International Journal of Engineering Science Invention
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org Volume 2 Issue 8 ǁ August 2013 ǁ PP.01-05

Retrofitting of Concrete Specimens and Reinforced Concrete Piles Using Basalt Fibres

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ABSTRACT: *The purpose of this experimental investigation is to study the behaviour of cubes, cylinders, prisms and reinforced piles retrofitted with basalt fibres. Several researches have been done in retrofitting of concrete beams and columns, but no work have done in retrofitting of piles using basalt fibres. The concrete used in this investigation was proportioned to target a mean strength of 30 MPa. Specimens such as cubes, cylinders and prism beams were used for this work. The specimens were singly and doubly wrapped with basalt fibre (woven-type). The mechanical properties such as cube compressive strength, cylinder split tensile strength and prism flexural strength were determined on the conventional specimens (without wrapping), singly wrapped specimens and doubly wrapped specimens. The results show that the specimen with double wrapping of basalt fibre gives better performance when compared with conventional and single wrapped specimens. All the results were tabulated and graphically plotted.*

KEYWORDS*: Basalt fibres, Double wrapping, Piles, Retrofitting, single wrapping*

I. INTRODUCTION

A structure is designed for a specific period and depending on the nature of the structure, its design life varies. For a domestic building, this design life could be as low as twenty-five years, whereas for a public building, it could be fifty years. Deterioration in concrete structures is a major challenge faced by the infrastructure and bridge industries worldwide. The deterioration can be mainly due to environmental effects, which includes corrosion of steel, gradual loss of strength with ageing, repeated high intensity loading, variation in temperature, freeze-thaw cycles, contact with chemicals and saline water and exposure to ultra-violet radiations. As complete replacement or reconstruction of the structure will be cost effective, strengthening or retrofitting is an effective way to strengthen the same. In this experimental work Basalt fibre was used as a retrofitting material. Basalt fibre is a material made from extremely fine fibres of basalt, which is composed of the minerals plagioclase, pyroxene, and olivine. It is similar to carbon fibre and fibreglass, having better physicomechanical properties than fibreglass, but being significantly cheaper than carbon fibre. Although the fibres and resins used in FRP systems are relatively expensive compared to steel and concrete, the labor and equipment cost to install FRP systems is much lower and these systems can be utilized in areas with limited access and where traditional strengthening techniques are impractical.

II. MATERIALS USED

The materials usually used in the concrete mix are cement, fine aggregate, coarse aggregate. The materials used in this project for concrete mix are,

- **Binding Material**

The cement used in this experimental study is 43 grade Ordinary Portland Cement. All properties of cement are tested by referring IS 12269-1987 specification of 43 grade Ordinary Portland Cement. The properties of cement are given in table 1.

Table 1. Properties of Cement

Sl.No	Property	Value
1	Specific gravity	3.15
2	Fineness	97.8
3	Initial Setting Time	45 min
4	Final Setting Time	385 min
5	Standard Consistency	30%
6	Fineness Modulus	6%

➢ **Fine Aggregate**

Fine aggregates are the aggregates whose size is less than 4.75mm. Sand is generally considered to have a lower size limit of about 0.07mm. Material between 0.06 and 0.002mm is classified as silt, and still smaller particles are called clay. In this project, clean and dry river sand available locally is used.The properties of fine aggregate are given in table 2

Table 2 Properties of Fine aggregate

Solano	Property	Value
1	Specific Gravity	2.8
2	Fineness Modulus	3.1
3	Water Absorption	0.5%
4	Surface Texture	Smooth

➢ **Coarse Aggregate**

The aggregates most of which are retained on the 4.75mm IS sieve are termed as coarse aggregates. In this project coarse aggregates of maximum 20mm size is used.The properties of coarse aggregate are given in table 3

Table 3 Properties of Coarse Aggregate

Sl.No	Property	Value
1	Specific Gravity	2.8
2	Fineness Modulus	7.5
3	Water Absorption	0.5
4	Particle Shape	Angular
5	Impact Value	15.2
6	Crushing Value	18.6

➢ **Water**

Water used in this project is portable water

➢ **Basalt fibre**

Basalt fibre is a relative newcomer to fibre reinforced polymers (FRPs) and structural composites. It has a similar chemical composition as glass fibre but has better strength characteristics, and unlike most glass fibres is highly resistant to alkaline, acidic and salt attack making it a good candidate for concrete, bridge and shoreline structures.Compared to carbon and aramid fibre, it has the features of wider application temperature range -452° F to 1,200° F (-269° C to +650° C), higher oxidation resistance, higher radiation resistance, higher compression strength, and higher shear strength. (Note that application temperatures of FRPs are limited by the glass transition temperature of the matrix, which is lower than the application temperature of the fibres.).

