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NUMERICAL ANALYSIS ON STRENGTHENING OF WOODEN FLOOR WITH COMPOSITES

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Abstract - Composite flooring mechanism is introduced to reduce the wood composites in wooden floor. Deformation and stress in wood composite mechanism is analysed by varying depth by using ANSYS 18.1. Yellow Poplar, Eastern White Pine and Douglas Fir are used as wooden panel materials. Different composite arrangement with wooden laminates such as Carbon Fiber Reinforced Polymer (CFRP), Glass Fiber (GF) and Polyethylene are used. From these worst perform wood under standard floor load by US code (40 psf) is identified.

Result showed that Yellow Poplar wood - Glass Fiber with 10mm panel width on top and bottom with Glass Fiber 20mm that possess optimal arrangement. It consumes 80.208 % less wood compared to conventional wooden floors. Modelling a wooden structure and introducing this wooden panel and identify the stress at joints. Here induced yield strength is very much less than the yield stress of wood. The use of wood with composites the wood consumption is saved and to easy to replace. From these arrangements it will lo carry load and structure remains stable.

Key Words: *Composite flooring, CFRP, Glass Fiber, ANSYS*

1. INTRODUCTION

Wood flooring is any type of permanent floor that has the appearance of wood, whether it is made out of natural or synthetic lumber. Wood is a versatile flooring material that comes in a number of styles, colours, and species. There are two main types of wood flooring, which are solid wood and engineered wood. Solid wood flooring is made from solid planks of lumber. Engineered wood flooring has a lumber veneer over a synthetic, reinforced underlayment made of something other than wood. A building engineer is recognised as being expert in the use of technology for the design, construction, assessment and maintenance of the built environment. Commercial Building Engineers are concerned with the planning, design, construction, operation, renovation, and maintenance of buildings, as well as with their impacts on the surrounding environment Building material is any material used for construction purpose such as materials for house building. Wood, cement, aggregates, metals, bricks, concrete, clay are the most common type of building material used in construction. The choice of these are based on their cost effectiveness for building projects. Many naturally occurring substances, such as clay, sand, wood and rocks, even twigs and leaves have been used to construct buildings.

2. OBJECTIVE

- To find the deflection of wooden panels of Yellow poplar, Douglas fir and Eastern white pine under dead and live loads.
- To find stiffness to weight ratio of the floor.
- To find the strength of wooden panel with Carbon Fibre, Glass Fibers, Polyethylene composites by design modification.
- To design an optimal arrangement and material of structural members with less consumption of wood with higher strength.

3. METHODOLOGY

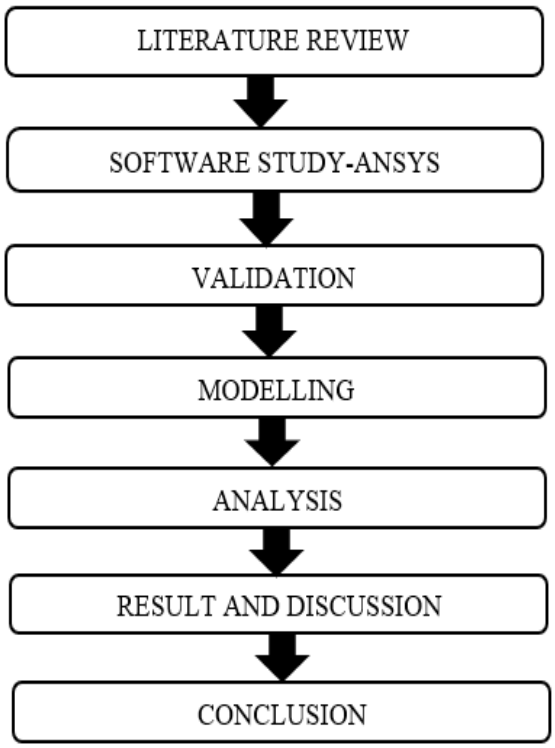

Fig.3.1 Flow chart showing methodology of the study

4. MODELLING

Wooden panel CLT of size 1500 x 1000 x 101.6 mm is modelled in ANSYS software. Materials such as CFRP, GF and Polyethylene are used for strengthening the wooden panel. Wood material properties are taken as orthotropic material properties. The properties are taken from the Wood Handbook reference. Material orientation directions for wood material are depicted in the Fig 4.1.

