Effect of multi-layers in Aluminium corrugated sandwich panels under blast loading.

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Abstract: Composites and sandwiched aluminium structures are of great importance when considering various structures of aerospace, mechanical and civil structural significance. The failure of these structures due to shockwaves and explosions are of critical importance when designing structures and hence in this study we investigate the dynamic response of aluminium corrugated sandwich panels based on the objective criteria composite layering. The result of these experiments are studied based on numerical explicit modelling of the panels and conclusions have been drawn to analyse the significance of parameters under such dynamic loads.

Keywords: Corrugated sandwich panels,TNT blast,layering,dynamic response.

1.Introduction

Terrorism is becoming a crisis that world is facing and recent attacks highlights the importance of building safety. Hence it is paramount to design blast resistant structures. On the basis of various studies, it is found that structures built using aluminium sandwich panels, either pre-cast or cast in-situ, shows great resistance against the blast attacks. Aluminium sandwich panels are extensively used in different fields such as construction works, industries, railway systems and marine works. It can be efficiently used in these fields, since it is having easier fabrication methods, low density and higher strength compared to monolithic plates. Also it can be used in various structures were weight savings are necessary.

Various studies have been conducted on static and dynamic response of aluminium sandwich panels. X Li etal[1]conducted an experimental study on dynamic response of aluminium corrugated sandwich panels using four-cable ballistic pendulum system. Numerical simulation were also performed on two configurations of specimens considered. Xiaochao et.al[2] proposed an auxetic re-entrant cell honeycomb cores and their dynamic response and blast resistance is numerically investigated. Shiqiang Li et.al[3] experimented on blast response of metallic sandwich panels with stepwise graded aluminium honeycomb cores. It was found that for graded panels with relative density descending core arrangement, transmitted force attenuation and energy dissipation were larger than ungraded panels. M.D.Goelet.etal[4]studied about the blast resistance of stiffened sandwich panels with aluminium cenosphere syntactic foam core. Quantitative assessment is used for the dynamic response study, focussing maximum central point deflection of back sheet of sandwich structure. The effect of foam thickness, stiffness configuration and strain rate are considered in the study .Zhang etal[5]conducted an experimental study on dynamic response of metallic trapezoidal corrugated-core sandwich panels subjected to air blast loading. Sigit.P.Santhosha etal[6] done similar study on response analysis of blast impact loading of metal-foam sandwich panels. Structural responses in terms of displacement, velocity and acceleration is taken into account.The experimental and numerical investigation of the blast response of flexible sandwich panels are also reported [7-13]

2.Experiment

2.1. Experimental setup

The corrugated sandwich panels for the experiment were collected and the face sheet and core were attached by hot melt adhesive members. The face sheet and core was made using AL-1200H18,and the mechanical properties are specified as follows: density $\rho=2.71\times10^3$kg/m^3,Youngs modulus

E=70GPa,Poissons ratio λ=0.33,tensile strength=210MPa,yield stress=140MPa.[1].A four cable ballistic pendulum system was used for the experimental process.It was used to measure the impulse applied on the specimen.Tthe entire experimental setup consists of clamp frames, a steel beam and counterweight balance, and the system was suspended using four wire ropes shown in Fig.1.The specimen was mounted onto the frame by 16 screws on the front of the pendulum. The explosive charge or the detonator was mounted in front of the specimen. A laser displacement sensor was mounded behind the pendulum inorder to measure its translation. From the recorded oscillated amplitude, the impulse exerted on the front face of the pendulum was calculated and from the exposed area of specimen effective impulse of the specimen was further calculated. The dimensions of specimen was 300mm×300mm and the blast exposed region had the dimension 250mm×250mm.A total of eight experiments was conducted for two different geometries. The experiment was conducted by Xin Li, in Shenzhen, China 2014.
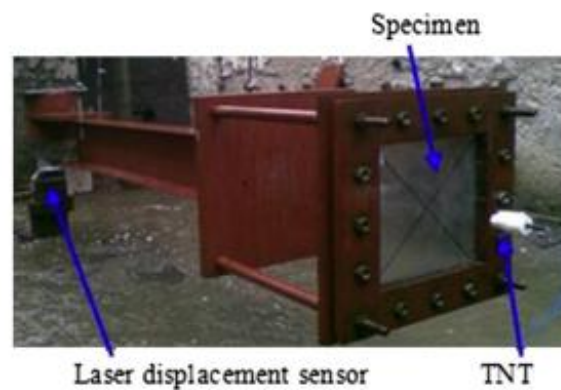

Figure.1.Four cable ballistic pendulum system[1]

Table1: Dimensions of corrugated sheets used in the experiment(X, Li etal

Configuration	H_f/Face sheet thickness	H_c/Core height	t/Core thickness	Length/a	Length/b	θ	Cell length/s
1	0.8	4	0.2	4	8	63.4	12
2	0.8	8	0.2	7	14	66.4	21

