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Research Article

Experiment and Simulation Verification on the Composite Mode of Enhanced Glulam

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Abstract

The structural glulam used in bridge engineering is huge, which exists many defects by full-scale experimental method to research its relevant properties. Both experiment and simulation verification of ABAQUS were carried to forecast the enhanced composite structure and to reveal the composite enhancement effect of glulam made up of plantation eucalyptus veneers with the reinforced materials of fiberglass mesh and aluminium foil, and the basic mechanical properties were viewed as the evaluation index. The results show that the simulation model is feasible and rational to be applied to choose the better composite mode, and the best enhanced composite structure of glulam is the central seven layers eucalyptus veneers with criss-cross assembling structure, the outer three layers eucalyptus veneers with parallel assembling structure and fiberglass mesh and aluminum foil interval distributed among every two veneers.

Keywords: Enhanced Glulam, Abaqus, Fiberglass Mesh, Aluminum Foil, Composite Mode, Mechanical Properties, Simulation Model

1. Introduction

Glulam is a kind of high quality material applied in bridge engineering and its enhanced composite mode and mechanics evaluation has always been the hot research topic [1,2,3]. Researchers devoted to confirm the performance on each part of timber bridges which were build in the late 1960s and early 1970s [1,4], Hurlbut and Davids discussed the property of timber as a structure material used in highway bridge [5,6]; Bakht analyzed the load distribution of plane laminated timber deck in highway bridge [7]; Hasebe, etc. researched the behavior of using the glued laminated timber as the steel beam of a bridge [8]; Morison discussed the structural integrity of wood bridge [9]; Gutkowski, etc. achieved the laboratory load testing of wood bridge.Burgers [10]; Burgers, etc. evaluated large scale wood bridge by shear peak [11]; Serrano established the nonlinearity three-dimensional finite element model and discussed the theory parameters of timberwork [12]. As mentioned, there is no research on the enhanced composite mode of glulam made up of wood veneers with the reinforced materials of fiberglass mesh and aluminium foil. However, fiberglass is an excellent inorganic nonmetallic material with good insulation and corrosion resistance, strong heat-resistant and also high mechanical strength, which is always used in composites [13,14,15]. And aluminum foil is a sort of soft metallic film with graceful silver luster, which is not only dampproof, airtight, shading, corrosion resisting, fragrance-holding, non-toxic and tasteless, but also easily processed out kinds of beautiful designs and patterns to be a kind of favorite and perfect packaging material [16,17,18]. Therefore, this research aims at forecasting the enhanced composite structure and to reveal the composite enhancement effect of glulam made up of plantation eucalyptus veneers with the reinforced materials of fiberglass mesh and aluminium foil by the experiment and simulation verification of ABAQUS with the evaluation index of basic mechanical properties, which will provide the scientific guide for the plantation wood widely in the field of bridge engineering.

2. Materials and Methods

2.1 Materials and Methods Experimental Materials

Plantation Eucalyptus Wood Veneer: The size is 1.27m×0.64m×1.3mm, the density is about 0.61g/cm3 and the moisture content is 5%-8%.

Aluminum Foil: The thickness is 0.05mm, the type is aluminum alloy 1060, the density is 2.71 g/cm3, the tensile strength≥75MPa and the offset yield strength≥35MPa.

Two-component Epoxy Adhesive: The A component is milky white or gray white sticky liquid, The B component is yellow-brown or red-brown sticky liquid, applicable period is 1 hour (25°C), the curing speed is 2.5-3.5 h (25°C) and the tensile shear strength≥8 MPa (25°C×48h).

Fiberglass Mesh: plain weave, the warp and weft density are 128×68.

2.2 Design Proposals of Specimens

Design proposals of specimens were shown in Table (1). 3 parallel specimens in each test group and 5 test groups in total. The enhanced effect of fiberglass mesh was obtained through the comparison of group 1A/2A/3A/5A, and the enhanced effect of aluminum foil was obtained through the comparison of group 1A/2A/4A/5A.

