andheri (W) Mumbai*

***Abstract*: Micro concrete and different types of fibre reinforced composite materials are becoming most frequently used in civil engineering structures. Strengthening of reinforced concrete columns by means of confinement with fibre reinforced composite materials and micro concrete is one of the most practical applications of these materials. In this paper comparative study of behaviour of reinforced and unreinforced circular concrete columns retrofitted by micro concrete and CFRP confinement is studied. The test result shows the increase in load carrying capacity and enhanced deformation of specimens confined with CFRP and micro concrete as compared to integral circular specimens without wrapping.**

***Keywords*: Circular columns, retrofitting, micro concrete, CFRP confinement**

## I. INTRODUCTION

Retrofitting is the process of strengthening or modifying something after it has been built or manufactured. From many years engineers have used different materials and techniques to retrofit existing structures. However it is necessary to employ innovative materials which can provide quick and reliable solutions to the deteriorating civil infrastructures. According to recent advances in composite materials technology, fibre reinforced polymers (FRP) have gained much importance in civil engineering field to repair and retrofit existing infrastructures or to design new. There are different methods of retrofitting such as, Grouting, jacketing, bracing, beam addition method, repaving method, addition of isolators and dampers, FRP sheet wrapping etc. Out of which in this work we have used retrofitting by micro concrete and CFRP wrapping.

Micro concrete is cementitious dry ready mix composition prepared for use in repairs of areas where the concrete is damaged and the area is restricted in movement making the placement of conventional concrete difficult. It is supplied as a ready to use dry powder which requires only addition of clean water at the site to produce free-flowing non-shrink repair micro concrete.

Fig. Micro concrete

FRP is basically composite material made of polymer matrix reinforced with fibres of glass, carbon or aramid while polymer is usually epoxy, vinyl ester or polyester thermosetting plastic. FRPs are commonly used in aerospace, marine,, automotive and construction industry.

Fig. FRP Reinforcing Elements

Micro concrete and FRP have advantages such as high strength and load carrying capacity, resistance to seismic forces and deflection, flexible etc.

## II. EXPERIMENTAL INVESTIGATION

### *2.1 Material Specification*

#### *2.1.1 Cement*

| | |
|---|---|
| Specific gravity | 3.1 |
| Initial setting time | 70 minutes |
| Final setting time | 430 minutes |
| Compressive strength | 56.11 $N/mm^2$ |

*2.1.2 Coarse Aggregate*

| | |
|---|---|
| Specific gravity | 2.7 |
| Fineness modulus | 2.12 |

*2.1.3 Fine Aggregate*

| | |
|---|---|
| Specific gravity | 2.62 |
| Zone | II |
| Fineness modulus | 3.52 |

*2.1.4 Microconcrete*

| | |
|---|---|
| Water/powder ratio | 0.15 |
| Fresh wet density | 2300-2400 kg/m$^3$ |
| Compressive strength | 75 MPa at 28 days |
| Flexural Strength | 8 MPa at 28 days |
| Modulus of elasticity | 25 N/mm$^2$ |

*2.1.5 Carbon Fibre Reinforced Polymer*

| | |
|---|---|
| Fibre orientation | Bidirectional |
| Modulus of elasticity | 285 KN/mm$^2$ |
| Tensile strength | 3500 N/mm$^2$ |
| Total weight of sheet | 230 g/m$^2$ |
| Thickness | 0.30 mm |

## III. EXPERIMENTAL PROGRAMME

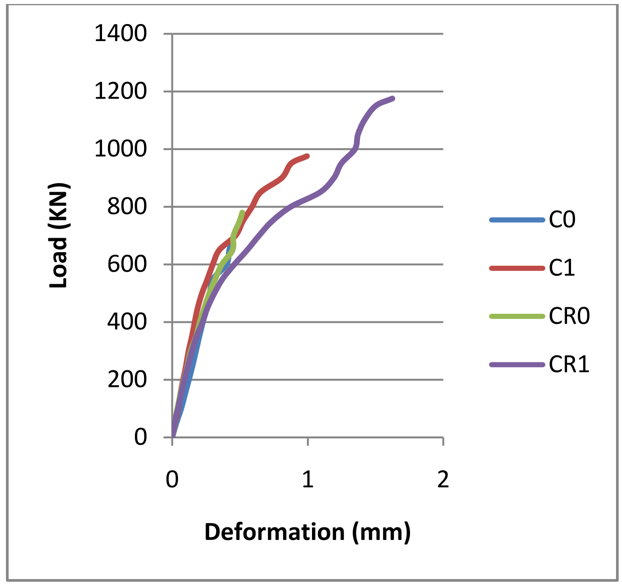
Circular concrete specimens, unreinforced and reinforced each 3 specimens are prepared for the investigation. M30 grade concrete and Fe 415 grade steel are utilised forpreparation of test specimens. Unreinforced and reinforced SMC specimens consist of unwrapped SMC specimen (M0 & MR0) and SMC specimen wrapped with one layer of CFRP (M1 & MR1). Unreinforced and reinforced integral circular specimens consistof unwrapped integral circular specimens (C0 & CR0) and integral circular specimen wrapped with one layer of CFRP (C1 & CR1). The behaviour under axial compression of all SMC specimens (300 mm height) is compared with integral circular specimens of the same dimensions.

