Durability Study on Basalt Fibre Reinforced Polymer (BFRP) Composites Wrapped Specimens for Retrofitting of RCC piles

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***Abstract*—This paper shows the test result on durability of Basalt Fibre Reinforced Polymer (BFRP) composite wrapped specimens evaluated by using acid resistance test and temperature resistance test. The main aim of this study is to depict the durability of RCC end bearing piles retrofitted with BFRP. The specimens were wrapped with basalt unidirectional fabric warp along with the circumference or hoop tension direction. 36 nos. of cube specimens were cast with and without BFRP wrapping to observe the fluctuation in compressive strength during acid and fire resistance tests. The acid resistance tests were carried out on specimens by using diluted hydrochloric acid solution. The acid immersed specimens were tested for determination of compressive strength after curing for 7 days, 30 days and 70 days. Similarly, the fire resistance tests were carried out by using hot air oven at 200°C for 1, 2 and 3 hours intervals. The comparison of the results between control specimens and BFRP wrapped specimens were made to evaluate the difference in compressive strength**

Keywords*— Pile, Acid resistance, Fire resistance, Compressive strength, Basalt Fibre

I. Introduction

Generally, concrete is a durable material widely used in construction. Its durability is governed by concrete mix design, environmental conditions, age of building, chemical attack, atmospheric weather, carbonation, sub soil water table, sub soil condition, permeability, quality of materials & works, shape and size of members, cover thickness, cement contents, water cement ratio, chloride content, alkali-silica reaction, finishing and initial curing of water properties, etc. The strength of concrete has a direct relation with its durability. Hence, the concrete should possess the ability to resist weathering action, chemical attacks, abrasion, deterioration, etc. Durable concrete retains its the original form, quality and serviceability even when exposed to aggressive environments. Over recent years, concrete durability researches are being conducted by technologists for saving the structures from cited cause and for maintaining the sustainability of the globe. Durability can be extended by using suitable methods of maintenance, repairing, rehabilitations and retrofitting or strengthening. Among the various methods of retrofitting, the FRP wrapping is one of the best methods. FRP supports in increasing the durability of concrete by reducing the permeability, resisting high temperature, resisting chemical attack, withstanding the fatigue action, sealing of micro pores, providing additional strength to the elements, etc. In this experiment, the basalt unidirectional fabric was used along the hoop direction that is along the perimeter. Durability experimental tests were tested in concrete cube specimens in addition to retrofitting of RCC piles by using basalt fibre. Various experiments are used for measuring the durability performance previously against the RCC pile retrofitting works. Even now, the experiment tests were done for axial load, lateral load, impact load and skin friction performance after retrofitting with BFRP composites. Gao et. al. found the performance of carbon and glass fibres reinforced polymer confined cylinders in freeze-thaw cycles and compared both with conventional cylinder specimens. Two different types of adhesives were used for confinement of cylinders. After freeze-thaw cycles, all the specimens showed decrement in strength, stiffness and ductility. CFRP confined cylinders showed more resistance to the freeze-thaw cycles than GFRP confined cylinders. Adhesive 1 used specimen showed more ductility than adhesive 2, but adhesive 2 is more susceptible to freeze-thaw cycles than adhesive 1 [1]. Erdil et. al. carried out durability test in low strength concrete, by confining the same with carbon fibres under the temperature cycles of 200°C. and temperature change between -10°C to 50°C. Single layer wrapped specimens possess 3 times more strength and five times more resistance to strain while comparing with control specimens. Confined and unconfined concrete specimens exhibit increased strength, but strain decreased when subjected to temperature cycles and sustained loads [2]. Shimomura and Maruyam found that chloride ingresses both in carbon and aramid fibre retrofitted concrete specimens. The CFRP specimens resist the chloride more than aramid and control specimens [3]. Kumuth and Vijai determined corrosion and chloride attack level in the GFRP wrapped concrete cylinder specimens and compared with conventional specimens. They found that the GFRP wrapped specimens resists corrosion and chloride attack effectively [4]. Shankarkumar et. al. investigated the effect of GFRP on M25 and M50 concrete mix in single, double and triple layers at 200°C temperature. After that, M25 grade of concrete compressive strength showed decrement at 200°C as 21%, 15%, 8%, 6% for 0, 1, 2, 3 layers of GFRP wrapped concrete respectively when compared with control elements. Similarly, M50 grade concrete specimens also showed decrement at a rate of 27%, 13%, 11%, 8% for 0, 1, 2, 3 layers respectively [5]. Ataders et.al. found out the FRP wrapped specimens durability in magnesium chloride and conducted flexural strength and pull-off tests in different environmental exposures for a period of 6 months and one year in the direct field [6]. Haider Al-Jelawy conducted durability test of CFRP wrapped beams by exposing to outdoor environment, sea water solution, leachate solution, UV radiation and dry heat the environment. In all the tests, the CFRP wrapped specimens are performed well while comparing with control specimens [7]. Murugan et. al. determined the durability in cubes and cylinder by exposing to natural outdoor weather and water immersion condition with Glass and Carbon fibers Uni and Bi direction. Carbon unidirectional fibre confined cube and cylinder specimens were taken more compressive strength when compared with control specimens, bi-direction confined specimens and glass fibre confined specimens. This study measured the durability of BFRP wrapped cube specimens by using dry temperature test and Hcl. acid solution test and compared with control specimens [8].