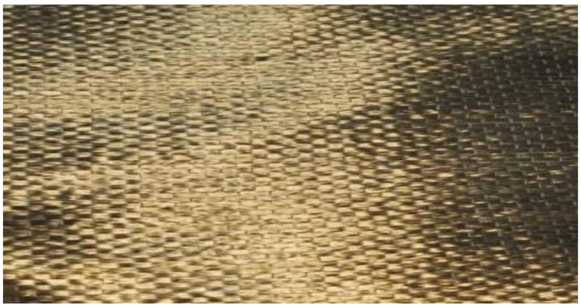

Fig 1. Basalt Fibre

III. EXPERIMENTAL TESTS

Mix design was done for M30 concrete as per the Indian standard code specifications (IS 10262-2007). Initial tests on all the ingredients of concrete was done and the results were tabulated.Fresh concrete tests such as slump cone test, flow table test etc., were also conducted.Testing of hardened concrete plays an important role in controlling and confirming the quality of cement concrete works.

- **Compressive strength test:**

Compressive test is the most common test conducted on hardened concrete, partly because it is an easy test to perform, the partly because most of the desirable characteristic properties of concrete are qualitatively related to its compressive strength.

The compressive test is carried out on specimens cubical in shape. The cube specimen is of the size 150 X 150 X 150 mm. The concrete is filled into the mould in layers approximately 5cm deep. The cubes are tested as per IS: 516-1979. The tests are done on an electro-hydraulically operated compression-testing machine and compressive load is applied on opposite faces axially, slowly at the rate of 800KN//minute. The compressive load is noted for the ultimate failure. 9 cubes were casted and tested to determine the compressive strength of conventional specimen (without wrapping) for 7, 14 and 28 days of curing (3 cubes each). Similarly 9 cubes were casted and tested to determine the compressive strength of singly wrapped specimen for 7, 14 and 28 days of curing (3 cubes each) and 9 cubes were casted and tested to determine the compressive strength of doubly wrapped specimen for 7, 14 and 28 days of curing (3 cubes each). Totally 27 cube specimens were casted and tested.

- **Split tensile strength test:**

Split tensile strength test is carried out on the 800KN capacity compressive testing machine. The 150mm diameter, 300mm length cylinders are used for this test according to IS516-1959. 9 cylinders were casted and tested to determine the split tensile strength of conventional specimen (without wrapping) for 7, 14 and 28 days of curing (3 cylinders each). Similarly 9 cylinders were casted and tested to determine the split tensile strength of singly wrapped specimen for 7, 14 and 28 days of curing (3 cylinders each) and 9 cylinders were casted and tested to determine the split tensile strength of doubly wrapped specimen for 7, 14 and 28 days of curing (3 cylinders each). Totally 27 cylinder specimens were casted and tested.

- **Flexural strength test:**

The flexural strength test is carried out on 400 TONNE capacity universal testing machine. The 100X100X500 mm prisms are used for this tests according to IS: 516-1959. 9 prism beams were casted and tested to determine the flexural strength of conventional specimen (without wrapping) for 7, 14 and 28 days of curing (3 prisms each). Similarly 9 prism beams were casted and tested to determine the flexural strength of singly wrapped specimen for 7, 14 and 28 days of curing (3 prisms each) and 9 prism beams were casted and tested to determine the flexural strength of doubly wrapped specimen for 7, 14 and 28 days of curing (3 prisms each). Totally 27 prism beam specimens were casted and tested.

Fig.2 Casted Specimens

Fig.3 Compressive strength testing

IV. RESULTS AND DISCUSSIONS

The compressive strengths results for the conventional (without wrapping), singly wrapped and doubly wrapped specimens are shown in table 1.

