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Numerical Study of Structural and Modal Performance of Steel, Aluminium, Hybrid Jute-Polymer and CFRP for Lightweight Bus Flooring

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Abstract: Lightweight and structural efficient floor system is critical in enhancing the performance, fuel efficiency and the payload capacity of the modern passenger buses. This paper demonstrates a numerical exploration of the bus floor thickness optimization and efficiency in terms of metallic and composite materials under practical service loading. An SML compliant S7 bus platform (BS-VI) was taken as a reference model and a simplified ladder frame supported floor domain, which symbolizes realistic seating areas, was created in ANSYS Workbench. To simulate realistic load transfer, static structural simulations were conducted with a gravity-based passenger loading with the use of seat-support locations. Candidate materials were tested within the range of 10 to 50 mm thickness. Performance was measured in terms of the total deformation and equivalent stress. The findings imply that the thickness was a very significant factor on the stiffness response and high-modulus carbon-fiber laminates offer great reduction in weight and acceptable levels of deformation relative to traditional metallic floors. The methodology combines realistic geometry, support conditions, passenger loading, and thickness variation within a single finite element model. The results help identify lightweight, strong, and cost-effective materials for bus floor design.

1. Introduction

The literature on bus-floor and vehicle-floor structural systems has progressively evolved from conventional metallic frame assessment toward lightweight composite sandwich configurations and multi-objective thickness optimization. Across public-transit and rail- vehicle applications, the floor panel remains one of the most critical load-bearing structural members because it directly transfers passenger, seat, and interior service loads into the chassis support frame. Therefore, the key performance indicators repeatedly addressed in prior studies are total deformation, equivalent stress, stiffness-to-weight ratio, manufacturability, and overall cost feasibility.

The recent trend shows that composite materials and their hybrids are increasingly being used as alternatives to steel dominated floor systems in buses and trucks. These provides

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considerable weight reduction without compromising strength and stiffness. Thickness optimization can be achieved with support conditions and material combinations.

1.1 Composite Floor Structures and Lightweight Design

The literature studies emphasize (i) floor structure lightweight design, (ii) thickness and material optimization, (iii) FEA simulation for validation, and (iv) selection of proper support for the floor structure to ensure a more reliable and effective design. Teli et al. [1] in their studies showed that glass-polymer floor panel stiffened with ribs a optimized through shape, size, and ply-level configurations. Author reported an approximate 30% reduction in structural weight and also reduced stress concentration areas. This study is more relevant because it shows that floor-panel performance can be improved through geometry and laminate design rather than by changing material alone. Similar study by Lee and Park [2] where a sandwich composite automotive floor was made of glass/vinyl ester face sheets, a urethane foam core, and steel edge supports. Static simulations and experimental testing confirmed that the composite floor remained structurally safe under payload and localized loading while being approximately 26% lighter than its steel counterpart. This work strongly supports the use of sandwich floor systems in bus applications where distributed seating loads dominate.

Additional proof of lightweight floor-system development is provided in [3] where high-speed train floor systems were optimized using fiber metal laminates (FML), FRP face sheets, and aluminum honeycomb cores. By selecting the face-sheet configuration and optimizing the core structure, the authors achieved nearly 62% reduction in weight. The methodology of this work is especially relevant because it correlates thickness selection, support behavior, and floor- panel response in a transport-vehicle setting.

Beyond the transport-floor studies, the hybrid composite literature further supports the use of natural-fiber and mixed-fiber laminates as viable load-bearing candidates. The jute hybrid bio- composite study in [4], [5] reported that hybridization improved flexural rigidity and strength while reducing weight, with thickness and stacking sequence playing a major role in performance. Similarly, the hybrid jute-glass composite work in [6] showed that static and dynamic structural response can be improved through fiber blending, which is useful for screening alternative low-cost floor materials. These studies are particularly relevant to the present paper because they support the use of jute-based and hybrid composite candidates in bus-floor optimization.

The comparative material-selection perspective is also reinforced by several authors. The study by Liu et. al [7] showed that hybrid carbon-glass laminates can provide strong flexural performance, while Dong et. al [8] highlighted that hybrid laminate performance depends strongly on material combination and stacking logic. Together, these studies justify considering both hybrid natural-fiber and hybrid synthetic-fiber laminates in a bus-floor design space.

All these studies support the idea that floor structures can achieve significant mass savings when the material system is chosen together with a sensible thickness-optimization strategy rather than by one-to-one substitution of metals.

