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INVESTIGATION OF LOW VELOCITY IMPACT RESPONSE OF ALUMINIUM HONEYCOMB SANDWICH PANELS

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ABSTRACT

Low velocity impact response of aluminium honeycomb core sandwich panels have been investigated by varying core height using a flat impactor of 25 x 25mm. The impact energy levels were varied from 6.32J to 49.72J and energy absorbed, peak load developed and maximum penetration were recorded for each test specimen. Quasi-static tests on aluminium facing sandwich panels of the same dimension (150 x 150mm) and boundary conditions as impact test using flat indenter of 25 x 25mm were conducted in order to co-relate these results with impact tests. A variation in core height of aluminium honeycomb core does not show any significant change in energy absorbing capacity of the sandwich panels. It is observed that an increase in core height increases the time taken to reach peak energy which is desirable for many applications like automobile bumper. Quasi-static test and impact test were co-related using impact factor in the linear elastic region.

Keywords: aluminium honeycomb core, low velocity impact, sandwich panels, quasi-static test, core height.

Notations

ρ^* = Density of solid from which it was made (kg/m^3)
ρ_s = Density of cellular material (kg/m^3)
$\Delta_{I.F}$ = Calculated deflection using impact factor (mm)
Δ_w = Static deflection for impactor weight (mm)

1. INTRODUCTION

For design and construction of lightweight transportation systems such as satellites, aircraft, high-speed trains and fast ferries, structural weight saving is one of the major considerations. To meet this requirement, aluminium honeycomb sandwich construction has been recognized as a promising concept. Recently, attempts to use aluminium sandwich panels as strength members of high-speed vessels hulls also been made [1, 2]. A sandwich construction provides excellent structural efficiency i.e., with high ratio of strength to weight, high specific bending stiffness and strength under distributed loads in addition to their good energy-absorbing capacity [3]. To enhance the attractiveness of sandwich construction, it is thus essential to better understand the local strength and energy-absorbing characteristics of individual sandwich panel members. For the same purpose low-velocity impact response of aluminium honeycomb core sandwich panels have been investigated by varying impact energy levels, and energy absorbed, peak load developed and maximum penetration were recorded for each test, which is presented in this paper. Yamashita and Gotoh [4] studied the quasi-static compression response of the aluminium honey comb in the thickness direction. The numerical investigation showed that the cyclic buckling mode takes place in every case and that the crushing strength attains the maximum value when the cell shape is regular hexagon. The mechanical properties of honeycomb structures under transverse loading were investigated both analytically and experimentally by Gibson and Ashby [5]. Wu and Jiang [6] focused on the investigation of the crushing phenomena of honeycomb structure under both Quasi-static and dynamic load condition. Considering the effect of cell dimension, material thickness and cell shape, they concluded that honeycomb with smaller cell size and higher strength material had higher energy absorption capacity. The aim of the present study is to investigate the influence of the core height on absorption capacity of honeycomb panel. Lagace and co-workers [7] conducted a series of quasi-static and low velocity impact tests on square sandwich panels using a hemispherical indenter. They showed that quasi-static and impact loads produced the same responses in terms of damage characteristics. It is understood that for loads with-in the shear yield strength of the core, the deflection produced both under static and dynamic loading is the same. This is supported through experimental investigation in the current study. This is extended to predict the impact behavior of sandwich panel under dynamic loads through static testing in the linear-elastic region of the core material.

2. NUMERICAL INVESTIGATION

The honeycomb core was modelled using Surface module of CATIA v5. Meshing of the geometry was done using HYPERMESH v.9.0. *2D* auto mesh was adopted to mesh the geometry; the size of the mesh was chosen to be 1.0mm for the core elements [8]. For the plates, 2D spline elements were generated using the nodes on top of the honeycomb core to get the top facing sheet and bottom nodes were used to obtain the bottom facing sheet, the final geometrical model was obtained as shown in Figure-1. Spline elements ensure connectivity between the nodes of the core and the plate.

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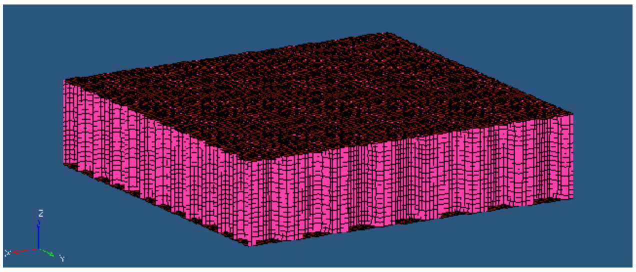

Figure-1. Finite element model of honeycomb panel.

