A Study on Fire Spread between Office Room and Atrium in the Atrium Building

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ABSTRACT

We could analyse the fire behavior using the developed software for fire safety assessment in a large space such as atrium. But Korean building law hasn't admitted the result of fire risk assessment in atrium. In the legislation fire resistant wall or shutter must be required between atrium and office rooms. That has obstructed development of building design and fire protection technique in Korea. From this point of view, we made scenarios of fire spread between atrium and office rooms, and then computed fire spread and fire phenomena using FASTLite and Breakl. In this study, we can decide that fire compartmentalization between atrium and office rooms doesn't require in Atrium building if the material and fire protection system were reliable. Consequently, Korean Fire Protection Regulations have to consider in direction of increasing freedom of building.

INTRODUCTION

By recent social requirement, intelligent building with the office automation, a various telecommunication, and building automation is introduced by large enterprises in Korea. Most of the Intelligent Building has atrium or large space to make employees comfortable. The atrium is a large space in building, however, it has a disadvantage in the point of Fire Protection. In advanced country, many studies of fire spread to make the atrium has been developed. Nowadays, In advanced country, if a building design include the way to protect fire and smoke spread by revise fire suppression system or else anything, it is allowed to be open between atrium and office or the other space. This study sets up the designed model through the architectural and system design revision and it shows that the design model has safety against fire by simulating fire behavior and smoke movement in atrium. We suggest the revise of the fire protection regulation in korean building law.

Comparison of the fire protection law for atrium

Korea

The fire protection law and architectural law don't prescribe the fire act of atrium, but it need to compart the office and the building which is 3rd and over floor because atrium is a large space. Floor and wall should be made of fire resistance and door should be made of fire resistant door including automatical fire resistant shutter.

Japan

Japanese architectural law prescribes compartmentalization in building and is similar to korean architectural law. But measure of fire protection in atrium were eased by the special regulation. Therefore, the newest intelligent buildings with the atrium were constructed about 30 by The special regulation in japan.

United State

United State Fire Protection Regulation is NFPA code. Fire Protection Regulation for Atrium is included in NFPA 101 and NFPA 92B. Atrium is separated from the other place by the fire wall which can resist fire over a hour, but it couldn't be applied to these case

① Atrium which has over 3 floors is open to the other place.
② If the automatic sprinklers were installed every 1.8m (6ft) along both sides of the glass within 0.3m (1ft) from the glass wall and should make all over the surface of glass wet in according to activate sprinkler head, fire resistant wall can be omitted.

The glass shall be tempered, wired, or laminated glass held in place by a gasket system that permits the glass framing system to deflect without breaking (loading) the glass before the sprinklers operate.

NFPA code prescribe that Sprinkler install in living room, corridor toward atrium, the other space. But if atrium height is over 17m(55ft), it was allowed not to be installed sprinkler. According to NFPA code, the concept of installed ventilation in atrium is making safe people in building from smoke produced by fire and give a time for their evacuation. The code require that smoke layer doesn't come down from the highest floor point of atrium to 1.5m point before Fire alarm within 10 minutes. It recommend the ventilation about 4~6 times per hour in according to atrium height and area, but generally building designers think the ventilation of exhaust times need about 6 times per hour.

U.K.

Regulation about fire protection is commented in "Building Act", "Building Regulations", "Fire Precautions Act", and British Standard in United Kingdom.

Atrium have been considered to outdoor in U.K. generally. Opening between atrium and the other place, it is required to exhaust smoke from atrium to outdoor as soon as possible. Separating between atrium and the other place by normal window glass, it was broken by high temperature gas or changed glass because of sudden cooling of sprinkler water. So window glass must be wired or boned glass. Fire suppression system is similar to NFPA code. And smoke ventilation was recommend that exhaust times should be over 10 times per a hour.

Simulation Software Selection and Principles about Ventilation

The most useful analysis models for predicted Fire behaviors were Zone model and Field model. CFAST (The Consolidated Model of Fire Growth and Transport) is one of zone models. It is based on solving a set of mathematical analysis equations that predict the change in the enthalpy and mass over time and predict fire behavior effectively. FASTLite is a collection of procedures which builds on the core routines of FIREFORM and the computer model CFAST to provide engineering calculation of fire phenomena for the building designer and fire protection engineer. But FASTLite doesn't have a tools for predicting window glass break time. So BREAK1 is used for it. FASTLite and BREAK1 were supplied by NIST (National Institute of Standards and Technology)

