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Experimental Development of a Molded Wood-Particle/Epoxy Composite Beam.

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Abstract

This study presents a preliminary experimental investigation of a molded wood-particle/epoxy composite beam intended as an early-stage material-development concept for beam-like timber elements. Plane tree (Platanus) wood particles were combined with chopped strand mat (CSM) fiber-reinforced polymer and one of two epoxy resin–hardener systems. Three individual beams were evaluated under point loading: one solid plane tree wood reference beam, one composite beam using Type 1 epoxy, and one composite beam using Type 2 epoxy. The beams had a nominal cross-section of 100 × 100 mm and an overall fabricated length of 1000 mm; the clear support span during testing was 650 mm. The maximum applied loads were 30.0 kN for the solid wood beam, 16.3 kN for the Type 1 composite, and 8.7 kN for the Type 2 composite. Only one specimen was tested for each condition, these values are descriptive rather than statistically representative. The Type 1 composite showed a more gradual visible deformation response before failure than the Type 2 composite, but load–deflection data were not available and therefore no quantitative ductility parameter is reported. The results suggest that the tensile and elongation characteristics of the epoxy system may be important variables for further optimization; however, the present study does not isolate the effects of epoxy formulation, fumed silica, or CSM independently. The work is therefore positioned as a preliminary exploratory study rather than a structural-design validation.

Keywords: Wood; wood-particle composite; epoxy resin; timber; chopped strand mat; FRP; flexural behavior; molded composite.

1. Introduction

Wood-based composite materials are increasingly investigated as alternatives to conventional structural materials because they can combine renewable wood

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resources with engineered binders and reinforcement systems. Engineered wood products and wood–polymer composites also provide opportunities to use wood particles that would otherwise have limited direct structural value. In parallel, fiber-reinforced polymer (FRP) systems have been investigated for improving the flexural performance of timber members, with bonding quality and reinforcement configuration identified as important variables [1,2].

The concept underlying the present work is related to future additive or mold-based fabrication of beam-like timber elements. A previous conceptual study proposed the use of wood particles, chopped fiber reinforcement, and epoxy-based adhesives for 3D-printed wooden structures, while a subsequent preliminary experimental study examined the axial compression behavior of molded wood-particle/epoxy specimens [3,4]. The present work extends that early material-development effort to a beam-scale point-loading test.

In this manuscript, the term “molded” is used because the wood-particle/epoxy mixture was placed into a mold to form the beam. The present study does not evaluate extrusion, printability, buildability, layer bonding, or other additive-manufacturing parameters. Any relationship to additive manufacturing is therefore prospective: the results are intended to inform future material optimization rather than to demonstrate a printable structural material.

The specific objective was to obtain an initial experimental comparison between a solid plane tree wood beam and two wood-particle composite beams produced with different epoxy systems. The study focuses on maximum point-load capacity and observed failure behavior. Because the experimental program contains one specimen per condition, the results are explicitly treated as preliminary and non-statistical.

2. Wood particles:

Plane tree (Platanus) wood was used as the raw material. One portion of the wood was retained for fabrication of the solid reference beam, while the remaining material was processed into particles. The particles were separated into two nominal groups. The larger particles were approximately 13 × 13 × 13 mm and 10 × 10 × 10 mm, while the smaller particles were approximately 8 × 8 × 8 mm and 6 × 6 × 6 mm. The reported moisture content was 12%, the unit weight was approximately 500 (unit as recorded in the original experimental data), and the reported compression strength parallel to grain was 34.94 MPa.

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Figure 1. Wood particles used in the composite mixture.

3. Chopped strand mat reinforcement

Chopped strand mat (CSM) was incorporated into both composite mixtures. The CSM was cut into pieces approximately 5 mm long. The total CSM mass incorporated into each composite formulation was 0.25 kg. The reported tensile strength of the CSM was 100 MPa. Because both composite beams contained CSM and no otherwise identical composite beam without CSM was tested, the independent contribution of CSM cannot be quantified from the present experimental program.



Figure 2. Chopped strand mat (CSM) used as fiber reinforcement.

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4. Epoxy Resin and Hardener Systems

Two epoxy resin–hardener systems were investigated. Type 1 was Epomax Liquid Glass and Type 2 was Epomax-L10. The manufacturer-reported properties used in the experimental program are summarized in Table 1. The two systems differed substantially in tensile strength and elongation at break, while Type 2 had higher reported compressive and flexural strength. Fumed silica was added to the Type 2 mixture to modify its formulation and reduce elongation. The present data do not permit the individual effect of fumed silica to be separated from the other differences between the two epoxy systems.

