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Fire Load Calculation on Hospital Buildings in India

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***Abstract* - The disaster of September 11th 2001, in New York has aroused the interest of all those concerned with building design and construction specially Hospital Buildings because it is most vulnerable on the issue of structural behavior in fire. In particular, since composite steel–concrete construction is often associated with steel which has high thermal conductivity (thus giving fast increase of temperature under fire exposure) and reduces strength and stiffness at elevated temperatures, the performance and safety of composite steel–concrete structures in fire will receive intensive attention. However, it should be pointed out that prior to the September 11th event, research studies on steel and composite structural performance in fire had been intensive, and advances in this field rapid particularly in Europe.The provision of structural safety in buildings is based on the specification of loads that the building is required to resist. The use of loads as a means to regulate structural safety (what structural engineers call the limit state design method) has two components. First is the definition of a load including how it acts on the building and the related engineering analysis and design methods .At present the fire load load factor in I.S. code is taken from prescriptive based codes from U.S. and U.K. countries so in this research I am trying to find out the value of performance based value of fire load and propose this value as a performance based fire load value for Northern region of India. I will try to identify the structural response of hospital building in fire as a R.C.C. and composite structure and compare their stability.**

***Keywords* - Fire load, Fire Safety, Hospital building.**

I. INTRODUCTION

The main objective of a fire-structure analysis is to predict the effects of fires in buildings, e.g. the fire resistance and the structure's performance under heating and cooling caused by fire. The results of such analysis can be applied in the design of fire protection systems, in the evaluation of fire safety and as an addendum of experiments. Advanced calculation techniques can be helpful in the areas where experiments encounter difficulties such as testing large specimens, implementation of loading and boundary condition, measurements and interpretation of specimen's behavior. A computational model used for fire-structural (member or global) analysis should properly represent the considered problem in terms of: type of analysis and solution methods, geometry, temperature dependent material properties, mechanical boundary conditions and loading, thermal conditions. The fire resistance analysis of reinforced concrete (RC) structures faces additional challenges and constitutes an important part in their design. From the constructional point of view, buildings and structures at fire have to carry mechanical loadings and thus provide safe people evacuation (rescue) and safe firemen work. High temperatures have a very significant adverse effect on thermo-mechanical properties of RC members. High temperature substantially reduces strength of concrete and steel, and causes significant increase in cracking, strains and deflections. Load bearing capacity of structure decreases and may fail at critical points. Depending on the simulated test scenario, three types of analysis can be considered: structural, thermal or coupled structural-thermal. Structural stress analysis should be able to take into account strains due to elastic and plastic deformation and due to thermal elongation if coupled structural-thermal analysis is performed. Creep strains can usually be omitted for transient analysis. Incremental, transient structural analysis should be based on explicit or implicit methods for time integration. Application of explicit methods in coupled structural-thermal fire analysis is not feasible due to consideration of relatively long time intervals. For the thermal calculations usually unconditionally stable implicit time integration is applied (Hallquist 2006). One can choose between general purpose commercial programs and research oriented specialized unique programs developed by academia. In both cases, the majority of today's computer programs, dedicated to structural analysis, are based on the Finite Element (FE) Method. For many years the ability of highly redundant composite framed structures to resist the effects of fire had not been quantified. The significance of this was first realized when, after a number of real fires in multi-story composite steel framed structures, structural failure did not occur. This accidental fire happened during the construction phase when the steel frame was only partially fire protected. Despite very high temperatures during the fully developed phase of the fire and considerable deflections in the composite slab there was no collapse. An investigation of the methods available to model compartment fires was carried out. Comparisons were made between predicted natural fires and atmosphere temperatures measured during experimental compartment fires. Heat transfer models were also tested against steel and concrete temperatures recorded during the Cardington tests . Using these design tools, natural fire curves were assumed and heat transfer calculations were made, to obtain steel and concrete temperature histories as inputs to structural analyses. A series of parametric studies was conducted on the two generic frames to investigate the response of the structure if the fire exposure or location changed. The fire scenarios included compartment fires on the whole floor, at the edge and corners of the structures. By altering the size and location of the compartment, the level of restraint to thermal expansion and thermal bowing of the structural elements changed. A further set of studies varied the number of beam members with applied fire protection. Three scenarios were tested. Primary and edge beams protected, only edge beams protected and all beams unprotected. In all studies secondary beams were unprotected and columns were protected to their full height. The tensile membrane behaviour of the slab and alternative load carrying mechanisms observed in the Cardington frame fire tests were confirmed in both generic frames and new phenomena was highlighted. Overall the generic frame structures behaved well and the partially protected composite frame structures were shown to continue to support load under the fire scenarios tested.