1.2 Thickness Optimization and Multi-Objective Design

The second major theme in the literature is optimization of thickness and material combinations under structural and cost constraints. Ant colony optimization (ACO) and Pareto-based decision logic were used to optimize rail vehicle sandwich floor panels. The study showed that there is almost 60% reductions in weight when compared with plywood with acceptable flexural stiffness and overall performance. Hudson et al. [9] in their studies highlighted that though greater weight reduction can be achieved by appropriate materials selection but it is not the always case as it may sharply increase the cost if costly materials is used. So, both cost and weight must be considered for design optimization.

Djamaluddin [10] studied aluminum-faced sandwich train floors with aluminum foam cores through combined experiments and finite element modeling. The most important conclusion was that core thickness governed most of the stiffness response, far more than face-sheet variation. This observation is directly applicable to the current bus-floor investigation because it implies that thickness must be treated as the primary optimization variable before material substitution.

A broader sandwich-structure perspective is provided in by Ashby and Brechet [6], which reviewed natural-fiber- reinforced polymer sandwich structures and showed that sandwich design remains highly sensitive to face-sheet/core interaction and thickness distribution. Although the paper is review- oriented, it is useful because it supports the general logic of sandwich-floor optimization and thickness-sensitive response. The support-condition study is also useful here because it shows that boundary conditions strongly influence displacement in sandwich plates. Fixed and clamped support cases reduce deformation more effectively than free or mixed supports, which supports the use of realistic chassis attachment conditions in the present ANSYS model.

A combination of these studies indicates that optimization is best achieved when thickness is varied systematically across a practical design range while continuously tracking deformation, stress, and cost implication.

1.3 Bus-Specific Structural Validation Under Passenger Loading

Bus-specific studies are most useful to the current bus-floor problem. A hybrid carbon-glass city bus floor element was investigated by Tujmer et.al [11] using finite elements and optical displacement measurement . The difference between experimental and numerical values of displacement was only 11.7%, which demonstrates strong correspondence between simulation and experiment. This provides confidence that layered composite floor models in bus structures can be studied reliably using FEA.

Vaidya et. al [12] in their studies used carbon and jute fibers for making composite floor panels. For their bus floor design , author made appropriate selection of stacking sequence and panel thickness. This resulted in better floor panel to withstand against repeated loads and provided safer design.

The hybrid-composite studies by various author as reported in [4], [13] also reinforce this direction by showing that hybridization of composite materials can improve stiffness, flexural strength, and lightweight performance. Natural fiber based composites also provide good vibration damping [14]. Although these studies do not directly focus on bus floor design, they show that natural fibers and their hybrid composites are promising materials for vehicle-floor applications.

1.4 Boundary Conditions and Support-Frame Influence

One of the most practically important aspects for any bus-floor FEA model is the definition of supports and chassis boundary conditions. This issue is addressed directly and indirectly in several studies. Yadav [15] developed the full low-floor bus finite element model for crashworthiness assessment under frontal, side, and rear impacts. Although main objective was crash analysis, the study directs that representing true support conditions are important for accurate modelling purpose.

A work in [16] provides more specific boundary-condition study. In this functionally graded sandwich panels were modeled under various support conditions using software ABAQUS.

The results clearly showed that fixed boundary conditions minimized total displacement and improved stiffness response relative to simply supported and mixed cases. This is highly relevant to the present ANSYS model, where fixed supports are assigned at the chassis contact members to conservatively represent the floor attachment to the ladder frame.
The boundary-condition sensitivity is also supported by [15]. The study showed that support configuration significantly alters displacement distribution in sandwich plates, and demonstrated that graded or layered material response depends strongly on through-thickness stress transfer and finite element formulation. These studies strengthen the methodological argument for using realistic support conditions and stable load-transfer paths in the floor model.
Moreover, the role of support-member spacing and local reinforcement in controlling floor bending is reinforced by [2], [11] . This literature strongly supports the inclusion of longitudinal rails, cross-members, and local secondary supports in the existing bus-floor model.
The literature is still dominated by idealized rail- floor sandwich panels, generalized automotive floors, or metallic bus frames. Very few studies combine:

- actual bus-floor geometry,
- real seat-support locations,
- distributed passenger loading,
- comparative composite material screening,
- systematic thickness sweep,
- cost-aware selection logic, and
- ANSYS static structural validation.