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Table 1: Design proposals of specimens

Test Group	Assembling pattern
1A	The central seven layers veneers with criss-cross assembling structure, the outer three layers veneers with paralleled assembling structure.
2A	The central seven layers veneers with criss-cross assembling structure, the outer three layers veneers with paralleled assembling structure, and fiberglass mesh placed every two veneers making up one half of the glulam and aluminum foil placed every two veneers making up the other half.
3A	The central seven layers veneers with criss-cross assembling structure, the outer three layers veneers with paralleled assembling structure, and fiberglass mesh placed every two veneers making up the glulam.
4A	The central seven layers veneers with criss-cross assembling structure, the outer three layers veneers with paralleled assembling structure, and aluminum foil placed every two veneers making up the glulam.
5A	The central seven layers veneers with criss-cross assembling structure, the outer three layers veneers with paralleled assembling structure, and fiberglass mesh and aluminum foil interval distributed among every two veneers making up the glulam.

2.3 Experimental Methods
According to the assemble pattern in Table (1) to assemble the specimens with a double spread of $350g/cm^2$, then the specimens were put into the cold press with the air temperature about 20°C, and then to be pressurized to 4MPa quickly and to be maintained for 1 hour, then the power source was turned off and the press-holding time was 23h. The sectional area of obtained specimens was 350×350 mm. The normal section of the Glulam was showed in Fig.1. The standard specimens were made and tested according to "Standard for Methods testing of Timber Structures" (GB/T 50329-2002) and "Plywood" (GB 9846-2004). The specimens for Testing MOR and MOE: Length×Width=300 mm×50 mm, they were loaded to failure at the rate of 10Pa/s and the loading methods were consulted "Test methods of evaluating the properties of wood-based panels and surface decorated wood-based panels" (GB/T 17657-1999). Test with parallel loading and vertical loading was showed in Fig.2.

2.4 Finite Element Analysis Proposal
The ABAQUS software was applied to study on numerical simulation verification.

3. Results and Analysis of the Test

3.1 Analysis of the Enhanced Composite Effect
The average of 3 parallel specimens in each group was taken, and the total test results of 5 groups of specimens were shown in Table 2.

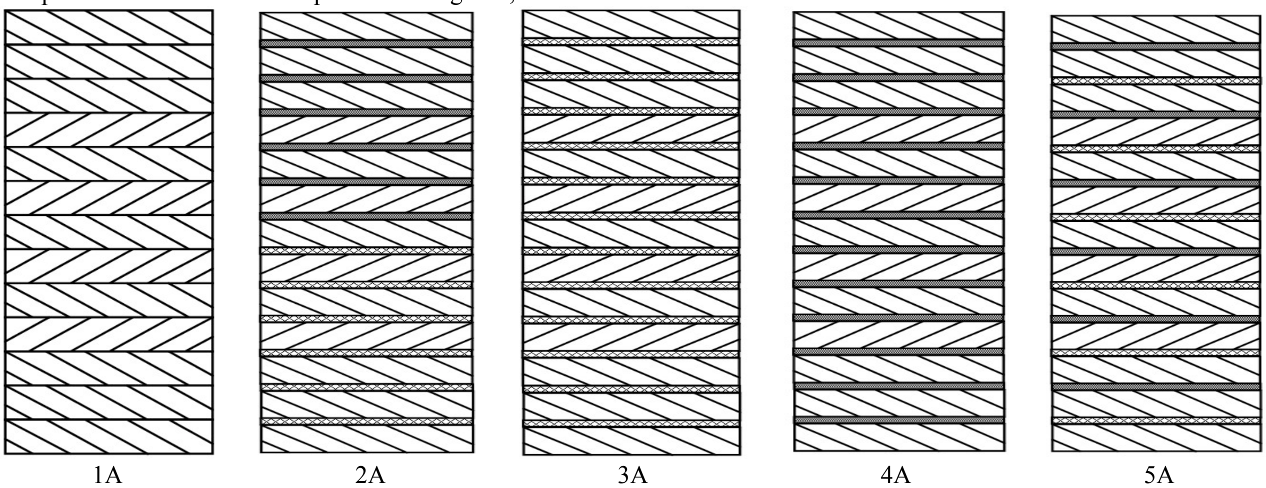
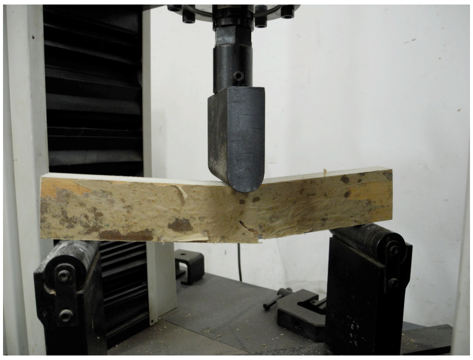