Table1: Dimensions of corrugated sheets used in the experiment(X, Li etal)

Eight test were conducted for two different specimens of varying face sheet thickness under the above experimental conditions.
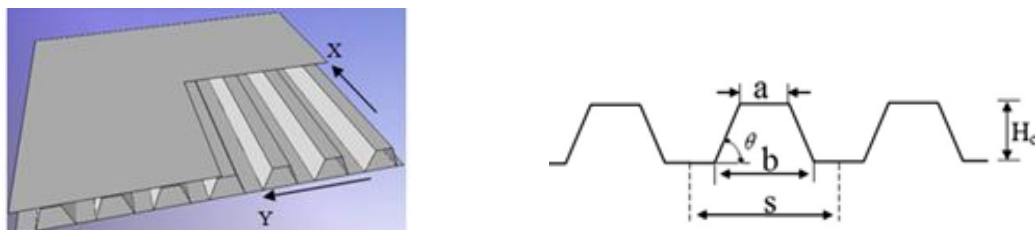

Figure2.Sketch of the specimen [1]

2.2. Test results

The residual back deflection of the back face sheet and failure modes of face sheets and core are analysed. Deformation o of the specimen is obtained by the time-displacement curve plotted by sensor. With the increase of TNT mass and decreasing the face off distance, the impulse exerted on the specimen increases which is listed in Table 2.
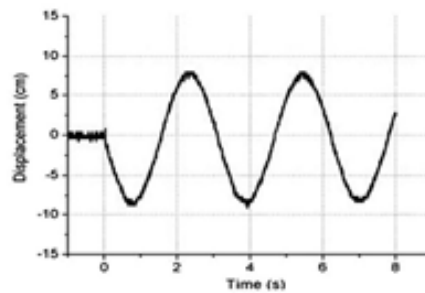

Figure3.Time-Displacement curve[1]

Table2. Impulse and maximum residual back deflection

Test number	1	2	3	4	5	6	7	8
Configuration	1	1	1	1	2	2	2	2
m/Mass of TNT(g)	10	10	15	30	15	15	30	30
R/Distance between panel and TNT(mm)	120	100	100	210	120	100	240	190
I/Impulse(NS)	11.8	13.7	14.3	23.8	13.2	14.1	19	26.7
δ/Maximum residual back deflection(mm)	13.5	19	23.6	43.4	21.7	24.5	41.4	61.5

Plastic deformations are only formed and no pitting failures are observed in the specimen.The core is divided into three regions, full-folded, partially-folded and clamped region.The plastic deformation is larger in the full-folded region, since it is located at the centre. The deformation or the impulse produced in the clamped region is small due to presence of clamped frame.

3.Methodology

3.1. Finite element model

The dynamic response study of sandwich panels are analysed using ANSYS AUTODYN software.150mm×150mmaluminium corrugated panels with core and face sheet dimensions as in Table.1, configuration 2 is modelled. A clamp frame 20mm×5mm is provided at the eddges of the ANSYS model in order to provide constrains to the panel.

Table.3. Mechanical properties of material

Density	2700 kg/m^3
Bulk modulus	6.862745×10^7
Poisson's ratio,λ	0.33
Yeild stress,σ	140MPa
Elastic modulus,E	70GPa
Shear modulus	2.631579×10^7
Yeild stress	1.4×10^5MPa
Tangent modulus	5×10^5

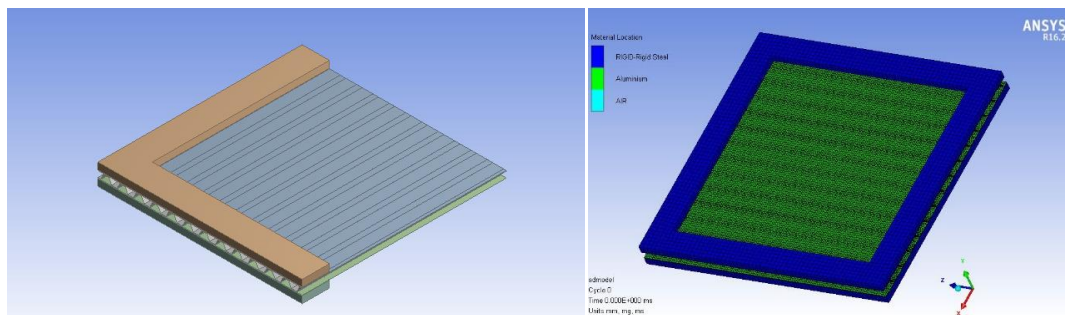Meshing is done after mesh convergence for 0.5mm mesh size with 1.9 lakh nodes.