The current study addresses this gap by utilizing realistic bus-floor dimensions, ladder- frame supports, hynrid composite with metal wire reinforcement. Also, for geometry, thickness variation from 5 to 50 mm is done to identify the most structurally efficient design solution for the bus floor. Several studies establish the structural feasibility by replacing traditional metal materials for floor with lightweight composites. As discussed, glass-polymer floor panel stiffened with ribs an optimized through shape, size, and ply-level configuration [1].
A closely related study in Lee[2] investigated a sandwich composite automotive floor made of glass/vinyl ester face sheets with a urethane foam core and steel edge supports. Static simulations and experimental testing confirmed that the composite floor remained structurally safe under payload and localized loading conditions while being approximately 26% lighter than its steel counterpart. This work strongly supports the use of sandwich floor systems in bus applications where distributed seating loads dominate.
Further evidence for advanced lightweight floor systems is presented in [3], where high-speed train floor structures were optimized using fiber metal laminates (FML), FRP face sheets, and aluminum honeycomb cores. By carefully selecting the face-sheet configuration and optimizing the core structure, the authors achieved nearly 62% weight reduction. The methodology used in this work is particularly relevant because it links thickness selection, support behavior, and floor-panel response in a transport-vehicle environment.
These studies collectively establish that floor structures can achieve substantial mass savings when the material system is selected alongside a rational thickness optimization strategy rather than simple one-to-one metal substitution.

1.5 Bus-Specific Structural Validation Under Passenger Loading

Initial finite element study was carried out on hybrid carbon-glass city bus for the case reported in [17]. The deviation between numerical and experimental displacement values was only 11.7%, demonstrating excellent agreement. This study provides strong confidence that layered composite floor models in bus structures can be reliably studied through finite element simulations.

Gusti et.al [17] in their study discussed about design for mini-bus floor panel. The authors compared ASTMA514 steel, AISI 1020 steel, and aluminum 2014- T4 under actual loading conditions for seats, driver mass, and passenger occupancy. Their findings showed that AISI 1020 produced the lowest deformation and providing high FOS among the tested metallic materials. Further, the study shows that passenger loads should be applied through seat-support locations to better represent real loading conditions instead of using only uniform pressure loads.

The FRP structural integrity study in [12] further strengthens the bus-specific composite case by demonstrating that layered FRP structural members can safely carry repeated service loads when the stacking sequence and panel thickness are properly selected. This directly supports the feasibility of exploring carbon-fiber, jute-based, and hybrid composite floor candidates in the current project.

1.6 Boundary Conditions and Support-Frame Influence

One of the important aspects for bus-floor FEA model is selecting and providing realistic support conditions representing physical prototype model in FEA . This issue is discussed by several authors in their studies.

Yadav [15] developed and validated full-bus finite element crash model for frontal, side, and rear impact conditions. Although the study focused on crashworthiness, it highlighted the importance of accurate underframe support paths and realistic structural connections . The results confirm the simulation strategy that bus-floor behavior cannot be isolated from the support frame beneath it.

Zenkour [16] analyzed functionally graded sandwich panels under multiple support conditions in ABAQUS. The results clearly showed that fixed boundary conditions consistently minimized total displacement and improved stiffness response relative to simply supported and mixed cases. This finding is highly relevant to the current ANSYS model, where fixed supports are assigned at the chassis contact members to conservatively represent the floor attachment to the ladder frame.

This literature strongly justifies the inclusion of longitudinal rails, cross-members, and local secondary supports in the current bus-floor model.

1.7 Overall Synthesis and Research Gap

The reviewed literature consistently demonstrates that composite and sandwich floor systems outperform conventional metallic designs in terms of weight reduction potential while maintaining structural adequacy. Thickness optimization emerges as the most influential design variable, especially in sandwich and hybrid floor systems where core stiffness strongly affects bending response.

A second major conclusion from the literature is that realistic support modeling and seat-load transfer methodology are essential for obtaining meaningful deformation and stress results. Studies involving city buses and medium bus floor frames confirm that boundary conditions, cross-member placement, and passenger load representation significantly influence the structural response.

However, a clear research gap still remains. Most available studies focus either on idealized rail-floor sandwich panels, generalized automotive floors, or metallic bus frames. Very few investigations combine:

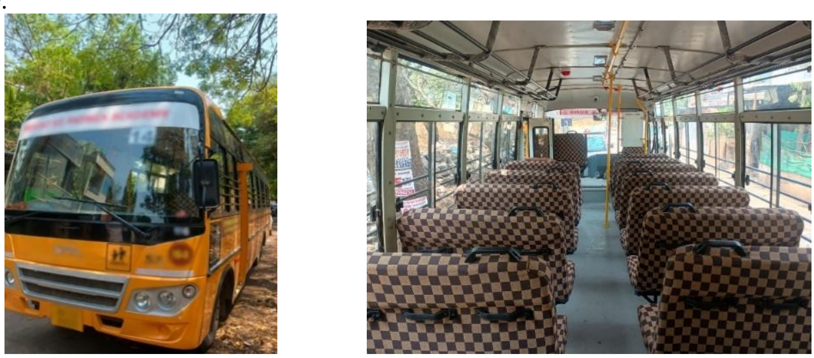
- actual bus-floor geometry,
- real seat-support locations,
- distributed passenger loading,
- comparative composite material screening,
- systematic thickness sweep,
- cost-aware selection logic

The present study addresses this gap by integrating realistic bus-floor dimensions, ladder-frame support conditions, multiple composite and metallic candidates, and thickness variation from 5–50 mm to determine the most structurally efficient and economically feasible floor solution.