Table 1. Epoxy resin and hardener

Type	Mixing ratio	Tensile strength (MPa)	Compressive strength (MPa)	Flexural strength (MPa)	Elongation at break (%)
1	100:58	42	60	50	14
2	100:23.5	25.7	70	63	2.2



Figure 3. Epomax Liquid Glass epoxy resin and hardener.

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Figure 4. Epomax-L10 epoxy resin and hardener.

5. Composite formulation and specimen fabrication

The wood-particle proportion was kept constant between the two composite formulations. The small-to-large particle ratio was 1:2. The epoxy resin and hardener together represented 35% of the stated composite mixture volume, while the FRP-to-epoxy resin-and-hardener ratio was reported as 8.3%. The practical wood-particle volume calculated for one 100 × 100 × 1000 mm test span was 6,500,000 mm³. The particle-volume breakdown used in the original experimental program is given in Table 2.

Table 2. Total practical wood volume for one beam (mm^3)

Small Parts	
Size (mm)	Volume (mm^3)
8	1238095.2
6	928571.4
Small Parts Total Volume	**2166666.6**
Large Parts	

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Size (mm)	Volume (mm^3)
13	2449275.34
10	1884057.95
Large Parts Total Volume	**4333333.3**
Total Volume of Wooden Particles	**6500000**

The wood particles, CSM pieces, epoxy resin, and hardener were mixed and placed into a mold to form the composite beam. The use of a mold is the basis for the terminology “molded wood-particle/epoxy composite beam” adopted in the revised title. No additive-manufacturing process was used in the present experimental program.



Figure 5. Solid wood beam.



Figure 6. Composite wooden beam made with epoxy resin and hardener type 1.



Figure 7. Composite wooden beam made with epoxy resin and hardener type 2.

6. Experimental program and loading configuration

Three individual beams were tested: one solid plane tree wood reference beam, one composite beam with Type 1 epoxy, and one composite beam with Type 2 epoxy. All beams had a nominal cross-section of 100 × 100 mm and an overall fabricated length of 1000 mm. During testing, the clear support span was 650 mm. The 650

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mm dimension reported in the original comparison table therefore refers to the clear span rather than the total fabricated beam length.

The specimens were tested in a Universal Testing Machine under a point-load configuration. The photographs show the load applied approximately at midspan between the supports. For the revised calculations, the 650 mm clear span and central point-load assumption are used. The original experimental record does not provide a numerical crosshead/loading rate or loading-nose dimension; these parameters are therefore not estimated or invented in the present revision. The limitation is explicitly recorded for reproducibility in future testing.

The nominal maximum bending stress was calculated for the central point-load configuration using:

$$\sigma = 3PL / (2bd^2)$$

where σ is the nominal maximum bending stress, P is the maximum applied point load, L is the 650 mm clear span, b is the beam width (100 mm), and d is the beam depth (100 mm). These calculated values are descriptive nominal stresses based on the documented geometry and loading assumption; they should not be interpreted as statistically established material properties or design values.



Figure 8. Solid wood beam under point load.

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Figure 9. Composite wooden beam with type 1 epoxy resin and hardener under point load.



Figure 10. Composite wooden beam with type 2 epoxy resin and hardener under point load.

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7. Experimental Test Results and Discussion

7.1 Maximum load and nominal flexural stress

The solid wood reference beam reached the highest maximum point load, 30.0 kN. The Type 1 composite reached 16.3 kN, whereas the Type 2 composite reached 8.7 kN. Under the central point-load assumption described above, the corresponding nominal maximum bending stresses are 29.25, 15.89, and 8.48 MPa, respectively. The Type 1 composite therefore reached approximately 54.3% of the maximum load of the solid wood reference, while the Type 2 composite reached approximately 29.0%.

Table 3. Maximum load and nominal flexural stress

Specimen	Epoxy	Overall length (mm)	Clear span (mm)	Cross-section (mm)	Maximum load (kN)	Nominal max. bending stress (MPa)	Observed failure / response
Solid wood reference	—	1000	650	100 × 100	30.0	29.25	Bearing damage followed by bottom-side flexural cracking
Composite	Type 1	1000	650	100 × 100	16.3	15.89	Large crack development; more gradual visible deformation before failure
Composite	Type 2	1000	650	100 × 100	8.7	8.48	Flexural failure with comparatively brittle response

Only one specimen was tested for each condition. Accordingly, no mean values, standard deviations, confidence intervals, significance tests, or statistical comparisons are reported. The values in Table 3 are individual experimental observations and should be interpreted as evidence of behavior trends rather than generalized population properties.

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Figure 11. Solid wood beam flexure failure under point load.

