

PERFORMANCE OF BFRP WRAPPED STEEL SHAFT SUBJECTED TO TENSILE LOAD

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Abstract - This paper deals with the study of the performance of BFRP wrapped steel shaft subjected to tensile load to examine the elongation of a MS Shaft sections with and without being wrapped by Basalt Fibre Reinforced Polymer (BFRP). Specimens were wrapped with BFRP in double layer by Epoxy Resin and allowed to dry and tested under Tensile Loading. In this experiment 15 nos. of Mild Steel Shaft with 450 mm gauge length and 10 mm dia. Were cast to predict the tensile loading capacity of conventional, BFRP double wrapped and retrofitted after 30%, 60%, 90% of preloaded. It was found that external bonding of BFRP with steel shaft significantly increased the load carrying capacity and Elongation and Tensile strength. Load carrying capacity of a specimen depends on the type of material and strengthening techniques used. Ultimate load carrying capacity and elongation of a MS Shaft elements retrofitted with BFRP after preloading to 30%, 60% and 90% withstand 2.5%, 1.0% and 0.5% more tensile load respectively than the conventional elements.

Key Words: MS Shaft, BFRP, load carrying capacity, Tensile strength, Elongation.

1. INTRODUCTION

Due to several reasons the structure is concerned with Fibre reinforced polymer (FRP) in civil engineering community which is used to retrofit and strengthen of existing RC, steel structures, composite structures etc. FRP is a material made from polymer matrix reinforced with high strength fibres. The fibres can be made of carbon, glass, aramind or basalt. The fibre quality, orientation, shape and fibre volumetric ratio determine the material properties. The polymer matrix is made from epoxy resin, vinyl ester or polyester thermosetting plastic. The fibres embedded in a polymer matrix contribute to most of the strength and stiffness of a composite and the resin transfers the load to the reinforcement fibers as well as protects the fibers from environmental damage. The FRP products are available in the forms of FRP flexible sheet, FRP rigid plate, FRP bar, FRP mesh, etc. the most commonly used FRP in the industry is made of mainly carbon fiber (CFRP), glass fibre (GFRP), aramind fibre (AFRP), and Basalt fibre (BFRP).

Basalt FRP (BFRP) is relative Newcorner to FRP composites, as compared with carbon FRP (CFRP) and glass FRP (GFRP). Basalt fibre is an environmentally friendly material. It has superior characteristics such as high strength to weight ratio, sound ductility and durability, high thermal resistance, and good corrosion resistance, and is cost effective. BFRP has been employed in engineering practices including post-earthquake rehabilitation and strengthening as external bonded sheet material. The density is 2.63 g/cm³. Basalt's colour normally is grey or black, but cools down to brown or rust because of oxidation of its iron rich minerals into hematite and other iron oxides and hydroxides.

The structural application of Mild steel shaft (MSS) in offshore structures become widespread due to its numerous advantages such as light weight, high strength, high torsional rigidity and adequate ductility to certain extents. And very recently discovered its economically advantages as well, at the same time. In addition to that infrastructures concerned with metallic structures were found to be structurally unsatisfactory due to overloading and deficiency in the design phase. Hence, the engineers are constrained to implement new materials and effective strengthening technique to efficiently combat this problem.

The conventional method of repairing or strengthening steels structures is to cut out and replace plating or to attach external steel shaft. However, such strengthening has some drawbacks due to bulky, heavy, difficult to fix and prone to corrosion and fatigue of these steel shaft, Fibre reinforced polymer (FRP) is an advanced material which is increasingly being used for strengthening and repair of existing metal structure.

