# EFFECT OF COMPOSITE WRAPPINGON CRASHWORTHINESS

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**Abstract:** Crashworthiness is the ability of a structure to protect its occupants during an impact. Depending on the nature of the impact and the vehicle involved, different criteria are used to determine the crashworthiness of the structure. The combination of metal and composite layers is known to displays plastics deformation and failure mode composite layered. The capable of structures to absorb large amount of energy are great interest in an effort to reduce the impact of collision. In this experimental study, the crashworthiness parameter of composite wrapped mild steel tubes when subjected to axial compression will be investigate. The efficiency is measured in term of the absorption performance that is higher in hybrid composites than in metallic and composite structures alone. Much of the working assessing the energy absorbing capability of composite materials and structures under compressive loading has been to a greater extent restricted to axis metric tubes. Therefore, it will contribute knowledge on how to develop a stable or controlled crushing response of hybrid composite material tubes under sustained axial loading.

**Keywords**: Axial Compression, Circular and Square Tube, Energy Absorption, Fiber Metal Laminated Mild Steel.

## I. INTRODUCTION

In the automobile and aerospace industries, structures which are light weight and have the highest energy absorption capacities will be selected. Public concerns on vehicle structural integrity and its ability to absorb crash as well as providing a protective shell around the occupants are being demanded to protect passengers involved in accidents. Structures of the vehicle must absorb sufficient energy and reduce the impact load even when the vehicle collides with each other at high velocities. Many materials used in designing crashworthy structures are rate sensitive were energy absorption capability is dependent on the speeds at which they are crushed [1] and the axial displacement of the tubes [2]. Thin wall tubes have been used as impact energy absorbers due to its behavior of progressively buckle like bending plastic hinges to absorb energy under axial low-velocity impacts.

The most common shapes are circular, square and rectangular and these tubes are used as front and side impact beams in vehicles. Experimental and analytical results have shown that energy absorption depend on various tube parameters such as geometry, material properties, boundary, length [3], thickness [4]-[5] and loading conditions of the tubes where it buckle in different modes of deformation, namely concertina, diamond and Euler collapsing modes. Taking consideration of these design parameters, and its methods can improve energy absorption characteristics of the tubes under axial loads significantly [6].

Composite structures in the other hand have a wide range of applications because of their high stiffness and strength with respect to their weight. It also provides ductile, and a stable plastic collapse mechanism as they progressively deform which eventually increases the energy absorption during collision of the vehicles [7]. Composite structures could stand high loads and provide a significant increase in the energy absorption when compared to similar metal structures. The energy absorption capability of composite structures is dependent upon the mechanism by which the structures collapse.

Due to the demand and requirement for lightweight applications, the application of fiber/resin composite technology had been utilized and slowly replacing metallic shell structures. E-glass fiber/resin composite tubes reinforced by carbon fiber have a significant increase in energy absorption when collision compared to the fully glass fiber/epoxy tubes [8]. The impact force displacement relationships of E-glass fiber/resin composites increased due to increasing impact energy of great specimen deflection related with significant membrane tensions [9]. Hybrid structures are excellent for energy absorption and have been extensively used in such engineering structures. As a result, several researchers have recently addressed metal tubes that are wrapped with a fiber-reinforced plastic composite where overwrapping the metal tubes with composite is an effective means of increasing energy absorption capacity and improving the crushing characteristics of such tubes [10].

## II. DETAILS EXPERIMENTAL

### 2.1. Specimen Fabrication

Initially,conventional mild steel (CMS) were prepared according to the required shape, size, and quantity as in**Fig. 1(a and b)**. The dimensions of the conventional mid steel (CMS) were given in **Table 1**. The E-glass fiber/polyester resin laminated mild steel (LMS) specimens were fabricated by hand lay-up process. Scratches were made over the outer shell surface of the conventional mild steel (CMS) specimen with fine sand paper (Grade 800) for better adhesion between mild steel metal surface and E-glass fiber/polyester resin laminate. Three sets of

laminated mild steel (LMS) were overwrapped on the outer surface of the conventional mild steel (CMS) by hand lay-up method to form a laminated mild steel (LMS) or hybrid shell. Percentage of glass fiber on the composite is maintained at 60%. The specimen will then left to cure for about five hours at room temperature and the thickness of the shell was maintained at 2.60-3.70 mm. The dimensions of the hybrid shells are given in **Table 2**.

