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Fire Risk Analysis in Buildings

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Summary

The Laboratório Nacional de Engenharia Civil – LNEC started to develop, about 8 years ago, a model for analysis of fire hazard in buildings. This model consists of 11 partial models and, in its late development stage, is expected to make it possible to assess the fire hazard in a building, regardless of the type of occupancy.

From the eleven models already completed, the models referring to the description of the building and to building evacuation have already been developed. This paper describes the essential aspects of these two models.

Introduction

The Laboratório Nacional de Engenharia Civil has launched, about 5 years ago, the development of an overall model of analysis to the fire risk in buildings [1]. The model was formed by 11 partial models: model describing the building, model of the building evacuation, model of the probability of occurrence of fire in the building, model of development of fire in the building, model of structural safety of the building, model of fire warning and detection, model of automatic fire extinction means, model of fire brigades associated with the building, model of reliability of the active protection systems, model of cost-advantage analysis, model of data management produced by the partial models.

The field of application of the overall model was intended to be the most comprehensive as possible, so as to be used as support to future regulations with a prescribing character. On the one hand, in the ultimate stage of development, the model will give the possibility, as regards the building under study, to determine the fire hazard, which will be compared with the maximum admissible value for that specific case. On the other hand, in an intermediate stage, it will make possible to determine the evacuation time of a building subject to fire and it will give the possibility of verifying if there are any persons who, due to the development of that fire, cannot leave the building.

Two of those partial models were developed in a first stage: the model describing the building and the model of evacuation of the building. The

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computer implementation of the latter model, in language for Windows environment, is to be completed before the end of 2004.

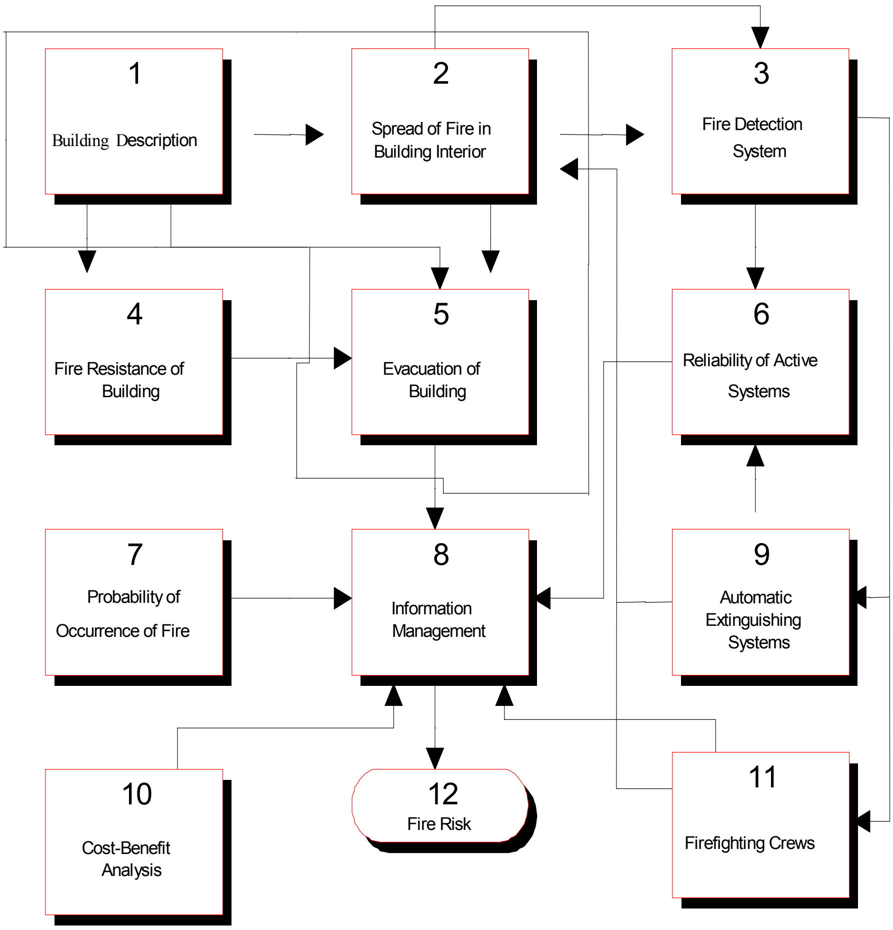

Figure 1 – Suggested diagram for fire risk analysis in buildings

Model Describing the Building

From a geometrical and physical point of view, the model describing the building makes possible to represent in detail the buildings (up to 30 floors and 10 stairs) with an irregular plan and variable from floor to floor, in accordance with the decomposition of the building in elementary networks.