Figure.4 a)Quarter model of Sandwich panel   b)Meshed model of Sandwich panel

Mass of 15gm TNT is placed at a stand-off distance 120mm vertical the middle point of the model as in test number 5 given in Table.2.and the FEM model of air is shown in Fig.5.
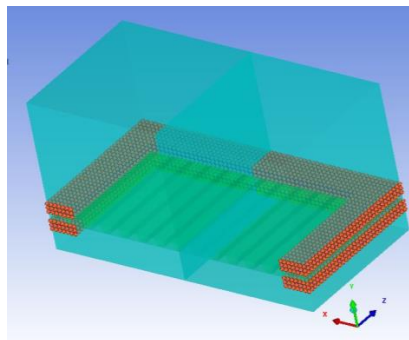

Figure.5.FEM model of air

3.2. Validation

The results obtained from the validation model shows acceptable agreement with the base journal. Displacement-Time graph is plotted and the results shows that the average error percentage is 4.73%, hence the numerical validation is considered acceptable shown in Table.4.

Table.4. Validation results

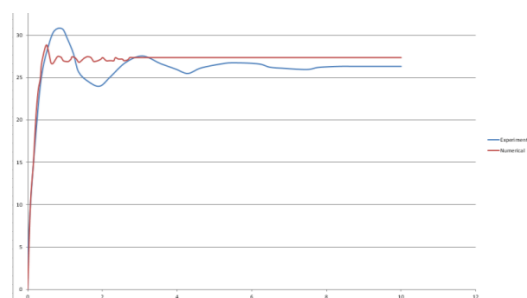|	Experimental result	Numerical result	Error
Maximum deflection	30.53	28.8	5.67%
Plastic deformation	27.3	26.3	3.8%

Figure.6. Validation curve
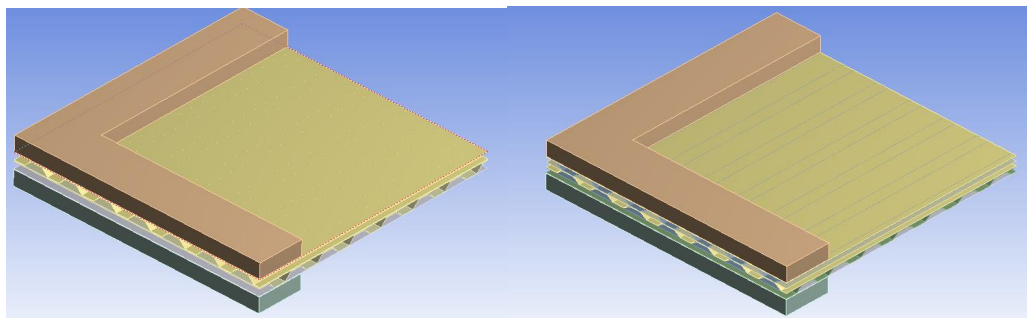
3.3. Project model

a)Geometric models

Eight geometric multi-layered models are done under the same volume and core height criteria that of the validation model. The corresponding face sheet and core thickness is adjusted using the acceptable gauge sizes of aluminium. The alignment and orientation of layers are altered in the various geometries. The geometric details of model is shown in Table.5.

Table.5. Details of project models

No.	Designation	Core height(mm)	Plate thickness(mm)	Core thickness(mm)
1	L2-SS-0-0	8	0.511	0.18
2	L2-SS-0-90	8	0.511	0.18
3	L2-SI-0-0	8	0.511	0.18
4	L2-SI-0-90	8	0.511	0.18
5	L3-SSS-0-0-0	8	0.361	0.16
6	L3-SSS-0-90-0	8	0.361	0.16
7	L3-SIS-0-0-0	8	0.361	0.16
8	L3-SIS-0-0-90	8	0.361	0.16

Four models are done for both double layer,L2 and triple layer,L3.The alignment of face sheets in each model are varied either straight,S or inverted,I accordingly. Also the orientation of selected plates along the vertical axis is varied by 90^0.Sample quarter model of L2-SI-0-90 and L3-SIS-0-0-90 are shown in Fig.7. 15gm of TNT is added at a standoff distance 120mm for 5millisececonds.

Figure.7.Quarter models of a)L2-SI-0-90 b)L3-SIS-0-0-90

b) Results and discussions

The deformation behaviour of double layer and triple layer is different in models. In double layer models(model no.1,2,3,4), it is deformed downwards and after maximum deflection point, the deformation is proceeded almost constantly.In triple layer models(model no.5,6,7,8),during the initial period, the sheet is deflected in the downward direction and after 0.8milliseconds it is found to be deflected back due to the vaccum created at the point of blast.Maximum deflection and minimum deflection of various models are shown in Table.6.From the results obtained it is observed that deflection values of triple layer models are less compared to that of double layer models.The maximum deflection is observed in L2-SI-0-0 and minimum deflection is observed in L3-SIS-0-0-0

and L3-SSS-0-90-0.The deformation behaviour of L2-SI-0-0 and L3-SIS-0-0-0 and the comparison curve of all the models are shown in Fig.8. ,negative deflection in Y- axis and time in X-axis.

