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Technical Note

NEW CHALLENGES IN BUILDING FIRE SAFETY

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ABSTRACT

As buildings grow higher and their uses become more complex, and as plastic-based combustible loadings increase, building fires become a complex problem. Dramatic progress has been made in fire protection engineering. Unfortunately, our local building and fire codes have lagged behind the current technology. Direct code applicatiön may not be the best and most economical solution. Alternative solutions must be equal to or better than the code requirements. Building fire safety is not accomplished only by installing a sprinkler system, but must also include an egress system that affords an acceptable level of life safety, an alarm and detection system that is reliable, an effective smoke control system, an economical fire protection covering for structural members, and a strategy for maximizing the capabilities and resources of the fire department. Integration of the various fire protection features is the new challenge in building fire safety.

INTRODUCTION

Ever since the beginning of human history, fires have been used for survival and productive purposes. When fires are uncontrolled, lives are lost, properties are destroyed, and business operations are disrupted. Unwanted fires must be suppressed at their points of origin and in their early stages. During a fire, hot and toxic gases migrate to other building spaces. These spaces will become untenable and in time combustible materials may ignite.

Suppressing building fires should not be left to the fire department alone. Buildings must be provided with fire protection features so that damages can be limited and occupants' safety can be assured. If fire protection features are to be adequate and reliable, yet economical, integration and coordination of the structural fire protection, egress system, standpipe and suppression system, fire department access, smoke control, and fire alarm and detection system is necessary.

BODY OF KNOWLEDGE

A sizeable body of knowledge on fire protection engineering has been developed. Some are suitable for use by non-engineers and some are highly technical in nature, some have not yet found its way to daily engineering routine. This body of knowledge can be found in a variety of references, including:

SFPE Handbook of Fire Protection Engineering
NFPA Fire Protection Handbook
NFPA Codes and Standards
Insurance Industry Guides,
    Practice and Data Sheets
Proprietary Fire Protection Systems Design Guides
Test Standards
Research Reports
Fire Technology, Journal of Engineering
Fire Journal, Fire Safety Journal
Model Building Codes

One of the most significant developments has been the release of Society of Fire Protection Engineers (SFPE) Handbook of Fire Protection Engineering, written by over 50 experts and published in 1988. This first of its kind handbook covers subjects ranging from fundamentals to state-of-the-art applications for predicting fire development and smoke spread. The emphasis of the SFPE Handbook is on quantitative calculation methods. These methods are slowly starting to find their way into codes and standards.

Another great development has been the computer models prepared at the various fire research institutions in the U.S. These computer models are used as tools by fire protection engineers and consultants. Computer models include the following:

ASET	-	Available Safe Egress Time
ASCOS	-	Analysis of Smoke Control System
LAVENT	-	Link Actuated Vent
FAST	-	Fire and Smoke Transport
HAZARD I	-	Fire Hazard Assessment Method
DETACT	-	Detector Actuation
EVACNET	-	Evacuation Network
FASBUS	-	Fire Analysis of Steel Building System
FIRES-T3	-	Fire Response of Structures - Thermal Three Dimensional
STEMFIRE	-	Steel Member Fire Protection Computer Program

BUILDING AND FIRE CODES

Both the National Building Code and the Fire Code of the Philippines were prepared and released in the 70's. These codes were written based on the technology available in the 60's. After more than two decades, there have been no amendments or updating of the fire protection provisions.

Because our local codes do not reflect the current technology, specific provisions may not be appropriate for direct application. Direct application of the provisions in the local codes must be done with caution and sound engineering judgement.

For example, if a building is considered high-rise, Rule 40 (High Rise Buildings) of the Fire Code requires that smoke control and automatic suppression system must be provided. Specifically, Section 40.104 (Smoke Control) of Rule 40 states that:

> *"High-rise buildings shall be designed so that in the event of fire the levels of smoke concentration in protected spaces can be maintained within values that can be tolerated by occupants for an indefinite period. The protected spaces shall include stairwells, at least one elevator shaft, and floor spaces readily accessible to all occupants and large enough to accommodate them. In the spaces to which the requirements for control of smoke level applies, the atmosphere shall not include more than one (1%) percent by volume of the contaminated atmosphere emanating from the fire area."*

The first and last sentences of Section 40.104 are vague and can not be directly incorporated into the design. Thus, code conformance is jeopardized.

In such a case, there is a need to develop an equivalent solution which would provide fire safety equal to or better than the code requirements. In our example of smoke control, the solution is to specify design criteria which can be measured in the field, such as differential pressures and air flow velocities. With absolute values on differential pressures and airflow velocities, these design criteria can be incorporated into the smoke control system and verified after installation.

