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Finite Element Analysis of Buildings under Blast Loading

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ABSTRACT
This paper deals with the effect of low-energy pyrotechnic explosive loading on brick masonry structures and the influence of various structural members in resisting the collapse. Different openings and incorporation of lintel and plinth beam are dealt in this study. The static response of brick masonry in the event of accidental explosion is analysed using the model proposed by ANSYS 14.5 software. It was observed that, by providing additional structural elements, the resistance of brick masonry against accidental overloading can be improved considerably so that progressive collapse of the entire structure can be avoided. This paper concludes that an alternate construction material is to be considered for the construction of fireworks and matchworks industrial buildings, which can perform satisfactorily than conventional brick masonry.
***Keywords*–** ANSYS,Blast loading, Brick Masonry, Deflection, Finite Element Analysis

I. Introduction

In the past few decades considerable emphasis has been given to problems of blast andearthquake. The earthquake problem is rather old, but most of the knowledge on this subject hasbeen accumulated during the past fifty years. The blast problem is rather new;information about the development in this field is made available mostly through publication of the Army Corps of Engineers, Department of Defense, U.S. Air Force and other governmental office and public institutes.

Due to different accidental or intentional events, the behavior of structural components subjected to blast loading has been the subject of considerable research effort in recent years. Normally, conventional structures are not designed to resist blast loads; and because the magnitudes of design loads are significantly lower than those produced by mostexplosions, these structures are susceptibleto damage from explosions.

Accidental explosions during the manufacture of fire crackers and safety matches are reported regularly in Sivakasi, well known as ***Mini Japan*** (***Kutty Japan***), situated in the Virudhunagar District of Tamil Nadu. Industries situated in and around Sivakasi satisfy about 90% of the global demand for fireworks products.Explosive accidents results in collapse of those brick masonry structures.

The main aim of a 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.

II. Literature Review

Chaf **[1]**, Salzano**[2]** suggested that when large amount of fireworks are stored in closed environment, explosive behavior can be observed.

T. Sekar **[3]** analysed the brick masonry structures against accidental explosions. He proved that the performance of models made of composite material can resist effectively against deformation.

S.N.Ramaswamy **[4]** inferred that static analysis with necessary modification factor can be adequate to study the performance of brick masonry structure under impulsive loading.

Scientific and technical publications are mainly available for high-energy explosives whereas less data are available for low-energy pyrotechnics. National Fire Protection Agency guidelines of flammable and explosive materials such as NFPA 1124, and NFPA 1126 **[5 & 6]** give several information on safety distances and recommendation for the handling of explosives and fireworks products. However the handling and storage design guidelines are neglected. Even the public military guidelines (TM 5-1300 and TM 9-1300-214) **[7]** are not really useful for the producers and design engineers when safety of manufacture and large storage of low-energy pyrotechnics in brick masonry structures are considered.

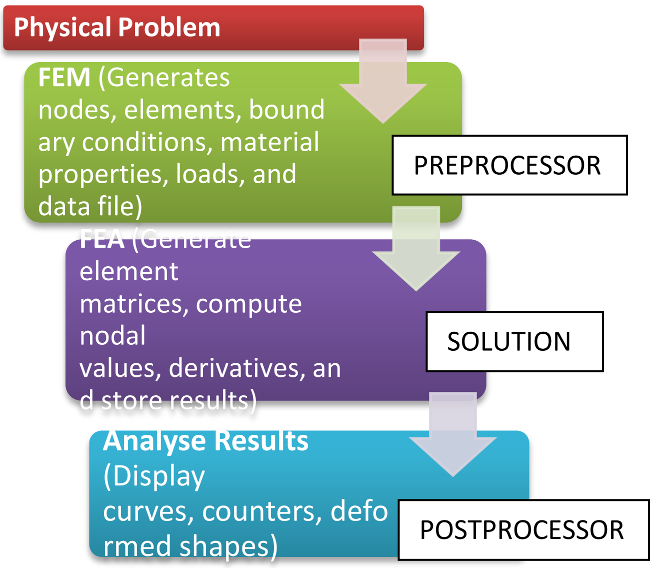
Dr. NVN Nampoothiri **[8]**stated that the deflection of the brick wall is very large under blast loading for which brick masonry cannot offer adequate ductility.

Ward **[9]** proposed few techniques to make the existing masonry walls stronger and more capable of resisting safely the effect of explosions. He proved conclusively that the retrofitted reinforced masonry support system is capable of providing the necessary strength to existing masonry walls to resist the effects of large blast loads. Furthermore, he stated that using the finite/ discrete element model it is possible to predict accurately the effects of a blast load on a strengthened wall and design the reinforcement pattern accordingly.

III. Methodology

In order to suggest a cost effective construction strategy/a structure which could perform satisfactorily against accidental explosions in fireworks manufacturing industries, analytical studies were conducted using ANSYS 14.5 **[10]**; to study the deflection behaviour of structure.

