

Stress Strain Behavior of SCC Columns Confined With Basalt Fiber Reinforced Polymer Sheets

S.Kirthika¹, N.Saravana Kumar²

PG Scholar, Department of Civil, Mepco Schlenk Engineering College, Autonomous, Tamilnadu, India¹

Assistant Professor, Department of Civil, Mepco Schlenk Engineering College, Autonomous, Tamilnadu, India²

ABSTRACT: Self-compacting concrete (SCC) is highly flowable, non-segregation concrete that spreads into place, easily fills formwork, without any mechanical vibration. To obtain the Self Compacting Concrete, Super plasticizer and viscosity modifying agent (VMA) were mixed to conventional concrete. Steel is highly corrosive, so it requires costly repair. Fiber Reinforced Polymers (FRP) act as an additional support for steel reinforcement. This paper involves study of reinforced concrete columns with SCC, externally wrapped with Basalt Fiber Reinforced Polymer Sheets. The fresh concrete test like U-box, V-funnel, L-box test and Slump Test were conducted. Five columns and five cylinders were cast. The specimens were externally wrapped with Basalt Sheet by wet layup process using epoxy resin. Those specimens have 10mm diameter bars as main reinforcement and 8mm diameter as transverse reinforcement. A control specimen were cast without wrapping sheets. For the remaining specimens, the wrapping were done in one, two, three layers, with a gap of 5mm at each ends and with an overlap of 150mm on the rolling side. Specimens were tested under concentric axial compressive force, in Universal Testing Machine. The effect of yield strength, ductility, and energy absorption capacity were studied from stress-strain and load displacement curves. Higher values of strength were obtained for wrapped specimens. The one and two layers increased the strength by 11% and 20% respectively. However, the additional third layer increased the strength only to a lesser amount. This is due to reason that, the third layer acts as a brittle layer.

KEYWORDS: Basalt Sheet, Epoxy Resin.

I. INTRODUCTION

Japanese first developed Self-Compacting Concrete in 1980's. It is highly workable, that can flow under its own weight, even under congested reinforcement without bleeding and segregation. Low Yield value is required to get high flow ability and a moderate viscosity to resist segregation and bleeding, homogeneity is needed during transportation. Though it is flowable, it has adequate structural performance and durability. The fresh concrete properties are passing ability, resistance against segregation and filling ability. Since there is no mechanical vibration, the cost of labors are saved.

To enhance the axial capacity of concrete columns, fiber reinforced polymer (FRP) are used extensively in many countries. In this method, along the exterior surface FRP was wrapped around columns. Along the hoop direction, fibers were installed. This confines the concrete and increases the compressive strength. This increased concrete strength, known as the confined compressive strength. This confined compressive strength starts only after the concrete in the column has begun to dilate and cracked (ACI 440 2008). The FRP prevents the cracked concrete from splitting out laterally. This is due to the reason that FRP confines the concrete and allows to carry additional compressive strength. In this paper, basalt fiber sheets were used to confine the concrete core.

The uniaxial compressive load applied to the specimens. The both column and cylinder is short column. The slenderness ratio falls below 12. Since it is short column, it is buckling failure. The sheets delays the failure.

A. Basalt Fibers

Basalt is a hard, dense natural, dark brown to black volcanic igneous rock, originated from the depth of hundred kilometers beneath the earth. The result is the surface magma. It is formed from solidification of molten lava. It is grey, dark in color. The production process of basalt fibers include melt preparation, extrusion, fiber formation, application of lubricates and at last winding. This method is also known as spinning. The Fiber is a material made into long filament with a density of order 300g/m² of 50cm.

