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Static and Dynamic analysis of fireworks industrial buildings under impulsive loading

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Abstract
Accidental explosions causing manmade disasters while manufacturing fire crackers are reported very often in Sivakasi region of southern TamilNadu. Collapse of brick masonry structures during explosion also cause loss of human lives and hinder the continuity of manufacturing process. Existing construction guidelines are inadequate to resist against failure / collapse of brick masonry structures in the event of accidental explosions.Hence, framing appropriate construction guidelines for explosion resistant performance is the most urgent need today. In this study, the performance of brick masonry model structure with sloped roofing was considered. Static and dynamic analysis was conducted using ANSYS software and the relative improvements in explosion resisting capacity are presented.
Keywords— *Explosion, Fireworks Industries, Brick Masonry, Deflection, ANSYS*

1. Introduction

Sivakasi town [1], situated in the Virudhunagar District of Tamil Nadu is famous for the manufacture of fire crackers and safety matches. About 600 authorized fireworks industries are situated in and around Sivakasi region of Tamil Nadu [2]. During the manufacturing process of fire-crackers and safety-matches in these industries, often explosion accidents are occurring, resulting in loss of human lives and infrastructure. The human casualties are caused not only by the accidental explosion, but also due to the disintegration & fragmentation of walls/roofs, shattering of windows, and partial/complete collapse of the industrial buildings. These lead to loss of continuity in production thereby the livelihood of workers is affected.

Since explosive materials are handled during the manufacturing of fireworks products, firework industries are regularized by The Explosives Act 1884 [3], The Explosives Rules 1983[4] and the TamilNadu Factories Rules 1956[5]. However, building construction aspects are not givenadequate importance in these laws. Manufacturing and packing of firework products are done withintraditional clay brick masonry structures, without incorporating any explosion resisting features.

In spite of frequent raids and safety awareness programmes organized by the government authorities, accidents are a common phenomenon nowadays. The main aim of structural designer is to reduce building damages associated with the accidental explosive loading and to maintain emergency functioning of the facility. Also, it is essential to reduce the severity of injuries caused from falling of building debris. This can be achieved by selecting appropriate materials for construction and proportioning of structural members so that cost effectiveness and attractive solution can be arrived at. If the failure behaviour of building structure is known, this objective can be achieved.

During the detonation of explosives on ground level, shock waves propagate through the floor/soil and strike the barrier (wall). The ground shock loading characteristics and the corresponding resistance of masonry structure against failure is to be studied for designing a protective structure against explosive loading.The behaviour of a structure under such a low duration, high peak impulse loading is a complicated phenomenon and therefore, the performance based design with therequired level of safety against collapse is strongly needed.

2.Literature Review

Bruce Ellingwood, E.V. Leyendecker and James T.P. Yao [6] (1983) illustrated the need of incorporating the effects of abnormal loads in codesand standards for the design of structures. Nurick.G.N, M.D. Olson, J.R. Fagnan and A. Levin (1995)[7][8]. Presented the experimental and numerical results for fully built-in stiffened square plates subjected to blast pressure loading.They observed that the plates showed large ductile deformation and then by tensile tearing failure as the load intensity increased.

Guowei Ma, Hong Hao, Yong Lu, and Yingxin Zhou (2002)[9] developed damage assessment at material level for reinforced concrete structure excited by underground-explosion induced ground motion. They adopted a numerical method of wave propagation in nonlinear and composite media to assess wave motion and structural damage of a two-story frame located at different surface distances from the underground explosion epicentre.

Christopher D. Eamon, James T. Baylot, and James L. O'Daniel (2004)[10] analysed concrete masonry unit walls subjected to blast pressure with the finite element method, to develop a computationally efficient and accurate model. Pedro F. Silva, Binggeng Lu and Antonio Nanni (2005)[11] examined the feasibility of assessing the blast resistant capacity of concrete (RC) slabs using Displacement Based Design (DBD) method. Ronald L. Shope (2006)[12] studied the response of wide flange steel columns subjected to constant axial load and lateral blast load using ABAQUS software.

Luccioni. B.M, R. D. Ambrosini and R.F. Danesi (2005)[13] analysed the structural failure of a reinforced concrete building that has suffered a terrorist attack caused by a blast load using a hydrocode. Panday.A.K,Ram Kumar, D.K. Paul and D.N. Trikha (2006)[14] demonstrated the effect of external explosion on the outer shell of a reinforced concrete containment structure using non-linear material model. Jun-xiangXu, Xi-la Liu (2008)[15] presented a numerical model using the coupled smoothed particle hydrodynamics-finite element method (SPH-FEM) approach for analysis of structures under blast loads. Robert S. Browning, James S. Davidson and Robert J. Dinan (2009)[16]studied the dynamic flexural resistance of multi-wythe foam insulated masonry walls for blast-resistant capacity.