Table 1. Results of Average Compressive Strength

Duration	Average Compressive Strength in N/mm^2		
	Conventional	Single Wrapping	Double Wrapping
7th Day	25.02	31.77	37.11
14th Day	31.18	37.33	47.25
28th Day	35.7	42.31	53.77

From the above table it is found that the average compressive strength of conventional specimen, specimens with single wrapping and specimens with double wrapping at 28 days was 35.7 N/mm^2, 42.31 N/mm^2 and 53.77 N/mm^2 respectively. It is clear from the above results that the specimens with double wrapping of

Basalt fibres gives more strength than the single wrapped specimen and conventional specimens. The comparison of compressive strengths between the different specimens is graphically shown below.

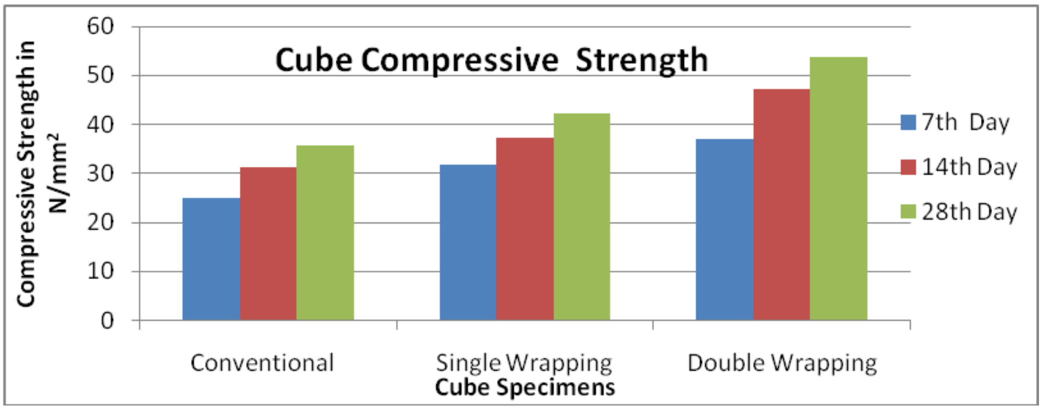

Fig 4. Comparison of Compressive strength

The split tensile strengths results for the conventional (without wrapping), singly wrapped and doubly wrapped specimens are shown in table 2.

Table 2. Results of Average Split Tensile Strength

Duration	Average Split Tensile Strength in N/mm^2		
	Conventional	Single Wrapping	Double Wrapping
7th Day	2.97	4.12	5.75
14th Day	3.6	5.99	7.68
28th Day	3.97	6.67	8.41

From the above table it is found that the average Split strength of conventional specimens, specimens with single wrapping and specimens with double wrapping at 28 days was 3.97 N/mm^2, 6.67 N/mm^2 and 8.41 N/mm^2 respectively. Hence it is evident from the above results that the specimens with double wrapping of Basalt fibres gives more strength than the single wrapped specimen and conventional specimens. The comparison of average split tensile strengths between the different specimens are graphically shown below.

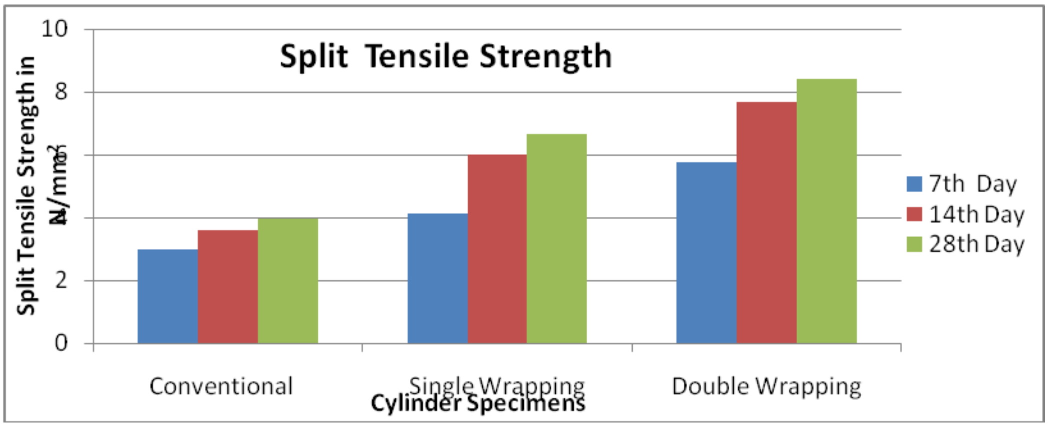

Fig 5. Comparison of Split Tensile strength

The flexural strengths results for the conventional (without wrapping), singly wrapped and doubly wrapped specimens are shown in table 3.

