Evaluation of Types of Shapes of Building Roof against Explosion

Ali Akbar Pouri Rahim, Mahdi Bitarafan, and Shahin Lale Arefi

***Abstract*—Identification of danger of probable damage plays an important role in preparation for encounter and resisting negative effects of terrorist attacks to urban areas. The goal of pathology is identifying facilities and solutions of immunizing buildings against terrorist attacks and resisting explosion effects. with regard to this matter that the resistance of a building against blast wave depends on the shape and form of the building and the roof, the number of gates and opening power and genus of the material been used, therefore the study and assessment of types of shapes of building roof against consequences from explosion become important. So this research is going to compare different types of shapes of buildings roof against explosion waves. In this research in order to assess types of buildings roof, first by the use of resources from libraries types of buildings roof identified then in order to assess roofs in addition to finite element modeling, ideas of experts had been received. Next the consequences from those two procedures had been compared and types of roofs had been ranked based on the decline of explosion effect. And finally it had been concluded that three factors are effective in selecting the proper form, first the reduction of the area of the sectional area of the roof by increasing the height, the area of the roofs picture on the vertical plate, and being aerodynamic nature of the building roof.**

***Index Terms*—Building roof, shape, explosion, finite element modeling.**

I. Introduction

Danger identification of probable damage plays an important role in preparation for encounter and resisting negative effects of terrorist attacks to urban areas. If the identification of dimensions of these dangers toward urban areas, and resultant probable damages studies truly, the level and type of resisting preparations against these damages could be defined and developed up to the scale of single buildings, widely. The goal of pathology is identification of facilities and immunizing solutions of buildings, against terrorist attacks and resisting the explosion effects. with regard to this matter that the resistance of a building against explosion wave depends on the building shape, form and the roof, the number of gates and opening, power and genus of the material been used, therefore the study and assessment of types of shapes of building roof against consequences from the explosion becomes important. As regards, terrorist attacks are mostly in the form of explosion on the ground level, the explosion is more effective on the building roofs which have less height than high rise buildings, because explosion waves in high rise buildings can't get to the roof and they will be absorbed by the building environmental body. As regards to diversity of the shapes been used in the building roof which sketchers use them in their plans, a deficiency would be felt that in order to resist terrorist attacks, which shapes of the roof are more resistant and more changeless (regarding to constant defaults like constant material or constant sectional area and etc.) against explosion effects. Selecting proper shape and form of building roof in plan and height can have great effect on the improvement of structure's behavior in explosion and it can reduce the incoming damages.

So this research is going to compare different types of building roofs against blast waves.

In FEMA-426 [1] the significance of building roof in declining explosion effects has been emphasized and in order to design the roof against explosion effects some considerations has been expressed.

In 2010 Norbert Gebbeken and Torsten Döge[2] had done some researches on the structure's geometry in preventing blast waves to get to building, and they concluded that basically in geometric shapes maximum pressures and maximum impulses depend on the distance from explosion location and the confliction angle of explosion waves, and the resistance against the progress of waves of structural shapes. The shape of structural ingredients or building ingredients can reduce the explosion loads certainly.

From other researches, the researches of M. Barakat and J. G. Hetherington[3] can be mentioned. They have practiced on blast effect on different forms of structures like cubic, cylinder, half cubic, and prismatic form and they have concluded that in addition to structural components of the building, also architectural forms can have great effect on reducing explosion effects in buildings.

From other researches, the researches of Maisam Mojtahed Pour[4] can be mentioned. He has researched on the effects of the structure's shape on stress distribution from explosion loading; he practiced more on structural aspect of the Issue; in some parts he practiced on the effect of indicatives in structures. In all researches been mentioned only assessment of the decrease level of explosion effect on form or material had been considered. The main goal of this research is ranking types of shapes and geometric forms of building roof against explosion effects.

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II. Cognitive Method of Performing the Model of Assessment and Analysis of Results

In this research in order to assess types of buildings, first by the use of resources from library, types of building roofs identified then in order to assess roofs, in addition to finite element modeling, the ideas of experts had been received. In order to receive the experts ideas a questionnaire for weighting to basic common forms in buildings, presented to 25 expert people who were familiar with civil engineering, architecture and crisis management. In order to assess the reliability of the questionnaire also the test of Cronbach's Alpha can be used [5]. Then obtained results from questionnaires had been analyzed by the use of SPSS software. Next the obtained results from the finite element modeling, and Delphi method had been compared to each other. Finally the level of compatibility of different types of building roof against explosion had been determined.