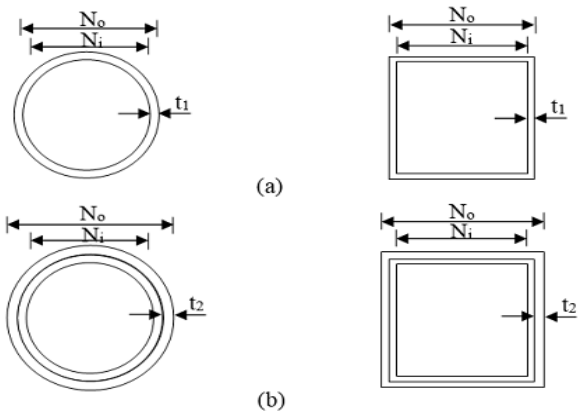


**Fig. 1. Geometrical details of (a) Conventional mild steel (CMS)& (b) Laminated mild steel (LMS).**

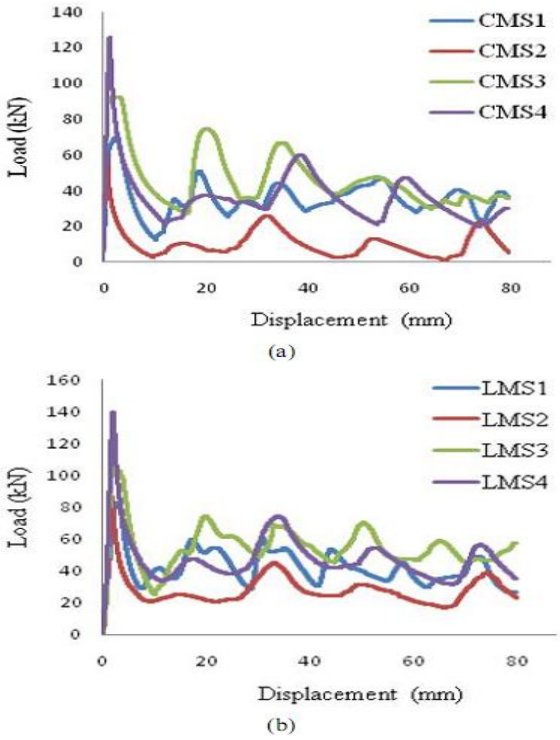


**Fig. 2. (a) Load-deformation curve for conventional mild steel (CMS) & (b) Load-deformation curve for laminated mild steel (LMS)**

**Table1: Dimensions of conventional mild steel (CMS) specimens**

| Model | Shape | Inner diameter/ base length ($N_i$)(mm) | Outer diameter/ base length ($N_o$)(mm) | Height ($H_c$)(mm) | Mild steel thickness (average) ($t_1$)(mm) | Total thickness (average) $t = (t_1 + t_2)$(mm) |
|---|---|---|---|---|---|---|
| CMS1 | Circular | 44.84 | 48.04 | 120 | 1.6 | 1.6 |
| CMS2 | Square | 47.04 | 50.24 | 120 | 1.6 | 1.6 |
| CMS3 | Circular | 44.27 | 48.07 | 120 | 1.9 | 1.9 |
| CMS4 | Square | 46.27 | 50.07 | 120 | 1.9 | 1.9 |

**Table2: Dimensions of laminated mild steel (LMS) specimens**

| Model | Shape | Inner diameter/ base length ($N_i$)(mm) | Outer diameter/ base length ($N_o$)(mm) | Height ($H_c$)(mm) | Mild steel thickness (average) ($t_1$)(mm) | Composite laminate thickness (average) ($t_2$)(mm) | Total thickness (average) $t = (t_1 + t_2)$(mm) |
|---|---|---|---|---|---|---|---|
| LMS1 | Circular | 44.84 | 50.30 | 120 | 1.6 | 2.73 | 4.33 |
| LMS2 | Square | 47.04 | 53.40 | 120 | 1.6 | 3.18 | 4.78 |
| LMS3 | Circular | 44.27 | 50.90 | 120 | 1.9 | 3.32 | 5.22 |
| LMS4 | Square | 46.27 | 53.60 | 120 | 1.9 | 3.67 | 5.57 |

### 2.2. Experimental Setup

The axial compression test was conducted on samples with the cross head speed of 5 mm/min on a Universal Testing Machine (UTM) of 20 ton capacity and it is integrated with the load displacement data recordable device. The specimens are placed in coaxial between top and bottom rigid platen and proper seating is ensured. The axial load is applied progressively from top end of truncated specimen. The mode of collapse of conventional mild steel (CMS) and laminated mild steel (LMS) was observed and also corresponding load displacement dataset were recorded up to 80 mm axial compression of the specimen. Three specimens were tested for each category of samples to ensure the repeatability of the results. The load displacement curve obtained from the experiment for conventional mild steel (CMS) and laminated mild steel (LMS) is shown in **Fig. 2 (a and b)** respectively. The energy absorption capabilities of the specimens were estimated from the area under the load displacement characteristic curves.