Fig.1. Normal section of the Glulam

Vertical loading



Parallel loading

Fig.2. Loading methods of the test

Table 2: Results of the testing

Test group	Vertical loading					Parallel loading				
	Width (mm)	Thickness (mm)	Fracture load (N)	Modulus of rupture (MPa)	Modulus of elasticity (MPa)	Width (mm)	Thickness (mm)	Fracture load (N)	Modulus of rupture (MPa)	Modulus of elasticity (MPa)
1A	50.60	27.46	1687	17.91	1770.6	26.68	50.46	7305	43.55	2627.0
2A	51.10	28.84	4555	43.40	3725.4	29.22	50.04	7920	43.84	2607.4
3A	50.72	27.70	4005	41.68	3811.5	28.30	52.90	9620	49.20	2948.2
4A	51.18	25.84	3560	42.19	4708.8	26.08	50.50	8050	49.02	3340.3
5A	51.14	25.16	4525	56.61	5407.1	25.48	50.64	9790	60.68	3658.4

According to the data from the group of 1A/2A/3A/5A, the results showed that fiberglass mesh had the enhancement effect on glulam. The effect of Modulus of Rupture and Modulus of Elasticity was enhanced more than two times with the vertical loading method and the enhancement effect of single fiberglass mesh was the worst. What's more, the enhancement effect of fiberglass mesh on fracture load, Modulus of Rupture and Modulus of Elasticity were not obvious with the parallel loading method.

According to the data from the group of 1A/2A/4A/5A, the results showed that aluminum foil had the enhancement effect on glulam. The effect of Modulus of Rupture and Modulus of Elasticity was enhanced more than two times with the vertical loading method and the enhancement effect of single aluminum foil was the worst. What's more, the enhancement effect of aluminum foil on fracture load, Modulus of Rupture and Modulus of Elasticity were not obvious with the parallel loading method.

Aforementioned results and analysis showed the enhancement effect of fiberglass mesh and aluminum foil were not obvious with the parallel loading method. Besides, the enhancement effect of single fiberglass mesh or single aluminum foil was worse than their composite enhancement effect. At the same time, different assembling pattern of fiberglass mesh and aluminum foil resulted in different enhancement effect. Table 2 showed that the best assembling pattern was 5A group which was the central seven layers eucalyptus veneers with criss-cross assembling structure, the outer three layers eucalyptus veneers with paralleled assembling structure and fiberglass mesh and aluminum foil interval placed among every two veneers.

3.2 Finite Element Analysis and Verification of Glulam

Verifying the rationality of specimen model and composite mode by comparison between the load and the deformation of the specimen in the whole test process with the specimen size and loading conditions same to the experiment. And the wood had the anisotropic characteristic while the other experimental materials were adopted isotropic characteristic.

(1) The project options of wood and epoxy adhesive

The anisotropic characteristic of wood: Young modulus of $E1=E2=E3$=10000Mpa; Poisson's ratio of $NU12=NU13$=0.4, $NU23$=0.04; Shear modulus of $G12=G13$=100, $G23$=50

The isotropic characteristic of epoxy adhesive: Young modulus of E=1000000Mpa, Shear modulus of $G1=G2$=1000000, Viscosity coefficient of $\mu=1.0\times e^{-5}$.

