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Effect of Pyrotechnic Explosion in Buildings

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ABSTRACT : *This paper deals with the effect of low-energy pyrotechnic explosive loading on brick masonry structures strengthened with various structural members in resisting the collapse. The response of brick masonry in the event of accidental explosion is analysed using the model proposed by ANSYS 14.5 software. It was inferred that static analysis is enough to find the deflection of the structure under blast loading. 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

The analysis of blast loading started in 1960's. 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. As masonry structures are primarily loaded in compression, the resistance of the materials to this type of loading is of general interest. 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 proper construction guidelines to fireworks manufacturing industries, analytical studies were conducted using ANSYS 14.5 **[10]**; to study the deflection behaviour of structure. In static analysis, the load or field conditions do not vary with respect to time, and therefore, it is assumed that the load or field conditions are applied gradually, not suddenly. The Static Structural analysis system is used to determine the response of a structure subjected to static loading conditions. The loads in this case are assumed to produce no or negligible time based loading characteristics. Using this type of analysis, displacement, stresses, and deformations of structures under static loading conditions can be determined. In dynamic analysis, the load or field conditions vary with time and are applied suddenly. Transient dynamic analysis is used to calculate the response of a structure to arbitrary time varying loads. Using this analysis, time-varying displacement, stresses and strains can be determined.

IV. PROBLEM DESCRIPTION

Accident explosions during the manufacture of fire crackers and safety matches are reported regularly in Sivakasi. 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.Studies conducted on the effect of openings show that minimum deflection is observed in 10% opening. But, three doors are provided for safe exit in the event of an unexpected fire/explosion. These three doors are provided without any windows, ventilators and electrical fittings.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 is applying in static analysis as a uniform pressure of 0.6MPa acting normal to the inner wall faces based on the recommendations of Sekar, et.al. In dynamic analysis, the pressure variation can be mathematically expressed as equation (1).

$$Ps(t) = 25.163\ (1 - 0.926\ t)\ e^{-1.94\ t} \qquad \text{………………………} (1)$$

where, P_s is the pressure in bars and t represents the time in milliseconds.

TABLE 1 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

CASE STUDIES

a. Brick walls with columns
b. Providing plinth beam and lintel
c. Providing column and lintel
d. Providing plinth beam and column
e. Providing plinth beam, column and lintel
f. Dynamic analysis
g. Using alternate material

V. RESULTS AND DISCUSSIONS

By analysing different combinations of providing columns, the minimum deflection at the considered location was observed when 300mm columns were provided at openings on longer walls. But the deflection on the wall without opening remained the same. Hence considering safety, four openings were also considered in further analysis. From the Fig. 1&2 it 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 when no structural elements are provided.Fig. 3&4 shows the deformation and equivalent stress of model with four openings provided with 150mm plinth beam, 150mm lintel and 300mm columns on openings in longer walls. Maximum deflection in brick wall decreased from 5.6047mm to 3.0419mm.

Considering utility purposes also, model with three openings were selected for doing the dynamic analysis. Fig. 5&6 shows the deformation and equivalent stress of model with three openings provided with 150mm lintel, 150mm plinth beam and 300mm columns on openings in longer walls, done using static analysis. Fig 7&8 shows the same case done using dynamic analysis. It can be seen that the value is greater in the case of static analysis done using equivalent pressure. In all the cases the location of maximum deflection in roof was observed at centre of roof and maximum Equivalent stress occurred at sides of roof above 3.6m brick walls. The deflection in R.C.C was found to be within permissible limits in all the cases. Fig 9&10 shows the deformation and equivalent stress of the model using shear wall as the alternate material. The deflection reduced from 5.6047mm to 2.0972mm when shear wall was used instead of brick masonry.