2. PAST RESEARCH

Harris and Bhuvaneshwari (2018) experimentally investigation on BFRP for ultimate load carrying capacity and stiffness of square wrapped hollow sections increased by 6.46% and 7.50% as compared to square conventional section. Ultimate load carrying capacity of square wrapped castellated section increased by 1.28% and 30.15% as compared to square castellated conventional section. Selvaraj and Madhavan (2016) experimentally investigated to achieve an strengthening technique to retrofit the damaged tall structures using carbon fibre-reinforced

polymer (CFRP). Anandakumar (2016) experimented the RCC end bearing piles retrofitted with BFRP composite subjected to the lateral loads BFRP double wrapped and retrofitted after 30%, 60% and 90% of preloaded piles and they found that the results ultimate load bearing capacity, deflection, stiffness, maximum stress and minimum stress were found out, tabulated and plotted and analysed. BFRP retrofitted pile elements are attained 186% and 200% more strength compared with conventional elements in free and midspan loading condition. Anandakumar (2014) experimented the RCC end bearing piles retrofitted with BFRP composite subjected to the Axial loads BFRP wrapped elements and 30%, 60% and 90% preloaded of ultimate compressive load & wrapped elements compared with conventional elements. The BFRP wrapped elements are enhanced more strength than that of conventional elements.

Information available from the literature, it is known that the steel structures are susceptible to damage and lose their strength due to buckling failure, web crippling or corrosion. So in order to overcome this problem high strength material such as FRP which has low self-weight, minimized disturbance to the structural system is wrapped over steel shafts or sections to enhance the stiffness, elongation, load bearing capacity and strength of steels.

3. EXPERIMENTAL PROGRAM

3.1 Materials Used

15 no of Mild Steel Shaft of length 610 mm and 10 mm dia with Gauge length of 450 mm and Basalt Fibre Reinforced Polymer (BFRP) of 0.3 mm thickness has been used.

3.1.1 Mild Steel Shaft

Mild steel contains approximately 0.05–0.25% carbon making it malleable and ductile. Mild steel has a relatively low tensile strength, but it is cheap and easy to form; surface hardness can be increased through carburizing.



Fig.1 MS shaft

Properties

Table 1: Properties of MS Shaft

Name and melting point	Properties and characteristics	Principal uses
Mild Steel 1600°c	Tough, ductile, malleable, good tensile strength, poor resistance to corrosion	General purpose engineering material

3.1.2 Basalt Fibre Reinforced Polymer

Basalt fiber is a material made from extremely fine fibers is by melting the quarried basalt rock. The molten rock is then extruded through small nozzles to produce continuous filaments of basalt fiber. It is known the basalt fibers, it have better tensile strength than E-glass fibers, greater failure strain than carbon fibers as well as good resistance to chemical attack. Basalt having a high modulus of elasticity and excellent heat resistance.



Fig.2 BFRP

Properties

Table 2: Properties of BFRP

Properties	Fibre value
Density	2.63 g/cm ³
Tensile strength	3.6 GPa
Youngs modulus	93 GPa
Elongation	3.17

3.1.3 Epoxy and Hardner

Araldite LY556 epoxy and Aradur HY951 hardener were used. Araldite LY556 is medium viscosity, unmodified liquid epoxy resin based on bisphenol-A, Aradur HY951 is a low viscosity, unmodified, aliphatic polyamine. Which can be added in the ratio of 1:0.25.



Fig.3 Epoxy and Hardner

Properties

Low viscosity system, glass fibre laminates are dimensionally stable, glass fibre laminates are practically free from internal stress and excellent water resistance.

4. TEST ON STEEL SHAFT

4.1 Details of Specimens

A total of 15 specimens used in this experiment, out of which 9 specimens are conventional with 6 specimens are preloaded under 30%, 60%, 90%, after that 9 specimens are wrapped with Basalt Fibre Reinforced Polymer (BFRP) using epoxy and Hardner were allowed to dry and then tested.

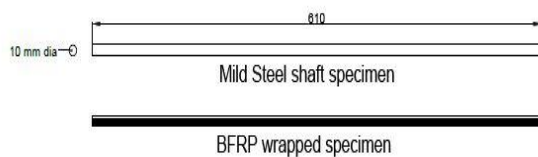


Fig.4 Specimen Details

4.2 Test Setup

All the conventional and wrapped specimens were tested under Tensile loading Universal Testing Machine (UTM) with a capacity of 40T. 3 specimens were tested for finding out the ultimate tensile load bearing capacity as conventional and 3 specimens were tested after BFRP double wrapping. The remaining 3 sets each sets containing 3nos. were preloaded at 30%, 60%, 90% of ultimate tensile load bearing capacity of conventional elements at with BFRP double wrapped mild steel elements to find out the performance. The above mild steel elements were named as TC1, TC2 & TC3 for conventional steel elements and TW1, TW2 & TW3 for doubly wrapped steel shaft.