II. METHOD OF TESTING

A. Acid Resistance test.

The ingredients and preliminary tests were conducted and the single and double layer of BFRP wrapped specimens performances were found out. Based on that, author a paper was published in international journal [9]. For this acid resistance test, cube specimens of 24 nos. were cast using M30 grade concrete. After 28 days of water curing the specimens were dried in the atmosphere for 36 hours weighed (initial weight) and then kept immersed in 2% HCl diluted solution as per the Table 1. Hcl. diluted acid solution properties were shown in Table 2.

TABLE I. DETAILS OF EXPERIMENTAL PROGRAM

Description of specimen	Specimens immersed in Hcl. acid solution - Duration			
	0 day	7 days	30 days	70 days
Control or conventional specimens in nos.	3	3	3	3
BFRP double wrapped specimens in nos.	3	3	3	3

TABLE II. ACID PROPERTIES

Properties of Diluted Hydrochloric Acid (Acid strength 2%)	Value
P^H Value	1.54
TDS	54.5 ppm

After the corresponding period of acid immersion, specimens were taken out of acid solution and weighed (Present weight). It is then tested for compressive load as per the IS code 516-1959. The test results were observed and compared with control & doubly BFRP wrapped specimens with respect to weight loss and strength loss.

Fig. 1. Cubes 7 days immersed in acid solution

Fig. 2. Cubes 30 days immersed in acid solution

Fig. 3. Cubes 70 days immersed in acid solution

Fig. 4. Cubes immersed in acid solution 7 days, 30 days and 70 days.

TABLE III. ACID RESISTANCES OF CONCRETE CUBES

Description		After 7 days			After 30 days			After 70 days		
Control	Cube	1	2	3	1	2	3	1	2	3
	Initial weight in gram	8460	8439	8594	8915	8663	8606	8563	8432	8323
	Present weight in gram	8451	8427	8583	8893	8638	8583	8525	8390	8279
	Weight loss in gram	9	12	11	22	25	23	38	42	44
	Compr. Strength in kN.	800	798	799	791	796	793	788	784	786
BFRP doubly wrapped	Initial weight in gram	8438	8622	8599	8701	8713	8609	8623	8595	8655
	Present weight in gram	8434	8616	8596	8694	8703	8601	8609	8583	8642
	Weight loss in gram	4	6	3	7	10	8	14	12	13
	Compr. Strength in kN.	1209	1205	1207	1204	1202	1203	1201	1200	1196