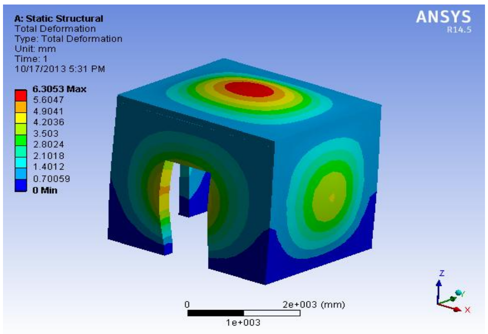

Fig. 1 Deformation when no structural members are provided

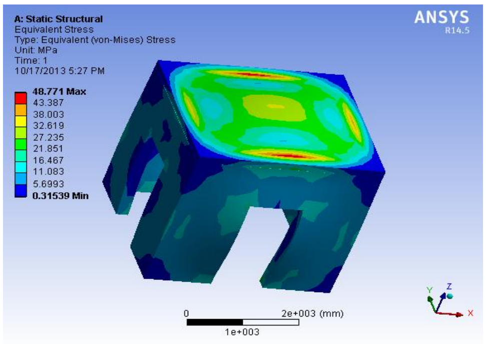

Fig. 2 Equivalent Stress when no structural members are provided

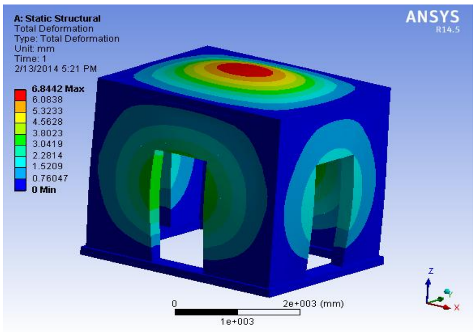

Fig. 3 Deformation of model with four openings provided with lintel, pb & 300mm columns at openings in longer walls

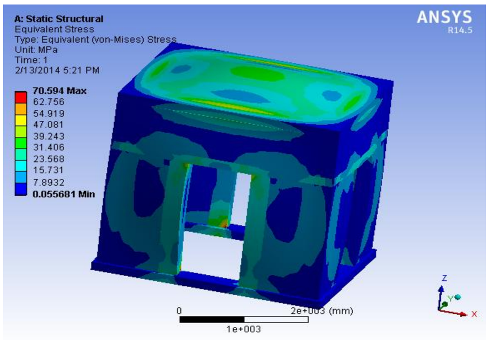

Fig. 4 Equivalent Stress of model with four openings provided with lintel, pb & 300mm columns at openings in longer walls

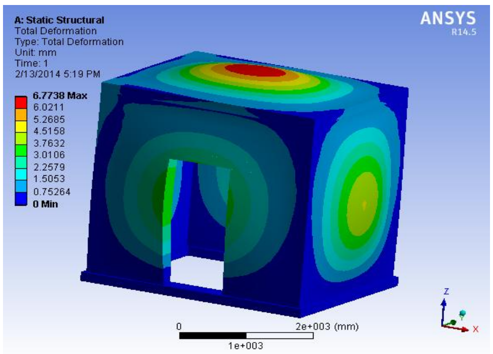

Fig. 5 Deformation of model with three openings provided with lintel, pb & 300mm columns at openings in longer walls

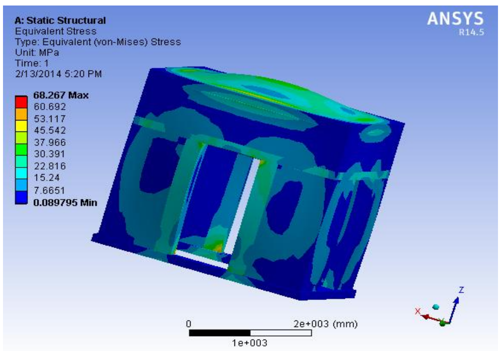

Fig. 6 Equivalent Stress of model with three openings provided with lintel, pb & 300mm columns at openings in longer walls

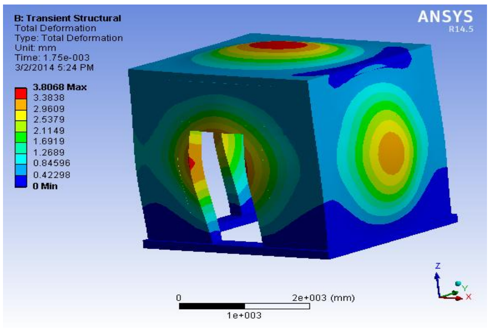

Fig. 7 Deformation of model with three openings provided with lintel, pb & 300mm columns at openings in longer walls (Dynamic Analysis) Analysis)

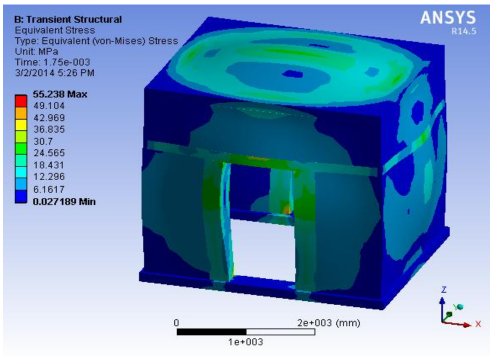

Fig. 8 Equivalent Stress of model with three openings provided with lintel, pb & 300mm columns at openings in longer walls (Dynamic