(2) Constitutive relation of fiberglass mesh showed in Fig.3.

The isotropic characteristic of fiberglass mesh: Young modulus of E=7000Mpa; Poisson's ratio of NU=0.22.

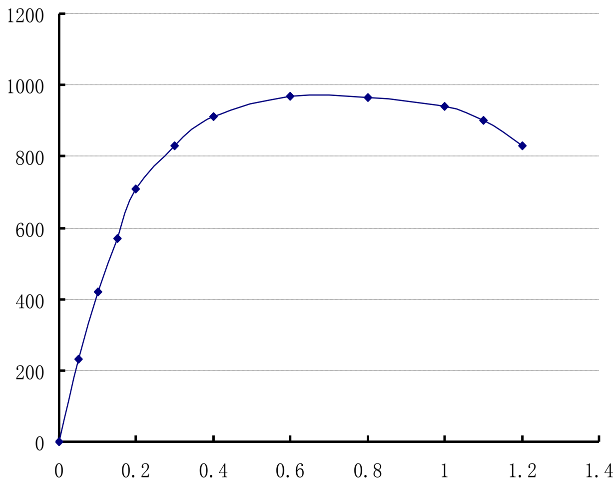


Fig. 3. The Constitutive relation of fiberglass mesh

(3) Constitutive relation of aluminum foil showed in Fig.4.

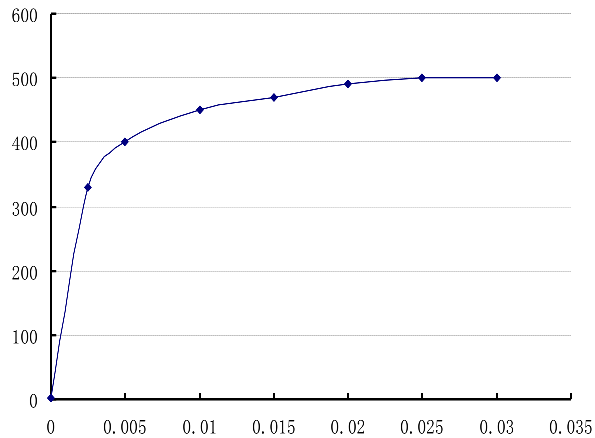


Fig. 4. The Constitutive relation of aluminum foil

As the damage of specimen mainly happened on stress concentration parts of mid-span and support point, the specimen model was divided into Five sections (in Fig.5), and the end and mid-span accounted for 1/10 of each specimen with thinner unit, while other parts with relative larger unit to improve the accuracy and speed of numerical analysis.

