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Design and Development of Bus Body Construction Using Composite Materials

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Abstract - *In present day cost of the traditional materials like steel,Aluminium is more costlier to construct vehicles Body structure. fiber-reinforced polymer (FRP) is a composite material manufacture specially by a combination of a polymer matrix and reinforcing fibers it has some unique properties exceptionally strong, lightweight, and durable it can be used to make bus construction for improve fuel consumption and provides safety for the Passengers, two wheelers and pedestrians' fiber provides toughness and structural strength to the flexible polymers and reinforces. The aim of the work is to Construct a Busses using of fiber reinforced polymer to improve fuel efficiency and safety for pedestrians. Fiber reinforced polymer is much cheaper than steels and easy to repair. The tensile strength of carbon fiber is 800-2000 mpa it is equal to the properties of steel. Carbon fiber made from carbon atoms bonded together in a crystal alignment that holds the structure of vehicle during load conditions. it is easy of reclamation process to recycling.*

***Key Words*:** *composite material, carbon fiber, high tensile strength, light weight, corrosive resistance, safety, low cost*

1.INTRODUCTION *(fiber reinforced polymer)*

Fiber Reinforced Polymers (FRPs) are the advanced composite materials that combine the strength of fibers with the versatility of polymer matrices. These materials consist of a polymer matrix reinforced with various types of fibers, such as glass, carbon, aramid, or basalt. The fibers provide high strength and stiffness, making them the primary load-bearing component within the composite structure. The demand for lightweight, durable, and environmentally friendly transportation solutions has led to the increasing adoption of Fiber Reinforced Polymers (FRP) in bus body construction. FRP, a composite material consisting of high- strength fibers embedded in a polymer matrix, offers exceptional mechanical properties, corrosion resistance, and design flexibility. The role of FRP in bus body construction is expected to grow, driving innovation and environmental stewardship. Hybrid fiber- reinforced composites, on the other hand, incorporate two or more types of fibers within a single matrix structure. In continuous fiber composites, fibers can be arranged either unidirectionally or bidirectionally within the matrix structure. This arrangement allows for efficient and effective load transfer from the matrix to the fibers. Fiber reinforced polymer contains Carbon fibers that are created when polyacrylonitrile (PAN) fibers, pitch resins, or rayon are carbonized through oxidation and thermal pyrolysis at high temperatures. Carbon fibers can be further processed through graphitizing or stretching to enhance their strength or elasticity. They are often wound into larger threads for transportation and used in various manufacturing processes, such as fiber mat, fiber cloth etc. FRPs exhibit excellent corrosion resistance, making them suitable for use in harsh environments and extending the lifespan of components. The versatility of FRPs allows for their application in a wide range of industries, including construction, sports equipment, and marine applications. Despite their numerous advantages, challenges such as the high cost of production and recycling difficulties persist. However, ongoing research and innovation aim development of hybrid fiber-reinforced composites, which combine two or more types of fibers within a single matrix structure, has also shown promising results in enhancing material properties and performance. Overall, FRPs represent a significant advancement in material science, offering a combination of strength, lightweight, and durability that continues to drive innovations and new applications in various fields. Since applications of FRP composite materials in automobile and aerospace industries grew commercially in the 1950's, this technology was soon being transferred to other industries due to its ease of production and moulding of complex forms. However, in the majority of applications, the material was not utilized in applications requiring fire performance at this time. Over the decades following, as with any new engineering material, hundreds of formulations were produced by an increasing number of manufacturers as they fine-tuned their base resin systems to enhance particular properties for each new application or process. As demand for resins with improved fire performance grew, formulators extended to add ingredients to existing resin systems to improve fire performance, often resulting in reduced mechanical performance and frequently making the resin difficult to work with. These resins were also more expensive to manufacture. As the application of composites spread into almost every sector of manufacturing, resins were produced with characteristics, including FST performance, for a specific industry/application/country. The majority of these are now readily available on the resins market but each has been formulated to pass the testing required to meet one particular FST specification. Fiber Reinforced Polymers (FRPs) represent a significant advancement in material science, offering a unique combination of strength, lightness, and durability. The growth of hybrid composites, improvements in resin formulations, and advances in manufacturing and processing techniques will continue to drive innovation and expand the use of FRPs in a wide variety of industries.

2. LITERATURE REVIEW

FRP Material in Bus body Construction comprehensively first reviewed by Baker et al. (1995).The latest review of FRP in Bus Body Construction is provided by Mathews, J., et al. (2020). The characteristics of Bus Body Construction can be