2. METHODOLOGY

2.1 Geometry acquisition and floor-domain definition.

The SML bus platform of Isuzu S7, which is BS-VI compliant was chosen as the reference vehicle in the current investigation. Chassis and floor dimensions were derived based on layout of vehicles available and simplified into structurally relevant floor-support domain. The optimized area was found to be the major passenger seating area and central and rear floor spans where most of the seat loads are exerted. The effective dimension of the floor plan that was used to carry out the simulation was (192 + 82 + 640) cm, 240 cm. The critical seating bay, the rear 640 cm zone was a key zone that was predicted to be the region with the highest bending response during the static loading of passengers. Investigations with ANSYS Static Structural enabled the 2D shell-equivalent structure of the floor panel to be taken into consideration to facilitate quick parametric studies. The method maintained the flexural action of the panel but saved a lot of cost in terms of computation when sweeps were being done on the thickness. Figure 1 shows the actual bus selected for current study. All dimensions and parameter were measured and taken for CAD modelling and FE simulation purpose.



(a) (b)

Fig. 1. (a) Exterior view of the bus used in current study, **(b)** Interior view showing seat arrangements

2.2 CAD modeling and support-frame idealization.

Initial modeling of the underfloor support frame was performed in SolidWorks as a ladder-like chassis model that consisted of longitudinal rails and cross-members at right angles (transverse). These members were installed such that this represented the support paths which would be found in the real bus chassis. Local reinforcement was added around high-load seating areas at the discretion of the engineers and initial deflections. This was then translated to CAD model which was imported into ANSYS Workbench, where any geometric complexities that were not necessary were deleted to enhance meshing capabilities. This simplification made sure that the structural response was controlled by the floor span and location of support and not secondary features.

2.3 Material selection and definition of engineering property

It was based on a comparative material screening approach to test both the metallic and composite applicant to bus floor usage. The shortlist resulted materials based on literature support, commercial viability, stiffness to weight and anticipated manufacturability. Natural fiber composites, carbon-fiber laminates, phenolic laminates, stainless steel and aluminum alloys were incorporated in the study. The material properties given in ANSYS were the density, Youngs modulus and Poisson ratio. All materials can also be charged with approximate cost per kilogram values as a way of optimizing costs in future.

2.4 Boundary conditions and service load model

The bottom chassis support members had a fixed support boundary condition to indicate a hard attachment to the bus under structure. This is a conservative estimate of the floor deflection response. Rather than manually loading a structure with point forces of several loads on the seats, the effect of gravitational acceleration was induced on the entire structure in such a way that the effect of self-weight was automatically taken into account in each material. The passenger and seat loading were modeled with the help of vertical seat-leg extrusion elements at the real seat support points. These extrusions were adjusted in geometry and density to provide a gravitational force generated by each extrusion that, when summed together with the mass of seated occupant and an average mass of a passenger of 80 kg gave a bilateral mass of the occupants equal to that of a whole seat. With this approach, there was a realistic load transfer route between the mass of passengers and the seat supports and eventually to the floor panel.

2.5 Mesh generation strategy

A finite element mesh was created on the shell-equivalent floor surface in a structure. Finer mesh controls were used around the areas of seat supports and cross-member crossing where one would expect concentration of stress. A trade-off between mesh density and computational time was also taken to make the bulk simulation of multiple thicknesses cases very efficient. Mesh strategy remained constant throughout all material thickness issues to ensure consistency in the responses throughout data generated

2.6 Parametric sweep of thickness and block Simulation plan

Thickness sweep, which was systematic, was conducted to understand how the panel thickness affects the overall deformation and equivalent stress. Thickness was also varied between 10 mm and 50 mm on most materials and the high-stiffness carbon-fiber cases were used to extend as thin as 5 mm to investigate the really ultra-lightweight feasible cases. The maximum total deformation, equal von Mises stress and elastic strain were noted in every iteration of the simulation. The parametric plan was chosen to be general in order to produce a rich set of data to be used later to build on machine-learning models.