III. The Type of Building Roof

Regarding to different architectural resources [8], the more ordinary and the more common shapes used in buildings are:

- Conical roof
- Flat roof
- Gable roof
- Dome roof
- Pyramidal roof

In order to assess these roofs besides the eruptive modeling in Abaqus, the finite element software, also the experts' poll had been used. Next the way of modeling in the finite element software has been brought.

IV. The Procedure of Finite Element Software

In this part, the characteristics of samples of finite element, the way of modeling samples, characteristics of material, loading and the analysis of element models will be expressed.

A. Geometric Characteristics of Finite Element Models

For assessing different types of roof applied in a building, five finite element models created, that the characteristics of each sample has been given in Fig. 1.

B. Mechanical Properties of Material

Material used in all samples of finite element model used in this dissertation, are supposed to be isotropic. In all samples, material presented as concrete. In order to modeling concrete, the concrete damaged plasticity has been used. Concrete damaged plasticity model is a synthetic model which has the ability of simultaneous consideration of fracture from pressure and tension in concrete [6].

TABLE I: Characteristics of Material Used in FE Models.

poisson's ratio	young's modulus (kg/m^2)	density (kg/m^3)	yield stress of tensional area (kg/m^2)	yield stress of pressure area (kg/m^2)
0.25	23500000	2400	3000	25000000

C. Steps of Explosion Modeling of Samples

In order to modeling the explosion conditions in finite element samples in Interaction part of the software, the Incident wave has bas been used. The characteristics of these waves have been defined as air blast [7]. Explosives as TNT have been considered. The weight of explosives is 1400 Kg and distance of the explosion is 10m from the exterior wall of building.

D. Meshing

One of the most important parts in finite element modeling is determining the model's meshing. In this modeling the software's meshes are tetrahedron with the seed part specific to each part of the shear wall and the mesh's type is Free Tet with standard elements, and 3D stress with linear geometric has been used. Of course determination of seed part numerical value has been done in the basis of convergence analysis of samples one by one.

V. Assessment of the Results of Finite Element and Questionnaire

As mentioned before, in order to assess and scoring these forms beside receiving expert's ideas, also the eruptive simulation in the Abaqus software has been used and later the results of these two procedures presented and will be compared.

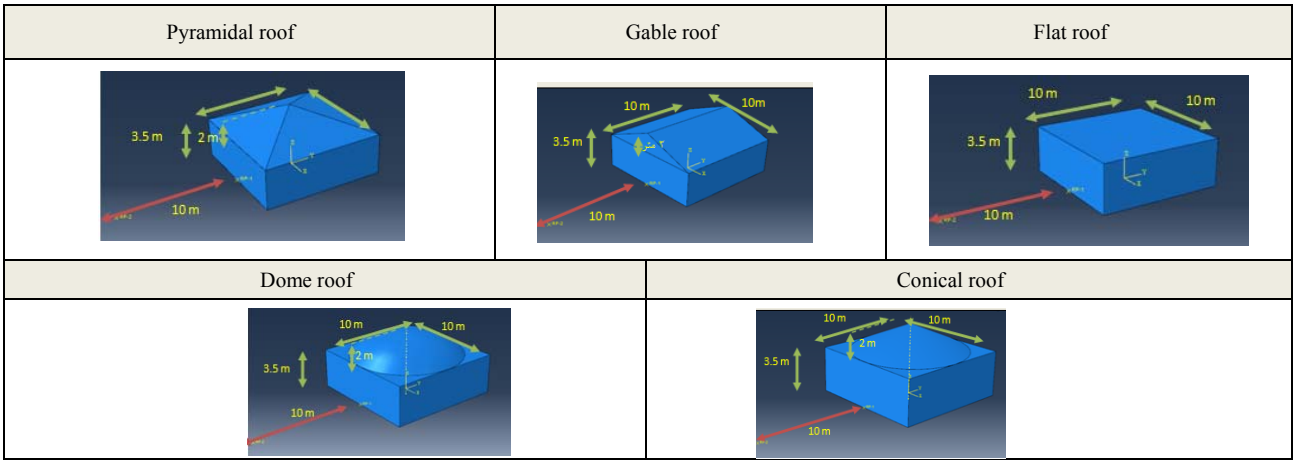

Fig. 1. Characteristics of samples of finite element built roof of the building.