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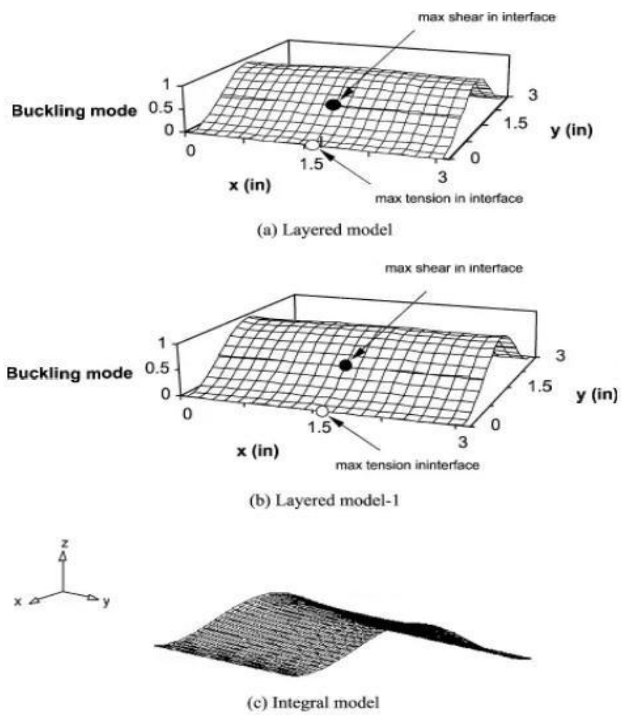
reported by many investigators. FRP exhibits exceptional mechanical properties, including high strength-to-weight ratio, stiffness, and resistance to fatigue and corrosion Bank et al., 2006; Keller, 2006. The use of FRP in bus body construction can lead to significant weight reduction, which in turn can improve fuel efficiency and reduce emissions. The performance of FRP composites in bus body construction is heavily influenced by their material properties. Al-Khatib et al. (2018) provide a detailed review of FRP composites, emphasizing their high specific strength and modulus, which are essential for lightweight vehicle design. These properties contribute to the reduction in vehicle weight, thereby improving fuel efficiency and reducing emissions. The manufacturing of FRP composites for bus bodies involves processes such as hand lay-up, resin transfer molding (RTM), and vacuum-assisted resin infusion. Kumar et al. (2013) describe the various techniques used in FRP bus body construction, noting that automated manufacturing methods, like RTM, are increasingly being adopted due to their cost-effectiveness and ability to produce high-quality, consistent parts. However, as highlighted by Ribeiro et al. (2020), there are still challenges in scaling up these manufacturing processes, particularly in ensuring consistent material quality and minimizing defects during production. The mechanical properties of FRP composites are crucial to their performance in bus body construction. Liu et al. (2017) examine the hybridization of fibers in FRP composites, showing that combining different fibers can improve both the mechanical properties and cost-effectiveness of the material. Singh et al. (2017) review the testing methods used to evaluate the mechanical properties of FRP composites, such as tensile, flexural, and impact tests, providing valuable data on the material's performance under different loading conditions. Additionally, Xia et al. (2011) present studies on the long-term mechanical performance of FRP composites, emphasizing the importance of testing these materials under conditions that simulate the bus's operational environment, including temperature fluctuations, moisture exposure, and UV radiation. A significant advantage of FRP composites is their resistance to environmental degradation. Thwe and Liao (2003) discuss the effects of environmental aging on the mechanical properties of FRP composites, showing that the materials maintain their strength and durability even after extended exposure to moisture, UV light, and temperature fluctuations. This is particularly beneficial for bus body construction, where materials are subjected to harsh weather conditions.

3. EXPERIMENTAL METHODOLOGY

Fiber reinforced polymer used in the outermost layer of vehicle it will enhance safety features for passengers and other pedestrians. FRP Material contains carbon fiber based on its desired strength resigns can be added like epoxy, polyester, or vinyl ester, which offer good mechanical properties, ease of processing, and compatibility with fibers.FRP has been placed over body frames during composite fabrication hand lay-up or vacuum infusion can be used based on the desired scale of production and component complexity. Measurements of the dimensional stability of the composite can be done, especially during the curing process. Materials that undergo significant shrinkage may lead to warping or deformation in bus body panels. Weathering and UV Exposure the FRP composite to simulated outdoor conditions using UV light, temperature variations, and humidity cycles (ASTM G154 or ISO 4892). This simulates the long-term exposure of bus bodies to outdoor environments and evaluates the material's ability to resist degradation from sunlight and weather. Since buses operate in harsh environments, especially in coastal or humid areas, the test of composite resistance to environmental factors can be done like saltwater and humidity. Tests like immersion in saltwater (ASTM B117) or humidity exposure (ASTM D2247) it evaluates corrosion resistance. Cyclic loading tests can be done (ASTM D3479 or ISO 13003) it is to determine the fatigue life of the composite. This helps evaluate how well the material will perform under repeated stress and strain, which is critical for components like bus panels that experience constant loading during operation. Numerical simulations of the FRP composites can be done.it is to optimize the design for bus body construction. FEA helps identify weak points and allows for design adjustments before physical testing. The tensile strength and modulus of the FRP composite using ASTM D3039 or ISO 527 standards can be measured and done. Geometric Modelling: The three-dimensional model is created using CATIA.

