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ORIGINAL ARTICLE

The architectural evaluation of buildings' indices in explosion crisis management

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Abstract Identifying the probable damages plays an important role in preparing for encountering and resisting negative effects of martial attacks to urban areas. The ultimate goal of this study was to identify some facilities and solutions of immunizing buildings against marital attacks and resisting explosion effects. Explosion and its coming waves, which are caused by bombardment, will damage the buildings and cause difficulties. So, defining indices to identify architectural vulnerability of buildings in explosion is needed. The Basic indices for evaluating the blast-resistant architectural spaces were identified in this study using library resources. The proposed indices were extracted through interviewing architectural and explosive experts. This study has also applied group decision making method based on pairwise comparison model, and then the necessity degree of each index was calculated. Finally, the preferences and ultimate weights of the indices were determined.

1. Introduction

Every day, around the world we witness destruction of resources, assets and national infrastructures of countries caused by cities bombardments and terrorist attacks. Accordingly, all military and non-military buildings should be equipped against these threats to be less vulnerable; an architectural design should be drafted to reduce the vulnerability of humans and buildings against unexpected threats.

In the design process, it is vital to determine the potential danger and the extent of it. Most importantly, human safety should be provided. Moreover, to achieve functional continuity after an explosion, architectural and structural factors should be taken into account in the design process, and also an optimum building plan should be considered [1].

According to the contemporary architectural theorists, the design of all spatial scales in a manufactured environment should be part of the architectural skills and knowledge. Thus, an architectural design is needed to reduce the potential vulnerabilities to human beings and buildings against threats [2]. In this regard, to identify the potential architectural

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vulnerability of buildings against explosion, the indices need to be defined. This study addresses the absence of a codified and detailed criterion to evaluate architectural compatibility of buildings against terrorist attacks and aerial bombardments.

1.1. Literature review

Some studies on architecture of threat resistant buildings have been conducted including the investigation of Khairuddin et al. [3]. They focused on the impact of architectural elements on the vulnerability of structures against earthquake hazard. The importance of space organizing in architecture of civil defense and its variants was also expressed by Hashemi Fesharaki et al. [4]. On the other hand, Gebbeken and Döge [5] researched on the geometry of buildings and the effect of surrounding systems to protect buildings from blasting waves. They concluded that the peak pressures and maximum impulses depend essentially on the distance of blasting center, the angle of reflected blast wave and the resistance against the waves. The structural elements of a building can reduce the explosive charges. Barakat and Hetherington [6] have studied the blasting effects on the various building forms such as cubic, cylindrical, hemisphere and prismatic forms and finally concluded that in addition to the structural components of the buildings, architectural forms can also be more effective in reducing the effect of explosion on buildings. Araghizadeh [7] has done a research on blast-resistant office buildings and represented 6 indices to evaluate these buildings and concluded that the location of the buildings toward the ground level is one of the most important factors in reducing the impact of explosion on buildings. We can also point to the study by Luccioni et al. [8]. The purpose of their research was failure analysis of buildings with concrete structures under explosion load; therefore, they modeled a three-dimensional model from a concrete building in AUTODYN software and finally they concluded that the failure mechanism started from the lower columns of the building and the building had been destroyed. Mojtahed-Pour [9] studied the effects of structures' shape on the stress distribution caused by the explosive loading and he mostly studied the structural aspects of the issue. In some parts of the research he studied the effect of indurative in buildings. In all mentioned researches only evaluating the reduction rate of explosion effect on form or materials has been considered. The main goal of this research was to rank various types of shapes and geometric forms of buildings' roof against explosion effects. Dermisi [20] proposes a layered approach for the protection and prevention of office buildings against terrorism attacks and the development of a city-wide Property Anti-Terrorism Taskforce, which will increase the cross-collaboration between real estate and law enforcement and emergency management agencies, while strategically preparing owners and property managers. Among other works, Hovaidafar [10] work can be mentioned which has investigated entrances and exits of shelters, and he further considered preventing explosion waves from entering into shelters and in the end he provided some considerations to design shelters' entrances. Bitarafan et al. [19] have conducted some researches on the entrance of secure underground spaces and proposed 17 patterns for secure arrival to the underground space. Rahim et al. [18] evaluated different shapes of the roof and the effect on the explosion. They modeled different kinds of roofs by element software and concluded that flat roofs are the best kind against the explosion. Among other studies in this sense, we can refer to Nadel [22] who has focused on Building Security - Handbook for Architectural planning and design. FEMA-426 (2003), FEMA-427 (2003), FEMA-428 (2003) and FEMA-429 (2003) have emphasized on mitigation potential terrorist attacks against buildings. Many other studies have examined the buildings' behavior against explosion, but most of these studies have focused only on the one or some (not all) of the factors affecting on buildings' behavior, but the present study has focused on the all architectural indices to consider the resistance of buildings against explosion.

2. Methodology

Basic indicators for evaluating the blast-resistant architectural spaces were identified in this study using library resources. The proposed indices were extracted from interviews with experts in the field of architecture and explosives (Table 1). A questionnaire was presented to 31 experts to acquire ideas for determining the effective indicators. The degree of each index was determined in a frame of the nine-point Likert scale by applying the group decision-making method based on a pairwise comparison model. Finally, the preferences and ultimate weights of the indices were determined. Moreover, the Cronbach's Alpha test was used to evaluate the validity of the questionnaires [17].

2.1. AHP method

Analytical Hierarchy Process is designed in accordance with human nature and mind and goes with it. This process is a set of judgments (decisions) and personal valuations in a reasonable approach. So it can be said that the technique in one hand, depends on personal impressions and experiences to form and plan an issue hierarchically, and in the other hand, it depends on logic, understanding and experience for decision making and final judgment.

AHP method is based on three steps: first, structure of the model; second, comparative arbitration of options and criteria and third, combination of priorities [12].

Forman (1985) believes that Analytical Hierarchy Process is one of the most comprehensive systems designed for multi-criteria decision-making, because this technique provides the possibility to formulate the problem hierarchically and also has the ability to consider various quantitative and qualitative criteria in the issue. This process involves different options in decision making and has the possibility of sensitivity analysis on criteria and sub-criteria. Furthermore, it has been

Table 1 Nine-point intensity of importance scale and its description. *Source:* Saaty (1980).

Definition	Intensity of importance
Equally important	1
Moderately more important	3
Strongly more important	5
Very strongly more important	7
Extremely more important	9
Intermediate values	2, 4, 6, 8