Table-1. The material type and material card as assigned in the pre-processing stage to the model.

Component	**Material**	**Shell element thickness** (mm)	**Material card**
Plate	Mat plastic kinematic	1	Mat 3
Core	Mat plastic kinematic	0.065	Mat 3

Boundary conditions are applied to simulate the exact test conditions, the top and bottom plates are fully clamped over an area extending up to 25mm from the ends on all four sides as shown in Figure-2, and a load over an area of 25 x 25 mm at the centre is applied to simulate the quasi-static testing conditions.

On solving the file by applying a load of 0.5kN and solving on OPTISTRUCT a maximum displacement of 0.25mm is obtained as shown in Figure-3. The load is varied and solved for the various conditions of loading.

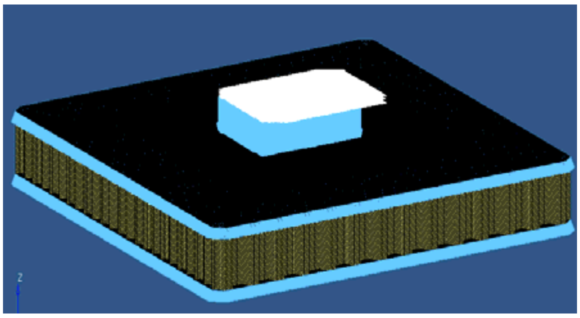

Figure-2. Boundary conditions applied to FE model.

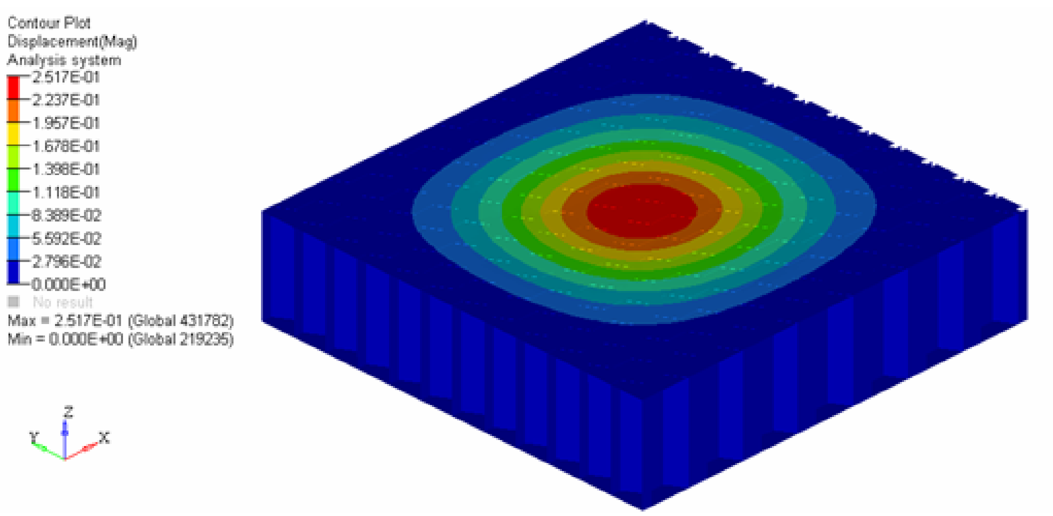

Figure-3. Deformation plot of sandwich panel.

3. EXPERIMENTAL INVESTIGATIONS

3.1 Details of test specimen

Table-2. Specimen details.

Specimen type	**Specimen height** (mm)	**Plate thickness** (mm)	**Core shell thickness** (mm)	**Cell size** (mm)	**Mass** (g)	**Core density** (kg/m^3)	**Relative density of the core** (ρ^*/ρ_s)
Aluminium facing/Aluminium honeycomb core (A- series)	19.95	1.02	0.06	6.32	179.5	74.88	0.0277
Aluminium facing/Aluminium honeycomb core (X -Series)	9.80	0.99	0.06	6.23	177.0	74.88	0.0277

The facing sheets and honeycomb core of A-series and X-series were made up of Aluminium alloy AA 3003 series. (Class: wrought). The facing sheets were bonded to the honeycomb core using epoxy resin (HY 951) of negligible thickness. The size of the specimen for both impact and quasi-static tests was 150 x 150mm. The test specimen was clamped on all four sides for both tests.