Fire Load

Fire load is defined as the heat energy that could be released per square meter of floor area of a compartment or story, by the complete combustion of the contents of the building and any combustible parts of the building itself .conveniently, the fire load is given by

$$\boxed{\mathbf{q_c = \sum m_v\, H_v / A_f}}$$

Where q_c = fire load (MJ/m^2) ; A_f = Floor area (m^2) ;m_v = Total mass of the combustible material (Kg) and H_v = Calorific value of the combustible material (MJ /Kg)

II. METHODOLOGY

Fire load calculation on hospital building in Indian scenario. The following points are to be considered while finding the fire load calculation on hospital building:

Prescriptive-based and Performance-based Codes

Over the past 25-30 years, there has been increased interest towards the adoption of performance-based codes. This has led to a gradual shift from prescriptive-based codes into objective or performance-based codes in several countries. These countries include Great Britain, New Zealand, Australia, Japan, Finland, Netherlands, Norway, Poland, Spain, Sweden, United States, and Canada.

Prescriptive-based Codes

Prescriptive codes usually specify requirements for broad classifications of buildings in terms of fixed values. These requirements are often given without stating the intent of the requirement. For example, in fire safety engineering (FSE), prescriptive-based codes will specify requirements such as minimum spacing of fire suppression and detection system, minimum fire resistance rating (FRR), water supply requirement and etc. However, the degree of damage cannot be explicitly quantified. For example, the loss before sprinklers activate or the amount of harmful gases before complete evacuation is not defined in prescriptive-based codes. According to Meacham and Custer [1], prescriptive codes may provide the designer with sufficient guidance for buildings that are 'typical' in size, shape and use. However, this may not be the case for more complex buildings or where the fire safety objective is to protect a property where there can be high property or life loss. For example, a small fire can be very devastating in occupancies such as telecommunication and power generation facilities. In such occupancies, simple application of prescriptive codes may not produce sufficient protection. It must however be noted that, in most codes, an alternative method or equivalency clause appears. This provides an opportunity for an engineering-based design approach through a standardized methodology [2].

Performance-based or Objective-based Codes

Performance-based codes provide safety goals or objectives, often expressed qualitatively, which the design must meet. Examples of the objectives are: 'safeguard people from injury', 'give adequate time to reach a safe place'. Performance-based codes reference acceptable methods that can be used to demonstrate compliance with their requirements. The codes allow the use of any solution that can demonstrate compliance to the specified requirements. The historic development of performance based codes has been well documented in the literature [1,3]. Hadjisophocleous et al [3], presented a summary of advantages and disadvantages of prescriptive-based and performance-based regulations, as summarized in Table 2-1. Performance-based codes offer several advantages over prescriptive codes. This includes flexibility, globalization aspect, cost effective fire protection, and measurable consistent levels of safety [3-5]. The major set-backs of the performance based codes are: the difficulty to prove compliance with the objectives and the definition of acceptable level of safety.Table.1. Shows comparative study of different methodologies to find the fire load on hospital building.

