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Full Length Article

Determination of Different aspects of Fire safety in buildings

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ABSTRACT
Fire safety is very important in construction of different types of modern buildings and it is known as a complicated system with several varieties. The present study focused on fire resistance since it is known as one of the most important parts of fire safety. It mainly concentrated on fire safety and limiting bodily injuries and property loss within the scope of valid regulations. The study determines the efficiency of existing structures made with wooden, steel, and/or concrete parts, in the case of fire and some solutions were proposed in order to increase fire safety in buildings. Finally, practical recommendations were provided in the case of fire safety in structures.
Keywords: *fire safety, fire resistance, wood, steel, concrete.*

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INTRODUCTION

Fire safety is very important in construction of different types of modern buildings [1]. Fire safety is a complicated system with several varieties. Very different methods exist regarding the behavior of fire, humans, and buildings. The present study focused on fire resistance since it is known as one of the most important parts of fire safety. In many buildings, structural and non-structural sections are fire resistant so that fire expansion and smoke are prevented and finally, the structure is saved from collapse during an uncontrolled fire.

Regulations of fire resistance are only a limited part of overall plan of fire safety to save lives and firefighters and to reduce damage to properties. Fire resistance is often regarded as inactive fire protection so that there is always preparedness against fire and such systems as automated water spraying nuzzles are considered during active fire protection. The fire safety plans are usually a blend of active and inactive endeavors.

Fire resistance is often less important at early stages of fire. However, when the fire gets out of control, it increasingly becomes important. The importance of fire resistance depends on the size of buildings and the objectives of fire safety. In order to provide safety for humans, fire resistance should be taken seriously in all buildings. This is particularly important for big and tall buildings and the ones which are difficult to move. Fire resistance is also important in order to protect properties in variety of buildings. There has been several studies on fire safety of different types of buildings, namely wooden buildings [2, 3], steel buildings [4, 5],concrete buildings [6, 7], and composite structures [8, 9].

The present study mainly concentrated on fire safety and limiting bodily injuries and property loss within the scope of valid regulations. The importance of protecting lives and property is different in various countries depending upon the type of buildings and efficiency in those countries. In new regulations, more emphasis is put on protection of lives rather than property. Overall, one wishing to adopt the guidelines mentioned in this paper should be able to fulfill the following prerequisites:

- Determination of the efficiency of existing structures in the case of fire;
- Information about the plan of steel and concrete structures for fire resistance;

- Estimation of temperature-time graphs for very developed fires;
- Understanding the hypotheses of fire intensity and fire resistance;
- Interpretation of structural requirements for fire safety.

DETERMINATION OF THE EFFICIENCY OF EXISTING STRUCTURES IN THE CASE OF FIRE

Building owners often have tendency to know whether a damaged building is repairable and restorable. Structural and civil engineers are able to fully determine the damage; however, they should be able to address the following criteria while doing that:

(1) Determination of the harshest ignitions and maximum temperature caused by a given fire;
(2) Separation of non-structural parts and rubbish in order to repair structural parts completely;
(3) Checking junctions among different structural parts in terms of rupture, damage of welded junction, and bolt properties;
(4) Local maximum temperatures caused by fire through the determination of melted materials;
(5) Duration of dire by considering the residues of heavy wooden parts burned to coal at 0.6 mm min^{-1}.

Majority of damages caused by fire are visible except for temperature damages to the resistance of materials. Large damages such as big displacements, local deformations, concrete swelling, and wood coalification are visible. Most deformed parts during fire should be replaced unless displacements do not influence the future use of structure. There should be boundaries on deformations occurred before fire. If there are many parts with torsion, the whole structure should be demolished.

1.1. Steel

Unprotected steel parts usually undergo extended deformations during a given fire whereas the protected parts normally remain undamaged. In most cases, no further analysis is required for steel parts exposed to fire after direct cooling. When conventional grids of structural steel are cooled after exposure to 600 °C, they will not get damaged.

Heating to higher temperatures results in reduction of resistance by 10 percent. The reduction in resistance is more pronounced for highly resistant steels with alloys such as vanadium. Variety of resistant bolts is exposed to heating during the manufacture process and they lose resistance after heating operation; in these cases, they can be readily replaced.

1.2. Concrete

Concrete structures generally have an acceptable behavior in the case of fire. Concrete slabs and beams with too many displacements should be replaced. Covering concrete with swellings and/or ruptures should be replaced by sprayed concretes leading to marginal strength. Concrete parts with visible damage may decrease resistance due to temperature of concrete or armature. When cooled, soft concrete armature retains the lost resistance. When heated to 400 °C, highly resistant steels, especially tendons, become sensitive to heat. When cooled down after exposure to 500 °C and 600 °C, tendons lose their resistance by 30 and 50 percent, respectively.