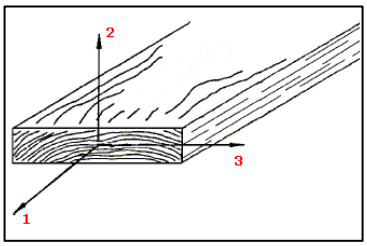

Fig. 4.1 Wood Material Orientation

Direction 1 is the longitudinal / fibre direction while 2 & 3 are the radial and transverse directions respectively. Properties of the materials used for modelling is shown in Table 4.1.

Table 4.1 Properties of wood

Wood	Properties									
	Young's Modulus (E) (MPa)			Poisson's ratio (ν)			Torsion (MPa)			Density (ρ) (Kg/m^3)
	E_1	E_2	E_3	V_{12}	V_{23}	V_{13}	G_{12}	G_{13}	G_{23}	
Yellow popular wood	8690	374	678	0.372	0.467	0.435	556	530	86	330
Douglas fir wood	12300	836	615	0.292	0.390	0.449	787	959	86	480
Eastern white pine	8158	700	341	0.329	0.410	0.344	466.6	430.7	44.9	340

Table 4.2 Properties of composites

Materials	Properties		
	Young's Modulus (E), (MPa)	Poisson's ratio (V)	Density (ρ), (Kg/m^3)
Carbon Fiber Reinforced Polymer	37000	0.33	1250
Glass Fiber	68900	0.183	2440
Polypropylene	200	0.4	895

Table 4.3 Model description

Model name	Model description
YP	Wooden Panel of Yellow Poplar material
EP	Wooden Panel of Eastern White Pine material
DF	Wooden Panel of Douglas Fir material
YPP70	Yellow Poplar wooden Panel with 70 mm depth
YPP95	Yellow Poplar wooden Panel with 95 mm depth
GYC95	Grid type panel of Yellow Poplar with CFRP (10 mm /75 mm/10 mm)
HYC95	Honey Comb type panel of Yellow Poplar with CFRP (10 mm /75 mm/10 mm)
WYG75	Wooden Panel of Yellow Poplar with Glass fiber (10 mm /75 mm/10 mm)
WYG40	Wooden Panel of Yellow Poplar with Glass fiber (10 mm /20 mm/10 mm)
WYP60	Wooden Panel of Yellow Poplar with Polyethylene (10 mm /40 mm/10 mm)
FYPGF	Framed structure with Yellow Poplar wood with Glass Fiber (20mm)

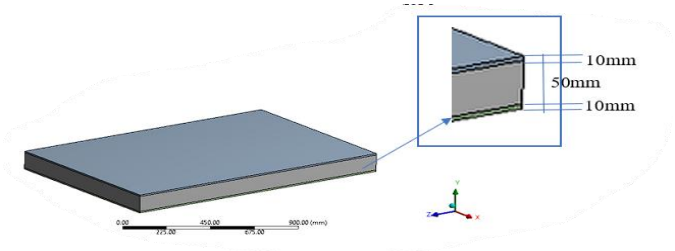

Fig. 4.2 Wooden Panel with 70 mm depth WP70

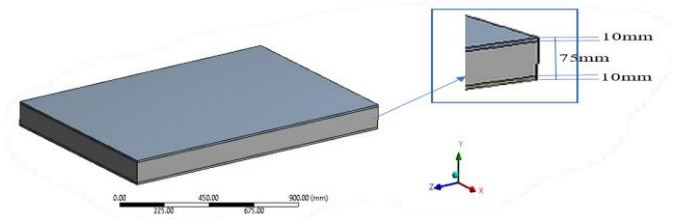

Fig. 4.3 Yellow Poplar wooden Panel with 95 mm depth (YPP95)