EGRESS SYSTEM

Various features of the building including the egress system have been the responsibility of the architects. Decision on travel distances to exits are based on the requirements of the building and fire codes. The codes provide absolute numbers on travel distances. If the building's egress system is in conformance with or in violation of the code, is it possible to determine the degree of safety afforded to building occupants? The answer, based on the latest technology available is "yes".

For egress system, the most important considerations are the time available for evacuation and the time required to evacuate. The onset of hazardous conditions on the egress system can be predicted. ASET can be used as a tool in determining the time when hazardous conditions will be attained. The time to reach hazardous conditions minus time needed for detection is the available time for evacuation. The time required to evacuate can be determined by actual fire drill or by using EVACNET as an engineering tool. Multiple rooms and floors can be modelled using the EVACNET computer model. If the time required to evacuate the compartment is less than the available time for evacuation, then the egress system is providing a certain degree of life safety. Otherwise, the egress system, wall finishes, etc. must be re-evaluated. Also, the response of the sprinkler system can be predicted using DETACT as a tool. This would indicate, whether the sprinkler system activates before or after the onset of hazardous conditions. If the sprinkler activates prior to the onset of hazardous conditions, then there is an added level of safety for the occupants.

ALARM AND DETECTION

One of the components of a complete fire protection program is an alarm and detection system. When buildings are in the planning stages, the architect often relies on the electrical engineer for fire detection and alarm system design. Building owners may also directly entertain offers from suppliers. An alarm and detection system should detect the fire at its early stages, provide ample warnings for the building occupants, and signal the nature and location of the fire. Such a system must not only be reliable but also economical.

In the past, the selection and location of fire alarm devices has been based on experience and engineering judgement. Recent developments in fire protection engineering allow the incorporation of new information about sound production and transmission so that the guess work in locating fire alarm sounders is eliminated. Sound transmission is a function of many factors, such as the location of the source relative to the target, the construction of walls, floors and ceilings, and the furnishings in the area. The method of Butler, Bowyer and Kew presented in the SFPE handbook can be used for this purpose.

Most codes require detectors to be spaced at intervals equal to the UL or FM recommended spacing. However, when buildings have high ceilings, deep beams, or substantial air movement, there is a need to evaluate UL or FM spacings. A sound engineering decision based on the knowledge of fire dynamics and smoke movement would require that the listed spacing must compensate for obstructions due to beams, joists, walls or sloped ceilings. For large flat ceilings provided with heat detectors, the challenge is to determine the maximum distance between detectors. This would entail predicting detector response time, based on fire size and growth rate, and detector characteristics. With the progress in fire protection engineering, this analytical exercise is now a reality. The analytical exercise can be facilitated by using the DETACT computer program.

FIRE SUPPRESSION

The most effective suppression method for building fires is an automatic water sprinkler system. When a fire occurs in a compartment and the sprinkler head activates and suppresses the fire within the compartment, the general conclusion is that the sprinkler system was designed and installed properly. When the fire spreads to other spaces beyond the room of fire origin, substantial number of sprinkler head activate, and the fire is subdued with assistance from the fire department, the conclusion is that the sprinkler system capability is inadequate.

The conventional method of sprinkler design is based on an established pipe schedule. This is a design approach where the size of a pipe is dictated by the number of installed sprinklers and the type of hazard classification. This approach is very conservative and does not provide information on the water density delivered, number of sprinkler heads operating, and the design area.

An alternative approach is to hydraulically design the sprinkler system. In this approach, pipe sizes are selected on a pressure loss basis to provide a prescribed density distributed with a reasonable degree of uniformity over a specified area. With the use of a computer program, hydraulic simulations can be done in a short period of time. The computer program allows investigations on the impact of reducing pipe sizes. For buildings which provide spaces for commercial purposes, such as shops, storage, etc, each distinct space must be evaluated based on its hazard characteristics and water density requirements. Hydraulic analysis runs must be performed to determine whether the sprinkler system is adequate to deliver the right amount of water at the required pressure. Commercial computer programs are now available to fire protection consultants. Hand calculations which are slow and prone to oversight errors are no longer necessary. When sprinkler systems are designed based on the hydraulic capacity of pipes, the result is an economical system.

For fire suppression to be effective, sprinkler systems must be installed in accordance with NFPA 13, Standard for the Installation of Sprinkler Systems. Sprinkler heads must be free of obstruction and pipes must pass leakage and hydrostatic tests. When buildings are provided with an automatic sprinkler system, protection is greatly enhanced.