Fig.5 Tensile Loading UTM machine

TRW 3-1, TRW 3-2 & TRW 3-3 are BFRP wrapped steel elements after 30% preloading; TRW 6-1, TRW 6-2 & TRW 6-3 are BFRP wrapped steel elements after 60% preloading; TRW 9-1, TRW 9-2 & TRW 9-3 are BFRP wrapped steel elements after 90% preloading steel elements. (Where, T indicates Tensile load, C indicates conventional, W indicates BFRP double wrapping, R indicates retrofitting and 3,9,6 indicates the preloading %).

The elements were tested under the 40 T capacity structural loading frame with mechanical setup. The test on Mild steel elements were carried out to determine the tensile load bearing capacity. Reading were taken for the loading intervals. Orientation of fibre is very important for load carrying and bearing capacity strength. In this experiment, fibre warps orientation made along the vertical direction of the steel elements.



Fig.7 Conventional Elements get Deformation Against Failure



Fig.8 BFRP Retrofitted Elements Testing Under Tensile Loading

Table 3: Properties of Tensile load

Elements	Maximum force (KN)	Displacement (mm)	Tensile strength (KN/mm ²)	Elongation (%)	Yield stress (KN/mm ²)
TC1, TC2, TC3	39.140	15.500	0.498	2.222	0.498
TW1, TW2, TW3	156.320	84.6	1.990	18.800	0.752
TRW3-1,TRW3-2, TRW3-3	112.280	64.3	1.429	15.2	0.675
TRW6-1, TRW6-2, TRW6-3	75.320	48.00	0.959	11.0	0.578
TRW9-1,TRW9-2, TRW9-3	47.400	26.200	0.578	3.66	0.510

From the above test observation, load vs deformation for MS Shaft elements are plotted in figures 8- 12 respectively with the mean values. Deformation were observed as shown below,

