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Experimental Investigation on Fatigue Behaviour of Basalt Fibre Reinforced Polymer (Bfrp) Bars

RAKESH P[1], SURANYA K V[2] ,PAVALAN V[3]

M.E SCHOLAR[1],PROFESSOR[2] , DEPARTMENT OF CIVIL ENGINEERING / SENGUNTHAR ENGINEERING COLLEGE / TIRUCHENGODE, INDIA
Corresponding Author Email: vpavalan.civil@scteng.co.in

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Abstract—
The tension-tension fatigue behaviour of sand-coated basalt fibre reinforced polymer (BFRP) bars was studied in this paper. The fatigue test was carried out at a stress ratio (R),$\sigma_{min}/\ \sigma_{max}$= 0.1 subjected to constant amplitude loading as per ASTM D3479-02.The loading frequency of this experiment was 5 Hz. The debonding of fibre/matrix interface was observed using scanning electron microscopy (SEM).The experimental test results were presented in the form of S-N curves, showing that the sand-coated BFRP bars have better fatigue performance than conventional steel bars.

Keywords: ASTM standards, BFRP bars, Steel bars, Fatigue behaviour

I. INTRODUCTION

Fibre reinforced polymers (FRPs) have been extensively used in various engineering sectors such as automotive, aerospace, marine and construction, etc. due to their high strength, corrosion resistance and excellent light weight characteristics. The usual internal and external reinforcements of FRPs are carbon, glass and aramid. Recently, basalt fibre reinforced polymer has emerged as optimistic alternative internal and external reinforcements. The use of BFRP reinforcements in concrete structures affords a potential for increasing life and environmental benefits. However, BFRP bars have not been listed in most design standards and specifications. This is due to lack of studies on the performance of BFRP bars under fatigue loading. Zhao et al. studied the tension–tension fatigue behaviour of basalt fiber reinforced epoxy polymer (BFRP) composites at different stress ratios and showed that the fatigue life decreases and the fatigue life deterioration rate increases with the decrease of stress ratio for examined BFRP composites. The stiffness deterioration is also sensitive to different stress ratios, showing a greater stiffness loss before failure at lower stress ratio. Wang et al. investigated the fatigue behaviour of basalt fibre reinforced polymer (BFRP) tendons and observed that the fatigue failure of a BFRP tendon is mainly induced by the debonding among fibre-matrix interfaces at the outer layer of the tendon. The fatigue stress range highly affects the fatigue life of BFRP tendons. The BFRP tendons can sustain 2 million cycling loadings under a stress range of 85MPa and maximum stress of 1018MPa.Moreover, the modulus of elasticity of BFRP tendons before failure remains constant regardless of the number of cycles. Refai et al. experimentally studied the fatigue behaviour of BFRP bars gripped at their ends with steel wedge anchors and reported that the fatigue life of the bar-anchor system was primarily affected by the applied stress range. Furthermore, continuous immersion of the BFRP bar in the alkaline solution increased its tendency to fracture prematurely in the anchor zone. The fatigue limit of the BFRP bar-steel wedge anchor system was determined to be 4% of its ultimate capacity, compared with 3 and 10% for the glass and carbon systems, respectively. In this paper, the fatigue life of sand-coated BFRP bars was clarified using advanced fatigue test machine.

II. EXPERIMENTAL PROGRAMME

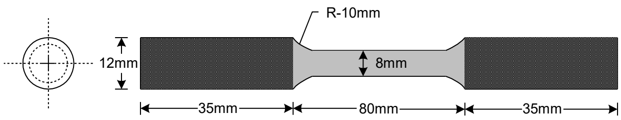
2.1 Materials

The sand coated BFRP bars of 12mm-diameter were provided by Go Green products, Chennai. The BFRP bars used in this study were produced using a pultrusion process, then the bars were applied with mixture of epoxy resin and hardener and braided with nylon wire, after that the quartz sand was coated on the bars as shown in Figure1.

Fig. 1 Sand-coated BFRP bars

2.2 Specimen Details

All of the test specimens were 150mm long, with a gauge length of 80mm between the tapered ends. The details of the specimens as shown in figure 2a and are according to the ASTM D3479/D3479M-02 ‘Standard test method for tension-tension fatigue of polymer matrix composite materials’. Figure 2b shows the photograph of the fatigue test specimens.



(a)

(b)

Fig.2 (a) Details of the specimens (b) Photograph of the fatigue test specimens

2.3 Test setup

The fatigue tests were carried out as per ASTM D3479/D3479M-02 using a servo hydraulic, 100kN fatigue testing machine (Instron, UK; Model No:8801) as shown in figure 3a.The tests were conducted under constant amplitude fatigue loading at 5Hz frequency and stress ratio (R), $\sigma_{min} / \sigma_{max} =$ 0.1.All fatigue specimens were performed at room temperature. The specimen was inserted between hydraulic –controlled jaws as shown in figure 3b. The fatigue loads were applied as percentages of ultimate tensile strength determined by tension test. The fatigue tests were stopped at specimen failure.

2.4. Results and Discussion

The failure modes of BFRP bars is shown in Figure 5 .All of the conventional steel specimens exhibited a similar failure mode in the middle portion whereas the BFRP specimens were failed in the grip portion due to rupture of fibres (Fig.4). The scanning electron microscope (SEM) photographs of the failure portion (Fig.6). An obvious fibre/matrix interface debonding and local longitudinal failure can be observed in Fig.6a & b. Tension-Tension fatigue tests were conducted on conventional steel and sand-coated BFRP specimen for four different stress levels such as 45%, 55%, 65% and 75 % of the ultimate tensile strength with stress ratio (R=0.1) and the frequency of 5Hz. The experimental test results were presented in the form of S-N curves as shown in Figure 4.The fatigue life of all conventional steel and sand-coated BFRP specimens decreased significantly when applied stress range increased. The sand-coated BFRP bars have shown better fatigue performance than conventional steel bars.