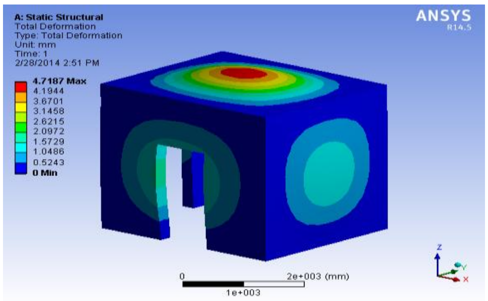

Fig. 9 Deformation of model with shear wall wall

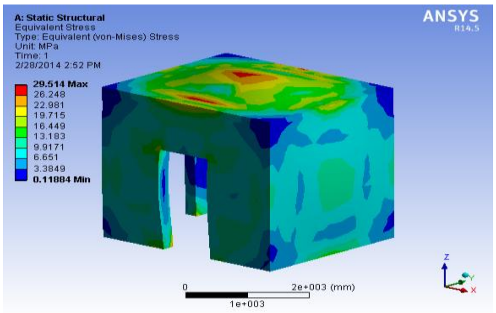

Fig. 10 Equivalent Stress of model with shear

The summary of analytical studies conducted on brick masonry model is tabulated in TABLE 2 and the comparison is given in Fig. 11.

TABLE 2 Summary of failure behaviour of model

S.No	Case	Description	Deflection (mm)		Location in Wall	Location in Roof
			WALL	ROOF		
1	No structural members provided	Openings on both 3.6m sides and one 3m side	5.6047	6.3053	At one side of opening of 3.6m walls	Centre of roof
2	With column a) Three openings	300mm columns @ openings on 3.6m walls	4.9314	6.3404	At centre of wall without opening	
	b) Four openings	300mm columns @ openings on 3.6m walls	3.56	6.4079	At top of opening of 3.6m walls	
3	With structural elements a) Three openings	300mm columns @ openings on 3.6m walls + 150mm lintel + 150mm pb	4.5158	6.7738	At centre of wall without opening	
	b) Four openings	300mm columns @ openings on 3.6m walls + 150mm lintel + 150mm pb	3.0419	6.8442	Around the opening on 3.6m walls	
4	Dynamic analysis	300mm columns @ openings on 3.6m walls + 150mm lintel + 150mm pb	3.3838	3.8068	At centre of wall without opening	
5	Alternate material	Shear walls provided with three openings	2.0972	4.7187	At one side of opening of 3.6m walls	

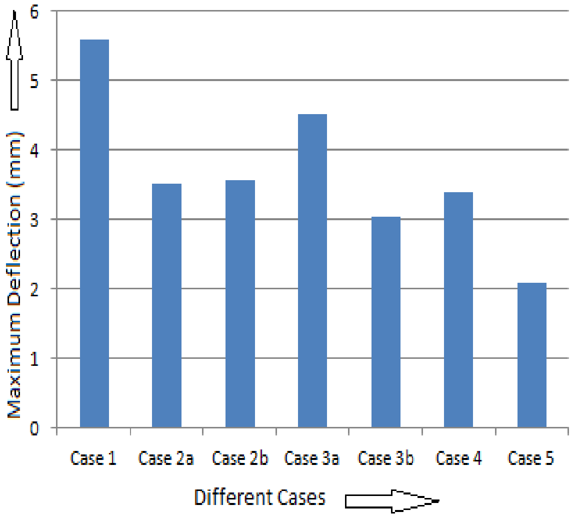

Fig. 11 Comparison of considered cases

VI. CONCLUSIONS

The deflection behaviour of brick masonry under pyrotechnic explosive loading was studied using static as well as dynamic analysis. The static analysis is enough to analyse the response of structure in the event of blast loading. It was observed that the deflection of brick masonry reduced from $1/40^{th}$ to $1/75^{th}$ of the wall thickness when the structure is strengthened with RCC bands. Both the deflection and equivalent stress in concrete roof were found to be within permissible limits. It is recommended to provide four openings with columns on openings in longer walls, plinth beam and lintel considering safety criterion only. Considering utility also, three openings can be provided, but with the structural elements. Since brick masonry cannot offer adequate ductility alternate material can be used. Hence, shear wall can be provided instead of brick masonry so as to reduce the deflection to $1/110^{th}$ of wall thickness.

VII. ACKNOWLEDGEMENT

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