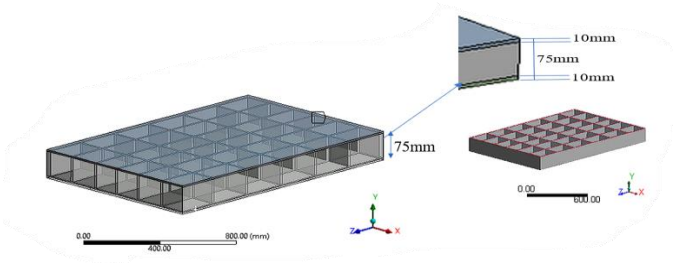

Fig. 4.4 Grid type panel of Yellow Poplar with CFRP (GYC95)

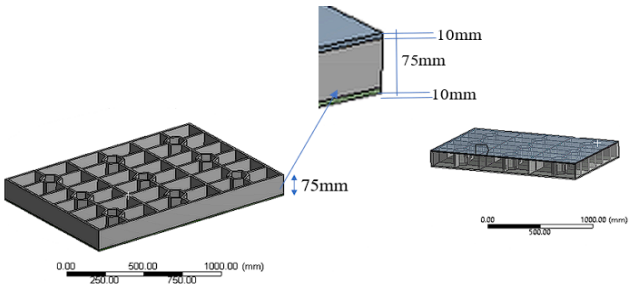

Fig. 4.5 Honey Comb type panel of Yellow Poplar with CFRP (HYC95)

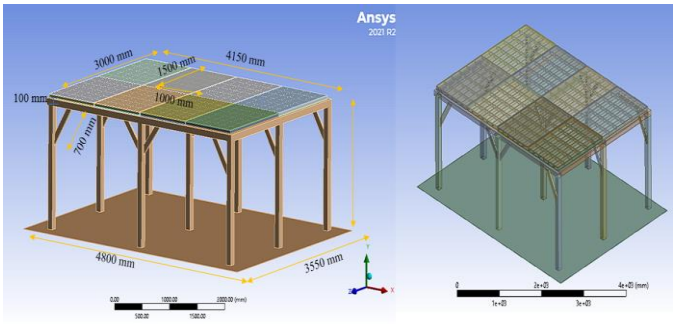

Fig. 4.6 Model of framed structure (FYPGF)

5. ANALYSIS

5.1 Analysis of wooden panel (CLT Analysis)

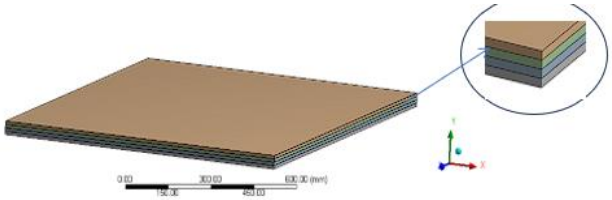

Fig. 5.1 Model of framed structure (FYPGF)

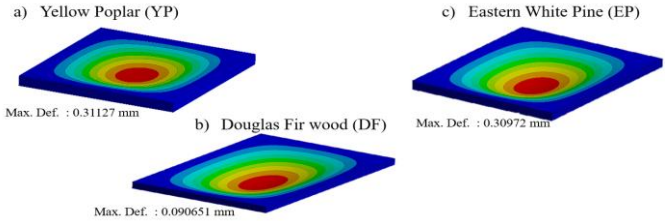

Fig. 5.2 Total deformation of various wooden panels (CLT)

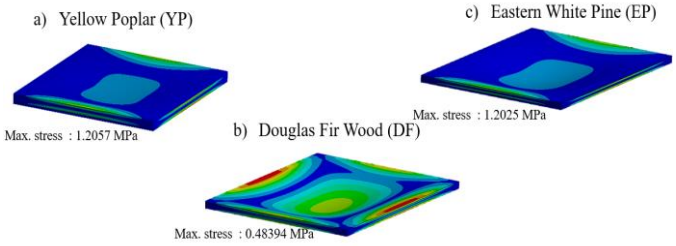

Fig. 5.3 Equivalent stress of various wooden panels (CLT)

Table 5.1 Results obtained from analysis of wooden panel

Model name	Total deformation (mm)	Maximum equivalent stress (MPa)
YP (28.8 Kg)	125.59	13.7
EP (56.76 Kg)	75.157	23.05
DF (48.36 Kg)	65.066	26.62