Table 3. Results of Average Flexural Strength

Duration	Average Flexural Strength in N/mm^2		
	Conventional	Single Wrapping	Double Wrapping
7th Day	2.2	3.25	5.28
14th Day	3.82	5.06	7.08
28th Day	5.4	7.24	9.09

From the above table it is found that the average flexural strength of conventional prism specimens, specimens with single wrapping and specimens with double wrapping at 28 days was 5.4 N/mm^2, 7.24 N/mm^2 and 9.09 N/mm^2 respectively. Hence it is evident from the above results that the specimens with double wrapping of Basalt fibres gives more strength than the single wrapped specimen and conventional specimens. The comparison of average flexural strengths between the different specimens are graphically shown below.

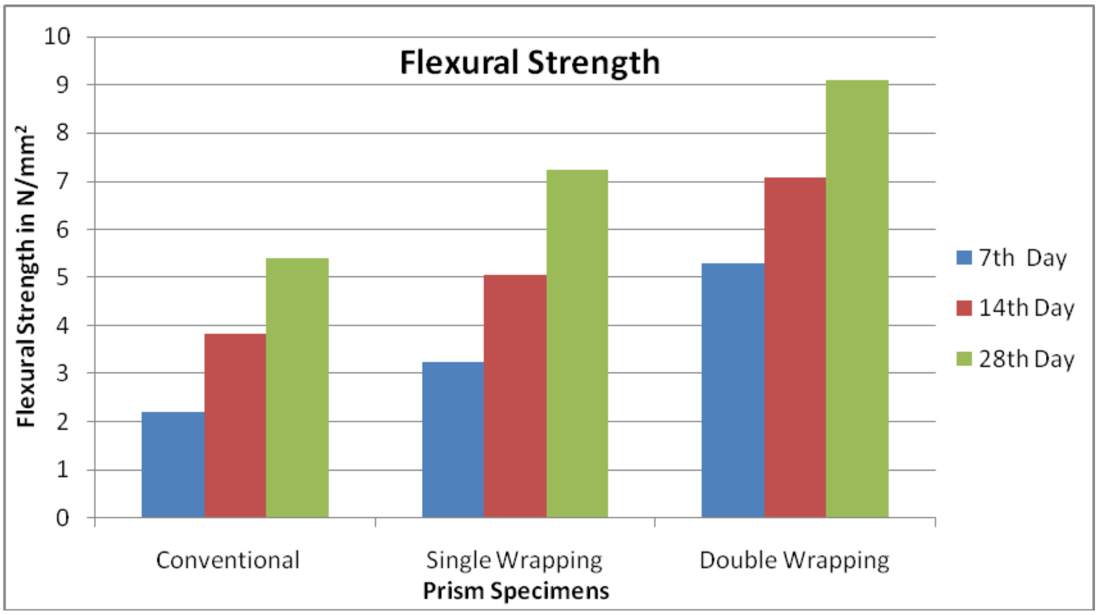

Fig 6. Comparison of Flexural strength

V. CONCLUSION

Based upon the results of experimental study carried out the following conclusions can be drawn:-

1) The compressive strength of specimens doubly wrapped with basalt fibres has shown an increase by about 25% over the compressive strength of conventional specimens.
2) The split tensile strength of specimens doubly wrapped with basalt fibres has shown an increase by about 100% over the split tensile strength of conventional specimens.
3) The flexural strength of specimens doubly wrapped with basalt fibres has shown an increase by about 68% over the flexural strength of conventional specimens.
4) Thus it can be concluded that Basalt fibre can be used as a retrofitting material for concrete specimens.
5) It is proposed to study the behavior of basalt fibre in reinforced concrete piles under lateral and impact loading.

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