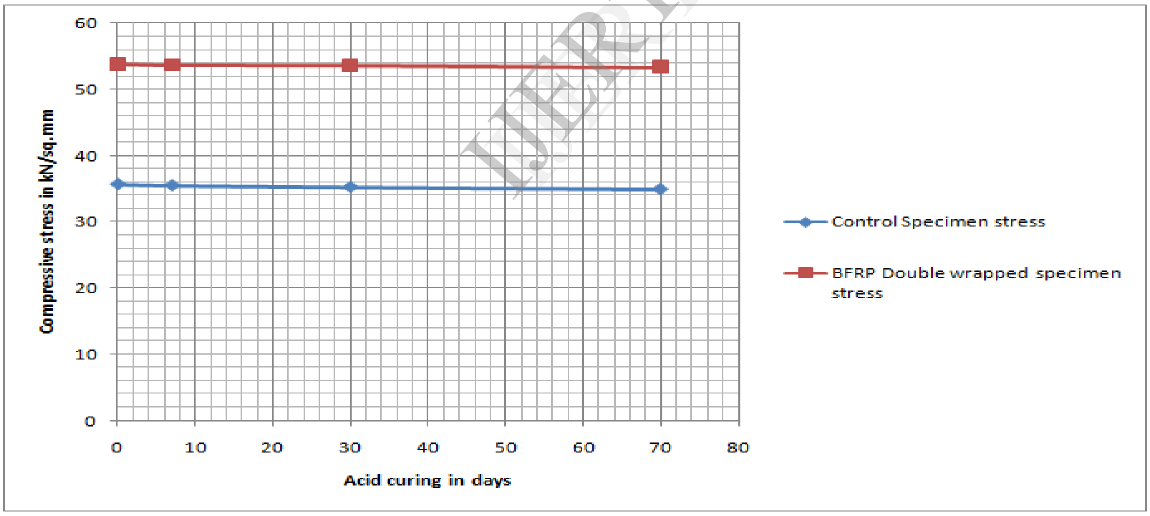

Fig. 5. Average Compressive stress of acid immersed concrete cube

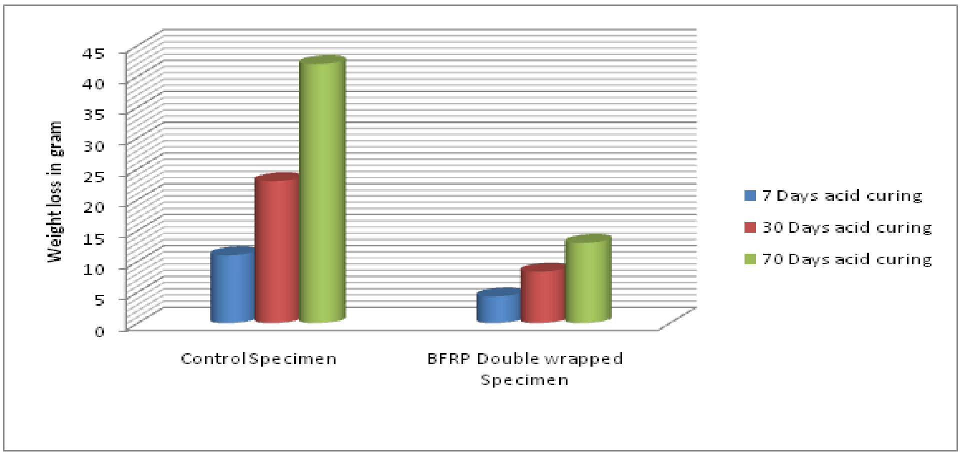

Fig. 6. Average weight loss of acid immersed concrete cubes

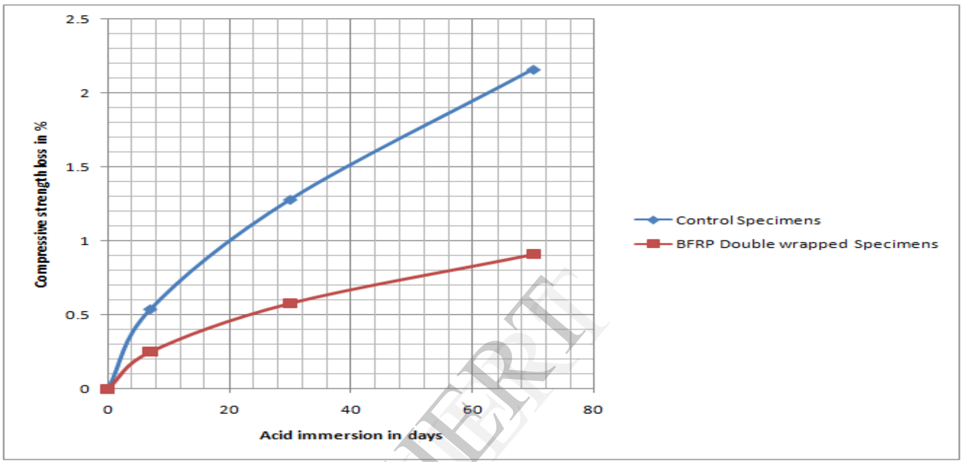

Fig. 7. Mean compressive strength loss after acid curing

B. Fire Resistance test.

Similarly, the specimens were weighed and kept in the hot air oven at 200˚C for duration of 1, 2 and 3 hours. In this experiment, temperature is kept at constant 200°C whereas the time varies in 1 hour interval upto three hours. The detailed data are given in below the Tables 4 to 6.