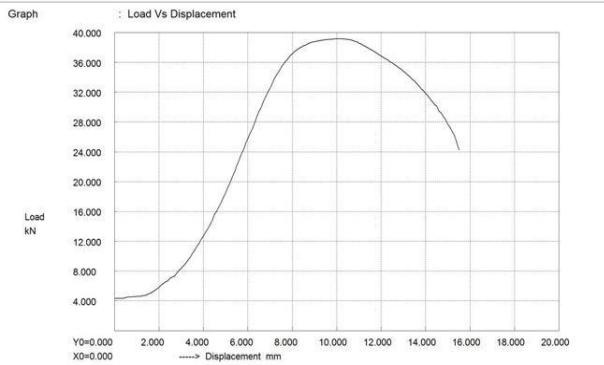


Fig.9 Conventional Elements

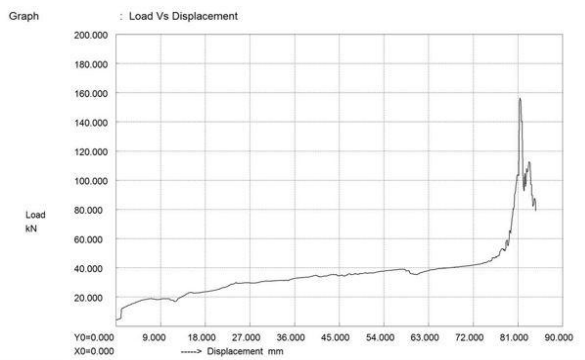


Fig.10: BFRP Double wrapped Elements

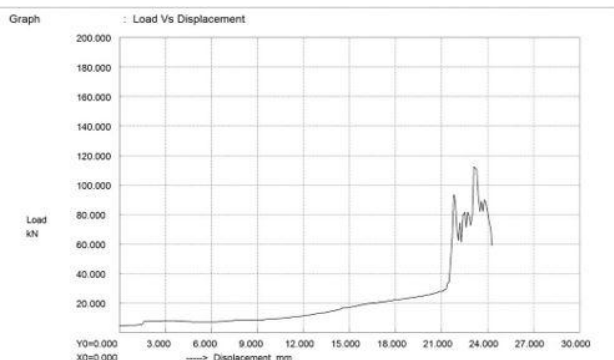


Fig.11: 30% preloaded & Retrofitted with BFRP Elements

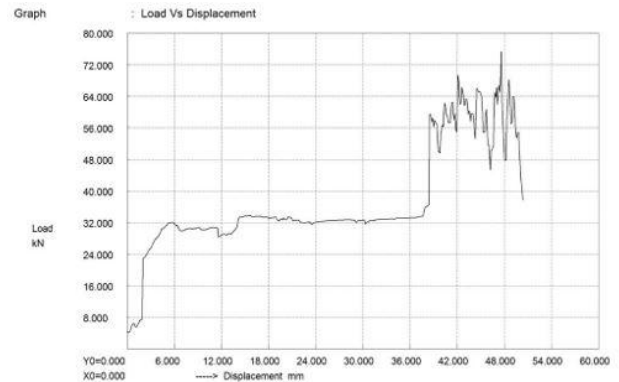


Fig.12: 60% preloaded & Retrofitted with BFRP Elements

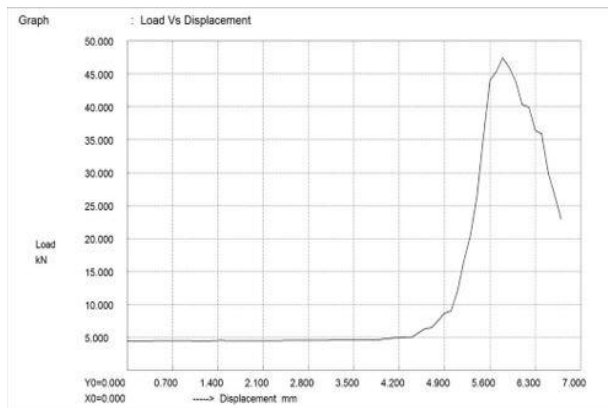


Fig.13: 90% preloaded & Retrofitted with BFRP Elements

5. RESULT AND DISCUSSION

5.1 Failure Modes of Specimen

Every specimens were tested till their ultimate failure. In order to evaluate the strengthening effect, failure modes of specimens were studied. Generally fibres posses good mechanical properties such as high tensile strength and high flexibility. While Tensile loading, the BFRP wrapped steel elements shows significant increase in strength more than the conventional elements; the comparison of the results are discussed below,

5.2 Load Carrying Capacity

Load carrying capacity of a specimen depends on the type of material and strengthening techniques used. Ultimate load carrying capacity and stiffness of a MS Shaft elements Elements retrofitted with BFRP after preloading to 30%, 60% and 90% withstand 2.5%, 1.0% and 0.5% more tensile load respectively than the conventional elements. The greater stiffness of the BFRP fibre helps in withstanding more tensile force and causes reduction in the deflection due to tensile loads than the conventional elements.

6. CONCLUSION

Following conclusion are made based on the results and experimental observations.

- Finally the retrofitted with BFRP in Steel shaft elements are withstand the more load, deformation or stiffness than that of conventional steel shaft elements. The enhancement of tensile load strength is due to wrapping of BFRP in the longitudinal direction. Basalt fibres are have high tensile strength than conventional rod. So, BFRP can be retrofitting of all Steel Structures in the same time the orientation of the wrap is very important for load carrying purposes.
- BFRP wrapping is to improve the elastic behavior also; it is proved by this experiment Elements retrofitted with BFRP after preloading to 30%, 60% and 90% withstand 2.5%, 1.0% and 0.5% more tensile load respectively than the conventional elements. The greater stiffness of the BFRP fibre helps in withstanding more tensile force and causes reduction in the deflection due to tensile loads than the conventional elements.

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