3.2 Quasi-static test

This test was performed using the digital flexural test machine which has a data acquisition system connected to a computer. A square impactor of dimension (25 x 25mm) was used in the tests. Three trials were conducted and the results obtained for one of the trials is shown below.

Table -3. Static Indentation results of A series sandwich panel.

Input parameters	**Output results**
Specimen: ST A01 (A-series)	Ultimate load (kN): 4.674
Specimen width(mm): 150	Ult. Compression strength(N/mm^2): 1.558
Specimen thickness(mm): 20	Displacement at max. load(mm): 5.61
Cross section area(mm^2): 3000	Maximum displacement(mm): 6.45
Test speed(mm/min): 10	Load/width (kN/cm): 0.312

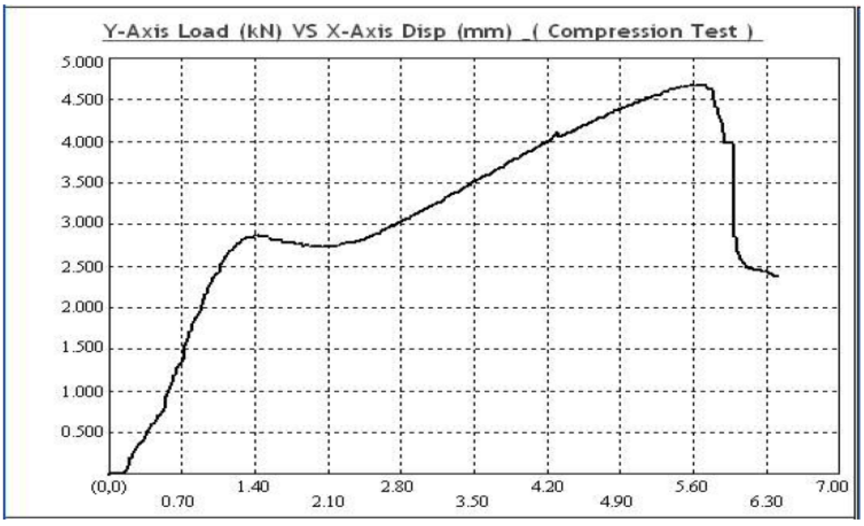

Figure-4. Load vs deflection (static indentation test).

3.3 Low velocity impact test

As an efficient way to perform low-velocity impact tests, drop-weight impact testing machine was used. However, because of the limit of the drop height, the impact velocity produced by the drop-weight impact testing machine is less than 10m/s. Five to six test specimens of the sandwich panel (A-series and X-series) were tested for different impact energies. All the tests were conducted according to ASTM standards (ASTM D3763).

Input parameters

Table-4. Impact test results of A series sandwich panel.

Specimen	: **A01** (A-series)	Mass (kg)	: 2.576
Face thickness (mm)	: 1	Height (mm)	: 750
Core thickness (mm)	: 18	Velocity (m/s)	: 3.836
Face material	: Aluminium	Impact energy (J)	: 18.95
Core material	:Aluminium	Impactor	: Square impactor (25X25 mm)

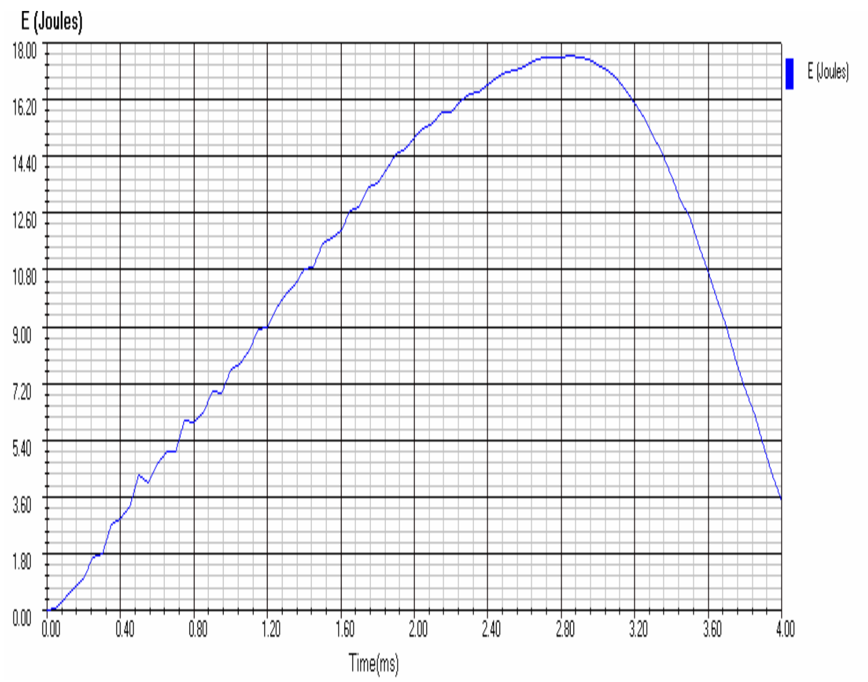

Figure-5. Load v/s time.