The model gives also the possibility of representing the obstacles existing in the spaces, of locating different signals, locating fire detectors and locating the occupants. It makes also possible to carry out the schematic drawing of the building and of all the data introduced and stored in a database that has been already computer implemented.

Model of Building Evacuation

As regards the model of building evacuation, special reference can be made to the following characteristics: possibility of carrying out a microscopic and macroscopic analysis of the persons' movements; variation of the velocity according to density, by determining groups of equal density varying with the proximity of the occupants (in each time interval of the simulation, the determination of the velocity of each occupant is defined in accordance with his proximity to other occupants); displacement of the occupants in any direction conditioned only by the existing obstacles; analysis of the interaction of flows in confluence zones; analysis of overcrowding situations, by modelling the phenomenon of formation of arches next to spans, in situations of high density; analysis of the condition of doors ensuring the connection between the various building spaces (that analysis is associated with the existence or absence of automatic closure devices, with the time they take to close after the door has been opened and with the proximity of the occupants that are to cross the span where the door is inserted); identification of each occupant throughout the entire evacuation process and considerations of some behavioural aspects of the occupants.

The model of building evacuation includes not only the individual analysis of each person, but also the analysis of the group where that person is integrated, so as to take into account the inter-relations that are established among the different occupants. The model makes use of the movement laws developed by Predtechenskii. Nevertheless, it exceeds the limitation related with the macroscopic approach of the latter (Predtechenskii considers a rectilinear movement through "*evacuation paths*"). This is achieved by considering that the movement is likely to occur in any direction. It means that one can disregard both the notion of single direction and the need to determine groups of persons that are displaced in the same direction with equal density, as can be observed in the Predtechenskii's study. By considering the knowledge available on how the phenomena under study take place, at a rectilinear macroscopic level, one can conceive what is likely to occur at a macroscopic level, extending the application of the one-dimensional macroscopic laws of velocity/density to the neighbourhood of each occupant and eventually obtaining a coherent macroscopic image.

The microscopic analysis is essential for obtaining a coherent model of simulation of the occupants' actions, either before they decide to leave the building, or after that decision-making. This is due to the fact that only such an analysis makes possible to take into account different factors that influence the persons' movements, such as: age, moving capacity, sex, cultural level, familiarity with the building, familiarity with evacuation exercises, hearing capacity, visual capacity and others.

In the present stage of development of the model, each occupant is perfectly identified by his position on the floor (using the introduction of the co-ordinates, within the overall reference principles, of the position he occupies), by his sex, age, moving capacity, as well as by his level of knowledge of the building.

As regards his moving capacity, the model considers that if the handicapped occupant is not isolated, then his displacement velocity will be the same as the group where he is integrated. On the other hand, if he is isolated, his velocity is affected by the coefficient that was defined by the user of the model. Nevertheless, after the beginning of his displacement he may find subsequently, other occupants and, then, he will acquire the velocity attributed to the group of persons where he is integrated, unless that group has a significant number of persons whose moving capacity is affected. In that case, the velocity adopted for the group is the average velocity of the persons forming it, except for those who are in perfect conditions. The latter, in that case, will eventually form the front of the group considered and will subsequently move to a position distant from the others.

Each occupant occupies a certain area of the space where he is. The user may define, either for that area or for the model established by approximation, the value of $0{,}125m^2$.

As refers to the knowledge of the building by the occupants, two types were considered: those who know the building and those who do not know the building. The influence of the level of the occupants' familiarity with the building, on their displacement path results from the conclusions of previous works developed by Jin. Those works considered that when the occupants know the building, the perturbation of the movement can only be observed for values of the extinction coefficient equal to or higher than 0,5. For those who do not know the building, that perturbation occurs for values of the extinction coefficient above 0,15.