## IV. RESULTS AND DISCUSSION

The results covering the following comparisons are presented in tables and graphs given below.

*4.1 Effect of Confinement on Integral Circular Specimens*

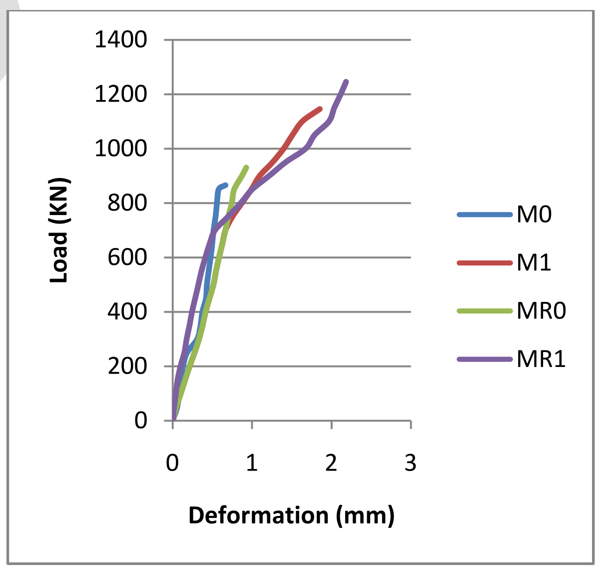
Due to confinement the load carrying capacity and deformation of plain integral specimen is increased to 1.46 and 2.27 times and of reinforced specimens to 1.51 and 3.1 times as compared to unconfined plain and reinforced specimens respectively.




Graph 1. Load Deformation Behaviour of Different Integral Specimens

*4.2 Effect of Confinement on SMC Specimens*

Due to confinement the load carrying capacity and deformation of plain SMC specimen is increased to 1.32 and 2.78 times and same of reinforced SMC specimen is increased to 1.34 and 2.36 times as compared to unconfined plain and reinforced SMC specimen respectively.

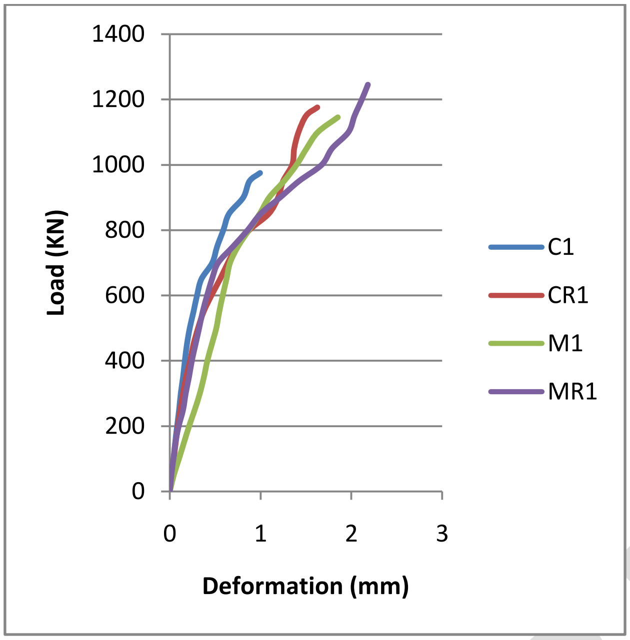



Graph 2. Load Deformation Behaviour of Different SMC Specimens

*4.3 Behaviour of Confined SMC and Integral Circular Column Specimens*

Due to confinement load carrying capacity and deformation of confined plain SMC specimens is increased to

1.18 and 1.86 times and of reinforced SMC specimens is increased to 1.05 and 1.34 times as compared to plain and reinforced integral circular specimens respectively.