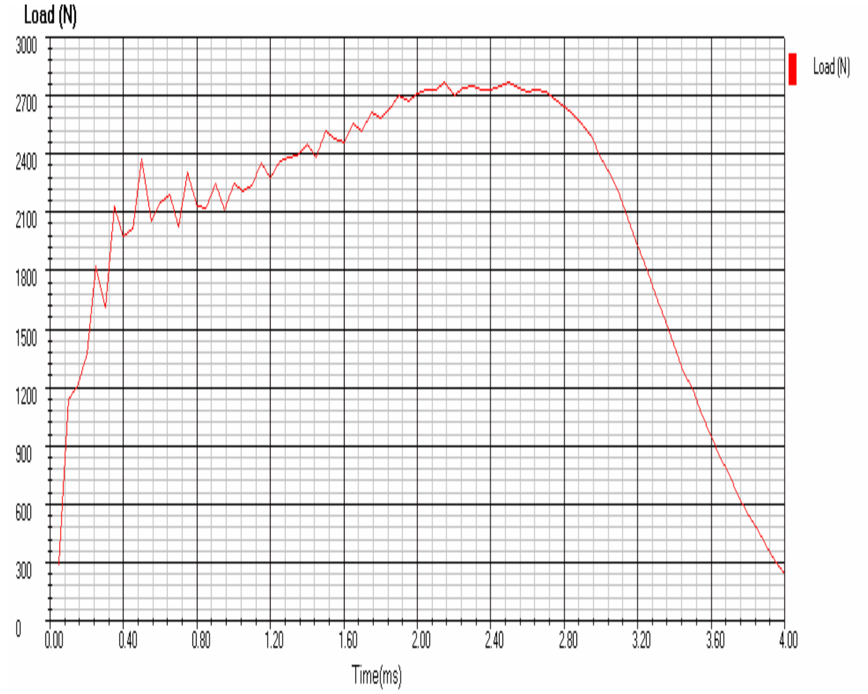

Figure-6. Energy v/s time.

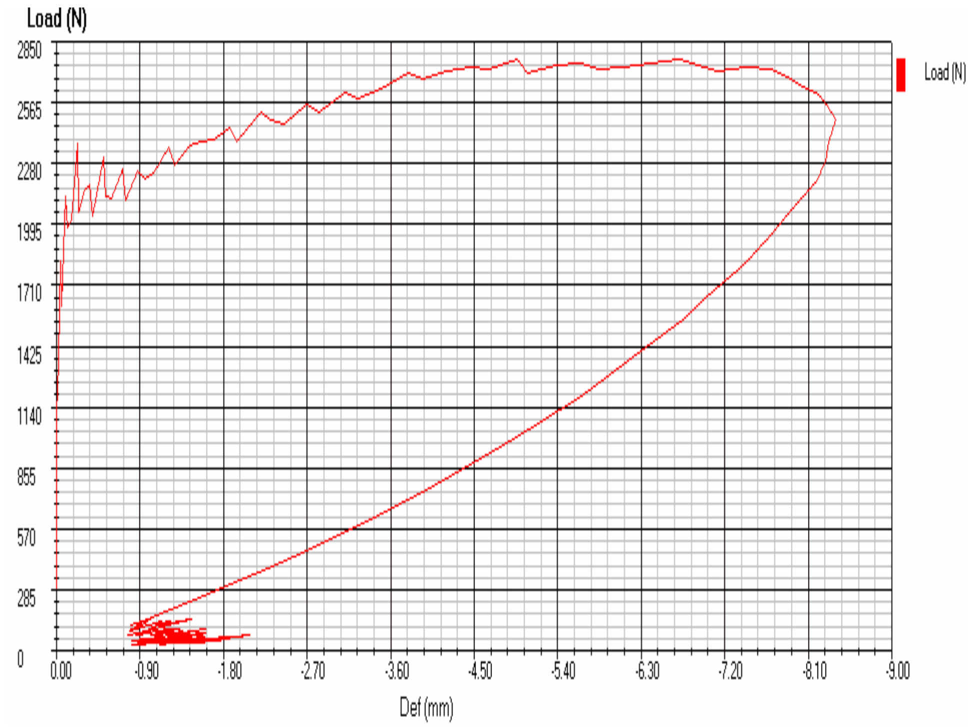

Figure-7. Load v/s displacement.