Table.6.Maximum and minimum deflection values of models

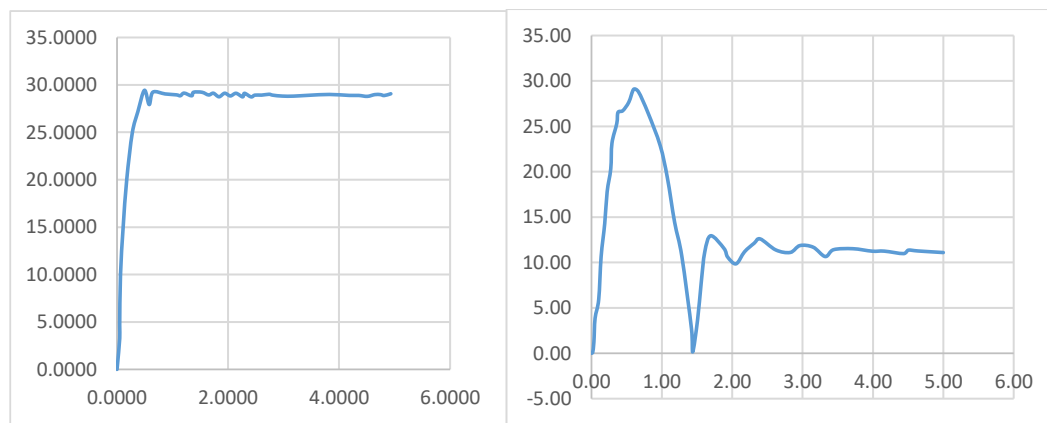| Model	Maximum deflection(mm)	Minimum deflection(mm)
L1-S-0(validation model)	28.8	24.35
L2-SS-0-0	29.35	23.93
L2-SS-0-90	28.61	24.61
L2-SI-0-0	29.19	29.063
L2-SI-0-90	29.43	28.23
L3-SSS-0-0-0	29.43	15.47
L3-SSS-0-90-0	29.07	11.19
L3-SIS-0-0-0	29.08	11.10
L3-SIS-0-0-90	27.76	11.43

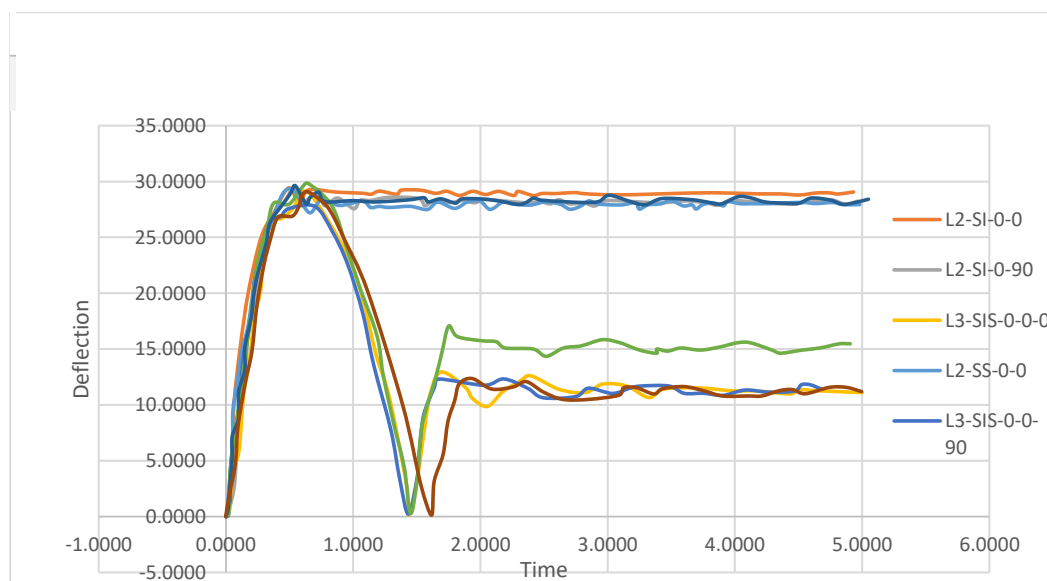**Figure.8**. a)Deflection-time curve of L2-SI-0-0 and L3-SIS-0-0-0.

Figure.8.b) Comparison graph of models.

Conclusion

The dynamic response of multi-layered trapezoidal panels under blast loading is studied and it is observed that, as number of layer of face sheet is increased, the panel deflection is decreased. It is found that triple layered, L3-SIS-0-0-0 and L3-SSS-0-90-0 models shows satisfactory results under the blast load.

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