5.2 Analysis of Yellow Poplar panel to determine the depth

i. Yellow Poplar wooden Panel with 70 mm depth (YPP70)

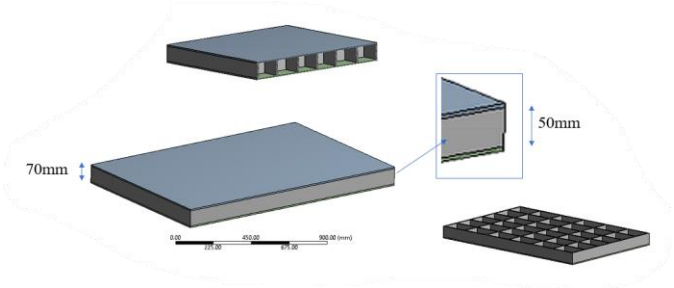

Fig.5.4 Model of WP70

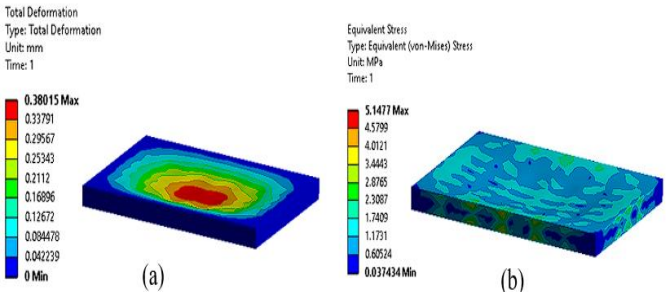

Fig. 5.5 WP70: (a) Total deformation (b) Equivalent stress

ii. Yellow Poplar wooden Panel with 95 mm depth (YPP95)

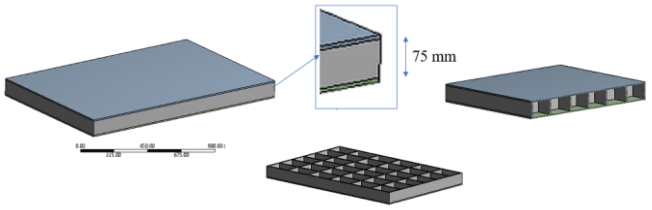

Fig.5.6 Model of WP95

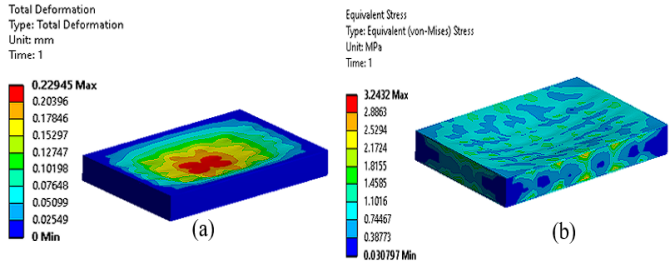

Fig. 5.7 WP95: (a) Total deformation (b) Equivalent stress

Table 5.2 Comparison of results of Yellow Poplar wooden frame varying depth

Model Name	Total deformation (mm)	Equivalent stress (MPa)
YPP70 (20.95 Kg)	0.38015	5.1477
YPP95 (25.734 Kg)	0.22945	3.2432

5.3 Analysis of Yellow Poplar panel with composites

i. Grid type panel of Yellow Poplar with CFRP (10 mm /75 mm/10 mm) (GYC95)