2.7 Optimization goal and decision logic

The proposed study has a final objective of optimization as the choice of a floor material and thickness combination which has the smallest possible weight, least cost and maintains safe deformation and stress limits during the process of taking passengers in the form of weight. The approach is thus a hybrid of deterministic response generation via FEA and data-driven surrogate optimization. The hybrid workflow has the significant benefit of minimizing the number of repeated costly finite element jobs in the last design exploration phase and offers a scalable approach to researching future lightweighting of bus floors.

3. Material Selection

3.1 Selection Criteria for Candidate Materials

Selection of candidate materials for bus floor optimization was based on structural performance, weight reduction potential, durability, and economic feasibility. Since the bus floor experiences distributed passenger loading, seat support reactions, and bending stresses transferred through chassis members, the selected materials were required to possess adequate stiffness, low density, and sufficient structural reliability.

For lightweight vehicle structures, the specific strength and specific stiffness of a material play a critical role in reducing dead weight without compromising safety. In addition, corrosion resistance, wear resistance, moisture tolerance, manufacturability, and cost were considered during screening. Based on these criteria, a combination of metallic materials, conventional composites, natural fiber composites, and hybrid composites were selected for investigation.

Special focus was given to hybrid composites because they offer the possibility of combining the benefits of multiple reinforcement systems while overcoming limitations of individual constituents.

3.2 Candidate Materials Considered

Table 1. Material Properties Used in Finite Element Analysis [13]

Material	Density (kg/mm2)	Young's (MPa)	Modulus Poisson's Ratio
Jute Composite	1.2845×10^{-6}	5180	0.09
Carbon Fiber (Bi-Directional)	1.50×10^{-6}	59000	0.30
Carbon Fiber (Uni-Directional)	1.49×10^{-6}	120000	0.27
Tufnol 10G/40	2.00×10^{-6}	26000	0.15
Stainless Steel 304	7.80×10^{-6}	200000	0.28
Aluminum 6063-T5	2.70×10^{-6}	68000	0.33
1Steel–6Jute–2Glass Hybrid Fibre	1.4717×10^{-6}	6950	0.10

3.3 Justification for Material Selection

3.3.1 Jute Composite

Jute composite was selected as a lightweight and sustainable natural fiber alternative. Its low density makes it attractive for weight reduction, while acceptable stiffness allows evaluation as a low-cost structural floor material.

3.3.2 Carbon Fiber Composites

Both bi-directional and uni-directional carbon fiber composites were selected as high-performance benchmarks. Their high specific stiffness and strength make them suitable candidates for minimizing deformation under passenger loading.
The bi-directional carbon fiber provides multidirectional load resistance, while the uni-directional variant offers superior stiffness along principal load directions.

3.3.3 Tufnol 10G/40

Tufnol was selected as an engineering laminate with favorable wear resistance, electrical insulation properties, and moderate structural stiffness. It provides an intermediate composite benchmark between natural fiber and advanced carbon composites.

3.3.4 Stainless Steel 304

Stainless Steel 304 was included as a conventional high-strength material. Its high modulus provides excellent structural rigidity and also it is corrosion resistance which makes it ideal for vehicle flooring.

3.3.5 Aluminium 6063-T5

Aluminium 6063-T5 was selected as a lightweight metallic benchmark due to its favorable strength-to-weight ratio, corrosion resistance, and widespread use in transportation structures.

3.3.6 Steel wire–6Jute–2Glass Hybrid Fibre Composite

The proposed hybrid composite was selected as the primary novel material candidate.

- Glass fibers improve moisture resistance, wear resistance, and tensile reinforcement.
- Jute fibers reduce density and material cost while contributing lightweight stiffness.
- Steel reinforcement enhances structural strength, rigidity, and load-carrying capability.

This hybrid combination was intended to balance lightweight performance, durability, sustainability, and structural integrity for bus-floor applications.

3.4 Preliminary Material Screening Discussion

Based on elastic modulus, density, and structural behavior, the materials represent a broad spectrum of design trade-offs.

- Stainless steel provides the highest stiffness but with major weight penalty.
- Aluminum offers moderate stiffness at reduced weight.
- Carbon fiber provides very high specific stiffness but at increased cost.
- Jute offers economical lightweight behavior but reduced rigidity.

- The proposed steel–jute–glass hybrid attempts to combine structural reinforcement with lightweight and cost advantages with stacking sequence as shown in Figure 2.