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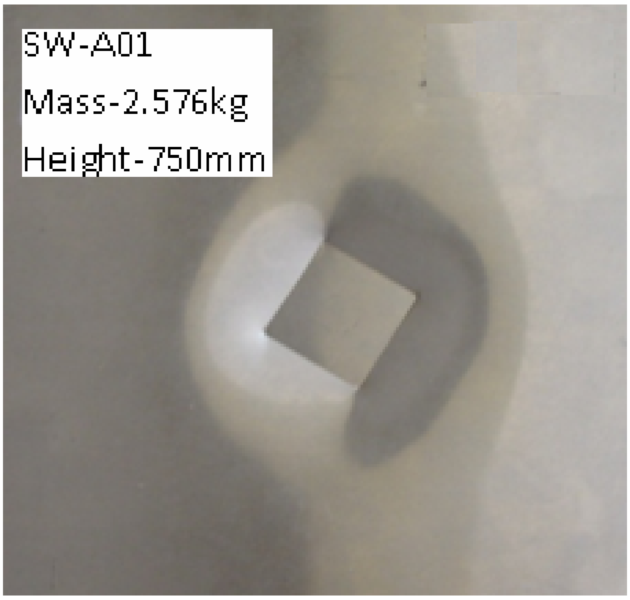

Figure-8. Impacted specimen.

4. RESULTS AND DISCUSSIONS

4.1 Variation of core height
(Impact height = 750mm, impact mass = 5.067kg)

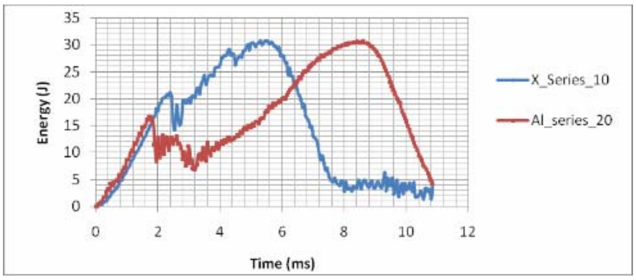

Figure-9. Energy v/s time for different core height.

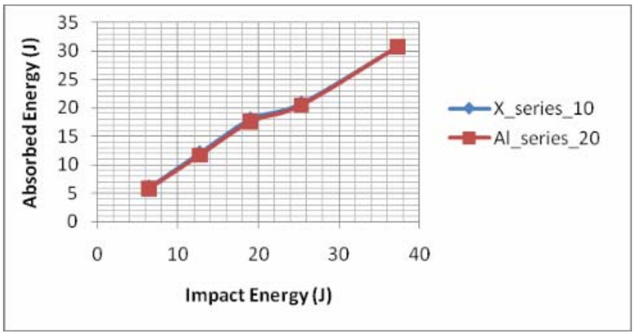

Figure-10. Absorbed energy v/s impact energy for different core height.

Observations

The transfer of impact energy from the top plate to the bottom plate is delayed with increase in core height. The change in core height does not have any influence on the peak absorbed energy.

4.2 Co-relation of quasi-static test and impact test

The co-relation of quasi-static and low velocity impact test was obtained using impact factor (I.F) for aluminum facing sandwich panels of height 20mm and cell size 6.25mm.

$$\text{Impact Factor (I.F)} = \frac{\text{Dynamic stress or deflection}}{\text{Static stress or deflection}}$$

$$\text{I.F} = 1 + \sqrt{[1+2*(h/y)]}$$

Where

h = Impact height (mm)

y = static deflection for peak impact load (mm)

For specimen A06 in Table-6;

$$\text{I.F} = 1 + \sqrt{[1+2*(250/0.68)} = 28.095$$

Calculated deflection using I.F

$\Delta_{I.F} = I.F * \Delta_w$

$= 28.095*.0532$

$\Delta_{I.F} = 1.495\text{mm}$

Table-6. Impact factor for different aluminium specimen.