The basalt fiber is a cloth, arranged in a rectangular pattern that are cross-linked by means of organic additives. The organic additives are mostly thermo reactive resins. The basalt cloth is a porous material. It allows impregnation. It exhibits properties like chemical stability, sealing, Anticorrosion and fireproof properties. It is used as an insulating material in automotive industries, civil engineering etc., and the basalt cloth can also be used as a reinforcing material, as stabilizing or separating layers, as a material for surface finish, or for sound insulation. The function of the fibers is to carry load and provide stiffness, strength, thermal stability and other structural properties.

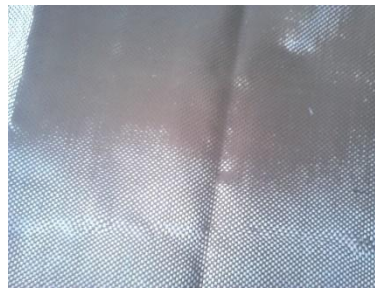


Fig 1. Basalt Sheet

II. LITERATURE REVIEW

Each paper provides the ideas for increasing the strength of the member. The compressive strength and axial strain increases as the number of layers are increased [1]. The maximum gain in axial strain is 12.7 times unconfined peak strain [1]. In other paper, the beams were strengthened by fiber after damaging the beams to 0%, 70%, 80%, 90% and 100%. 0%, 70%, 80% degree damaged beams showed higher performance in terms of load carrying capacity. 90% and 100% damaged beams did not show appreciable increase in load carrying capacity [2]. In self-compacting concrete, the T-beams were strengthened with CFRP sheets. The addition of nylon fibers show minor effect on the improvement of compressive and tensile strength. Addition of steel fibers show additional effect. CFRP sheets increased ultimate load to 33% [3]. The beams that are weak in flexure were strengthened by U-wrapping to cover three faces of beam. Strength increased to 20% comparing with the control specimen. I, II layers of basalt sheets increased compressive, tension and flexural strength when compared to III layer. The III layer acted as brittle layer [4].

A. Properties of Materials

1) Cement

The cement used is commercially available 53 Grade Ordinary Portland Cement (OPC) Cement conforming to IS 12269:2013. The Specific Gravity of Cement was found to be 3.14.

2) Silica Fume

Addition of silica fume to concrete improves the durability of concrete through reduction in the permeability, refined pore structure, leading to a reduction in the diffusion of harmful ions, reduces calcium hydroxide content. The specific gravity of silica fume is 2.1.

3) Superplasticizer

The superplasticizer used here in conplast SP430. It has high degree of workability. It is extensively used in self-compacting concrete that requires less compaction. Conplast satisfies ASTM C 494-80 as Type G retarding, High Range Water Reducing Admixture. The specific gravity is 1.26 at 30C. The optimum dosage range from 0.35 to 0.9 liters/100kg of cement for normal mixes and 0.5 to 1 liter/100kg for high cement content mixes.

4) Viscosity Modifying Agent

The VMA used is Master Glenium Stream 2. Concrete containing Master Matrix 2 admixture exhibits superior stability and controlled bleeding characteristics, thus increasing resistance to segregation and facilitating placement. Relative Density is 1.01 ± 0.01 at 25°C and $pH \geq 6$. specifications are as per EFNARC-VMA Guidelines 2006. The dosage is 0.05 to 0.5% of powder as per as per Modified Nan-Su Method.

5) Epoxy Resin

Epoxy is a common name for a type of strong adhesive used for sticking things together and covering surfaces, typically two resins that need to be mixed together before use. Epoxy resin and hardener were mixed in 2:1 proportion to form adhesive material, which is applied over concrete surface. Basalt sheet is stuck using the resin.



Fig 2. VMA and Epoxy Resin & Hardener

B. Mix Proportion

The Modified Nan-Su Method was used for mix design. {JagadishVengala, R.V. Ranganath, “Mixture proportioning procedures for self-compacting concrete” (2004), The Indian concrete journal}.