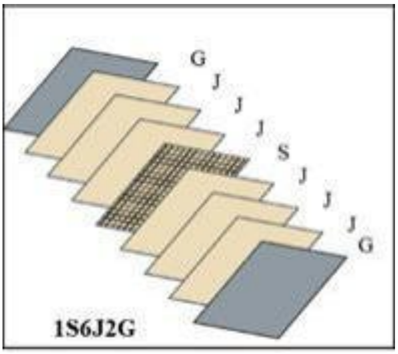


Fig. 2. 1S6J2G Hybrid Composite Layer Stacking sequence

Table 2. Response ranges and thickness sweep matrix.

Material	**Thickness (mm)**	**Total Deformation (mm)**	**Eq. Stress (MPa)**
Carbon Fibre- Uni-Directional (120 GPa)	5–50	0.827–1.436	16.8–20.4
Carbon Fibre- Bi-Directional (59 GPa)	10–50	0.45–0.56	10.2–13.5
Stainless Steel 304	10–50	0.31–0.37	10.8–14.0
Aluminium 6063-T5	10–50	0.43–0.54	10.8–12.9
8 Jute	10–50	1.82–2.14	24.8–30.1
1Steel 6Jute 2Glass Hybrid Fibre	10–19	1.13–1.248	22.294–24.299

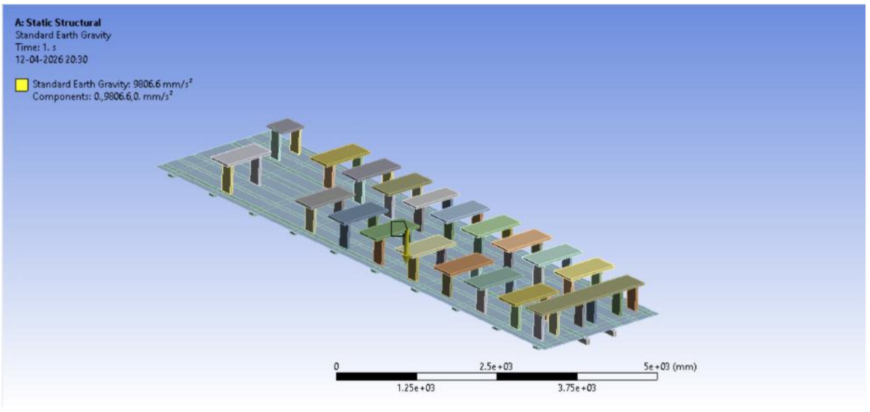


Fig. 3. FE Model in ANSYS Workbench

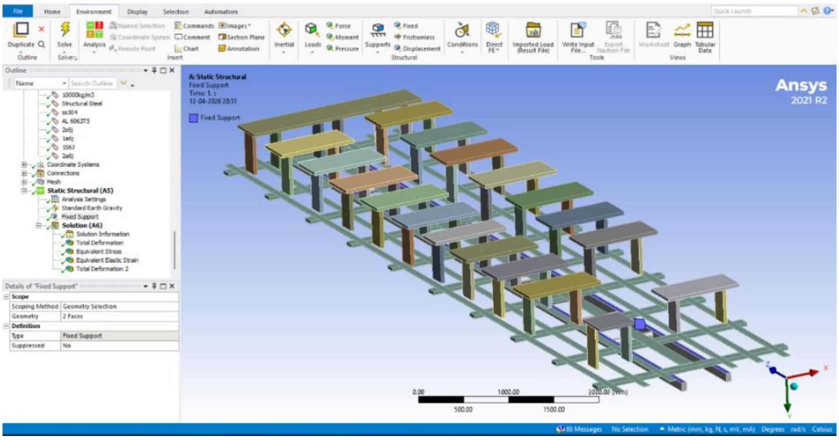


Fig. 4. Support frames

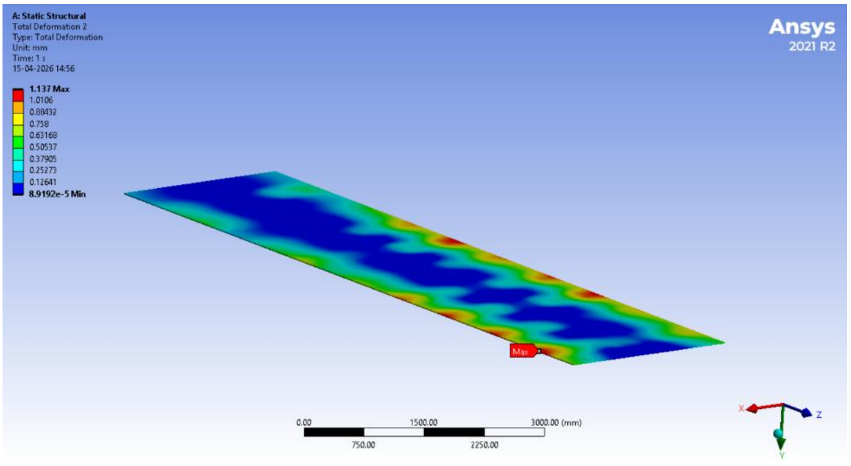


Fig. 5. Simulation results of 1Steel 6Jute 2Glass Hybrid Fibre - Total Deformation