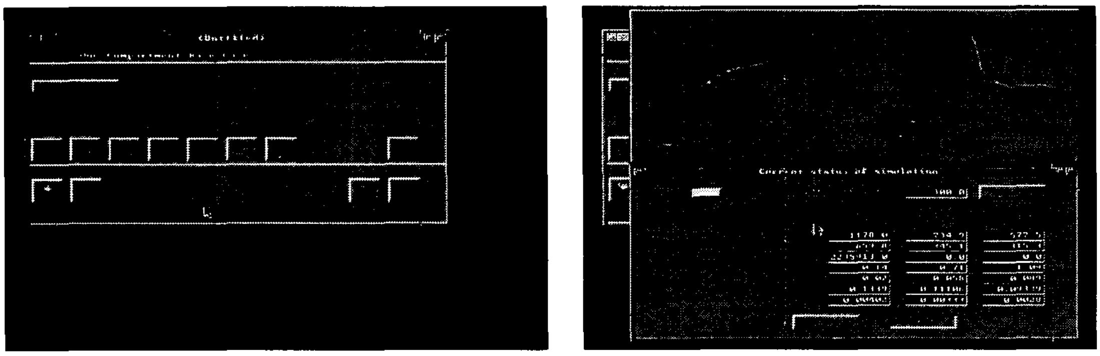

Fig 1. Input window and running of FASTLite

The equation about exhaust times is then.

The required number of extract vents(N) is then given by:

$$N \geq \frac{M}{M_{CRIT}}$$

where N = The required number of extract vents

M = The mass flow rate entering the layer(ie M_f), kg/s

M_{CRIT} = The critical exhaust rate, kg/s

The volume of combustion products entrained in a rising plume in the hot smoke zone is relatively small, compared with the volume of air in the total mixture. Consequently, the smoke produced by a fire will approximate the volume of air drawn into the rising plume. the rate of smoke production becomes:

$M_f = CePY^{3/2}$ kg/s

where, Ce = 0.188 for large-space rooms such as auditoria, stadia, large-plan offices, atrium floors, etc where the ceiling is well above the fire

Ce = 0.210 for large-space rooms. such as open-plan offices, where the ceiling is close to the fire

Ce = 0.337 for small-space rooms such as unit shops. cellular offices, hotel bed rooms, etc with ventilation openings

P = Perimeter of the fire, m
(sprinklered offices 14m, unsprinklered offices 24m)

Y = Height from the base of the fire to the smoke layer, m

Note) As the two values are approximately similar and the demarcation between them uncertain. then the value for all large-space rooms is taken to be 0.188 for the purposes of design.

The minimum smoke exhaust rate for exhaust smoke production is the critical exhaust rate. This critical exhaust rate may be found from:

$M_{CRIT} = \beta (gD^5 T_0 \theta / T^2)^{1/2}$ kg/s

where M_{CRIT} = Critical exhaust rate, kg/s

β = 1.3 for a vent near a wall, kg/m^3
1.8 for a vent distant from a wall, kg/m^3

g = Acceleration due to gravity, m/s^2

D = Depth of smoke layer below the extraction, m

T_0 = Absolute ambient temperature, K

θ = Excess temperate of smoke layer, ℃

$T = T_0 + \theta$, K

the volumetric flow rate of a plume is

$$V = C_v \frac{m}{\rho_P}$$

where, V = volumetric smoke flow rate at elevation z , m^3/s

C_v = 1

m = mass flow in plume at height z, kg/s

ρ_P = density of plume gases at elevation z, kg/m^3

Setup of Fire Scale and Building

simulation model for building were assumed 11 stories atrium. The scale of building were assumed 11 floor because multi-story building should be legally over than 11 floor. In laying the atrium in the center, there are offices in bothsides and balcony is connected to offices to escape in emergency.

The glass wall between the atrium and the office is composed of wired glass in upper and lower and tempered glass in the middle.

○ Height of Building : 56m., ○ Floor area : 3686.4㎡
○ Floor area of atrium : 1152 ㎡(24 m × 48 m)
○ Nos. of story : 11 ○ Height of Floor : 1st floor : 6m , 2nd ~ 11th : 4.2m
○ Height of atrium: 56m
○ Main Purposes : Office Building

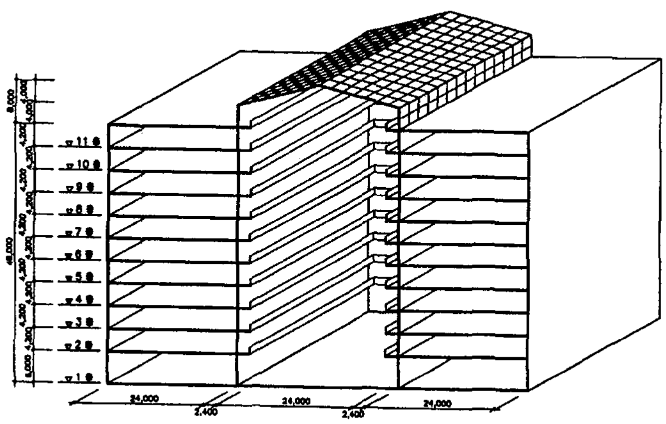

Fig 2. Picture of Simulation Model Building

The initial fire growth Curve was assumed the Medium growth and Fire scale 5 MW.