In ANSYS, the general purpose of finite element analysis is divided into three main phases, preprocessor, solution, and postprocessor.



The preprocessor is a program that processes the input data to produce the output that is used as input to the subsequent phase (solution). Following are the input data that needs to be given to the preprocessor:

1. Type of analysis (structural)
2. Element type
3. Real constants
4. Material properties
5. Geometric model
6. Meshed model
7. Loadings and boundary conditions

The input data will be preprocessed for the output data and preprocessor will generate the data files automatically with the help of users. Solution phase is completely automatic. The FEA software generates the element matrices, computes nodal values and derivatives, and stores the result data in files.The output from the solution phase (result data files) is in the numerical form and consists of nodal values of the field variable and its derivatives. The post processor processes the result data and displays them in graphical form to check or analyse the result.

IV. Problem Description

The present construction practice of fireworks and match works industries is: The room size is 3.6m (length) x 3m (breadth) x 3m (height). The walls are made of 230mm thick brick masonry without plastering. In this study, flat RCC roof is considered. Generally three doors are provided without any windows, ventilators and electrical fittings. These three doors are provided for safe exit in the event of an unexpected fire/explosion.

Finite element studies were conducted on brick masonry model structure of size 3.6m (L) x 3.0m (B) x 3.0m (H) and 230mm thick. Material Properties considered in this study are given in TABLE 1. Explosive loading of is applying as a uniform pressure of 0.6MPa acting normal to the inner wall faces based on the recommendations of sekar, et..al.

TABLE1 Material Properties

PARAMETER	BRICK MASONRY	RCC
Density (kg/m^3)	1900	2500
Modulus of Elasticity (N/mm^2)	1.2X10^4	3.5X10^4
Poisson's Ratio	0.2	0.18

V. Case Studies

a. Brick walls with different openings.
b. Providing Lintel all around brick masonry
c. Providing Plinth beam of different size

VI. Results and Discussions

Different type of opening was provided by varying percentage of opening from 5% to 20%. The minimum deflection was observed in the case of 10% Openings- openings provided both on 3.6m side. But as per construction guidelines, three openings are provided for safe exit during explosion. So the case of 15% openings (two on 3.6m sides and one on 3m side) was chosen for further analysis. From the Fig. 1&2it can be seen that the maximum deformation of

brick wall occurred at side of opening of 3.6m wall as 5.6047mm and maximum equivalent stress of 32.619MPa at bottom of 3.6m sides with or without opening.
Fig. 3&4 shows the deformation and equivalent stress of model provided with lintel. Maximum deflection in brick wall decreased from 5.6047mm to 5.3005mm after providing lintel. The location of maximum deflection and maximum equivalent stress in brick wall remained same.
Fig.5&6 shows the deformation and equivalent stress of model with 150mm plinth beam. Plinth beam of sizes 100mm to 300mm were analysed. Maximum deflection in brick wall decreased with increase in size of plinth beam. But the decrease is not significant. The location of maximum deflection and maximum Equivalent stress in brick wall remained same.
In all the cases the location of maximum deflection in R.C.C wall was observed at centre of roof and maximum Equivalent stress occurred at portion of roof above 3.6m brick wall on all four sides. The deflection in R.C.C roof was found to be within permissible limits in all the cases.
The summary of analytical studies conducted on brick masonry model is tabulated in TABLE 2. The comparison of deflection of brick masonry in different considered cases is given in Fig. 7.

TABLE2 Summary of failure behaviour of model

S.No	Case	Description	Deflection (mm)		Remarks
			BRICK WALL	RCC ROOF	
1a	Different Openings (%)	On both 3.6m sides (10%)	4.7932	6.1626	Max. deformation is on 3.6m walls and centre of roof.
1b		On both 3.6m sides and one 3m side (15%)	5.6047	6.3053	
1c		On both 3m sides and one 3.6m side (15%)	6.9554	6.1826	
2	With lintel	150mm lintel alround	5.3005	6.815	
3	With plinth beam	Walls on 150mm plinth beam	5.5944	6.2937	