Reduction in concrete resistance is less important than that in armature resistance. The heated area is usually not very deep, which is explained by low heat conductance of concrete. In bending parts with simple support, pressure area above the slab or beam is not exposed to high temperatures. Reduction in resistance of concrete near the surface can be estimated by using a hammer. Some types of concrete undergo deformation after being exposed to heat, which depends on the components of concrete. The heated conventional concrete would remain unchanged by 300 °C, heated concrete by 300-600 °C is pink in color, the one heated by 600-950 °C is grayish white, and the one heated by over 950 °C is buff in color. When heated to 300 °C, concrete will not undergo considerable reduction in resistance whereas at higher temperatures, the reduction of resistance will occur. When cooled after heating, concrete will recover its resistance but it will never be as resistant as it was before fire. Ceramic bricks lose their resistance in part by heating to 1000 °C but mortar gets damaged a little. Concrete materials should be analyzed like armed concrete.

1.3. Wood

When wood is burned, the damages of fire-exposed parts will be visible. Heavy wooden parts (beams, columns, and heavy wooden floors) get damaged on the surface but the woods will remain undamaged inside because the coalified layer is considered to have a complete resistance. The remaining cross-section is obtained by scraping coalified and discolored parts. Fire-exposed wooden parts undergo lower deformation than corresponding steel parts.

Fire-damaged wooden parts will not need to be replaced if the remaining cross-section has sufficient resistance against the loads. For fire resistance, marginal supports such as gypsum boards should be

incorporated so that marginal resistance is provided against fire. Highly damaged parts should be replaced but beams and columns with partial damage can have marginal layers.
Light wooden structures are protected against fire by using gypsum boards. After a severe fire, plating below the ceiling and wall will be damaged. Some plates might come off as a result of fire and/or firefighting activities. All damaged plates should be separated in order to determine the extent of damage to junctions. All coalified wooden beams have reduced load capacity. The resistance of remaining parts should be estimated carefully.
Checking gypsum boards result in a criterion for completely extended ignition. When gypsum board is exposed to fire, it is dehydrated continuously from the heated surface. The depth of dehydration can be viewed by breaking and opening a small part of the board between hydrated gypsum and main gypsum of the first board. The conventional gypsum board is normally hydrated at 0.5 mm/min.

DESIGN OF STEEL STRUCTURE FOR FIRE RESISTANCE

Structural design for fire resistance is theoretically similar to the structural design for normal temperature regime. Before designing, it is important to follow clear purposes and determine the extent of fire. Designing is carried out by allowable stress and final resistance. The main differences of fire plan compared to normal temperature plan during a given fire are as follows:

- Incoming loads are low;
- Internal forces are formed by thermal expansion;
- Material resistance may decrease with higher temperatures;
- Cross-section might decrease as a result of coming off;
- Lower safety coefficients are adoptable due to their lower probability;
- Deformations are not important unless they influence material resistance;
- Different failure mechanisms should be assessed.

Defining a design for fire resistance demand a condition where incoming loads are lower than the loading capacity of structure during the fire design. This demands the following relation:

$U^*_{fire} \leq \quad R_{fire}$

where U^*, R, and Q_f stand for design's incoming forces during fire, nominal loading capacity in fire, and fire resistance reduction coefficient, respectively. The indexU^*could be N^* (axial force of fire),M^* (bending moment), and/or V^* (shear force), which are calculated separately or in addition to loading capacity.
Fire resistance reduction coefficient, Q_f, depends on the resistance of materials and size of cross-section. Fire resistance plan is based upon the most probable predicted resistances. Therefore, majority of national and international regulations define $Q_f = 1$.in European regulations, partial safety coefficient γ_M is 1; in Northern America and Europe, design relation for fire is as follows:

$U^*_{fire} \leq R_{fire}$

This relation is considered for steel, concrete, and wooden structures.
It is seen by determination of stress-strain relations in high temperatures that yield strength and elasticity module decrease with higher temperatures; however, final ultimate tensile strength increase somewhat at average temperatures.

Design for fire safety

We determined structure behavior in the case of fire and provided fire safety by using covering insulators. We first designed a building in SAP90 according to normal plan based on national regulations of building and calculated the resistance and strength of structural parts in the case fire without insulators or increased cross-section and found that fire resistance in buildings with normal design (without fire safety considerations) is 17 min for beams and 20 min for columns. We present the following suggestions to increase fire strength:

(1) Fire strength can increase by 120 min by using gypsum covers at 36 mm for beams and 26 mm for columns;
(2) Fire strength can increase by 120 min by using mineral fiber covers at 20 mm for beams and 16 mm for columns;

CONCLUSIONS

Fire safety is very important issue in civil engineering projects and construction activities. Fire resistance and safety of buildings were scrutinized in this paper in terms of the type of materials used for construction. Taken together, the following recommendations are presented in order to render fire safety to buildings:

(1) Passing compiled and comprehensive regulations and rules by authorities so that fire safety is validated and enforced like other regulations;
(2) Establishment of fire research centers with equipped laboratories in order to specify appropriate regulations corresponding to climatic condition of country;
(3) Provision of inclusive fire plan for cities prepared in order to determine the probability of fire in society to limit or reduce the risk of fire;
(4) Inclusion of a course named building strengthening against fire in order to make students aware of the issue;
(5) Determination of other types of buildings and provision of a comprehensive fire plan for all types of buildings.

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