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RESEARCH ARTICLE

Role of architectural space in blast-resistant buildings

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Abstract
The design of all spatial scales in a manufactured environment is part of the architectural skills and knowledge. Therefore, an architectural design should be drafted to reduce the vulnerability of humans and buildings against unexpected events, such as terrorist attacks and bombardments. Human casualties and equipment destruction inside the buildings could be prevented by designing a suitable architectural space. This study addresses the absence of a codified and detailed criterion to evaluate architectural spaces and their design. Hence, all proposed indices for architectural spaces have been extracted using the ideas of experts in the field of architecture and explosives.
Questionnaires were presented to 25 experts to weigh the effective indices using the analytic hierarchy process method. The human-oriented (ergonomic) characteristics of the building space is found to be the most important factor in facilitating crisis management, followed by the location of critical spaces.

1. Introduction

Huge budget is spent annually worldwide in constructing public and private buildings using various architectural designs. At the same time, the destruction of resources, assets, and national infrastructures of countries are seen daily in every corner worldwide because of bombardments or terrorist attacks. These activities have not yet ceased and are currently unfolding.

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Thus, all military and non-military buildings should be designed with less vulnerability against these threats. A design should be drafted for buildings exposed to such threats. Architectural space is an important part in building design, which prevents human casualties and destruction of equipment inside the buildings. In the design of architectural spaces, the necessity of people to evacuate and their ability to leave the building after an explosion is crucial. Easy access paths all over the building should also be provided for rescue teams.

Therefore, this study primarily addresses the absence of a codified and detailed criterion in the evaluation and design of architectural spaces. Numerous studies on building structures that are resistant against threats have been conducted. Khairodin et al. (2007) focused on the impact of architectural elements on the vulnerability of structures against earthquake hazards. Fesharaki et al. (2011) investigated the importance of space organization in architecture as a passive defense and its variants.

Gebbeken and Döge (2010) examined the geometry of buildings and the effects of the environment to prevent blast waves from reaching the building. Essentially, the peak pressures and maximum impulses were found to depend on the distance from the blast center, angle of reflected blast wave, and resistance against the waves. They also found that the structural elements of a building can also reduce the explosive charges. Barakat and Hetherington (1998) studied the blast effects on various building forms, such as cubic, cylindrical, hemisphere, and prismatic forms, and concluded that in addition to the structural components of the buildings, architectural forms can be effective in reducing the effects of explosion on buildings.

Araghizadeh (2011) investigated blast-resistant office buildings in 2011 and presented 11 indices to evaluate these buildings. This study showed that the location of a building with respect to the ground level is one of the most important factors in reducing the impact of explosion.

Numerous studies have been conducted on blast-resistant buildings without considering the role of architectural space. However, structural factors or architectural forms are very important, particularly after the blast waves reach the interior of the building. Moreover, people should have access to shelters in buildings especially at the time of aerial bombardment. Therefore, some architectural space factors, such as ergonomics, can facilitate access to secure spaces.

Thus, this research aims to determine the position of architectural space on blast-resistant buildings and its effective indicators.

The methodology of this study was created, and effective indicators were proposed by considering several factors to achieve appropriate architectural spaces 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 15 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 and the analytic hierarchy process (AHP) were used to evaluate the validity of the questionnaires (Carver and Nash, 2009).

2.1. AHP method

The AHP method developed by Saaty (1980) aims to determine the relative importance of a set of activities in a multi-criteria decision problem. According to this method, the decision maker could incorporate and translate judgments on intangible qualitative criteria alongside tangible quantitative criteria (Badri, 2001). The AHP method is based on three steps, namely, the structure of the model, comparative judgment of the alternatives and criteria, and finally, the synthesis of the priorities (Dăgdeviren, 2008). The recent developments in the decision-making models based on the AHP method are listed below:

- Medineckiene et al. (2010) applied AHP in a sustainable construction;
- Podvezko et al. (2010) used AHP in the evaluation of contracts;
- Sivilevicius (2011a) applied AHP in modeling a transport system;
- Sivilevicius (2011b) used AHP to determine the quality of technology; and
- Fouladgar et al. (2011) applied AHP in prioritizing strategies.

During the first step, a sophisticated decision problem is structured in a hierarchy. This method breaks down a sophisticated decision-making problem into hierarchies, such as objectives, criteria, and alternatives.

These decision elements comprise the hierarchy of a structure such that the goal of the problem is at the top of the hierarchy, criterion is at the middle, and all the alternatives are at the bottom.

During the second step, alternatives and criteria are compared. In AHP, comparisons were performed based on a standard nine-point scale (Table 2).

Let $C = \{C_j | j = 1,2,\ldots,n\}$ be the set of criteria. The result of the pairwise comparison on n criteria can be summarized in an $(n \times n)$ evaluation of matrix A in which every element $a_{ij}(i,j = 1,2,\ldots,n)$ is the quotient of weights of the criteria, as

Table 1 Pairwise comparison matrix of the architectural indicators compatible with the purposes and principles of passive defense.

	X_1	X_2	X_3	X_4	X_5
X_1	1	0.444	0.537	3.383	3.384
X_2		1	1.038	5.491	5.491
X_3			1	4.877	4.877
X_4				1	1
X_5					1