By analyzing the results of the questionnaires, the score for each type of roofs presented is in the Table II.

TABLE II: THE RESULTS FROM THE CORRELATE QUESTIONNAIRE WITH BUILDING'S ROOFS.

Pyramidal roof	Dome roof	Conical roof	Gable roof	Flat roof
5.11	8.07	6.18	4.07	3.44
compatible	Very compatible	compatible	incompatible	incompatible

In simulating finite element, the dimensions of samples have been selected so that the height of all roofs would be equal. In order to assess the results of finite element models, the diagram of reaction force against time was plotted (Fig. 2).

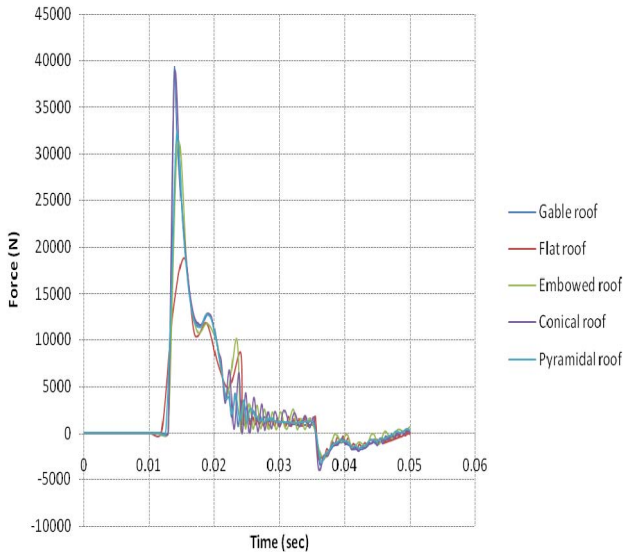

Fig. 2. Force-time relationship for each modeled form FE modeling.

TABLE III: RESULTS OF FINITE ELEMENT MODELS IN ABAQUS.

Model's title of finite element	Ranking types of roofs on the basis of results of finite element	Maximum forces (N)	Level of compatibility
Flat roof	1	18728.1	Very compatible
Gable roof	5	38666.6	Very incompatible
Conical roof	3	32232.1	incompatible
Dome roof	2	31068.1	incompatible
Pyramidal roof	4	38128	Very incompatible

- Flat roof

Based on obtained results, the created force in building's abutment with flat roof is 18728.1 N and among other types of roofs placed in the first rank. The reason which this type of roof has a better behavior compared to other types of roofs can be due to the less area of the vertical picture of flat roof versus other roofs, in fact less surface has been exposed to explosion waves so less force has been entered on the building. From the viewpoint of the experts the flat roof is placed on fifth rank. The reason for much difference between the expert's idea and results of finite element is that the experts because of their wrong subjective impression about the way of explosion operation, they consider the aerodynamic effect of the roof and because this roof is not aerodynamic, they considered it as the worst status. Subsequently, with regard to the results of analysis of finite element, this type of roof is supposed to be the most compatible type of resistant roof against explosion.

- Gable roof

Based on obtained results, the created force in building's abutment with gable roof is 18728.1 N and among other types of roofs placed in the fifth rank. The reason which this type of roof has a worse behavior compared to other types of roofs can be due to the much area of the vertical picture of gable roof versus other roofs, in fact more surface has been exposed to explosion waves so more force has been entered on the building. From the viewpoint of the experts the gable roof is placed on third rank and they also believed that this type of roof will not operate well against explosion. Subsequently, with regard to the results of analysis of finite element, this type of roof is supposed to be the most incompatible type of resistant roof against explosion.