Fig -1: **Buckling modes of FRP Bus panel under compression.**



a) **Finite Element Analysis:** The three-dimensional model created using CATIA is imported to ANSYS software, and

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it is meshed. The meshed model is called as the Finite Elemental Model.

b) **Suitable Boundary Conditions:** The meshed model is subjected to certain bound conditions and analysis is completed using ANSYS software. This will helps to understand the material's capacity to withstand stretching forces. To Conduct a three-point or four-point bending test (ASTM D7264 or ISO 14125) to determine the flexural strength and modulus, which is crucial for assessing the material's ability to resist bending stresses.

c) **Flame Retardancy:** Conducted a flame spread tests according to standards such as UL 94 or ASTM E84 to assess the FRP's fire resistance. For bus body construction, it's essential to meet fire safety standards, especially in interior materials.

Table-1 Mechanical properties

Table Head	**Materials**		
property	***Fiber reinforced polymer***	***Steel***	***Aluminum***
Density	1800-2000	7850	2700
Tensile strength (Mpa)	400 - 1,500	370 - 600	250 - 550
Flexural strength (Mpa)	300 - 1,200	250 - 700	150 - 450
Modulus of Elasticity (Gpa)	20 - 45	210 - 220	70 - 80
Thermal Expansion $(10^{-6}/°C)$	4 - 10	11 - 15	22 - 24
Weight (kg/m^2)	20 - 30 1 mm thickness	78 - 80 Per 1mm thickness	35 – 40 Per 1mm thickness

4. BOUNDARY AND LOAD CONDITIONS

The boundary condition used in the analysis is totally different according to the operative circumstances of the bus. Throughout the static loading case the most loads that are considered are acceleration 27778 mm/s², breaking load and impact load.

Equations :

Weight Reduction Equation:
FRP has its lower density compared to traditional materials like steel. The weight of an FRP bus body can be expressed as:

WFRP=ρFRP⋅V (1)

- WFRP is the weight of the FRP body,
- ρFRP is the density of the FRP material (kg/m^3)
- V is the volume of the body (m^3).

Flexural Modulus for FRP:

The flexural modulus is a measure of the material's stiffness under bending stress, which is critical for ensuring that the bus body maintains its shape under load. It is calculated using:

EFRP=4⋅δ⋅b⋅h3L3⋅F (2)

Thermal Expansion Coefficient :

FRP materials also need to perform well under temperature variations. The coefficient of thermal expansion (CTE) for FRP can be expressed as: Where:

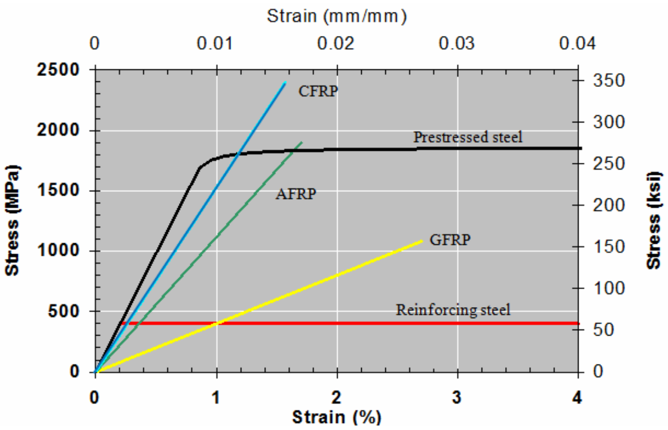
ΔL=α⋅L0⋅ΔT (3)

- ΔL\Delta LΔL is the change in length (m),
- α\alphaα is the coefficient of thermal expansion (1/°C),
- L0L_0L0 is the initial length (m),
- ΔT\Delta TΔT is the change in temperature (°C).

Cost Analysis Equation
The overall cost of using FRP in bus body construction involves both the material cost and the manufacturing process cost. A simplified equation for total cost could be

C total=C material + C manufacturing (4)

- C total is the total cost of constructing the bus body with FRP
- C material is the cost of the FRP material (per unit volume or weight),
- C manufacturing is the cost associated with the molding, shaping, and assembly processes.



Graph 1- stress strain curve Fiber reinforced polymer

5. CONCLUSION

In this project FRP Bus Body Construction was designed and analyzed. Because the some of the materials can be used as traditionally and the cost of the material is more higher then fibers. The FRP provides structural strength corrosion resistance and reduces the overall weight of the vehicle it will gives more mileage and improve safety features for the passengers. Material can be easily recycling it cannot be affects the environment mainly focused on fuel efficiency and safety. Fiber Reinforced

Plastics (FRP) have proven to be a transformative material in bus body construction due to their exceptional properties. FRP offers a unique combination of strength, lightweight nature, and resistance to corrosion, making it an ideal material for improving the durability and performance of buses. Its lightweight characteristics contribute to better fuel efficiency and reduced wear on components, while its resistance to environmental factors ensures a longer service life. Additionally, FRP allows for greater design flexibility and can be molded into complex shapes, offering aesthetic and functional advantages. While the initial cost of FRP might be higher compared to traditional materials, the long-term benefits, including lower maintenance costs and improved operational efficiency, make it a cost-effective choice. As advancements in manufacturing techniques and material properties continue, FRP is expected to play an increasingly important role in the evolution of modern, sustainable, and efficient bus transportation.

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