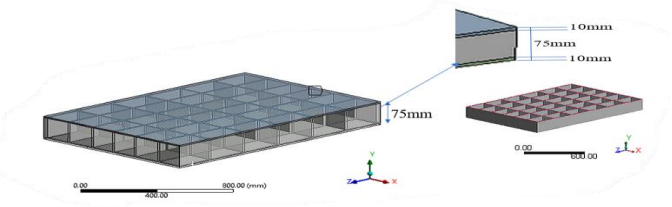

Fig.5.8 Model of GYC95

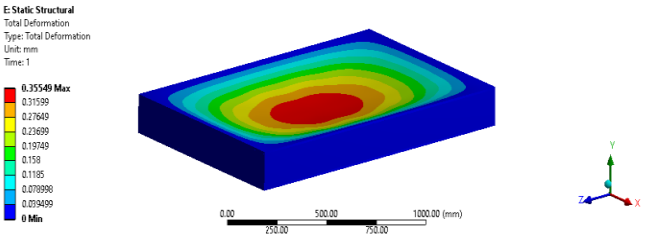

Fig. 5.9 Total deformation of GYC95

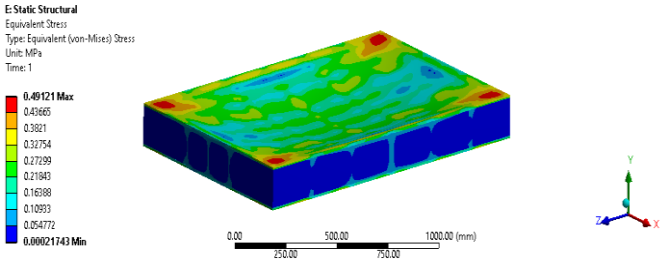

Fig. 5.10 Equivalent stress of GYC95

ii. Honey Comb type panel of Yellow Poplar with CFRP (10 mm /75 mm/10 mm) (HYC95)

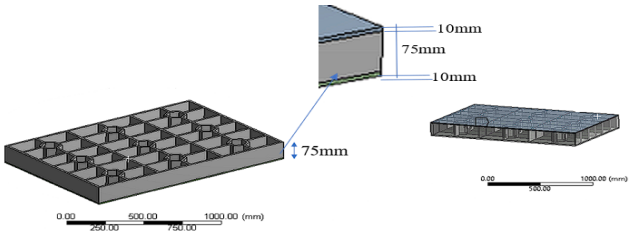

Fig.5.11 Model of HYC95

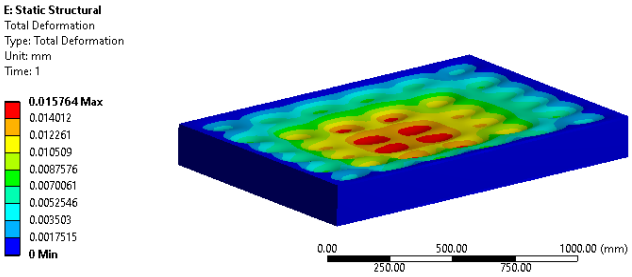

Fig. 5.12 Total deformation of HYC95

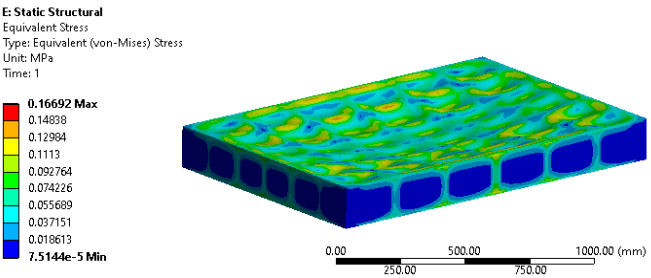

Fig. 5.13 Equivalent stress of GYC95

iii. Wooden Panel of Yellow Poplar with Glass Fiber (10 mm /75 mm/10 mm) (WYG95)