Tab I. Mix Proportion for M40 Grade, One Cubic Meter

C (kg)	FA (kg)	CA (kg)	SF (kg)	W (Liter)
394.28	855.79	712.52	142.12	190

C. Fresh Properties of SCC

The fresh concrete test for self-compacting concrete are L Box Test, V Funnel Test, U Box Test, Slump Flow Test.

1) L Box Test

After moistening the apparatus, 14-liter concrete was poured inside the L Box apparatus. Leave it stand for 1 minute. Lift the sliding gate and allow the concrete to flow out into the horizontal section. Start the stopwatch and record the time, for the concrete flowing from H1 to H2. Calculate H2/H1, the blocking ratio. The whole experiment should be performed within 5 minutes. The ratio of height difference was (H2/H1) 0.92. The allowable Range is 0.8-1.

2) U Box Test

About 20 liter of concrete was poured in the moistened apparatus. Leave it to stand for 1 minute. Lift the sliding gate and allow the concrete to flow out into the other compartment. Measure the height difference in the compartment (H1 & H2). Whole test was performed in 5 minutes. The height difference (H1-H2) in the U-box test was 10mm. The allowable Range is maximum of 0-30mm.

International Journal of Innovative Research in Science, Engineering and Technology

An ISO 3297: 2007 Certified Organization

Volume 4, Special Issue 5, April 2015

International Conference On Emerging Trends in Engineering and Technology (ICETET'15)

On 13th & 14th March 2015

Organized by

Pandian Saraswathi Yadav Engineering College, Arasanoor, Sivagangai, Tamilnadu, India

3) V Funnel Test

The trap door is closed and 12-liter concrete was filled inside the apparatus. The trap door was opened within 10 seconds after filling. Time taken for complete discharge was measured. The flow time in the V-funnel was 10 seconds. The permissible Range is 10-12seconds.

4) Slump Test

The slump cone was placed above the base plate. Concrete was filled in the slump. The slump cone is raised above vertically, without disturbing the fresh concrete. Concrete was allowed to flow freely. The diameter of spread was measured. The workability from the slump flow was 660mm. This value is in accordance with EFNARC specifications.

D. Testing of Cube and Cylinder

After casting the cubes and cylinders of M40 grade, they were tested for compressive strength.

Tab II. Mix Proportion for M40 Grade, One Cubic Meter

Specimen	Cube	Cylinder
Compressive strength (N/mm ²)	42.59	43.51



Fig 3. Testing of Cube and Cylinder

E. Specimen Detailing

The reinforcement for the column was 4.nos of 10mm dia bars as main reinforcement and 8mm bars as transverse reinforcement at spacing 130mm C/C. and for cylinder 4.nos of 10mm diameter bars as main reinforcement and 8mm bars as transverse reinforcement at spacing 100mm C/C.



Fig 4. Specimen Detailing

F. Procedure to bond BFRP

After casting the specimen, it was allowed to cure for 21 days. Then it was allowed for surface dry for a day. Using epoxy resin and hardener, the sheets were wrapped around the specimen. The ratio of epoxy and hardener is 2:1. After mixing it, it was applied around the tried surface of concrete specimen. For 7 days, drying was allowed.

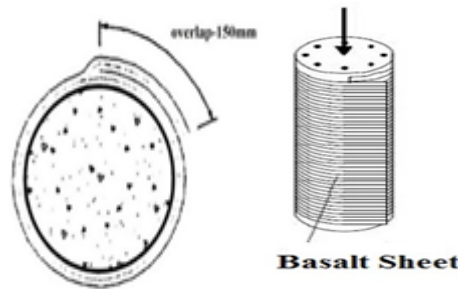


Fig 5. Wrapping of Sheets Fig 6. Testing of specimen

G. Testing of Specimen

The specimens are tested in the Universal Testing Machine, of capacity 1000kN. For each specimen, the peak load and graphs are obtained, and comparison is made. The specimens were subjected to concentric axial loading.