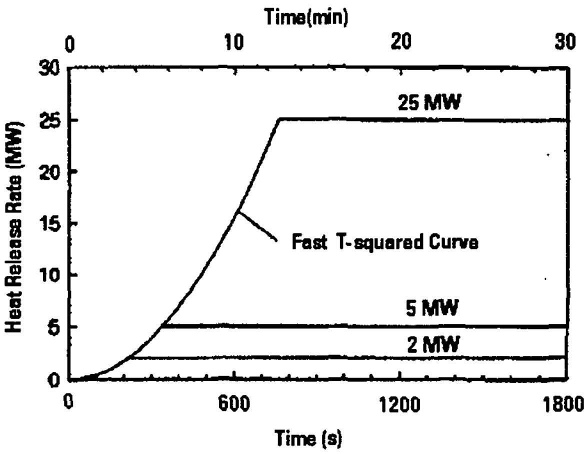

Fig 3. Fire Curve with fast t-square growth up to a steady size of 2, 5 and 25 MW

Result of Simulation

The result of simulation on fire spread in the atrium.

In case of fire in the atrium, we would run the Simulation 5MW and 1MW each other. In case of the fire of 5MW, the fire size was 4.95MW, upper layer temperature was 318.5K and the temperature of ceiling was 300.85K. Therefore it showed the fire in the atrium was similar to free fire in outdoor. In case of 1MW, fire size was 1.05MW, the maximum temperature of the upper layer 27℃ and the smoke temperature of ceiling 22.6℃. So, it showed as the size of atrium fire was smaller, as the smoke temperature of the upper layer was very lower. In case of 5MW fire smoke exhausting were required 10 times per hour to prevent any damages by smoke.

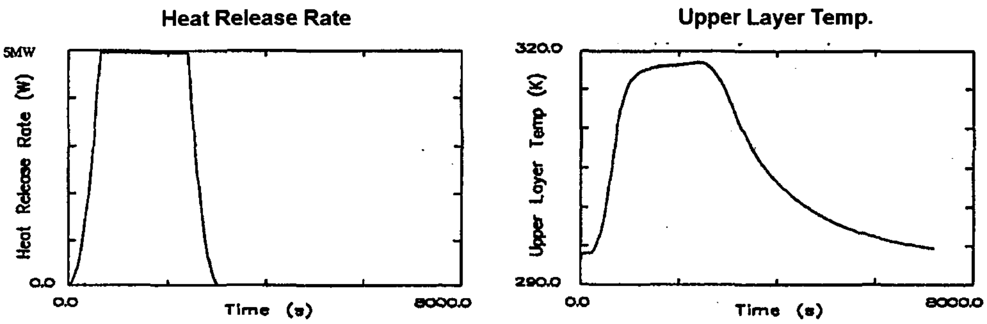

Fig 4. The result graph of atrium fire (5MW)

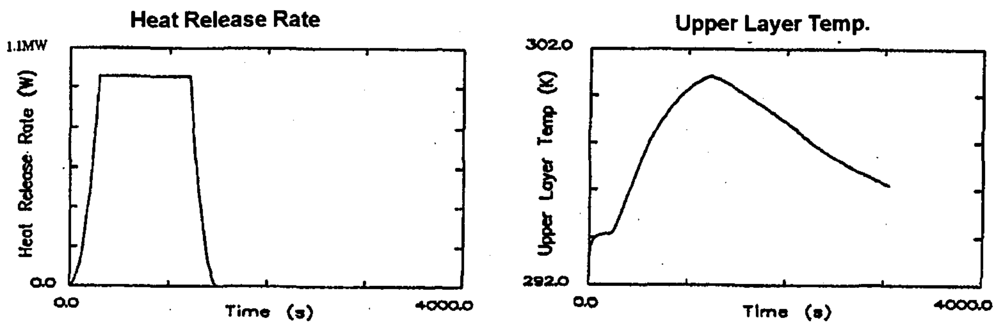

Fig 5. The result graph of atrium fire (1MW)

The result of simulation on fire spread from 5th floor to atrium

In case of fire in the office room on the fifth floor, that fire size was 506.2kW and maximum temperature of upper layer 117.5℃ (390.6K). Activating sprinklers simultaneously at 207.3sec, 213.1sec, and 276.8sec, each other, the fire was extinguish there was no breakage of the windows. No activating sprinkler, the peak fire size was 4.96MW by flashover and maximum temperature of upper layer is 1101.2℃(1374.3K). The windows were broken at 300sec, and then smoke and flame moved toward atrium. The mass flow rate of smoke was 15kg/s and the volume flow rate of smoke $28.74m^3/s$. The average temp. of smoke in atrium was 40.8℃(313.9K) and there was no damage by the heat. If atrium had the ability of smoke control, the egress times could granted to residence people. As the result of calculation, smokes exhaust times is required 3 times per hour.