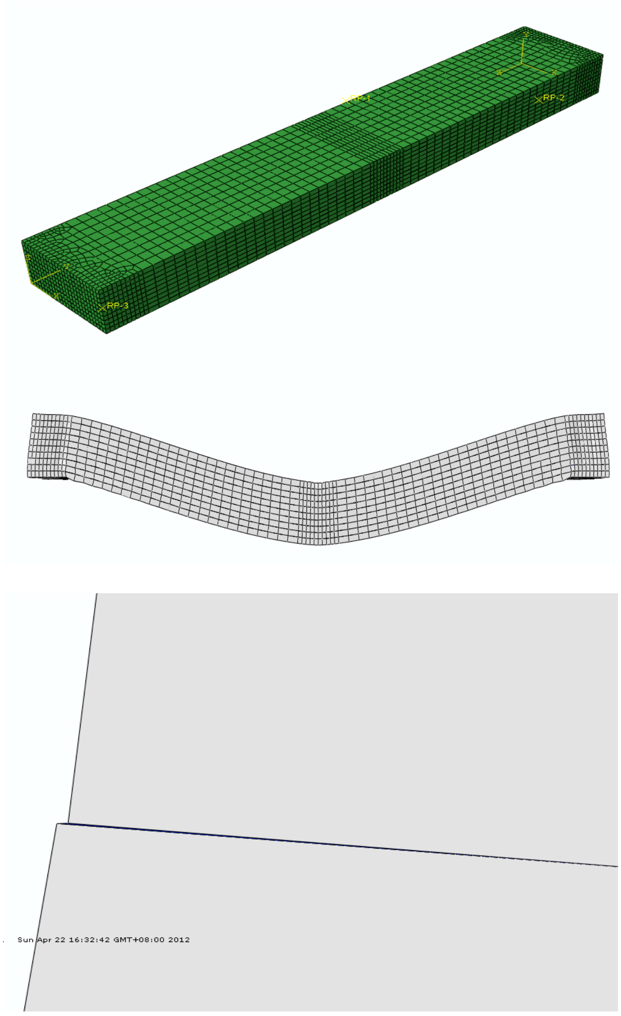


Fig.5. Component stress unit

(5) The comparison between experiment results and simulation results

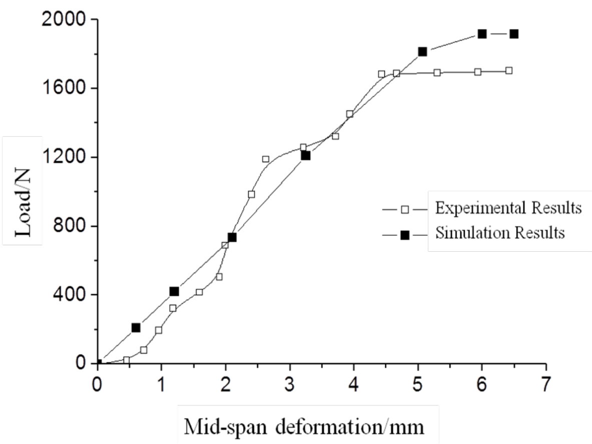


Fig.6. The curve between the load and mid-span deformation of group 2A with vertical loading method

The process and results of the specimen and the simulation model with the vertical loading and the parallel loading method was shown in Fig.6 and Fig.7, respectively. The experimental results from loading to yielding, to specimen failure formed the curve between the load and mid-span deformation which had some fluctuation, which resulted from the damage of wood and reinforcing materials were gradually and the redistribution of internal force. The finite element numerical simulation results were relatively ideal. The comparison of the curve between the load and mid-span deformation showed that numerical simulation results and experimental results were basic coincide. Especially the relative error of ultimate bearing capacity and ultimate deformation is small. The results indicated that the specimen model was feasible and rational which can be used for choosing the better composite mode of the enhanced glulam.

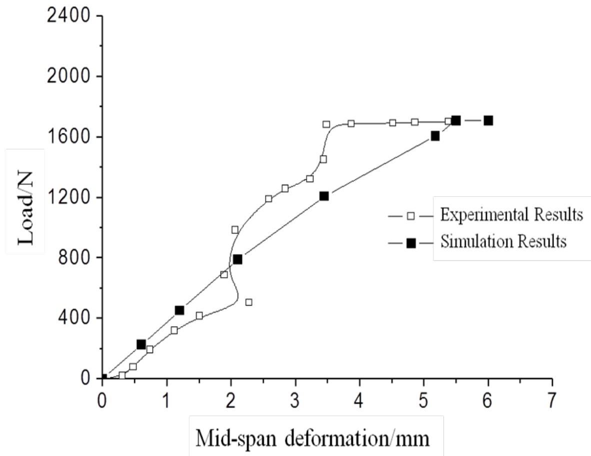


Fig. 7. The curve between the load and mid-span deformation of group 2A with parallel loading method

4. Conclusions

The comparison between experiment results and simulation results shows that the specimen model was feasible and rational for choosing the better composite mode and forecast the mechanical properties of glulam made up of plantation eucalyptus veneers with the reinforced materials of fiberglass mesh and aluminium foil.

The best enhanced composite structure of glulam is the central seven layers eucalyptus veneers with criss-cross assembling structure, the outer three layers eucalyptus veneers with paralleled assembling structure and fiberglass mesh and aluminum foil interval distributed among every two veneers.

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