## III. RESULTS AND DISCUSSION

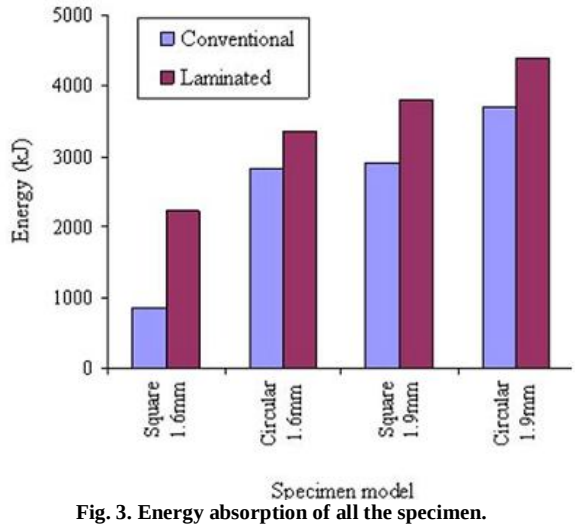


**Fig. 3. Energy absorption of all the specimen.**

### 3.1. Effect of E-Glass Fiber/Polyester Laminate

The effect of composite wrapping on crashworthiness was studied by comparing bare mild steel and the hybrid specimens.

From the curve, it is clear that the hybrid specimens has higher peak and mean load than bare mild steel. High peak load is defined as the highest load level that the specimen sustain during axial compression. Mean load is defined as the equivalent constant load required to be applied on the specimen over the measured deformation. It was also observed that, all hybrid specimens have higher crashworthiness capability than bare mild steel specimens. The first collapse load, peak load and mean load was extracted for the load-displacement curve of each specimen is shown in **Table 3**. The energy absorbed by the specimen up to 80 mm of axial compressionwas considered to calculate the energy absorption capability of the specimen. Crush load efficiency (CLE) is one of the important factors to be considered to justify the crashworthiness of hallow shell structure. It is defined as the ration between mean load and maximum load of each specimen.

Lamination effect or strengthening factor is calculated from the energy absorbed by bare and composite wrapped circular and square tube. It is defined as the percentage of increase of energy absorption due to overwrap. From the results shown in **Table 3**, it is understand that the hybrid specimen has 3-5 times greater energy absorption than bare aluminium shell. The table also shows the comparison of energy absorption or crashworthiness of all bare and overwrapped hybrid specimen. Here, the specimen CMS3 and LMS3 has higher mean load than all other bare and overwrapped specimens respectively. When CMS3 and LMS3 alone were compared, the specimen LMS3 gains higher energy absorption than CMS3.

**Fig. 3** shows performance level of bare and hybrid square and circular mild steel for 80 mm of axial crash. From the curve, it is significant that E-glass fiber/polyester resin laminated mild steel has higher energy absorption capability than bare mild steel shell.

**Table 3: Energy absorption characteristics**

| Model | Shape | Weight (kg) | Axial Load (mm) | Mild steel thickness (average) ($t_1$)(mm) | Max peak load (kN) | Mean load (kN) | Energy (kJ) | CLE % | SEA (kJ/kg) |
|---|---|---|---|---|---|---|---|---|---|
| CMS1 | Circular | 0.19 | 80 | 1.6 | 70.42 | 35.48 | 2838.10 | 50.38 | 14937 |
| CMS2 | Square | 0.24 | 80 | 1.6 | 60.52 | 10.54 | 843.16 | 17.42 | 3513 |
| CMS3 | Circular | 0.22 | 80 | 1.9 | 92.49 | 46.20 | 3696.35 | 49.95 | 16802 |
| CMS4 | Square | 0.31 | 80 | 1.9 | 125.99 | 36.45 | 2916.03 | 28.93 | 9407 |
| LMS1 | Circular | 0.22 | 80 | 1.6 | 82.74 | 41.94 | 3355.41 | 50.69 | 15252 |
| LMS2 | Square | 0.30 | 80 | 1.6 | 86.27 | 27.80 | 2223.97 | 32.22 | 7413 |
| LMS3 | Circular | 0.24 | 80 | 1.9 | 105.85 | 54.95 | 4396.32 | 51.91 | 18318 |
| LMS4 | Square | 0.36 | 80 | 1.9 | 139.36 | 47.68 | 3814.70 | 34.21 | 10596 |

## CONCLUSIONS

The energy absorption capacity of conventional mild steel (CMS) and laminated mild steel (LMS) shell were analyses by experimental methods. The modes of failure and load displacement graphs were extracted from experimental data. Crush load efficiency (CLE) and specific energy absorption (SEA) are important factors to be considered to justify the crashworthiness of hallow shell structures. Model with higher crush load efficiency (CLE) and specific energy absorption (SEA) are always chosen in fabrication of structures.Both conventional mild steel (CMS) and laminated mild steel (LMS) specimens shows similar trend in load displacement curve but the laminated mild steel (LMS) has higher initial crush and greater average load than conventional mild steel (CMS). The E-glass fiber/polyester resin laminated mild steel (LMS) shows higher initial collapse load, higher average load, and high ultimate peak load than of conventional mild steel (CMS) specimens and it absorbs more energy. The ability of this family of hybrid to absorb more energy due to combination of two materials with different properties that is significantly better than any materials currently on the market.

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