Numerical Investigation of Steel Cabin Subjected to Confined Explosion

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***Abstract** - The use of steel cabins are very common nowadays in military areas and in areas of short duration construction due to advantages like low cost, lesser time for construction, easy replacement etc. The damage to these structures occur from accidents i.e., internal explosions which are confined in nature. Explosions in confined spaces lead to complicated patterns of shock wave reflection and interactions causing higher effects than unconfined explosion. This work focuses on extracting the failure modes and predicting damage of steel cabin structure under internal blast loading by a series of three-dimensional numerical simulations using FE software AUTODYN. Effect of using varying scaled down cabin configuration when subjected to internal blast is also undertaken.*

***Key Words:** Blast load, steel structures, FE model, AUTODYN, modes of failure.*

1. INTRODUCTION

In the recent years, the terrorist activities in the nation have risen to the highest. Majority of these attacks are aimed at public buildings or public transport systems. Thus, an attack on the pier structures is just a matter of time. As science is evolving, the chemicals used for creating the explosions are also evolving. Some of the new chemical explosives cannot be detected even by using state of the art explosive detection techniques. So, it is better that we stay prepared to face such a scenario. So in addition to natural and technological hazards, in recent years owners tenants, and design professionals have had to consider design criteria to address an additional hazard to public buildings- the deliberately placed bomb.

Damage to the assets, loss of life and social panic are factors that have to be minimized if the threat of terrorist action cannot be stopped. Designing the structures to be fully blast resistant is not a realistic and economical option, however current engineering and architectural knowledge can enhance the new and existing buildings to mitigate the effects of an explosion.

The analysis of the blast loading on the structure started in 1960s. US Department of the Army, released a technical manual titled "Structures to Resist the Effects of Accidental Explosions" in 1959. The revised edition of the manual TM 5-1300 (1990) has been most widely used by military and civilian organizations for designing structures to prevent the propagation of explosion and to provide protection for personnel and valuable equipments.

Researches in Ref [1_4] have shown that internal explosions are complicated and that they are more destructive than normal explosions. Existing researchers related to internal explosion are rare. Huetal et al [5] investigated the characteristics of confined blast loading in unvented structures, the results show the blast load is magnified compared with unconfined blast. Xiang-Shao et al [6] investigated the failure modes of steel cabin structure under internal blast loading and concluded that confined explosion causes more damage than a similar external free-air explosion. Neuberger et al[7] and Duo Zhang et al.[8] also highlighted various studies on the applicability of scaling laws for comparison of similar blast events using different explosive mass on steel cabin structures subjected to internal blast loading. J.M. Pereira et al and Feng Zhu1 et al [9] conducted studies on retrofitting of structures subjected to blast. They showed that to improve the blast resistance, cracked steel structures were stiffened using carbon fibre-reinforced polymer (CFRP) composite patches. Weihong Hou et al [10] studied the blast effect on metallic sandwich structures with aluminium foam as core material and showed that foam infill reduce the deflections.

Steel box structures are common in military areas, ships, van-body trucks, and steel buildings. The ships, trucks and buildings are facing the threat of internal explosion for many reasons, such as occasional explosion, terrorism attack and military strike. Single steel cabin and multi-steel cabin structures are commonly available and nowadays the demands for these steel cabins are increasing mainly in military areas and industries. So the threat of terrorist attacks, or occasional explosion is high. This paper therefore focuses on predicting the damage features of steel cabin structure under internal blast loading by a series of three-dimensional numerical simulations using FE software AUTODYN.

2. NUMERICAL SIMULATIONS

Full-scale models involving actual geometries and charges are complicated in terms of both preparation and measurements. Thus, scaled-down models are highly desirable.

To investigate the dynamic response of steel cabin when subjected to internal explosion, corresponding 3D finite element simulations have been undertaken using the AUTODYN software.