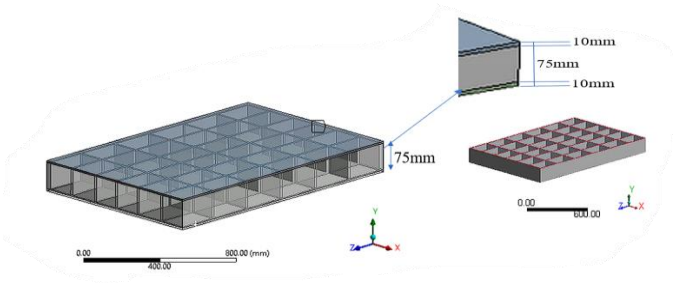

Fig.5.14 Model of WYG95

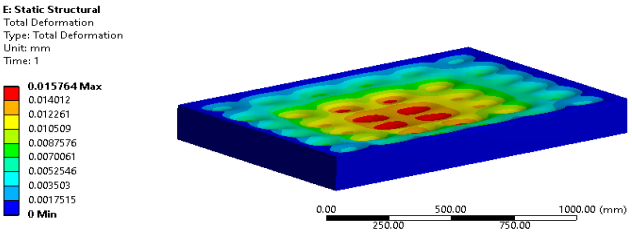

Fig. 5.15 Total deformation of WYG95

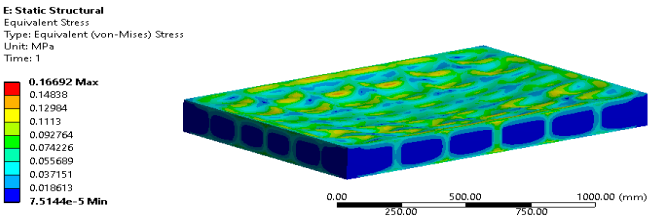

Fig. 5.16 Equivalent stress of WYG95

iv. Wooden Panel of Yellow Poplar with Glass Fiber (10 mm /20 mm/10 mm) (WYG40)

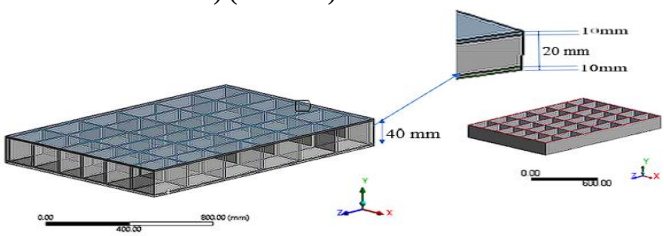

Fig.5.17 Model of WYG40

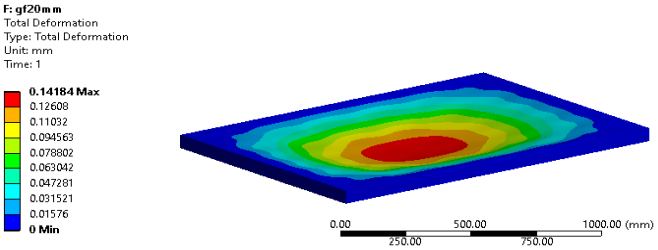

Fig. 5.18 Total deformation of WYG40

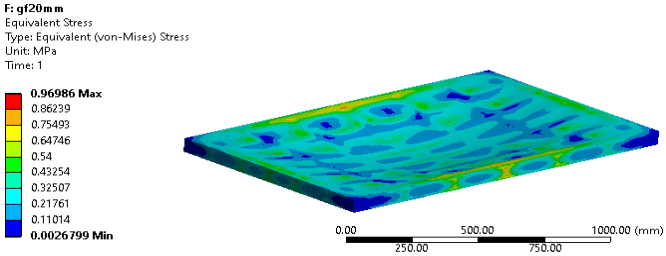

Fig. 5.19 Equivalent stress of GYC95

i. Wooden Panel of Yellow Poplar with Polyethylene (10 mm /40 mm/10 mm) (WYP60)

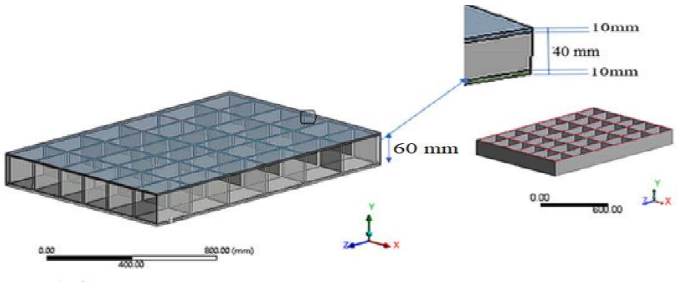

Fig. 5.20 Model of Wooden Panel of Yellow Poplar with Polyethylene (10 mm /40 mm/10 mm) (WYP60)