Table.1. Advantages and Disadvantages of Prescriptive-based and Performance-based Codes

Code	Advantages	Disadvantages
Prescriptive Codes	• Straight forward evaluation of compliance with established requirements. • No requirements for high level of engineering expertise	• Requirements specified without statement of objective • Complexity of Structure of codes. • No promotion of cost effective designs • Very little flexibility for innovation • Presumption that there is only one way of providing the

		level of safety
Performance Codes	• Establishment of clear safety goals and leaving the means of achieving those goals to the designer • Permit innovative design solutions that meet the performance requirements	• Difficult to define quantitative levels of safety (performance criteria) • Need for education because of lack of understanding especially during first stages of application

Table 2. Shows the questioner survey sheet for calculation of fire loads on hospital building.

Table.2.Fire Load Data Entry Sheets

Hospital Building Occupancies:……………………………… Date:………………….

Room length (m)_______________ Room Width (m)_____________Total Floor Area (m^2)					
Designation of Fixed Fire Load	Type	Quantity	Mass (kg)	Dimensions (m)	Surface Area Exposed (m2)

III. RESULT AND DISCUSSION

As per loading concern this standard code of practice was first published in 1957 for the guidance of civil engineers, designers and architects associated with planning and design of buildings. It included the provisions for basic design loads (dead loads, live loads, wind loads and seismic loads) to be assumed in the design of buildings. In its first revision in 1964, the wind pressure provisions were modified on the basis of studies of wind phenomenon and its effects on structures, undertaken by the special committee in consultation with the Indian Meteorological Department. In addition to this, new clauses on wind loads for butterfly type structures were included; wind pressure coefficients for sheeted roofs both curved and sloping were modified; seismic load provisions were deleted (separate code having been prepared) and metric system of weights and measurements was adopted.

As per I.S. 1641, 1988

Classification of Building Based On Ocupancy

General Classification (Table.3)-All buildings should be classified, according to the use or the character of occupancy in one of the following groups:

Table.3. Classification of different types of building (as per Bureau of Indian standards)

Group A	Residential
Group B	Educational
Group C	Institutional
Group D	Assembly
Group E	Business
Group F	Mercantile
Group G	Industrial
Group H	Storage
Group J	Hazardous

As per national building code for India (NBC part-4), the fire load density with respect to different types of buildings presents in table.4.

Table.4. Typical values of fire load Density

Sl. No.	**Building Type**	**Fire load Density(Expressed as wood Equivalent Kg/m^2**
(i)	Residential (A-1 and A-2)	25
(ii)	Residential (A-3 to A-5)	25
(iii)	Institutional and Educational (B and C)	25
(iv)	Assembly (D)	25-50
(v)	Business (E)	25-50
(vi)	Mercantile (F)	Up to 250
(vii)	Industrial (G)	Up to 150
(viii)	Storage and Hazardous (H and J)	Up to 500

IS 875 code (Part 5) deals with loads and load effects (other than those covered in Parts 1 to 4, and seismic loads) due to temperature changes, internally generating stresses (due to creep, shrinkage, differential settlement, etc) in the building and its components, soil and hydrostatic pressure, accidental loads, etc. This part also includes guidance on load combinations.

IS 875 code (Part 5) deals with loads and load effects due to temperature changes, soil and hydrostatic pressures, internally generating stresses (due to creep, shrinkage, differential settlement, etc), accidental loads etc, to be considered in the design of buildings as appropriate. This part also includes guidance on load combinations. The nature of loads to be considered for a particular situation is to be based on engineering judgment. Expansion and contraction due to changes in temperature of the materials of a structure shall be considered in design. Provision shall be made either to relieve the stress by provision of expansion/contraction joints in accordance with IS : 3414-1968* or design the structure to carry additional stresses due to temperature effects as appropriate to the problem.