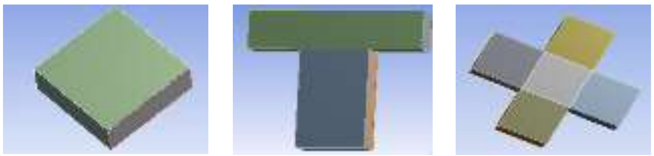
2.1 Material model and parameters

In this numerical model, the steel cabin is modelled as a surface body based on bilinear hardening condition with isotropic strain hardening. The cabin model is made up of 3mm thickness Q235B steel plates, respectively. All surfaces of the model were meshed using four –noded element type SHELL163 with an element size of 15mm and equation of state (EOS) adopted is linear. The boundary condition for the steel cabin is simply supported. Map file is created on multi-material Euler mesh. In Lagrange/Lagrange interaction, frictionless type is adopted and in Euler/Lagrange interaction, coupling type chosen is fully coupled.

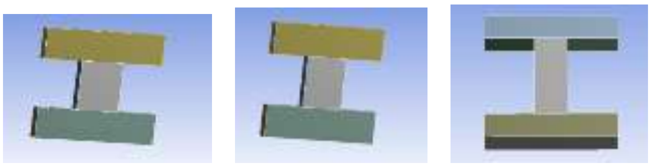
Table -1: Mechanical properties of Q235B steel plate

Steel plate	Yield strength (MPa)	Ultimate strength (MPa)	Youngs modulus (GPa)	Percentage elongation (%)
Q235B	368	484	200	29

Fig- 1 shows the designed models of six steel cabin with constant volume. The height of the designed model is fixed as 200mm. For comparison, gauge point selected is 100mm to the top plate from the center of gravity of each model. Table 2 shows the details of designed models.



(a) Model C1 (b) Model C2 (c) Model C3



(d) Model C4 (e) Model C5 (f) Model C6

Fig -1: Designed Model Geometry

2.2 Blast Setup

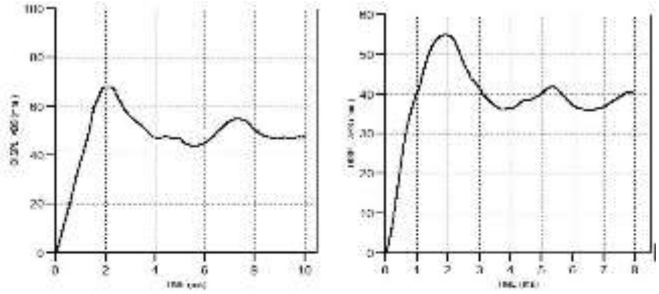
Table –2: Details of Designed Models.

Model No	Volume (mm³)	Height (mm)	Width (mm)	Length (mm)	
Model C1	91125000	200	675	675	
Model C2	91125000	200	300	Flange 760	Web 758.75
Model C3	91125000	200	300	Horizontal direction 309.37	Vertical direction 300
Model C4	91125000	200	250	Flange 710	Web 402.5
Model C5	91125000	200	200	Flange 890	Web 498.12
Model C6	91125000	200	200	Flange 800	Web 678.12

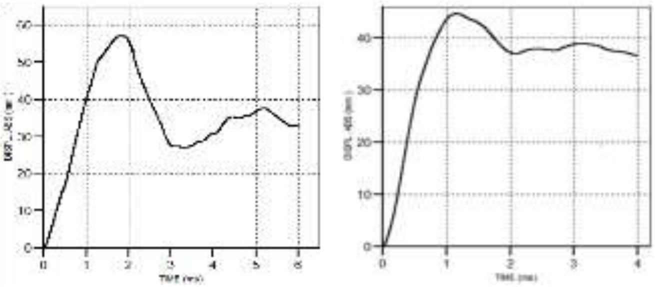
TNT explosive of 79.1g with a density of 1.5 g/cm3 is used in the present study for it is a standard high explosive which is chemically safe and easy to cast. The TNT explosive is suspended in the center of the central cabin. Air and TNT is modelled using euler mesh with a detonation time of 4ms in AUTODYN.

2.3 Results and Discussion

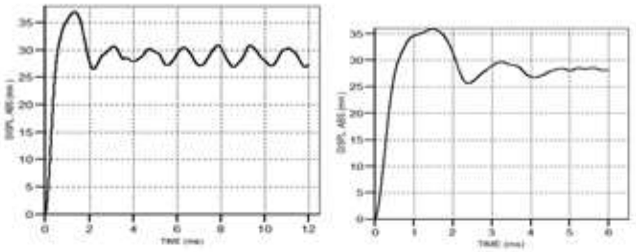
The result of numerical models shows outward bulging in all side plates and inplane buckling of the boundary plate. The displacements vs. time graph of six designed models are shown in Chart 2. The residual displacement obtained for six model w.r.t to gauge point is 44, 40, 34, 37, 30 and 28 mm respectively. Thus for the model 6 i.e. I shape model shows least residual displacement. From the FEA result shown in Figure 2, outward bulging of the plates and inplane buckling at edges are observed.