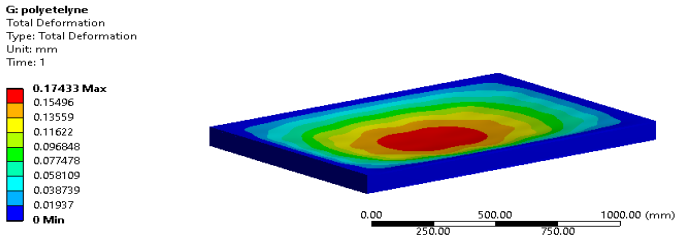

Fig. 5.21 Total deformation of WYP60

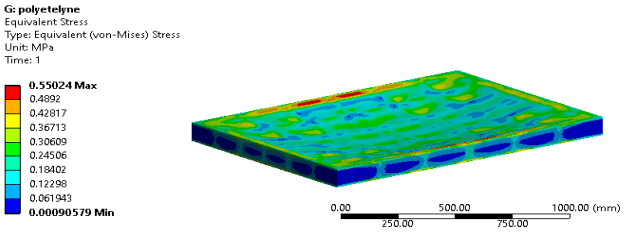

Fig. 5.22 Equivalent stress of WYP60

Table 5.3 Comparison of results Yellow Poplar wood and Composites

Model name	Total deformation (mm)	Equivalent stress (MPa)	Weight of Yellow Poplar wood (Kg)	Weight of composite (Kg)
GYC95	0.35549	0.49121	5.7	61.486
HYC95	0.34045	0.47253	5.7	61.486
WYG95	0.015764	0.16692	5.7	62.24
WYG40	0.14184	0.96986	5.7	16.597
WYP60	0.17433	0.55024	5.7	19.112