The occurrence of accidental loads with a significant value, is unlikely on a given structure over the period of time under consideration, and also in most cases is of short duration. The occurrence of an accidental load could in many cases be expected to cause severe consequences unless special measures are taken:
The accidental loads arising out of human action include the following:
a) Impacts and collisions,
b) Explosions, and
c) Fire.
Characteristic of the above stated loads are that they are not a cocequence of normal use and that they are undesired, and that extensive efforts are made to avoid them. As a result, the probability of occurrence of an accidental load is small whereas the consequences may be severe.
Thermal Effect During Fire - The thermal effect during fire may be determined from one of the following methods:
a) Time-temperature curve and the required fire resistance (minutes), or
b) Energy balance method.
If the thermal effect during fire is determined from energy balance method, the fire load is taken to be:

$$\boxed{q = 12t_b}$$

Where

q = fire action (K J per m* floor), and
t_b = required fire resistance (minutes) (IS : 1642-1960).

The fire action is defined as the total quantity of heat produced by complete combustion of all combustible material in the fire compartment, inclusive of stored goods and equipment together with building structures and building materials.
The various loads should, therefore, be combined in accordance with the stipulations in the relevant design codes. In the absence of such recommendations, the following loading combinations, whichever combination produces the most unfavorable effect in the building, foundation or structural member concerned may be adopted (as a general guidance). It should also be recognized in load combinations (shows in Table.5).

Table.5.Different load combination for designing structure.

Individual load on building	**Dual load combination**	**Multiple load combination**	**Multiple load combination with temperature load**
DL	DL+IL ,DL+WL DL+EL , DL+TL	DL+IL+WL DL+IL+EL	DL+ IL+ TL DL+WL+TL DL+EL+TL DL+IL+WL+TL DL+IL+EL+TL

(DL = dead load, IL = imposed load, WL = wind load, EL = earthquake load, TL = temperature load).
When we are going to design a structure we can take above mentioned load combination for designing purpose, so as you can see that combination (i) to (l) there is a combination of temperature load and this factor is depend upon prescriptive based code so this is the gap of our designing code because as we early discussed that if we will able to convert this factor to performance based in zone wise distribution in India we can certainly reduce the cost of construction.The critical role of ventilation was recognized by individuals like Phillip Thomas and Margaret Law, who suggested that the fire load per unit window area might make a better design parameter [Thomas et al, 19672]. Law, like Ingberg wrote of designing spaces so that they could suffer complete burnout without local or global collapse. She [Law 1971] and Thomas further refined the approach to account for the effects of compartment ventilation and heat loss to boundaries by adding terms for each to the fire severity equation as shown below. A few years later Gross suggested the Thomas enhancement to account for heat losses and ventilation [Gross 1977]. The so-called effective fire resistance is defined as:

$$\boxed{\mathbf{T_f = KL/A_f \, x \, A_f/(A_w A_t)1/2 \; (min)}}$$

Where: **T_f** is the effective fire resistance (min)
K is approx 1.3 (range 0.7 to 1.5) (m2/kg)
L is the fire load (kg)
A_f is the floor area (m2)
A_w is the ventilation area (m2)
At is the area of compartment surfaces to which heat is lost (excluding the ventilation area) (m2)
The data collection survey methods used in this study have been defined as follows:
- **Weighing Method** - mass obtained from direct weighing and estimations based on pre-weighed item table
- **Inventory Method** - mass obtained from direct measurement of volume with subsequent conversion based on corresponding density
- **Combination Method** - mass obtained from the use of the two methods described above.
- **Questionnaire method** - mass obtained from tabular look-ups based on hand delivered questionnaires

IV. CONCLUSIONS

The aim of this research has been to develop a performance based design methodology for Hospital structures in fire, addressing the concepts of risk and reliability. This goal was complemented by the need to develop further suitable analytical techniques for the assessment of a structures response in fire.

The study is going to identify through review of literature that several factors may account for variations in fire load data sets. Those factors include: the survey methodology, regional and Cultural differences, time, taste, etc. The current study focused on the impact of survey Methodology on fire load (Both Govt. and private hospital rooms), it will be also interesting for research to consider the impact of other factors such as time, regional and cultural differences, and scenario.

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