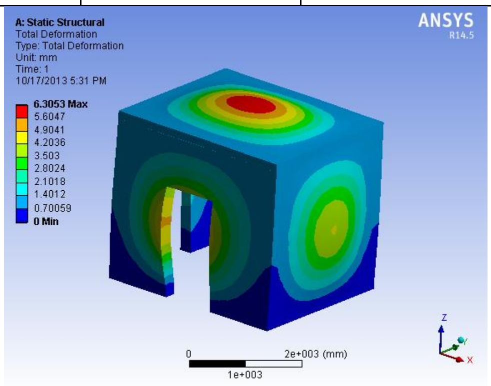


Fig. 1 Deformation of basic model

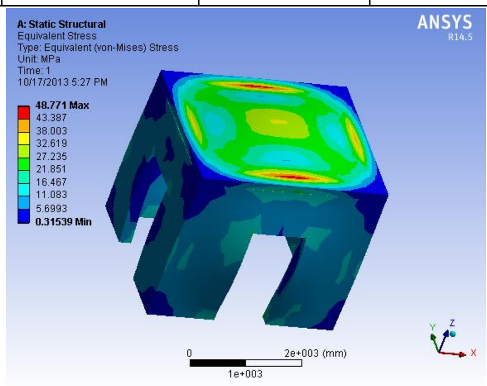


Fig.2 Equivalent Stress of basic model

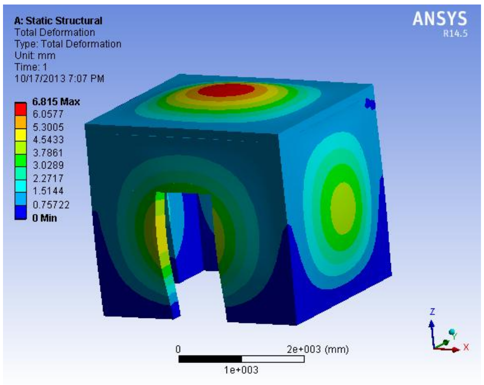


Fig.3 Deformation of model with lintel

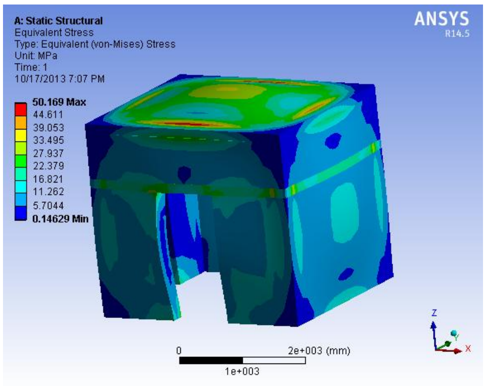


Fig.4 Equivalent Stress of model with lintel

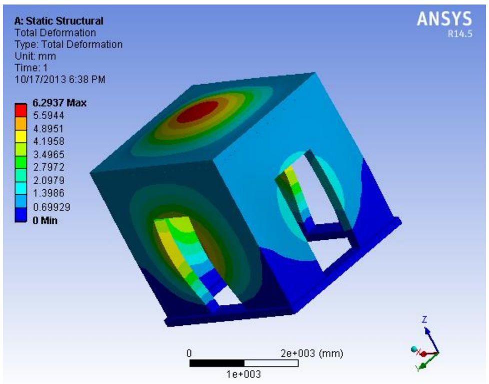


Fig.5 Deformation of model with 150mm pb

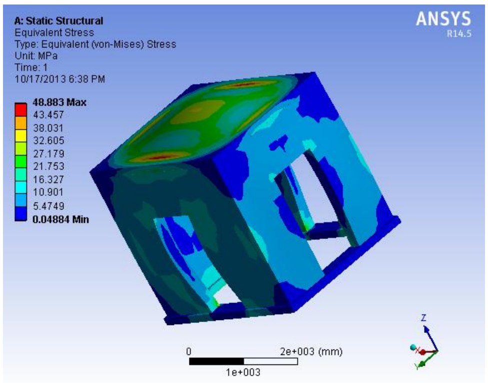


Fig. 6 Equivalent Stress of model with 150mm pb

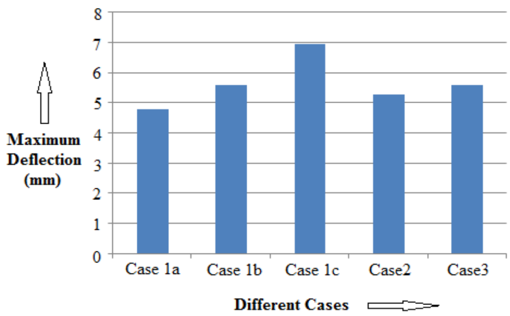


Fig. 7 Comparison of considered cases

VII. Conclusions

The deflection behaviour of brick masonry under pyrotechnic explosive loading was studied using static analysis. It was observed that the deflection of brick masonry is more than one fortieth of the wall thickness. The study was done for brick walls with different openings, with lintel and with plinth beam. In the case of different openings, the minimum deflection was observed at 10% opening. Both the deflection and equivalent stress in concrete roof were found to be within permissible limits. The deflection in brick masonry was reduced after providing lintel and plinth beam. But it is clear that the deflection is very large for which brick masonry cannot offer adequate ductility. Hence, alternate materials such as ferrocement, fibre-reinforced plastics, etc., can be considered for the construction of walls in fireworks and matchworks industries which can also offer adequate ductility and resistanceagainst failure in the event of any accidental explosive loading in these industries.

VIII. Acknowledgement

We thank Prof. S.N. Ramaswamy of Kalasalingam University for his help in this work.

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