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Evaluation of underground spaces evacuation effectiveness

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Abstract

As the need for the construction of underground spaces is growing, the need to integrate human behavior analysis into their design studies is obvious. In order to make this happen, the current belief that subterranean structures are unsafe needs to be altered. Increasing the safety of these spaces is the key factor that will achieve the most comfortable and effective utilization by the public. The purpose of this paper is to evaluate underground spaces as regards to their evacuation effectiveness and to compare them with similar above-ground buildings. To accomplish this, on one hand the factors that affect the evacuation effectiveness have been defined and on the other hand a tailor cut evaluation system has been developed. Among the factors influencing the evacuation effectiveness, the location of the exit doors/routes is of primary importance. Therefore, the evacuation evaluation methodology is based on the location of the exit doors design. The developed software, apart from checking the compliance of a given underground space with the evacuation regulations regarding the exit door location, assesses and evaluates all possible combinations of exit doors location based on the evaluation system developed. The grading for each combination results from the value of the variables that affect the evacuation procedures (i.e. exit door distance), according to the evaluation function developed. The evaluation system developed can give the evacuation safety profile of any space (under and above ground), helping a lot not only to check the safety of a given space, but also to design safer structures as well. The results of the comparative study of various areas prove that underground structures are quite safe in reference to evacuation procedures even in case where only two exits are available.

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1. Introduction

Over the years the attention of manufacturers is increasingly turning to the occupants' safety and the installation itself. Increased safety offering comfortable working place and increases employee productivity and occupants' attendance as well. Moreover, the more effective is the security system and the emergency plan of an organization the less will be the financial losses and injuries of the occupants in the event of an emergency (e.g. fire). Although the attention is focused on prevention, emergency situations cannot be avoided. For this reason, the facilities will be able to offer an effective response plan for staff and visitors.

Underground spaces and facilities nature affect occupants' behavior in normal or emergency conditions. Although the environmental stressors related to underground work, such as poor lighting, temperature and humidity levels can now be controlled to a level which is almost identical to any other office environment, designers often have to take a balance between effectiveness and efficiency and sometimes the operating cost may be unacceptable (Roberts, et al., 2016). To improve the profile and usage of underground space, several studies approach this project from a different view, such as space connections, within underground and with above ground improvement to encourage the use of underground space (Zhao & Künzli, 2016). Main factors that obviously discriminate underground and over-ground areas and affect people attendance, tried to be assessed in order to support underground design, especially in high use structures such as transport stations (Durmisevic & Sariyildiz, 2001).

In this paper an approach to evaluate the evacuation effectiveness of a structure[†] is presented. The evaluation is determined based on two parameters that affect the evacuation effectiveness: evacuation time and overcrowding effect that are mainly influenced by three evacuation parameters that are included in standards and regulations: travel distance, travel in dead end and angle between exit doors (National Fire Protection Association, 2009). In order to compare the affect to evacuation procedure, evacuation parameters are converted to mathematical functions, which show the contribution of each parameter in the evacuation effectiveness.

Specialized study of emergencies and evacuation procedures in underground spaces is an essential tool, so that the actual and the appreciable safety the public perceives in such places is equalized with that of conventional over-ground buildings.

2. Safety Evaluation

Last decades, organizations and companies have adopted a safety evaluation tool or rating system, either to improve their own products or services or to provide public with a safety degree of a widely use product that involves a variety of hazards. A wide known safety rating system is the NCAP (New Car Assessment Program) that by using an assessment in four important areas (Adult protection - driver and passenger, Child protection, Pedestrian protection and Safety Assist technologies), determine the overall star rating of car safety. In construction section there are other types of evaluation such as the roadside safety degree (RSD) for mountainous highway in China, in which by evaluate four categories factors (such as, geometry alignment, traffic volume, history crashes) determine the safety performance of the road (Li, et al., 2006). The proposed Safety Star Rating Scheme (SSRS) is an injury prevention initiative to lift the performance of workplace health and safety in New Zealand businesses. Every business is being assessed against pre-developed standards in two stages: online self-assessment and on-site assessment by independent assessors (WorkSafe_New Zealand, 2016).

An effective management safety system for structures or other "products" that involve hazards, is a crucial point in the development of a life extension and credibility. A key component of such a system is a means of monitoring and determining the condition and safety services of an existing or under construction structure (Bergmeister & et al, 2003).

[†] "Structure" definition will be used in this paper and includes any type of building, workplace, underground area etc.

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