5.4 Analysis of framed structure by the combination of Yellow Poplar with Glass Fiber (FYPGF)

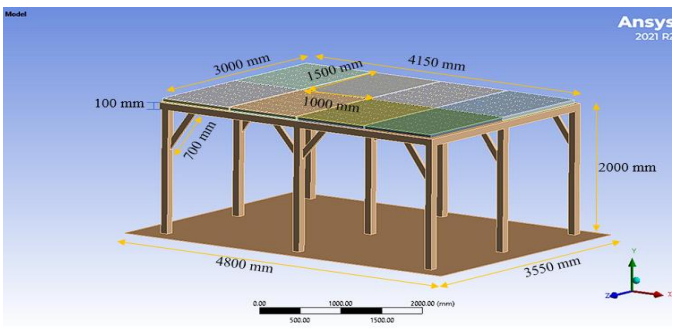

Fig. 5.23 Modelled FYPGF

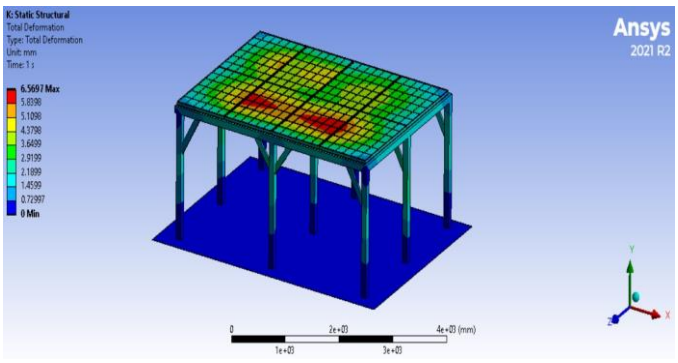

Fig. 5.24 Modelled FYPGF

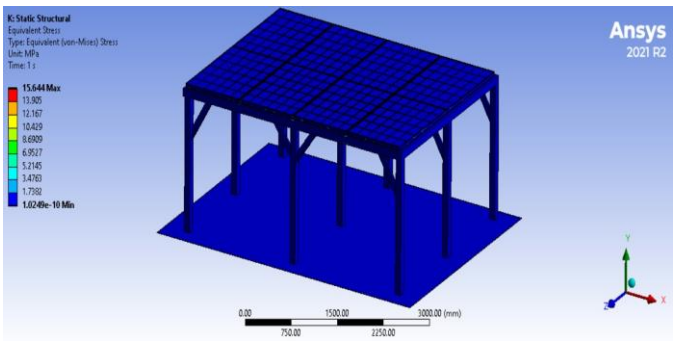

Fig. 5.25 Total deformation of FYPGF

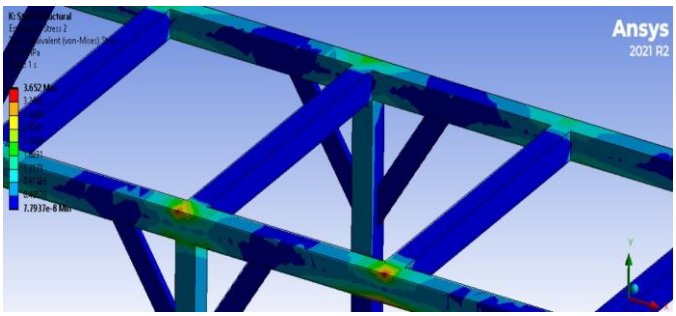

Fig. 5.26 Stress at joint FYPGF

6. RESULTS AND DISCUSSION

Wooden panels of Yellow Poplar, Douglas Fir and Eastern White Pine were analysed to examine the deformation, stress and weight. From the analysis of wood Yellow Poplar wood panel shows higher deformation of 0.31127mm and stress of 1.2057 that is low strength.

Table 6.1 comparison of wooden panels.

Material	Deformations (mm)	Maximum equivalent stress (MPa)	Weight of wood (Kg)
YP	0.31127	1.2057	28.8
DF	0.090651	0.48394	56.76
EP	0.30972	1.2025	48.36

An optimum model is attained by changing its depth.

Table 6.2 comparison of results of deformation wooden panels.

Model Name	Total deformation (mm)	Equivalent stress (MPa)
WP70	0.38015	5.1477
WP95	0.22945	3.2432

In order to increase the strength of Yellow Poplar panel by introducing the composites of CFRP, GF and Polyethylene. The depth of composite is varied, the depth of wooden panel is 10mm in each at top and bottom which shows the wood reduction. From this Yellow Poplar wood with Glass Fiber with 20mm thickness shows this less weight (16.597 Kg) is comparatively low and also the deformation (0.14184 mm). The deformation and weight of the structure is reduced. Table 6.3 shows the strengthened results of Yellow Poplar wood panel with the composites.

Table 6.3 Comparing the results of wood and Composites

Model Name	Total deformation (mm)	Equivalent stress (MPa)	Weight of Yellow Poplar (Kg)	Weight of composites (Kg)
GYC95	0.35549	0.49121	5.7	61.486
HYC95	0.34045	0.47253	5.7	61.486
WGF95	0.015764	0.16692	5.7	62.24
WGF40	0.14184	0.96986	5.7	16.597
WYP60	0.17433	0.55024	5.7	19.112

Table 6.4 Comparison of CLT panel and Yellow Poplar-Glass Fiber

Model Name	Deformation (mm)	Equivalent stress (MPa)	Stiffness (N/mm)	Weight of wood (kg)	Stiffness to weight	% of wood reduced
YP	0.31127	1.2057	0.3752	28.8	0.01303	80.208
WGF40	0.14184	0.96986	0.1375	5.7	0.0024	

Table 6.5 Comparison of wooden property with wooden frame

Stress for wooden frame structure (FYPGF)	Yield strength of wood
3.652 MPa	41.4 MPa

7. CONCLUSION

- CLT panel of Yellow Poplar wood shows an increase in deformation and increase in stress compared to CLT panels of Eastern White Pine and Douglas Fir woods.
- In Grid and Honey comb structure both shows a slight deformation and equal weight of the panel.
- Grid type is easier to install and construction than Honey comb structure.
- Glass fiber has high strength and stiffness when compared to composites of CFRP and Polyethylene.
- Combination of Yellow Poplar and Glass Fibre composites of 20mm panel thickness shows the maximum resistance to deflection.
- Deflection is controlled and the amount of weight is reduced which shows better results.
- Compared to normal consumption, 80.208 % of wood is reduced.
- It can be concluded that the combination of wood with Glass Fiber is effective in reducing deformation and increase the weight to strength ratio.
- By the property of the wood, the if the induced stress is greater than the yield strength of wood the structure become failure.
- Here, the Yield strength is very much lesser than wood yield strength that is 11.366 MPa < 41.4 MPa so there is no failure.

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