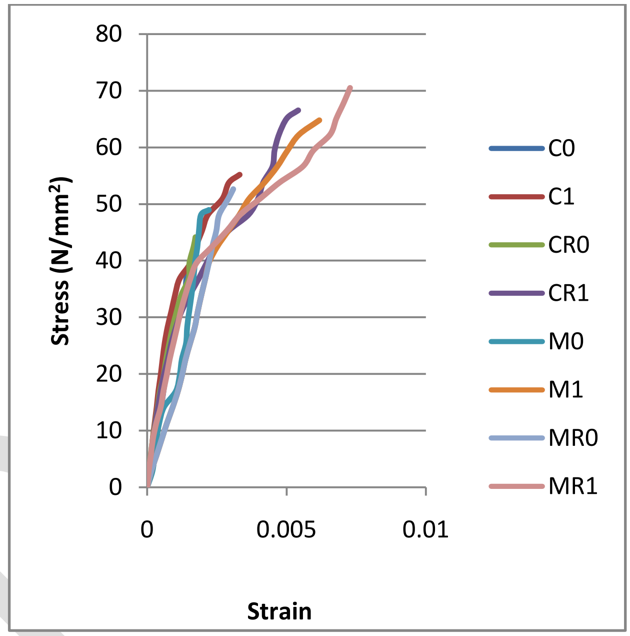

Graph 3. Load Deformation Behaviour of Different Confined specimens

*4.4 Comparative Behaviour of Different Column Specimens Tested*

The following table shows the comparative behaviour of different categories of specimens plain and reinforced retrofitted with micro concrete and CFRP confinement.

**Table 1. Comparative Behaviour of Different Column Specimens Tested**

| Sr. No. | Designation | Ult. Stress | Ult. Strain | Increase in Stress in terms of C0 & CR0 | Increase in Strain in terms of C0 & CR0 |
|---|---|---|---|---|---|
| Unreinforced | | | | | |
| 1 | C0 | 37.91 | 0.001462 | 1.00 | 1.00 |
| 2 | C1 | 55.17 | 0.003315 | 1.46 | 2.27 |
| 3 | M0 | 48.95 | 0.002217 | 1.29 | 1.52 |
| 4 | M1 | 64.79 | 0.006173 | 1.71 | 4.22 |
| Reinforced | | | | | |
| 1 | CR0 | 44.14 | 0.001729 | 1.00 | 1.00 |
| 2 | CR1 | 66.49 | 0.005416 | 1.51 | 3.13 |
| 3 | MR0 | 52.63 | 0.003087 | 1.19 | 1.79 |
| 4 | MR1 | 70.45 | 0.007277 | 1.60 | 4.21 |




Graph 4. Stress Strain Behaviour of Different Column Specimens Tested

From the above table and graph 4 it is seen that the ultimate load carried by the plain Integral Column is 670 KN with the ultimate compressive stress of 37.91MPa and ultimate deformation is 0.4386 mm with an ultimate strain of 0.001462. On confining of single layer of CFRP i.e. for specimen C1, ultimate load and ultimate deformation get enhanced by 1.46 and 2.27 times that of C0. Specimen M1 resists the higher ultimate compressive stress of 1.71 times and strain capacity of 4.22 times that of C0.

The compressive stress of all specimens varied between 37.91 MPa to 70.45 MPa and ultimate strain varied between 0.001462 to 0.007277.

## V. CONCLUSION

48 circular column specimens consisting of 24 square micro-concreted to circular (SMC) specimens and 24 Integral circular specimens were tested up to failure for axial compressive loading. The SMC specimens consist of unconfined reinforced (MR0) and confined reinforced specimens (MR1) and unconfined unreinforced (M0) and confined unreinforced specimens (M1). Similarly, the Integral circular reinforced specimens consist of unconfined reinforced (CR0) and confined reinforced specimens (CR1) and

unconfined unreinforced (C0) and confined unreinforced specimens (C1).