TABLE IV. FIRE RESISTANCE TEST AT 200°C – 1 HR.

Specimen type	Initial weight in kg	After heating weight in kg	Ultimate load carrying capacity in kN	Compressive strength in N/mm^2	Average compressive stress
Control cubes	8.701	8.698	806	35.82	35.80
	8.639	8.634	805	35.77	
	8.538	8.529	806	35.82	
BFRP double wrapped cubes	8.775	8.771	1211	53.82	53.82
	8.835	8.83	1210	53.77	
	8.810	8.806	1211	53.82	

TABLE V. FIRE RESISTANCE TEST AT 200°C – 2 HRS.

Specimen type	Initial weight in kg	After heating weight in kg	Ultimate load carrying capacity in kN	Compressive strength in N/mm^2	Average compressive stress
Control cubes	8.473	8.449	795	35.33	35.31
	8.516	8.496	796	35.37	
	8.561	8.543	793	35.24	
BFRP double wrapped cubes	8.867	8.847	1205	53.55	53.46
	8.623	8.609	1203	53.46	
	8.465	8.446	1201	53.37	

TABLE VI. FIRE RESISTANCE TEST AT 200°C – 3 HRS.

Specimen type	Initial weight in kg	After heating weight in kg	Ultimate load carrying capacity in kN	Compressive strength in N/mm^2	Average compressive stress
Control cubes	8.415	8.401	783	34.8	34.84
	8.354	8.339	786	34.93	
	8.430	8.418	783	34.80	
BFRP double wrapped cubes	8.440	8.428	1190	52.88	52.97
	8.565	8.552	1192	52.97	
	8.580	8.568	1194	53.06	