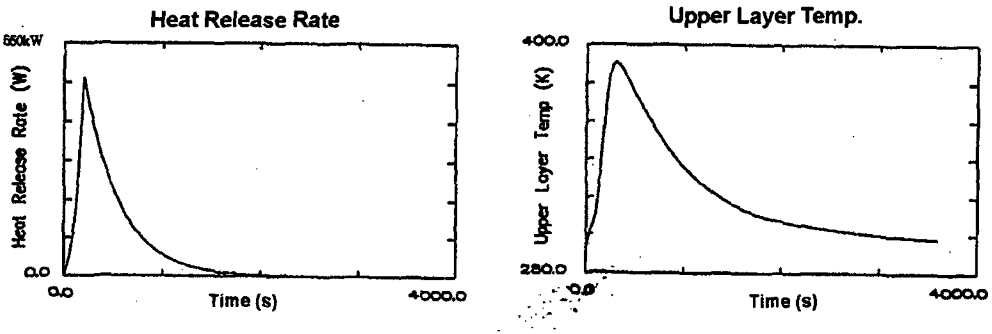

Fig 6. The result graph of 5th floor (Installed sprinkler)

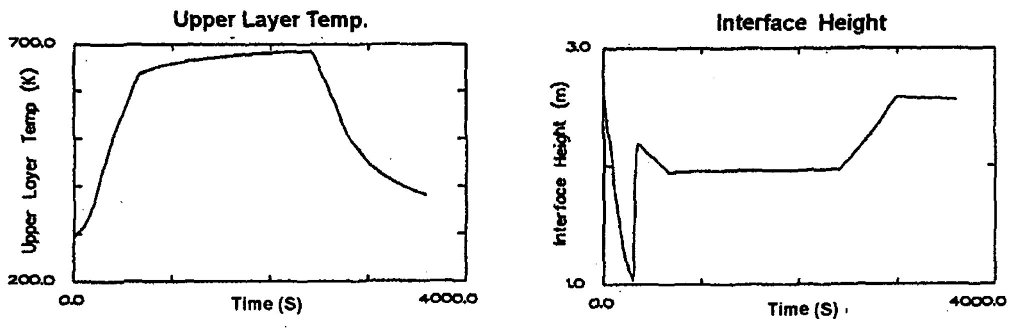

Fig 7. The result graph of 5th floor fire with window breaking

Conclusion

In this studies, we recommended make new fire regulation for atrium which is suitable to building construction circumstances in korea. We recommended as following, If the size of atrium were large, the ceil open, smoke and heat were controlled, the sprinkler head or the drencher system were installed along both glass walls and makes wet all over the surface of glasswall, it should be permitted to the fire compartmentalization. If atrium was larger than over standard and had open ventilation toward outlet and controled smoke, fire regulation should permit the open between atrium and the other space by fire simulation result and technical investigation.

Reference

1. John H. Klote, "Method of Predicting Smoke Movement in Atria with Application to Smoke Movement", NIST, 1994.
2. G.O.Hansell and H.P.Morgan, “Design approaches for Smoke control in Atrium Buildings“, BRE Report, 1994.
3. NFPA, “Guide for Smoke Management System in Mall, Atria and Large Areas”, NFPA 92B, 1994.
4. V.Powell-Smith and M.J. billing, "The Building Regulations", Black well Science Ltd, 1995.
5. R.W.Portier, R.D.Peacock, "FASTLite:Engineering Tools for Estimating Fire Growth and Smoke Transport", NIST, 1996.
6. A.A.Joshi, "User'Guide to BREAK1", NIST, 1991.
7. 日本建築學會, "アトリウムの 環境設計", 1995.
8. 堀内三郎監修, "新版 建築防火", (株)朝倉書店, 1994.

9 宮川保之,“センチュリタワーの防災システム”, 火災, Vol 41 No 3(192),1993.

10. NFPA, “Fire Protection Handbook”, 7th Edition, 1993.
11. V.Powell-Smith and M.J. billing, "The Building Regulations", Black well Science Ltd, 1995.
12. R.D.Peacock, CFAST, "The Consolidated Model of Fire Growth and Smoke Transport", Nist, 1994.