Fig 7. Specimens

III. RESULTS AND DISCUSSIONS

A Effect of Confinement

The main advantages of providing additional confinement are to increase the concrete ductility and strength. In earthquake regions, buildings require higher ductility. This would reduce the damages to the structures. Here, additional confinement was done externally. As a result, it helps the structure to sustain larger deformations. In addition, the confinement increase compressive strength; in turn, it compensates strength and loss from spalling of concrete cover.

From the results, increasing the layer of basalt cloth around the concrete specimen increases the ultimate load bearing capacity. The strain was reduced, since the ductility was increased using the externally wrapped sheets. As per the result obtained, the strength increased when the layer of basalt sheet wrapped around the specimen. The one and two layers increased the strength by 11% and 20% respectively. However, the additional third layer increased the strength only to a lesser amount. This is due to reason that, the third layer acts as a brittle layer.

B. Stress Strain Curve

In order to study the behavior of concrete, one of the major step is to establish appropriate analytic stress-strain models that could capture the real (observable) behavior. The better stress-strain model results in reliable estimation of strength and deformation behavior of the structural members. In order to study the comparison, both confined and unconfined

concrete behavior was studied. The confined concrete produces better ductility when compared to unconfined concrete. Thus, the stress strain curve for both reinforced concrete, without wrapping and with wrapping were obtained.

The below result shows the stress strain curve for columns with no wrapping, single, double, and triple layers of basalt sheets.

Tab 3. Results For Column And Cylinder

Specimen	Ultimate Load (kN)	Ultimate Compressive Strength (N/mm ²)	Ultimate Strain (x10 ⁻³)
CY Control	699.613	38.59	1.28
CY 1 Layer	717.107	40.58	1.245
CY 2 Layer	775.968	43.91	1.292
CY 3 Layer	841.691	45.63	1.6278
CO Layer	520.708	39.23	1.046
CO 1 Layer	542.742	40.89	0.0839
CO 2 Layer	563.05	42.42	0.0851
CO 3 Layer	573.27	45.99	0.0913

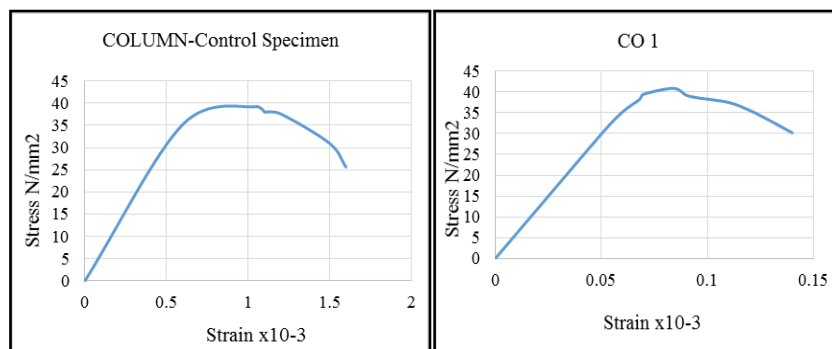


Figure 8. Stress Strain Curve for Control Specimen. Figure 9. Stress Strain Curve for CO 1 (Single Layer wrapped over column)

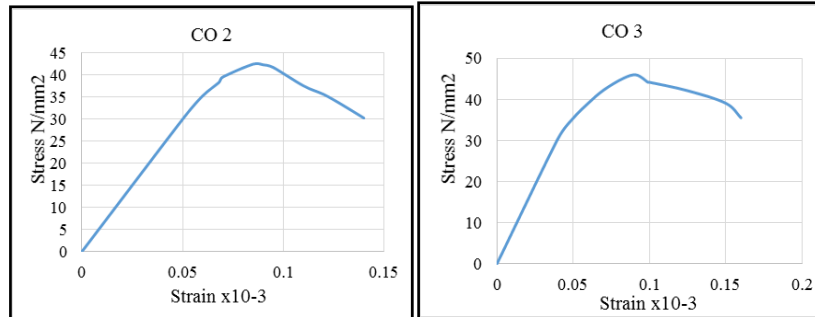


Figure 10. Stress Strain Curve for CO 2 (Double Layer wrapped over column) Figure 11. Stress Strain curve for CO 3 (Triple Layer wrapped over column)

As the load increased beyond the ultimate load of the control specimen, the wrapped specimens carried more load comparing to others. When the load is applied, cracks start developing. The steel reinforcement resist these. In this case, additionally the cracks are resisted by increasing confinement effect of basalt sheet. Which increases the ductility and strength of concrete.