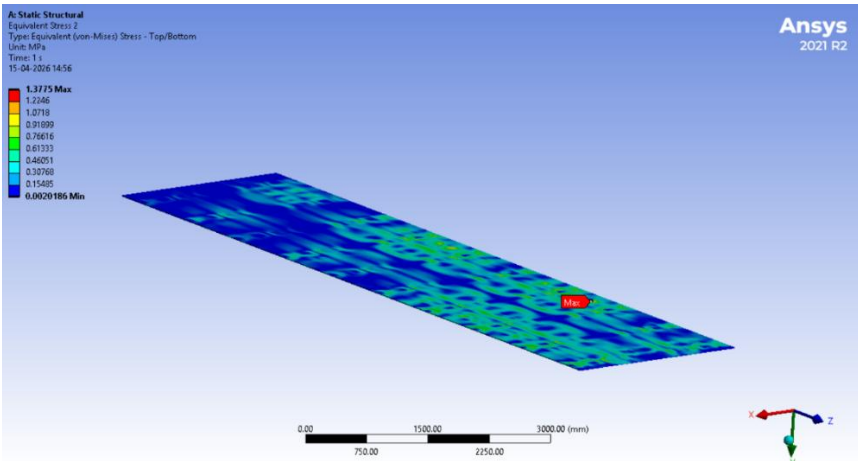


Fig. 6. Simulation results of 1Steel 6Jute 2Glass Hybrid Fibre - Equivalent Stress

4. RESULTS AND DISCUSSION

FE model of the structure is shown in Figs 3 and 4. The results obtained from ANSYS Workbench simulations, FEA software , provide a detailed understanding of how different materials configurations behave under actual loading conditions in a bus floor structure. The study mainly focuses on estimating maximum deformation and equivalent stress here Von-misses stress. This was calculated for all thicknesses and material configurations.

4.1 Effect of Thickness on Structural Response

It was observed from the trend that thickness parameter is most influencing factor which affects the bus floor deformations and maximum stress for all selected materials and geometry. As per the classical plate theory and bending mechanics theory, with rise in thickness increases the stiffness of the floor panel and hence reduces the deformation.
For every material, thin structure resulted in significant deformation as expected. However, this issue is more significant in materials having low modulus of elasticity, such as jute-based composites. Jute composite panels showed deformation in the range of approximately 1.82 mm to 2.14 mm, which is substantially higher compared to other materials under consideration.
On the other hand, increasing thickness beyond a certain limit does not result any significant improvement. This means increasing thickness does not always leads to structural advantage. Since higher thickness also increases weight and cost, hence can not be considered as good design approach. Therefore, thickness should be optimized carefully to achieve a balance between structural performance, weight, and cost.
This provides important insight that optimization of floor thickness has to be balanced instead of merely increasing it. Adding more thickness leads to additional weight, which is not a good design practice.

4.2 Comparative Performance of Materials

4.2.1 Carbon Fiber Composites

Uni Directional (UD) Carbon fiber polymer composite with 120 GPa as modulus showed superior performance in terms of stiffness-to-weight ratio. Even at very low thickness values as low as 5 mm, the deformation observed was in acceptable limits. It was approximately 0.827 mm to 1.436 mm. The woven carbon fiber polymer composite with modulus 59 GPa showed also less deformation values around 0.45 mm to 0.56 mm due its balanced directional properties. However, this performance comes with higher cost as carbon fibers are very costly. So application of carbon fiber can be justified for high end applications.

4.2.2 Stainless Steel (SS304)

The panel made up of SS304 for floor system shows lowest deformation compared to other materials.. This was observed in the range of 0.31 mm to 0.37 mm. This is expected as steel has highest modulus of 200 GPa. This is stiffest material among all under consideration . However steel density is also very high which makes floor heavy weight. Due to this, it may not be ideal for applications where lightweight design is main criteria, such as modern fuel efficient electric vehicle.