Based on experimental investigation carried out, the following conclusions are made:

1. Retrofitting by CFRP confinement results in enhancing the ultimate load carrying capacity and ultimate deformation of circular column specimens of both Plain and Reinforced, Integral and SMC column specimens.
2. In the case of plain concrete specimens, CFRP confinement of one layer increases the ultimate load by 1.46 times than Integral specimen and 1.71 times in SMC specimen and similarly, ultimate deformation by 2.27 times in Integral specimen and 4.22 times in SMC specimen.
3. In the case of reinforced concrete specimens, CFRP confinement of 1-layer produced enhancements of ultimate load and ultimate deformation of 1.51 times and 3.13 times in case of Integral specimens whereas similar enhancements in the case of SMC specimen were 1.6 times and 4.21 times in comparison to unconfined integral specimens.
4. In the case of reinforced concrete specimens, CFRP confinement of 1-layer produced enhancements of ultimate load and ultimate deformation of 1.51 times and 3.13 times in case of Integral specimens whereas similar enhancements in the case of SMC specimen were 1.6 times and 4.21 times in comparison to unconfined integral specimens.
5. Between the Integral specimens and SMC specimens, both in the case of reinforced and unreinforced specimens, SMC specimens exhibit slightly better performance in terms of ultimate load and ultimate deformation.
6. All unconfined specimens developed vertical cracks leading to the crushing of concrete at ends of specimens in Integral specimens and debonding at the concrete- micro concrete interface in SMC specimens followed by some concrete crushing. Failure was delayed in RC specimens.
7. The failure in CFRP-confined specimens was characterised by bulging of concrete prior to shipping and rupture of CFRP sheetsand rupture covering over 60% of the height of columns. The crushing of concrete in case of Integral specimens and spalling of concrete in SMC specimens also took place. Not much difference between unreinforced and reinforced specimens occurs.

## REFERENCES

[1]. Rajeev Kaul, R. Sri Ravindrarajah, Scott T. Smith (2006) – “Deformational Behaviour Of FRP Confined Concrete Under Sustained Compression”, Third International Conference on FRP composites in Civil Engineering, 1-4.
[2]. Rahai A.R, Sadeghian P and Ehsani M.R (2008) – “Experimental Behaviour of Concrete Cylinders Confined with CFRP Composites”, The 14th World Conference on Earthquake Engineering, 1-9.
[3]. Riad Benzaid, Nasr-Eddine Chikh and Habib Mesbah (2009) – “Study of the Compressive Behaviour of Short Concrete Columns Confined By Fibre Reinforced Composite”, The Arabian Journal for Science and Engineering, Volume 34, Number 1B, 1-12.
[4]. Ciprian Cozmanciuc, Ruxandra Oltean and Vlad Muntean (2009) – “Strengthening Techniques of RC Columns Using Fibre Reinforced Polymer Materials”, Bul. Inst. Polit. Iaşi, t. LV (LIX), f. 3, 1-8.
[5]. Claudio Modena (2010) – “Repair and Strengthening Interventions on Vertical and Horizontal Elements”, Engineer’s Seminar - Historic Buildings and Earthquake, 11-12
[6]. N. Chikh, M. Gahmous, R. Benzaid (2012) – “Structural Performance of High Strength Concrete Columns Confined with CFRP Sheets”, Proceedings of the World Congress on Engineering, Vol III, 1-6.
[7]. K.P. Jaya, Jessy Mathai (2012) – “Strengthening of RC Columns using GFRP and CFRP”, 15 WCEE LISBOA, 1-10.
[8]. Pham, Minh T, Doan, V. and HadiM. N. (2013) - “Strengthening square reinforced concrete columns by circularization and FRP confinement”, Research Online - Construction and Building Materials, 490-499.
[9]. Mohammad M. Zaki M. Afifi (2013) – “Behaviour of Circular Concrete Columns Reinforced with FRP Bars and Stirrups”, A dissertation submitted for Doctor of Philosophy, University of Sherbrooke, Canada, 1-261.
[10]. Manish Kumar Tiwari, Rajiv Chandak, R.K. Yadav (2014) – “Strengthening of reinforced concrete circular columns using glass fibre reinforced polymers”, Int. Journal of Engineering Research and Applications, ISSN: 2248-9622, Vol. 4, Issue 4 (Version 4), pp.50-54.
[11]. Azadeh Parvin and David Brighton (2014) – “FRP Composites Strengthening of Concrete Columns under Various Loading Conditions”, Polymers, Volume - 6, 1040-1056.
[12]. J. Raja Murugadoss, Byung-Jae Lee, Jin Wook Bang, G. Ganesh Prabhu and Yun Yong Kim (2015) – “Performance Analysis of CFRP Composite Strips Confined RC Columns under Axial Compression”, Hindawi Publishing Corporation Advances in Materials Science and Engineering, Article ID 170295, 1-18.
[13]. Sameh Yehia (2015) – “Behavior of Low Compressive Strength Short Columns Strengthened With External GFRP Strips/Jacket Techniques”, International Journal of Technology Enhancements and Emerging Engineering Research, Vol. 3, Issue 04 1 ISSN 2347-4289.