Fig.3 (a) Fatigue Testing machine Instron 8801(b) Specimen inserted between the hydraulic-controlled Jaws.

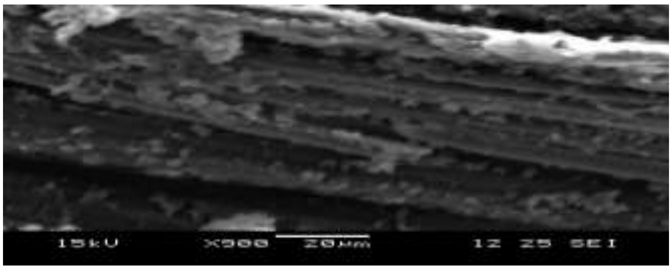
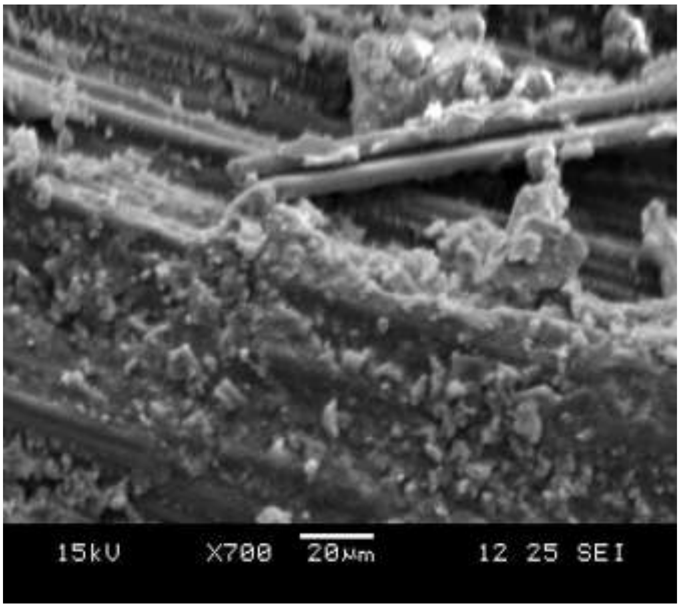


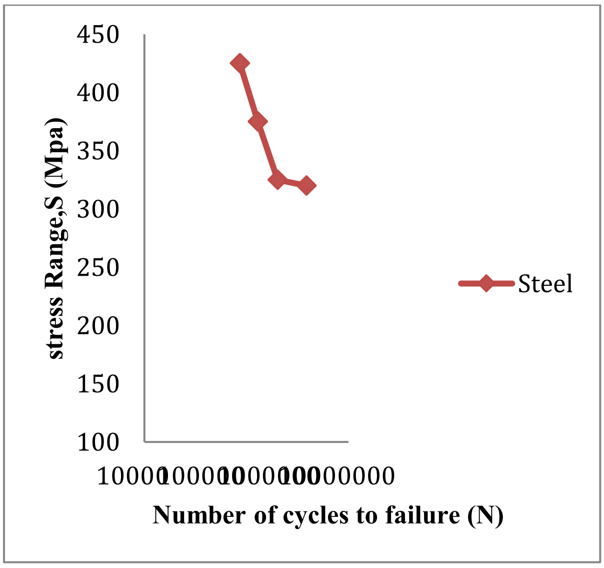
Fig.4 Fracture modes of sand-coated BFRP specimen

(a)



(b)

Fig.5 SEM images (a) Fibre/matrix interface debonding (b) local longitudinal failure.



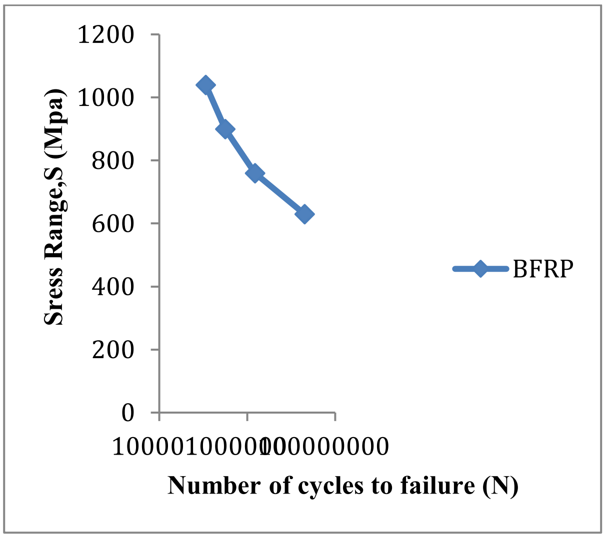


Fig. 6 S-N curves for all conventional steel and BFRP specimens

III. CONCLUSION

In this paper, the fatigue behaviour of sand-coated basalt fibre reinforced polymer (BFRP) bars were investigated. The following conclusions can be drawn:

Tension-Tension fatigue test were performed on conventional steel sand-coated BFRP specimens for four different stress levels such as 45%, 55%, 65% and 75 % of the ultimate tensile strength with stress ratio (R=0.1) . The conventional steel and sand-coated BFRP specimens decreased significantly when applied stress range increased. The sand-coated BFRP bars have shown better fatigue performance than conventional steel bars.

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