4.2.3 Aluminium Alloy (Al 6063-T5)

Aluminium bus floor showed balanced performance, with deformation values ranged between 0.43 mm and 0.54 mm. This offers a substantial reduction in weight due to its lower density. This makes Aluminium a strong competitive material. From an engineering design perspective, Al comes out as promising alternative, especially for applications requiring a balance between cost, weight, and performance.

4.2.4 Jute Fiber Composite

Jute-polymer composite has low modulus in the range of 5.10 GPa. Since modulus is less, this shows higher deformation compared to other materials and therefore considered as structurally less efficient if used alone though it is environmentally friendly material. However, using this in combination of steel wire mesh and glass can be more effective as will be discussed in next section.

4.2.5 Hybrid Jute–Glass–Steel Composite

In order to overcome all drawback discussed for above all materials with respect to weight, cost and performance, here it is proposed new innovative materials 1S6J2G (1 Steel – 6 Jute – 2 Glass layers) that author has studied [13] experimentally in earlier studies. The properties of these materials are used obtained from experimental testing in current FE simulations. This hybrid composite presented an interesting balance between performance and cost. The deformation ranged approximately from 1.133 mm to 1.248 mm, which is higher than pure jute but less than metals and carbon fiber. The inclusion of glass and steel layers has improved stiffness. Also the equivalent stress values are within acceptable limits (~22–24 MPa), indicating that the hybrid structure can safely withstand working loads. This hybrid configuration stands out as a cost- effective and sustainable alternative, especially when designed with proper layering strategies. Simulation results are shown in Figures 5 and 6.

4.3 Equivalent Stress Distribution

The finite element simulations carried out for all material configurations across all thickness and give boundary conditions for bus floor system showed that the equivalent stress values and maximum deformations remained well within safe limits, indicating that none of the configurations are subjected to failure under the applied loading conditions. Key observations include: Stress variation across thickness was relatively small compared to deformation changes, High-stiffness materials (steel, carbon fiber) showed lower stress concentration. Composite materials showed slightly higher stress but still within safe limits. The design of the bus floor is more deformation-driven i.e. stiffness controlled than stress driven. In real applications, excessive deformation can lead to: passenger discomfort, structural fatigue, long-term durability issues. Thus, controlling deformation becomes more critical than simply minimizing stress.

4.4 Structural Behavior and Load Transfer

The FE simulation results confirmed that modelling approach was correct and effective. The model included seat-leg load transfer, gravity loading, and realistic support conditions. The results showed that max deflection was at middle and rear section of the floor panel and high stress was at support and cross-member connections. These are consistent with actual vehicle floor behavior, indicating that the model accurately represents real operating conditions.

4.5 Key insights from Results

A crucial outcome of this study is the identification of the trade-off between weight and structural performance:
Steel : Best stiffness, more weight
Carbon fiber : Best performance, highest cost Aluminium , Balanced solution
Jute composite : Lightweight but less stiff.
Hybrid Composite : Best compromise between cost, sustainability, and performance.
From an engineering perspective, the following conclusions can be drawn from the results: Thickness is the dominant design variable influencing deformation. Material stiffness governs overall structural efficiency. Composite materials offer significant weight-saving potential, but require careful design. Hybrid materials provide a promising middle ground, especially for sustainable design. Realistic loading and boundary conditions are essential for accurate simulation outcomes

5. Conclusion

The paper has constructed a thickness and material optimization theoretical model of a passenger-bus floor panel using a realistic service loading scenario with support configurations and finite element (FE) simulation. The ANSYS Workbench was used to model a simplified structural floor domain, which relied on a BS-VI compliant SML Isuzu S7 platform and evaluated various candidate materials, such as SS304, Al 6063-T5, jute composite, carbon-fiber laminates as well as Tufnol, over a thickness range of 550 mm. The findings revealed that the crucial governing parameter that affects deformation and equivalent stress is the thickness of the floors, whilst material stiffness considerably impacts the stiffness-weight ratio of the construction. Carbon-fiber laminates demonstrated the best lightweight behavior and acceptable level of deformations, but the stainless steel offered the lowest level of deformation at the cost of the mass of the structure. The aluminum provided a good middle position between reduction of weight and structural integrity, and the natural-fiber composites demonstrated the viability of low-cost lightweight structures with optimal choice of thickness. The suggested workflow with realistic geometry, distributed loading of passengers, chassis-supported boundaries, and parametric thickening control offers a trustworthy foundation to the efficient and cost-conscious design of the structure of the bus-floor and facilitates the use of future information to optimize the transport vehicle structures. From the above findings it is concluded that, Hybrid Jute Glass composite fibre provides the best results as its outer layer is made of glass, preventing water absorption by resin, increasing overall durability.

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