Specimen No.	**Impact height** (mm)	**Impactor mass** (kg)	**Impact energy** (J)	**Maximum deflection** (mm)	**Static deflection at peak load** Δ_d(mm)	**Impact factor I.F.**	**Calculated deflection Using I.F.** $\Delta_{I.F}$(mm)	**Static deflection for impactor weight** Δ_w (mm)
A06	250	2.576	6.32	1.4838	0.682	28.095	1.495	0.0532
A04	500	2.576	12.64	2.44	0.9	36.369	1.935	0.0532
A01	750	2.576	18.95	3.177	1.2	37.609	2.00	0.0532
A05	1000	2.576	25.27	3.496	1.15	42.71	2.27	0.0532
A07	750	5.067	37.28	5.2483	1.15	37.129	2.599	0.0699

Comparison of experimental penetration and theoretical penetration

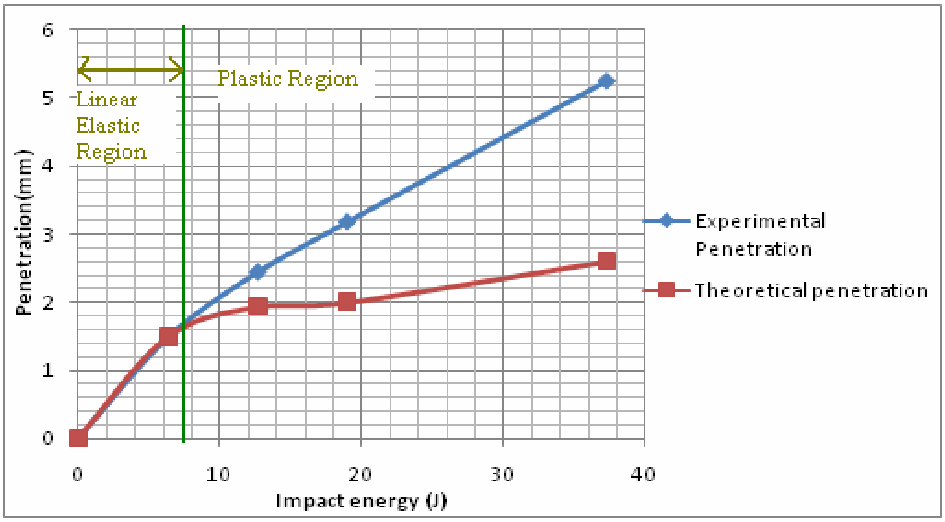

Figure-11. Deflection for various impact energies obtained from impact factor and through experiment.

The tests were conducted for various impact energies and also theoretical penetration for the same conditions was calculated and the comparison is given in the Figure-11. It is observed that the values obtained from experiments are in agreement with the theoretical values up to a point where the load reaches the shear yield strength of the core. Beyond that the behaviour is unpredictable due to rapid core crushing.

4.3 Comparison of numerical and experimental results

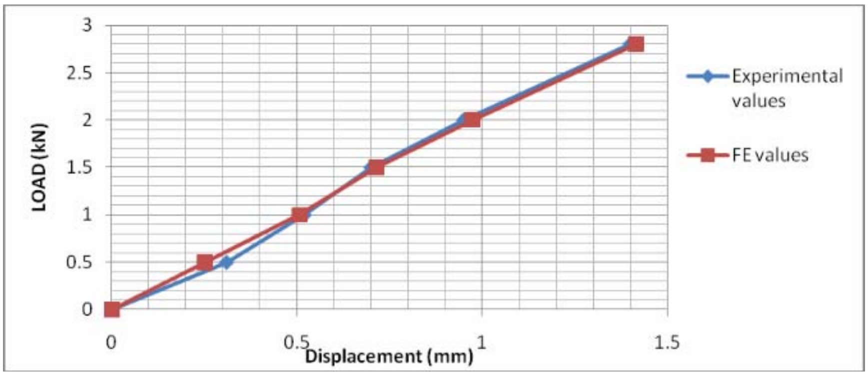

Figure-12. Graph of Load vs. Displacement.

5. CONCLUSIONS

Low velocity impact response of honeycomb core sandwich panels has been investigated by varying the core height and it has been observed that while it does not show significant change in energy absorbing capacity of the sandwich panels as the top face absorbs more energy when compared to the core, it increases the time taken to reach the peak energy which is desirable for many applications like automobile bumper. Quasi-static test and impact test were co-related using impact factor in the linear elastic region. Hence quasi-static test can be conducted to determine the dynamic properties within shear yield strength of the core.

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