3.Description of the Problem

Most of the studies were conducted using the vehicle driven high-energy explosive loading on the concrete/composite masonry wall buildings simulating terrorist attack. Since brick masonry buildings are being used even today for the construction of fireworks/match works industries in Sivakasi town, the performance of such buildings to low-energy pyrotechnic explosive loading needs investigation.

Hence, in this research work, an attempt has been made to explore the possibility of improving the explosion resisting features in the conventional fireworks and match works industrial buildings by providing sloped curved roofing. Material properties considered in this study are given in Table 1 while loading parameters are given in Table 1.Impulsive loading was applied as uniform pressure on the wall surface based on the recommendations of Sekar, et.al [17].

Table 1: Material properties

Parameter	***Brick Masonry***	***RCC***
L x B	3.60m x 3.0m	
Density	1900kg/m^3	2400kg/m^3
Young's Modulus	1.2x10^4 N/mm^2	2.3x10^4 N/mm^2

Table 2: Loading parameters

Parameter	***Maximum value***	***Unit***
Static pressure Pso in bars	25.163	bars
Shock pulse duration tb in milliseconds	0.450	millisecond
Time of drag td in milliseconds	0.630	millisecond
Equivalent Pressure	6.75	bars
Equivalent Impulse	320.625	Ps (N– msec /m^2)
Time Period	0.303	seconds
Peak ground Acceleration	587	g

* Note: 1 bar = 100kN/m^2

Static and Dynamic impulsive load of 600kN/m^2 was applied on all the walls as uniform pressure acting on the walls.

Finite element studies were conducted on brick masonry model of wall thickness 115mm. RCC roofing of 100mm thickness were taken into account various shapes such as flat, sloped and curved were considered in this study. The deflection behaviour of model structures wasstudied using ANSYS[18] (version 12) software.

4.Results and Discussion

Figs. 1-2 represent the results of static analysis. From Fig. 1, it can be seen that the maximum deformation occurred atthe mid point of long wall as 0.0076mm. Also, maximum equivalent stress of 47431 Pa was noticed at mid point of the long wall as in Fig. 2.Overall deformation under static loading is presented in Fig. 3.

Dynamic results indicate that, maximum deformation of 0.00856mm was noticed at the mid point of long wall vide Fig. 4. Also, maximum equivalent stress of 53360 Pa was seen as in Fig. 5, at the mid point of long wall. Also, the overall deformation is presented in Fig. 6.

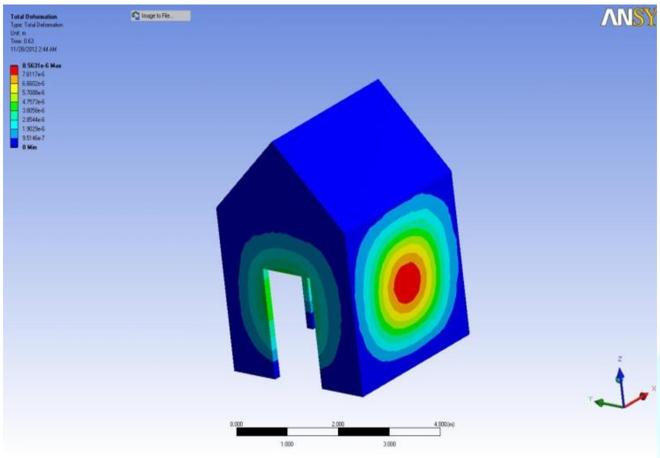

Fig.1 Deformation of walls (Static)

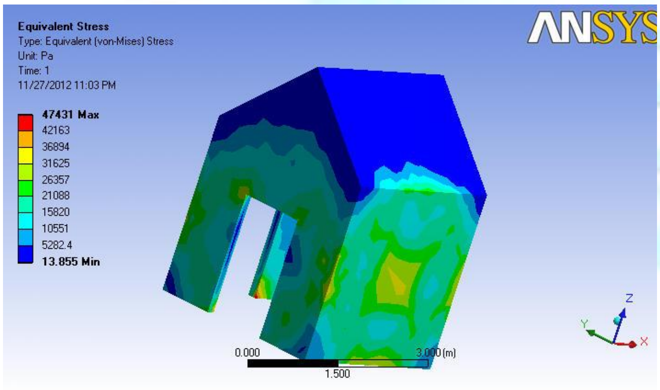

Fig. 2 Equivalent stress (Static)