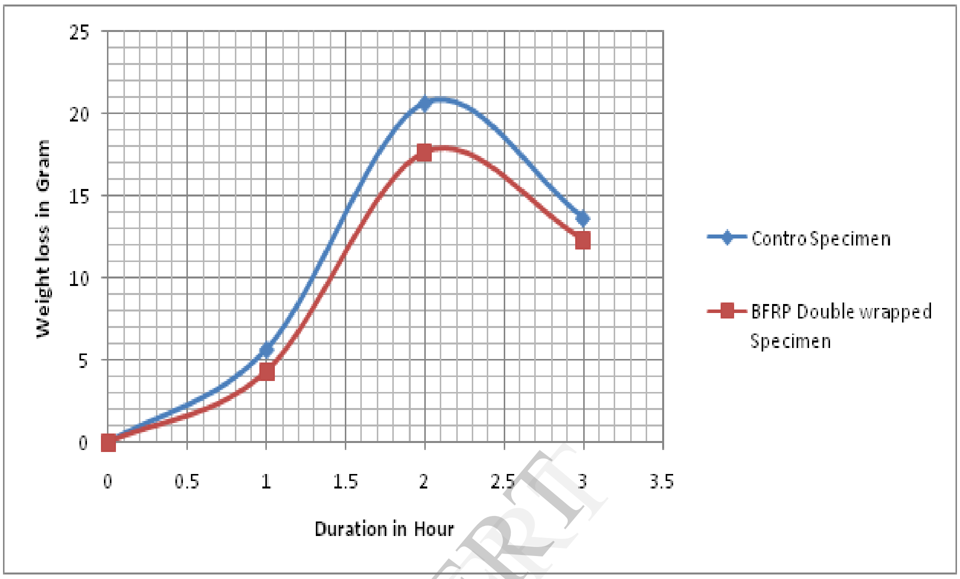

Fig. 8. Concrete cubes weight loss due to temperature

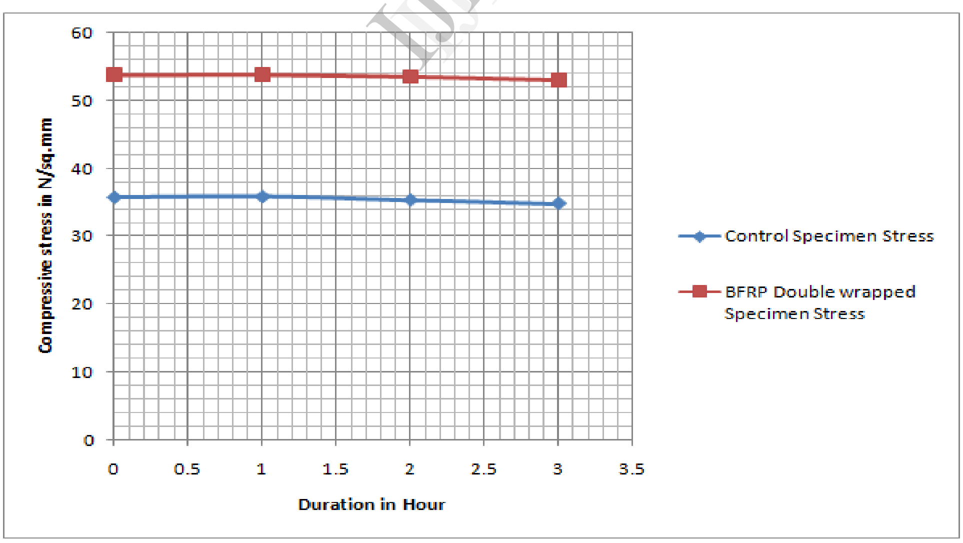

Fig. 9. Concrete cube compressive stress after dry temperature

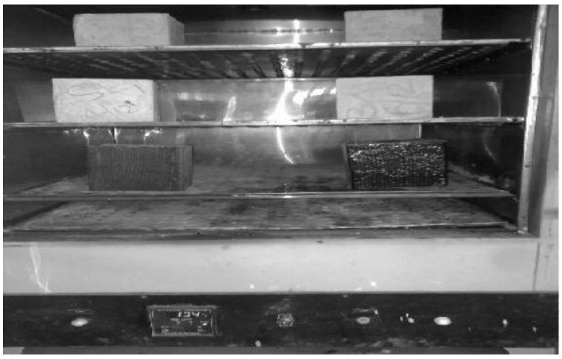

Fig. 10. Temperatures 200° C – 1 Hr.

Fig. 11. Compressive strength test on cube

III. RESULTS AND DISCUSSION

From those experiments, the following inferences were made.

The BFRP double wrapped concrete specimens possess higher acid resistance than that of the control concrete specimens.

The decrement in compressive strength of control specimens after acid immersion for 0, 7 days, 30 days and 70 days are 35.7 N/mm^2, 35.51 N/mm^2, 35.24 N/mm^2 and 34.92 N/mm^2 respectively shown in Fig. 5.

The decrement in compressive strength of BFRP double wrapped specimens after acid immersion for 0, 7 days, 30 days and 70 days are 53.77 N/mm^2, 53.64 N/mm^2, 53.60 N/mm^2 and 53.33 N/mm^2 respectively shown in Fig. 5.

The BFRP double wrapped concrete specimens are having higher dry temperature resistance more than that of the control concrete specimens.

The decrement in compressive strength of control specimens after subjecting to dry temperature of 200^{o}C for 0 hour, 1 hour, 2 hours and 3 hours are 35.7 N/mm^2, 35.8 N/mm^2, 35.32 N/mm^2 and 34.83 N/mm^2 respectively shown in Fig. 9.

The decrement in compressive strength of BFRP double wrapped specimens after subjecting to dry temperature of 200^o C for 0 hour, 1 hour, 2 hours and 3 hours are 53.77 N/mm^2, 53.80 N/mm^2, 53.46 N/mm^2 and 52.95 N/mm^2 respectively shown in Fig. 9.

IV. CONCLUSION

From the research results it is concluded that BFRP double wrapped cube specimens withstands more load carrying capacity after acid immersion and thermal effects than the conventional elements. Purpose of the study was proved in this experimental. BFRP wrapping endures durability and increase the life of the elements. Thus, it can be concluded that BFRP wrapping can be used for retrofitting of RCC piles prevails.

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