

Strengthening Mechanical Properties of Glulam with Basalt Fiber

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Mechanical Properties of Glulam with Basalt Fiber. *Advances in Natural Science*, 4(2), 130-133. Available from: URL: <http://www.cscanada.net/index.php/css/article/view/j.ans.1715787020110402.137>
DOI: <http://dx.doi.org/10.3968/j.ans.1715787020110402.137>.

Received 17 September 2011; accepted 19 November 2011

Abstract

This paper describes the strategy of improving the Mechanical Properties of timber and other wood-based glulam structures. This is achieved by bonding Basalt Fiber Reinforced Polymer (BFRP) composites to structural substrate externally.

FRP Composite materials have been proven to be an effective way to traditional steel plate strengthening techniques for concrete structures from results of a variety of researchers over the past two decades; this paper shows the use of this material for same strengthening purpose in timber structures.

The experimental program consisted in testing glulam flexural elements as follows: laminates are glued with two different Adhesives and two different lengths, both in natural form and reinforced by BFRP. All specimens were tested under three point bending at a predetermined loading increment rate, the lateral deflection were recorded regularly. The data processing consisted of bonding processes, load, deflection and moment curvature plots construction which were used for analysis and observations.

The results revealed that there was a marked increase in the load bearing capacity of the timber flexural element, due to BFRP strengthening and there was also an increased rigidity in the member characteristics.

Key words: Basalt Fibre Reinforced Polymer Composites; Structural Strengthening and Reinforcement; Glulam; HMR; BFRP

ZHANG Pengyi, SHEN Shijie, MA Chunmei (2011). Strengthening

INTRODUCTION

Timber is the most ancient and widely used traditional construction material. Glued laminated (glulam) timber material has been in existence since the 1800s^[1]. It has been used in numerous applications including arches for airplane hangers, timber for floors, dome structures, timber bridge decks etc.

The earliest recorded studies on wood beams reinforced with fibre and FRP materials were in 1964 and 1965 by Wangaard^[2] and Biblis^[3] respectively when they studied the effect of bonding unidirectional fibre-glass/epoxy reinforced plastic to the compression and tension faces of wood cores of various species and Theakson^[4] in 1965 studied the feasibility of strengthening both laminated and solid wood beams with fibre-glass. In 1974, Krueger^[5] studied laminated timber reinforced in the tension zone with a composite of high-strength bronze coated woven steel wire and epoxy. Later in 1981, Spaun^[6] studied finger-jointed western hemlock cores reinforced with wood veneers and fibre-glass roving.

By the 2000s, better enhanced FRP composites called hybrid FRP and Ultra hybrid FRP composites were being developed and more research work into their uses were made. Fiorelli and Dias in 2002^[7] analysed the strength and stiffness of timber beams reinforced with carbon fibre and glass fibre composites. Lopez-Anido and Xu^[8] that same year published work they had done on the structural characterization of hybrid FRP-glulam panels for bridge decks.

In 2006 Dempsey and Scott^[9] studied the effects of mechanically fastening FRP strips to wood members as a strengthening feature. That same year, Johnsson,

Blanksvard and Carolin^[10] worked on some glulam members strengthened by carbon fibre reinforcement by first running pull-out tests on four pairs of glulam members at four different anchoring lengths.

Xiongchen Fu studied the bonding performance between BFRP (Basalt fiber reinforced polymer) and timber^[11], the results shows that: the treatment of wood surface greatly enhanced the bonding performance between BFRP and wood composite materials by HMR(hydroxy methylated resorcinol). The stripping rate reached 0.00% to 1.03% on the layer between wood composite and the BFRP which is treated by HMR, and it reached the ASTM D2559 standard requirements (outdoor structure with a laminated strip ratio <1%).

In 2008, Li Yunfeng, etc. studied the bonding performance of BFRP-Structural laminated timber, the results shows that the time is a greatly important factor for the bonding performance of BFRP- Structural laminated timber, while the unit pressure and the amount of glue still need further test to be determined^[12]. In 2010, Li Long, Zhang Peng-Yi studied the bonding performance of BFRP- bamboo-wood composite laminated glulam, the large daters shows the optimum gluing process of BFRP- bamboo-wood composite laminated glulam by Polyurethane adhesive^[13].

1. MATERIALS

1.1 Basalt FRP

The bonding experiment used was Basalt Fiber, which is a basalt fiber directional sheet, of thickness 1.4 ± 0.01 mm made by Hicome in Nanjing, and designed for the strengthening of structural members against tensile, shear and impact forces. The mechanical properties of the basalt fiber had been measured in the experiment. The sheet is supplied with Vinyl resin and forms the Basalt Fiber Externally Bonded Reinforcement System.

1.2 Laminates

The strengthened glulam material consisted of 48 Larch laminate sections, prepared for bonding experiment and flexural testing; 24 samples were cut in lengths of 1000mm with widths 50 mm, and other 24 samples were cut in lengths of 500mm with widths 50 mm The thickness of the laminate material used was 25mm, which is provided by IKEA Wood in Mohe.

1.3 Adhesives and Coupling Agents

Two types of adhesives were prepared, one is Resorcinol Adhesive, and the other is Polyurethane Adhesive. Both were provided by related company. Coupling agent is constituted by Formaldehyde, Sodium dodecyl sulfate, Sodium hydroxide, Resorcinol, and water. They were purchased in the chemical store.

2. SPECIMENS PREPARATION

The laminate materials were cut to sizes consisting three beam members for width and cleaned with aid of a sharp sand paper to ensure a flat, clean and degreased surface. Saw dust particles were removed with the aid of a hand vacuum cleaner. Likewise, the BFRP reinforcing material was cut to the same widths as the beams and vacuumed ready for application.

