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Numerical Analysis of Composite Bracket Joints Used in Glue Laminated Timber Bridges

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ABSTRACT:Glued laminated timber, also abbreviated glulam, is a type of structural engineered wood product constituted by layers of dimensional lumber bonded together with durable, moisture-resistant structural adhesives. In North America, the material providing the laminations is termed laminating stock or lamstock. By laminating a number of smaller pieces of lumber, a single large, strong, structural member is manufactured from smaller pieces. These structural members are used as vertical columns, horizontal beams, and arches. Glulam are readily produced in curved shapes and are available in a range of species and appearances.[1] Connections are usually made with bolts or steel dowels and steel plates. This paper mainly determines the comparison of weight and strength between the steel bracket and different types of composite brackets like Fiber Reinforced Polymers (FRP), PrePreg (PP) and Short Fiber Composite (SFC). The analysis is done using ABAQUS software.

KEYWORDS: Glulam, Short Fiber Composite, PrePreg, Fiber Reinforced Polymers, Lumber

I. INTRODUCTION

Glued laminated timber, also abbreviated glulam, is a type of structural engineered wood product constituted by layers of dimensional lumber bonded together with durable, moisture-resistant structural adhesives. In North America, the material providing the laminations is termed laminating stock or lamstock. Glulam optimizes the structural values of wood. Because of their composition, large glulam members can be manufactured from a variety of smaller trees harvested from second-growth forests and plantations. Glulam provides the strength and versatility of large wood members without relying on the old growth-dependent, solid-sawn timbers. As with other engineered wood products, it reduces the overall amount of wood used when compared to solid-sawn timbers by diminishing the negative impact of knots and other small defects in each component board.Glulam has much lower embodied energy than reinforced concrete and steel, although it entails more embodied energy than solid timber.However, the laminating process allows the timber to beused for muchlonger spans, heavier loads, and more complex shapes than reinforced concrete or steel.

Glulam is one tenth the weight of steel and one sixth the weight of concrete; the embodied energy to produce it is one sixth of that for a comparable strength of steel. Glulam can be manufactured to a variety of shapes, so it offers architects artistic freedom without sacrificing structural requirements. The high strength and stiffness of laminated timbers enable glulam beams and arches to span large distances without intermediate columns, allowing more design flexibility than with traditional timber construction. The size is limited only by transportation and handling constraints. Glulam is made of dimensional lumber; trued, finished and glued on the faces; with the grain laying parallel to layers above and below. The individual lumber is selected and positioned according to defects and grain structure to maximize structural integrity. It can be made for straight, cambered and bent/arch applications, and other arrangements.It is available in standard dimensional and custom sizes.

Glulam pedestrian bridge

The type of raw material using here for the glue laminated timber bridge is the Douglas fir wood. The Douglas wood is an evergreen conifer species in the pine family. It is native to western north America. It is also known as Douglas spruce, Oregon pine and Columbian pine. Douglas firs are medium-size to extremely large evergreen trees, 20–100 meters. It is one of the finest timbers for heavy structural purposes including glulam beams and roof trusses.Commonly, Douglas fir is a species of softwood, but it is also considered to be one of the widely used types of lumber, especially in fencing, home construction and decking in the United States. It is also popular due to its perfect proportion of weight and strength.It is known for its dimensional strength, it resists natural elements such as strong wind, storms and earthquakes. It is also known as the toughest Western softwood and is very easy to mold.

Douglas fir wood lumber

ANALYSIS OF COMPOSITE BRACKET

The bracket connection is made using the composite brackets to avoid the corrosion problems when these are constructed across the water bodies like rivers, swimming pools, etc. The composite bracket is analyzed with 2 number of bolts and 3 mm thickness. The strength and weight of the structure is determined with the specifications shown in table.

Dimension and loading specifications

Specifications	Value
Bridge length	55 m
Distance between consecutive cable	6 m
No. of primary load bearing members	2
Pedestrians load	4.07 kPa
Load on each beam	2.035 kPa

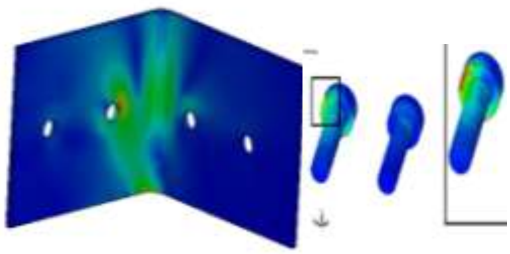
Analysis of Fiber Reinforced Polymer (FRP)

The first composite material we are using is the Fiber Reinforced Polymer (FRP). The bracket is designed with different specifications given below. The stress value on the bracket, bolt and the member as a whole is determined. The maximum load carrying capacity on the bracket is also found out by using explicit analysis method. It is found out by using a stress vs time graph.