IV. CONCLUSION

From the experimental investigation, the following conclusions were made: The use of basalt sheets as external shear reinforcement for the columns efficiently delayed the debonding failure and in addition reduced the brittle failure. The specimens showed a good ductile behavior, with maximum gain in axial strain. The confinement of columns with BFRP wrap increased the strength and ductility of concrete column. Basalt fibers offers only moderate strength increase, but leads to uneconomic design and durability. Applying double layer of BFRP is more effective. BFRP confinement in the lateral direction leads to increment of ultimate load and ductility.

ACKNOWLEDGEMENT

The authors acknowledge the contributions of the students, faculty of MepcoSchlenk Engineering College, for helping in the design of test circuitry, and for tool support. The authors also thank the anonymous reviewers for their thoughtful comments that helped to improve this paper. The authors would like to thank the anonymous reviewers for their constructive critique from which this paper greatly benefited.

REFERENCES

- [1] Eythor Thorhallsson, (M.Sc., Associated Professor). Arngrimur Konradsson, (M.Sc., student). Stefan Kubens (Ph.D., Research Scientist). "Concrete Cylinders Confined With Basalt Fibre Reinforced Polymer" Reykjavik University, Menntavegi 1, Reykjavik, Iceland.
- [2] Akshay P. Gholkar, H. S. Jadhav (2014) "Experimental Study Of The Flexural Behavior Of Damaged Rc Beams Strengthened In Bending Moment Region With Basalt Fiber Reinforced Polymer (Bfrp) Sheets" Int. Journal of Engineering Research and Applications ISSN : 2248-9622, Vol. 4, Issue 7 (Version 1), July 2014, pp.142-145E. Belding-Royer and S. D. C. Perkins, "Ad hoc on-demand distance vector (AODV) routing," July 2003.
- [3] Arjan Fakhraldin Abdullah, Mazin Burhan Adeen, Alya'a Abbas Al-Attar (2014) "Studying Flexural Behavior Of Reinforced Fibrous Self-Compacted Concrete T-Beams Strengthened With CFRP Sheets" International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075, Volume-3, Issue-8, January, 2014. Elissa, "Title of paper if known," unpublished.
- [4] R. Singaravavelan, N. Sakthieswaren and Dr. K. L. Muthuramu (2012) "Experimental Investigation On The Behaviour Of Flexural Strengthening Of Beam Using Basalt Fiber" International Conference on Automotive, Mechanical and Materials Engineering (ICAMME/2012) Penang (Malaysia) May 19-20, 2012
- [5] P. Sangeetha, R. Sumathi (2010) "Behaviour Of Glass Fiber Wrapped Concrete Columns Under Uniaxial Compression" International Journal of Advanced Engineering Technology IJAET/Vol. 1/ Issue 1/April-June, 2010/74-83.
- [6] A. Serbescu, M. Guadagnini & K. Pilakoutas, A. Palmieri & S. Matthys (2010) "Basalt FRPs For Strengthening Of RC Members" CICE 2010 - The 5th International Conference on FRP Composites in Civil Engineering September 27-29, 2010 Beijing, China.
- [7] EFNARC: Specification and guidelines for self-compacting concrete, February 2002. [8] M.S. Sheety, "Concrete Technology", 1 Edition, (2005) ISBN: 81-219-0003-4.R.