The coupling agent was made up at the specified ratio, and then, the coupling agent applied with the aid of a roller onto the surface of BFRP and laminate materials. They were then left to place in the next 24 hours.

The BFRP was then placed onto the tension face of the ply beam at equidistance from the beam centre line and set firmly onto the substrate using a suitable hand roller. The specimens were then formed on through different bonding processes. The following picture is a schematic diagram of the Bonding Process.



Figure 1
The Process of Bonding

3. TEST PROCEDURES

Six groups BFRP samples in universal mechanical testing machine for BFRP bending, inter-laminar shear, tensile test, which is shown in Figure 2, the inter-laminar shear performance of BFRP. The loading rate is 2mm per minute.

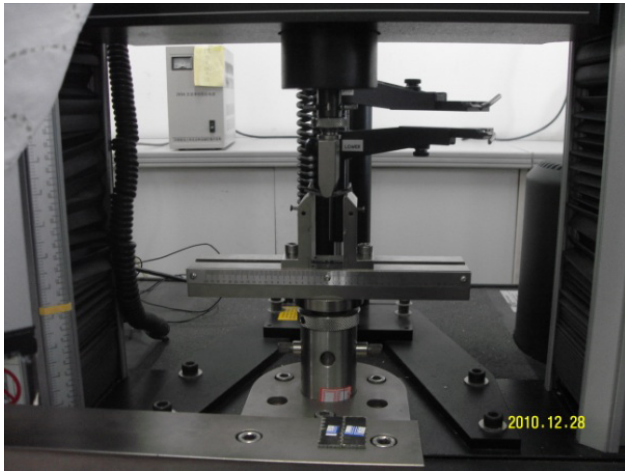


Figure 2
The Test of BFRP Mechanical Properties

Each beam was placed on the inverted test rig on a clear base. The Strengthening side is close to the steady. An external load was applied on the either side of the beam centre line. A picture of the beam test arrangement is placed in Fig. 3. The beams were loaded to failure on the three point bending test apparatus; the load rate was 3mm per minute.



Figure 3
Beam Test Arrangement

4. TEST RESULTS

Results from the first test showed that the mechanical properties of the basalt fiber had a good performance. The average Inter-layer strength was 252.69MPa, the average

tensile strength was 940.00MPa, and the average bending strength was 1011.20MPa. Fig.1 shows the process of testing.

Table 1
Average BFRP Mechanical Properties Results from Experiments

Samples	Bending Modulus of Elasticity (GPa)	Bending Strength (MPa)	Tensile modulus of Elasticity (GPa)	Tensile Strength (MPa)
1	45.35	1004.74	46.33	947.78
2	39.14	940.65	47.91	974.83
3	42.61	1003.95	43.95	940.86
4	44.67	1073.60	50.09	944.76
5	42.10	999.30	47.55	921.92
6	45.51	1045.38	46.03	873.84
Average	43.23	1011.27	46.98	934.00

Results from the second test showed that BFRP timber can significantly enhanced the elastic modulus and bending strength, while the corresponding deflection reduced, which is shown in Figure 4 and Table 2.

Table 2
Average Failure Load and Deflection Results from Experiments

The type of adhesive	Specimen Description	Average Failure Load	Average Deflection at Failure
Resorcinol adhesive	76x50x500mm control	14.52kN	7.39mm
	76x50x500mm BFRP	16.74kN	6.62mm
	76x50x1000mm control	11.20kN	15.20mm
	76x50x1000mm BFRP	13.19kN	12.10mm
Polyurethane adhesive	76x50x500mm control	18.39kN	6.78mm
	76x50x500mm BFRP	19.06kN	5.24mm
	76x50x1000mm control	16.11kN	13.52mm
	76x50x1000mm BFRP	17.97kN	11.09mm

Statistics show that, the average tensile strength parallel to grain can reach 90MPa and the bending strength is about 90MPa for China's timber, while results show that the average tensile strength parallel to grain of Basalt Fiber can reach 940MPa, and the bending strength is 1011.20MPa. Therefore, it is greatly active and effective to use BFRP for enhancing the mechanical properties. And the results also proved the same conclusion.

Tests show that the strength of BFRP reinforced timber increased by 10% than the unreinforced timber, while the deflection of the specimen reduced by 16% under the conditions of the resorcinol adhesive. And the strength of BFRP reinforced timber increased by 15% than the unreinforced timber, while the deflection of the specimen reduced by 16% under the conditions of the resorcinol

adhesive. This proves that the basalt fiber reinforced structural glulam effectively.

CONCLUSIONS

This paper has presented experimental results aimed at establishing the effectiveness of BFRP composite systems flexural strengthening of glulam beams. Two alternative length measurements and two different types of adhesive for the upgrading system have been investigated.

All twenty-four plywood beams were subjected to three-point loading and the upgraded ply beam lengths reached and exceeded the plastic collapse load of like-width un-strengthened ply beams.

Further investigations are currently pursued to examine various beam widths, strengthened with more than one layer of BFRP composites hoping to further improve the beam properties.

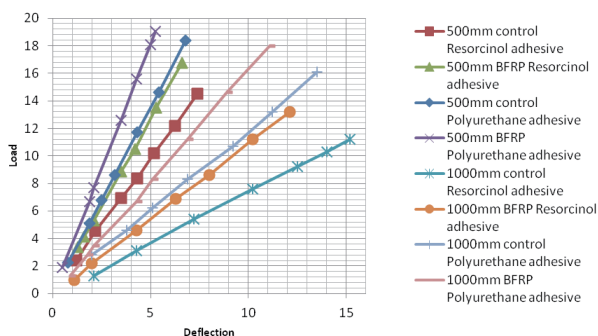


Figure 4
Load Deflection Graph for BFRP Reinforced Ply Beams

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