Specifications of Fiber Reinforced Polymer

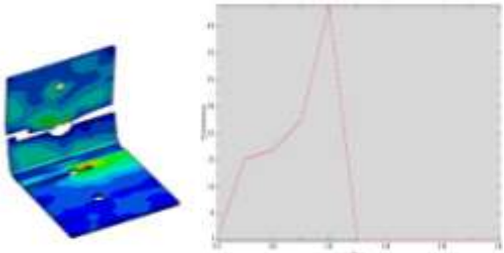
Parameters	Value	Unit
Tensile strength	77.22	MPa
Yield strength	137	MPa
Modulus of elasticity	210	GPa
Poisson's ratio	0.3	
Density	1300	Kg/m^3

A uniformly distributed load is a force that is applied evenly over the flange of a structural member. The von mises stress is determined in the bracket and the maximum stress was found near the bolt hole. The behavior of the bolt was also analyzed and the maximum stress was in the bolt head. The model was designed and analyzed using ABAQUS software.



Stress on bracket **Stress on bolt**

The maximum value of stress on the bracket is 80 N/mm^2 and on the bolt is 50 N/mm^2. So, the stress in the member as a whole is 80 N/mm^2. The next figure shows the explicit analysis and stress vs time graph on FRP.



Explicit analysis and Stress Time graph on FRP

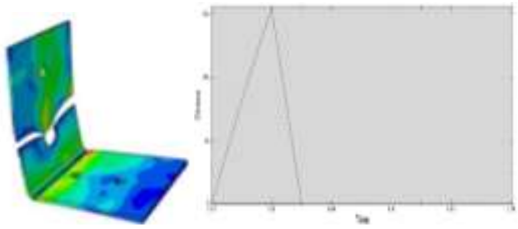
The load applied on the bracket is 10000 N. The maximum load carrying capacity of the bracket is obtained by multiplying it with the failing load from the graph and it is 4000 N. The volume is obtained directly from the software and it is 140644.75 m^3. The weight is obtained by multiplying the volume with the density from the specifications and it is 0.183 kg.

Analysis of PrePreg (PP)

The next composite material we are using is Prepreg (PP). The bracket is designed with different specifications given below. The maximum load carrying capacity on the bracket is found out by using explicit analysis method. It is found out by using a stress vs time graph.

Specifications of PrePreg

Parameters	Value	Unit
Tensile strength	4137	MPa
Yield strength	827.4	MPa
Modulus of elasticity	138	GPa
Poisson's ratio	0.23	
Density	181	Kg/m^3



Explicit analysis and Stress Time graph on PP

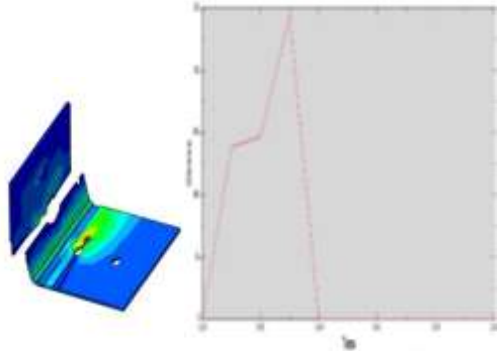
Next figure shows the explicit analysis and stress vs time graph on PP material. The load applied on the bracket is 10000 N. The maximum load carrying capacity of the bracket is obtained by multiplying it with the failing load from the graph and it is 2000 N. The volume is obtained directly from the software and it is 140644.75 m^3. The weight is obtained by multiplying the volume with the density from the specifications and it is 0.255 kg.

Analysis of Short Fiber Composite (SFC)

The next composite material we are using is Short Fiber Composite (SFC). The bracket is designed with different specifications is given below. The maximum load carrying capacity on the bracket is found out by using explicit analysis method. It is found out by using a stress vs time graph.

Specifications of Short Fiber Composite

Parameters	Value	Unit
Tensile strength	3310	MPa
Yield strength	662	MPa
Modulus of elasticity	68.9	GPa
Poisson's ratio	0.276	
Density	254	Kg/m^3



Explicit analysis and Stress Time graph on SFC

The next figure shows the explicit analysis and stress vs time graph on SFC material. The load applied on the bracket is 10000 N. The maximum load carrying capacity of the bracket is obtained by multiplying it with the failing load from the graph and it is 3000 N. The volume is obtained directly from the software and it is 140644.75 m^3. The weight is obtained by multiplying the volume with the density from the specifications and it is 0.36 kg.

Comparison of results

Material	Load (N)	% Decrease in load	Weight (N)	% Increase in weight
FRP	4000	-	0.183	-
PP	2000	50 %	0.255	39.34
SFC	3000	25%	0.36	96.72

II. CONCLUSIONS

The best material that is suitable for the construction of joints in glue laminated timber bridges is selected based on the higher load carrying capacity and less weight. From the above analysis, it is clear that FRP material is having higher load carrying capacity when compared with PP and SFC. There was a decrease of 50 % and 25 % load carrying capacity for PP and SFC respectively. Also, the weight of FRP material is low. There is an increase of 39.34 % and 96.72 % of weight for PP and SFC respectively when compared with FRP. Therefore, the best material for the construction is FRP.

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