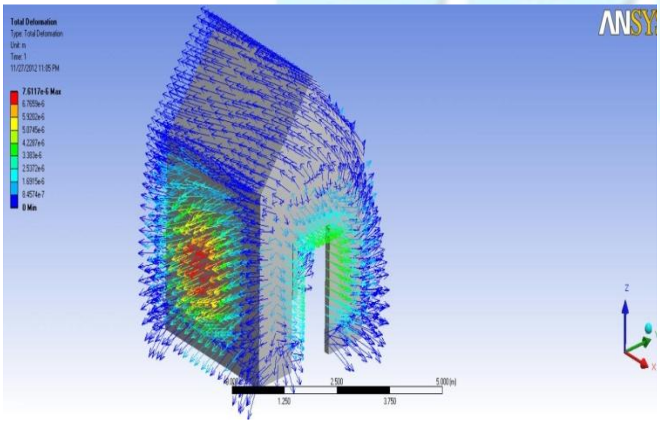

Fig. 3 Overall deformation (Static)

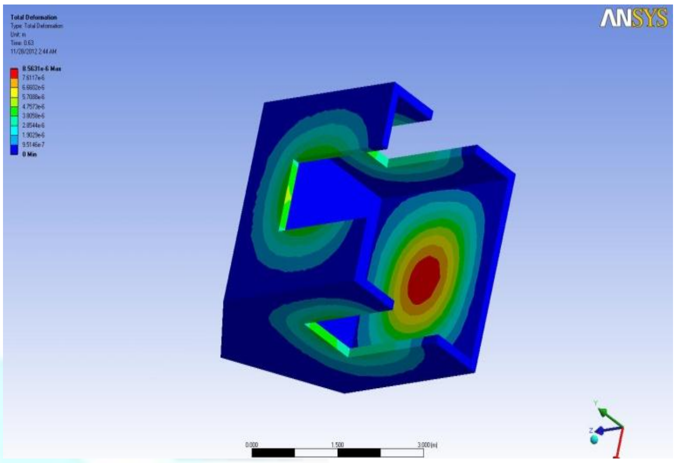

Fig.4 Deformation of walls (Dynamic).

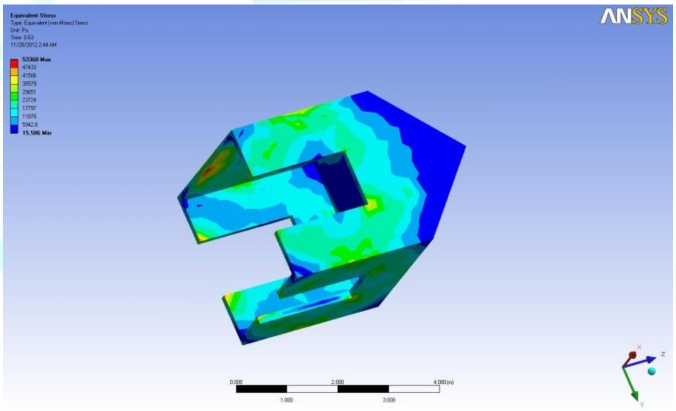

Fig.5 Maximum stress (Dynamic).

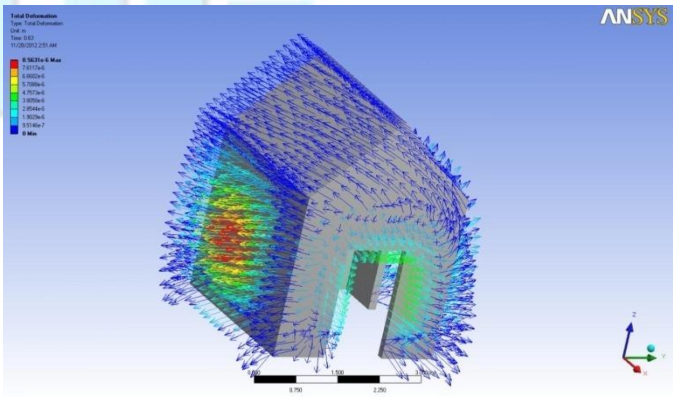

Fig. 6 Overall deformation (Dynamic).

The comparative results are tabulated in Table 3.

S.No	*Parameter*	*Static*	*Dynamic*
1.	Deformation	0.0076mm	0.00856mm
2.	Stress	47431 Pa	53360 Pa

Table 3: Comparative results

5.Conclusion

The deflection behaviour of brick masonry under pyrotechnic explosive loading is studied in both static and dynamic analysis.Based on the above studies, a dynamic multiplication factor of 1.12 is noticed for maximum deflection and for maximum stress. Thus, it can be inferred that static analysis with necessary modification factor can be adequate to study the performance of brick masonry structure under impulsive loading.

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