- Conical roof

With regard to, the created force in the eruptive modeling of conical roof, the maximum force of abutment is 32232.1 N. This roof is placed among incompatible roofs. Based on receiving the ideas of experts this type of roof is placed on second rank and based on results of finite element placed on third rank and based on both results this type of roof is placed among the incompatible roofs against explosion. The reason for this matter can be the less area of the picture of conical roof in vertical plane versus gable roof and Dome roof, which caused the less absorption of energy in this roof.

- Dome roof

Based on obtained results, the maximum force created in Dome roof is 31068.1 N and among other roofs placed in the second rank. From the viewpoint of the experts the Dome roof is placed on first rank and they believe that this type of roof because of its being aerodynamic will operate well against explosion, while with regard to its more area of vertical plane obtains a remarkable force then unlike the idea of experts Dome roof considers as an incompatible kind of roof.

- Pyramidal roof

The maximum force created in pyramidal roof's abutment is 38128 N, which in comparison with other roofs places in the fourth rank. From the viewpoint of the experts this kind of roof is placed in third rank. In this roof the area of its picture on vertical plate is less than gable roof but is more than other roofs so it obtains much energy. Consequently this type of roof is considers as the most incompatible roof.

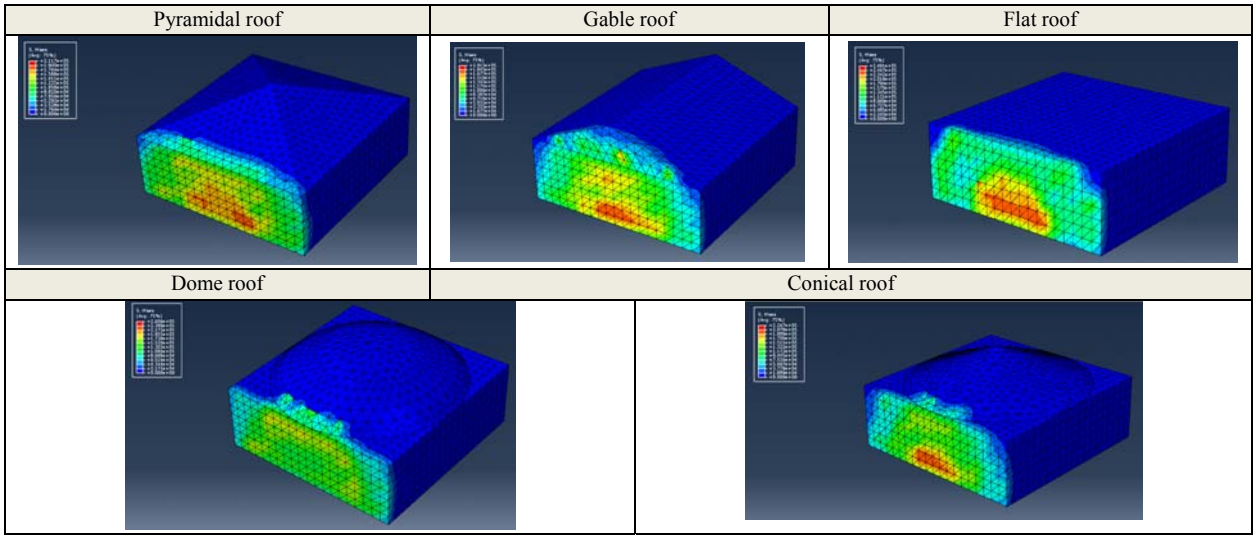

Fig. 3. Kind of roof and stress counter.

VI. Conclusion

In this article the emphasize is much on explosions on the ground level but if the explosion take place in a higher level than the ground level (about the building's height) then the pressure of explosion's wave has more influences on the building's roof, therefore in farther distances more influence will be on building's face. It's clear that in case of explosions on higher than the ground level there is less protection for buildings. With regard to considered points, this article by the use of its studies is going to introduce the use of a proper type of roof to resist the waves from explosion. By analyzing the obtained results from finite element models in this article, it can be concluded that in building roof there are three main effective factors:

- The decrease of area of roof's sectional area by the increase of height.
- The area of roof's picture on vertical plane.
- Being aerodynamic of the roof.

With regard to the results of finite element, the flat roof is from those very compatible roofs and gable and conical roofs are from the category of incompatible roofs against explosion. Dome and pyramidal roofs categorized in very incompatible roofs.

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