7.2 Failure behavior and interpretation of epoxy effects

The solid wood beam showed bearing damage before the final flexural failure, followed by cracking on the lower side of the beam. The observed sequence is consistent with a beam response in which local bearing damage develops before the final flexural crack. Because only one solid-wood specimen was tested, the observation is descriptive and should not be generalized to all plane tree beams.

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Figure 12. Composite wooden beam with type 1 epoxy resin and hardener flexure failure under point load.

The Type 1 composite beam reached 16.3 kN. Compared with the Type 2 beam, the Type 1 specimen showed a more gradual visible deformation response before failure. The original test program did not include load–deflection or strain measurements; therefore, the present study does not quantify ductility or establish a plastic stage. The difference is described only as an observed deformation trend.

The higher load capacity of the Type 1 specimen is plausibly associated with the higher tensile strength and elongation at break of its epoxy system relative to Type 2. However, the two formulations also differ in mixing ratio and formulation, and Type 2 additionally contained fumed silica. Because there was one specimen per condition and no factorial control of these variables, the present results cannot establish a single causal mechanism. Replicated experiments with controlled resin formulation, elongation, tensile properties, and fumed-silica content are required to isolate these effects.

Both composite beams used CSM. Consequently, the present experiment cannot demonstrate that CSM itself was ineffective compared with an unreinforced

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composite. The appropriate conclusion is narrower: in the tested configuration, CSM reinforcement was insufficient to prevent substantial cracking or to achieve the maximum load of the solid wood reference beam. Future work should compare CSM, GFRP, and CFRP using otherwise identical composite formulations.



Figure 13. Composite wooden beam with type 2 epoxy resin and hardener flexure failure under point load.

The Type 2 composite beam reached 8.7 kN. Its epoxy system had lower tensile strength and substantially lower elongation at break than Type 1. The observed lower beam capacity is consistent with the possibility that the lower tensile/elongation response of the binder system contributed to earlier cracking and failure. Nevertheless, because the formulation variables were changed simultaneously, the effect cannot be assigned uniquely to fumed silica or to tensile strength alone. The reported compressive strength of the epoxy system is also not sufficient to explain the beam response because flexural behavior involves combined tension, compression, shear, and interfacial bonding mechanisms.

8. Limitations of the study

This investigation is intentionally preliminary. The principal limitations are: (1) only one beam was tested for each condition; (2) no inferential statistical analysis is

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possible; (3) the original experimental record does not contain a numerical loading rate or loading-nose dimension; (4) load–deflection and strain data were not recorded in the available test documentation; (5) the independent effects of CSM, fumed silica, epoxy tensile strength, elongation, and bonding quality were not isolated through a factorial experimental design; and (6) durability, moisture sensitivity, creep, fire performance, and long-term bond behavior were not evaluated.

Accordingly, the results should not be used directly for structural design or for claims of code-level material performance. The present contribution is limited to an initial comparison of three individual beam specimens and identification of variables that warrant controlled follow-up testing. Future work should include replicated specimens, controlled material formulations, documented loading rate and displacement measurement, standardized flexural testing, moisture conditioning, durability assessment, and longer-term mechanical evaluation.

9. Conclusions

A preliminary experimental investigation of molded wood-particle/epoxy composite beams was presented. Three individual specimens were compared: a solid plane tree wood reference beam and two composite beams using different epoxy systems. The overall fabricated beam length was 1000 mm, while the clear test span was 650 mm and the nominal cross-section was 100 × 100 mm.

The solid wood beam reached 30.0 kN, the Type 1 composite reached 16.3 kN, and the Type 2 composite reached 8.7 kN. Under the central point-load assumption and 650 mm clear span, the corresponding nominal maximum bending stresses were approximately 29.25, 15.89, and 8.48 MPa. These values are individual observations and are not statistically generalizable.

The Type 1 composite showed a more gradual visible deformation response than the Type 2 composite, but quantitative ductility cannot be established because load–deflection data were not available. The higher performance of Type 1 is plausibly related to its higher tensile strength and elongation at break, but the present experiment cannot isolate these effects from other formulation differences, including fumed silica in Type 2.

Because both composite beams contained CSM and no CSM-free control was tested, the experiment does not establish the independent effectiveness of CSM. In the tested configuration, CSM was insufficient to prevent substantial cracking or to match the load capacity of solid wood. Future experiments should compare reinforcement types and binder formulations using replicated specimens and controlled variables.

Overall, the material system should be regarded as an early-stage exploratory composite rather than a validated structural beam material. The results provide a

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basis for further optimization of particle size, binder chemistry, fiber architecture, bonding, and processing before any structural application is considered.

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