SMOKE CONTROL

Smoke, which includes toxic gases, is the major killer in building fires. When the central air conditioning system of a building operates on a smoke control function, the safety of occupants is upgraded and fire fighting operations by the fire department are more efficient. Without smoke control, fire fighters will have difficulty entering the building and fire fighting operations may be limited on the outside. At the same time, occupants may be overcome by smoke and their escape hindered.

Compartmentalization as a method to control smoke is not the most effective approach. The integrity of the compartment is often greatly reduced because of building leakages and utility penetrations. Building zone pressurization is currently the best approach to controlling smoke. The central air conditioning system can be optimized to provide building pressurization during fire emergencies. In zone pressurization, a building can be divided into a number of smoke zones by using walls, partitions and floors as barriers. One floor or more than one floor in a high-rise building, can be designated as a smoke zone. When an alarm is sounded during a fire event, automatic control dampers leading to the supply fans from the exhaust fans dump all return air, to the outside and no recirculation is permitted. To create the desired pressurization, dampers can be added where the return air enters the main shaft. All dampers in the return air have to be closed, except for the dampers in the smoke zone.

Because of the number of variables involved in smoke control, namely; number of smoke zones, position of doors, wind velocity, condition of windows, building leakages, number of stairways, elevator shafts, and the number of fire scenarios, engineering analysis requires the use of computer as a tool. Several computer models have been written to analyze air movement in buildings for purposes of smoke control and smoke movement. The ASCOS (Analysis of Smoke Control System) computer model prepared by the National Institute of Science and Technology (NIST) in the U.S. can be used to analyze stairwells with vestibules, elevators with elevator lobbies, zoned smoke control system, and pressurized corridors.

There is a need to consider all the variables in the engineering analysis because of the danger of creating excessive differential pressures. If there is too much differential pressure there will be difficulty in opening door. On the other hand, if the differential pressure is less than the required, hot toxic gases may penetrate other building spaces. Computer models, such as ASCOS, enable fire protection consultants to determine these situations.

STRUCTURAL FIRE RESISTANCE

Structural members are required to have a certain degree of fire resistance to prevent structural collapse. Fire ratings prescribed by the building code are based on results of a standard test, ASTM E-119 (Standard Methods of Fire Tests of Building Construction and Materials).

Reinforced concrete systems have a good experience record with regard to structural collapse due to building fires. On the other hand, when a steel member is exposed to a temperature of 538°C (1000°F) its yield strength is approximately 60% of its value at normal room temperature. To protect steel members, insulation in the form of board products, spray-applied materials or concrete encasement can be installed.

Once a decision is reached on the fire rating, for example, 4 hours, the conventional approach is to draft the technical specifications to read:

> *"All structural members must have a 4 hour fire rating. Materials use for insulation must be UL approved or equivalent."*

This allows the contractor the freedom to consult suppliers of insulation or refer directly on the UL Fire Resistance Directory. Because the thickness is not specified, technical information will then be provided by the supplier.

An alternative method is to quantify the minimum thickness required to attain the specified fire rating during the design phase. The STEMFIRE method developed by AISI (American Iron and Steel Institute) can be used by the fire protection consultant. STEMFIRE is a calculation procedure which determines the most economical thickness for commonly used fire protection materials for steel beams, columns and trusses. This method has been adopted by the three model building codes in the U.S. and is recognized by Underwriters Laboratories, Inc. (UL).

Comparison of thickness derived from the UL Directory and STEMFIRE shows that with the STEMFIRE method the thickness as required are about 16 to 50% less than those recommended by the UL Directory. Reduction of thickness means reduction of insulation materials. Thus, economy is derived using the latest advances in structural fire resistance.

RESPONSE OF THE FIRE DEPARTMENT

If the sprinkler system malfunctions or is unsuccessful, a public fire department is often required to combat a fire. Ideally, the fire department should be consulted during the planning stage. Information such as staging area, location of hose connections, central alarm and detection room, pump room, stairways, etc. must be known to the fire department. When this information is known to the fire department, time is used effectively during fire fighting operations. Also, rescue of occupants can be carried out efficiently if the fire department is familiar with the layout of the building and location of the different fire protection features must be provided to the fire department. This information will prove to be useful during fire emergencies.

CONCLUSIONS

As urban areas are dotted with tall buildings providing residential, institutional, and commercial spaces, life safety and protection of properties must be concerns not only of the owners but also of the design team. Fire protection features of a building do not have the luxury of a second chance during fire emergencies. They must be complete, reliable, effective and, most important, cost effective. Substantial savings can be generated if the new developments in fire protection engineering are integrated in the planning and design of the buildings' fire protection features. Fire protection provisions contained on our local codes must be understood and their applications carefully evaluated so that the intent of the code is upheld.