(a) Model C1 (b) Model C2

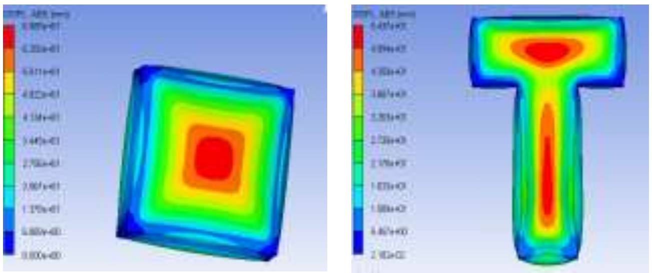


(c) Model C3 (d) Model C4

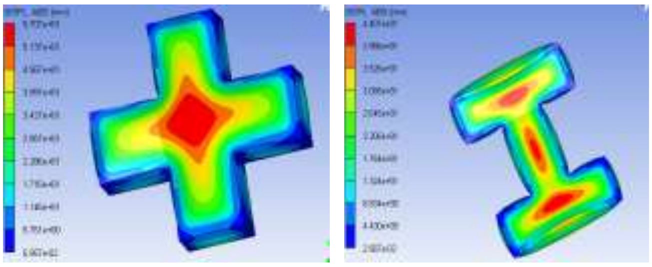


(e) Model C5 (f) Model C6

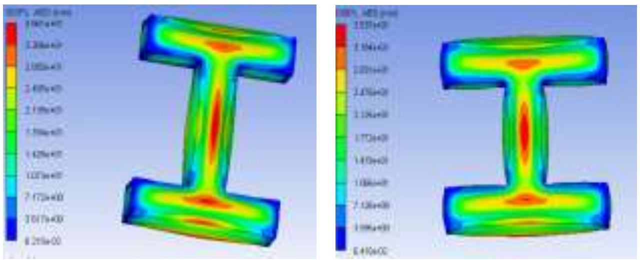
Chart 1: Displacement vs. Time Graph



(a) Model C1 (b) Model C2



(c) Model C3 (d) Model C4



(e) Model C5 (f) Model C6

Fig -2: FEA results

3. CONCLUSIONS

The present work addresses the influence of blast wave on dynamic response of steel cabin with varying shape. Numerical method is introduced and numerical simulations are carried out for six set of steel box models using the finite element software AUTODYN. Through analysing the numerical results, model C6 (I shape model) is found to have least residual displacement. The combined displacement vs. time graph is shown in Chart 2.

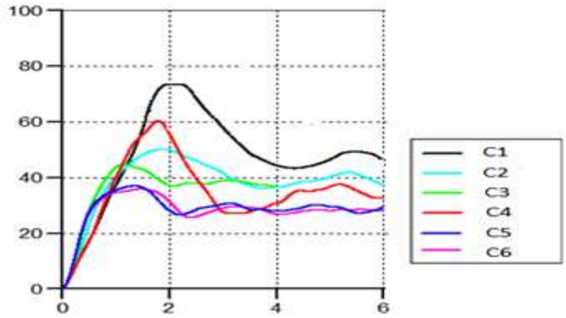


Chart 2: Combined Displacement vs. Time Graph

This is because the plate's play a major role in absorbing most of the blast energy and also the mises stress distribution is less for model C6 compared to others. The deformation features of all tests are similar with outward bulging of side plates.

Further research on steel box structures with different configuration under internal blast loading should be conducted to study the failure and deflection mechanism in detail. Also, additional research on strengthening of steel cabin should also be carried out. For that different materials can be selected as core materials like concrete, Aluminium foam etc in sandwich structures.

ACKNOWLEDGEMENT

The authors wish to gratefully acknowledge the support from the management and staff from CIVIL Department of Federal Institute of Science and Technology, Angamaly.

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BIOGRAPHIES

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