Regarding the occupants' age, the only element that can be integrated in that phase of development of the model, refers to the area occupied by children, which is obviously less than the one occupied by the adults. It is considered that in most situations, during building evacuation, the children are usually accompanied by their relatives, and their behaviour is then associated with the one of the adults, since the isolated children are generally not capable of preparing an escape plan on their own, and very often, instead of trying to exit the building they simply try to hide themselves. As for very young children, who cannot move by their own, and must be carried by other persons, they are not considered as another occupant. In that case, the adult carrying the child is assumed to occupy a larger area than he would occupy if he were on his own.

As regards the persons' behaviour in a fire situation, in the present stage of development, the behavioural aspects were considered after the decision of leaving the building has been made. The previous stage, in which sometimes a few occupants develop actions that are in no way related with exiting the building, was not thus considered. Some aspects were taken into account, which were related with the capacity of preparation of an evacuation strategy, and with the attempt to find the ways to leave the building (*wayfinding*), on basis of the works developed by Horiuchi, Weismam, Sime, and others. Thus, when the occupants have the possibility of choosing different evacuation paths, the choice is made, in each step of the simulation, by taking into consideration various factors. Those factors are: the distance, the flow of persons allowed by the various evacuation paths, the occupants' visibility of the exits, by defining thus the factor of attraction (which results from the attribution of different weights to the factors previously mentioned) exerted by the different paths on each occupant. The model describing the building illustrates with high accuracy the various obstacles and signals, providing the occupants with the possibility of identifying them and therefore either "see" or not the exits and all the existing signals. Thus, it becomes possible to carry out the adaptation of the results of the studies previously mentioned (aspects related with the most appropriate colour for recognising the signals are not yet modelled, because it is considered that there is not enough information available for the purpose). An algorithm was developed to determine the paths followed by the occupants. That algorithm takes into account not only the distances to be transposed (it does not consider a minimisation of the paths), but also the flows allowed by the evacuation paths, the occupants' visibility of the exits and their knowledge of the building, by simultaneously defining factors of attraction of the exit networks on the occupants.

In that stage of the model development, some behavioural aspects were already considered, which referred to the occupants' reaction to events associated with the fire (temperature, radiation and visibility), which impose the blocking of spaces, where those magnitudes present a higher value than the limit considered, and, force thus the occupants to find alternative paths, if they exist. These factors depend on the information provided by the sub-model of fire development, which will subsequently operate in articulation with the others.

From the point of view of visibility, two separate aspects are placed: one referring to the environmental conditions and the other referring to the ability of the occupant in identifying obstacles, different signals, etc. The existence of smoke and the consequent diminution in the visibility may influence in different ways, the persons' movements in an emergency situation, leading to a decrease in the displacement velocity or even to the interruption of the movement. That fact is dealt with on basis of the consideration of a factor of reduction of the velocity (deduced from records obtained by different authors). That factor is a function of the extinction coefficient, the movement being interrupted whenever the extinction coefficient reaches a given value.

Mention should also be made of the fact that, another method of determination of the evacuation time of the building has been simultaneously developed. That method uses only the minimisation of the distances to be transposed by the occupants, since the place where they are located until the outside of the building.

The model presents in that initial stage some limitations, which are to be subsequently overcome, such as the disregarding of actions previous to the decision-making of leaving the building.

Another extremely important aspect, which is to be eventually integrated in that model, is the one referring to the concentration of toxic gases resulting from the development of the fire. These gases may be lethal if the concentrations exceed certain values and in case of exposition times considered as excessive.

The knowledge on the people's behaviour is to be developed through co-operation with the fire services, so as to collect information from the occupants involved in fires, as well as through the execution of scenarios at LNEC facilities, in order to perform experiments on the people's behaviours, formation of arches, etc.

Reference

[1] **Leça Coelho, A. (1997)** – Modelação Matemática da Evacuação de Edifícios Sujeitos à Acção de um Incêndio. Porto: Faculdade de Engenharia da Universidade do Porto, Novembro de 1997. Tese de Doutoramento.