A Study on the Performance Design using the Sprinkler System for Fire Spread Prevention of Building Exterior

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1.1 Introduction

● Fire Cases in the curtain wall buildings

Curtain wall building

Hig-rise Building Fire in China

Winsor Tower Fire in Madrid, Spain

CCTV HQ Fire in China

Goden Suite High-rise Bldg. Fire in Korea
CCTV HQ Fire in China

Fire spread

1.2 Introduction

● Fire protection issues in the curtain wall buildings

Apply to the design

1 Fire Code

Reinforced
Glass Wall

2 Building Code

Korea Fire Code

● Apply sprinkler system

Fire
Protection
Method

Korea Building
Code

● Fire Resistance Rating Test

1.3 Introduction

● Issues in the current curtain wall protection system

**Effective and Efficiency approach
Meet the minimum required Fire Resistance Rating**

**Current water curtain system
Issues**

- ❏ Open area performance test
- ❏ Unlimited water capacity
- ❏ Therefore, Not available guideline for water based curtain wall protection system

1.4 Introduction

● Fire protection issues in the curtain wall buildings

1 Exterior Glass Wall Fire Risk

2 Current Code

Temperature Curve
Problem

3 Issues

Performance Test Fail

Approved by the expert
group judgment

Reliability, Uncertainty

Performance Based Design Verifying System

🖥️ Verifying Procedure though PBD standards 🖥️ Fire/Bldg. Code shall be applicable

2.1 Fire Performance Test of Curtain Wall

● Normal Curtain Wall vs. PBD Curtain Wall Fire Protection System

2.2 Fire Performance Test of Curtain Wall

● Breakage Test of Normal Curtain Wall vs. PBD Curtain Wall Fire Protection Sys.

Normal Curtain Wall

Size of the specimen of glass curtain wall

Normal Curtain wall and Curtain wall with protection system(sprinkler)

Installation location of temperature measuring sensors and a sprinkler

2.3 Fire Performance Test of Curtain Wall

● Breakage Test of Normal Curtain Wall vs. PBD Curtain Wall Fire Protection Sys.

Specimen of glass block

Installation of sprinkler head

Heptane full burner and temperature measurement point

Temperature measurement points and distance between specimen and burner

2.4 Fire Performance Test of Curtain Wall

Size of Fire

Full burner (Diameter 1m)

Full burner fire

Fuel Spill Volume (V)	21.1	gallons
Fuel Spill Area or Dike Area(A_{dike})	8.45	ft ²
Mass Burning Rate of Fuel (m'')	0.101	kg/m ² -sec
Effective Heat of Combustion of Fuel($DH_{c,eff}$)	44600	kJ/kg
Fuel Density(r)	675	kg/m ³
Empirical Constant(kb)	1.1	m ⁻¹
Ambient Air Temperature(T_a)	40	°F
Gravitational Acceleration (g)	9.81	m/sec ²
Ambient Air Density(r_a)	1.27	kg/m ³

$$Q = m'' DH_{c,eff} (1 - e^{-kbD}) A_{dike}$$

Where,

Q = pool fire heat release rate (kW)

m'' = mass burning rate fuel per unit surface area (kg/m²-sec)

$DH_{c,eff}$ = effective heat of combustion of fuel (kJ/kg)

A_{dike} = A dike = surface area of pool fire (area involved in vaporization) (m²)

kb = empirical constant (m⁻¹)

D = diameter of pool fire (diameter involved in vaporization, circular pool is assumed) (m)

Pool Fire Diameter Calculation

$$A_{dike} = \pi D^2 / 4$$

Where,

A_{dike} = surface area of pool fire (m²)

D = pool fire diameter (m)

A_{dike} = surface area of pool fire (m²)

D = pool fire diameter (m)

$$D = \sqrt{(4A_{dike} / \pi)}$$

$$D = 1.0m$$

Heat Release Rate Calculation

$$Q = m'' DH_{c,eff} (1 - e^{-kbD}) A_{dike}$$

$$Q = 2358.83 \text{ kW}$$

3. 1 Result on Fire Performance Test of Curtain Wall

● Breakage Test of Normal Curtain Wall vs. PBD Curtain Wall Fire Protection Sys.

[0Min. 1Sec.] Ignition

[0Min. 30Sec.] Normal of frame and glass

[1Min. 54Sec.] Good, no work of sprinkler

[1Min. 56Sec.] Operation of horizontal side wall sprinkler installed in the right and top panel

[2Min. 36Sec.] Crack in the right center of left panel

[5Min. 20Sec.] Crack in glass of left panel and overall burst (Photo of rear curtain wall)

[21Min. 30Sec.] Failure of inside left panel. Stop operating the sprinkler of the top and right panel

[22Min. 0Sec.] Experiment finish. Generally failed in the left panel glass (Photo of rear curtain wall)

3.2 Result on Fire Performance Test of Curtain Wall

● Breakage Test of PBD Curtain Wall Fire Protection Sys.

Result on curtain wall with fire protection system (Temperature)

Result on the survey of temperature change in the center of the specimen

3.3 Result on Fire Performance Test of Curtain Wall

● Breakage Test of PBD Curtain Wall Fire Protection Sys.

Result on curtain wall with fire protection system (Temperature)

Result on the survey of temperature change for the glass block with sprinkler (right side of the specimen)

3.4 Result on Fire Performance Test of Curtain Wall

● Breakage Test of Curtain Wall Sys.

Result on curtain wall without fire protection system (Temperature)

Result on the survey of temperature change for the glass block with no sprinkler (left side of the specimen)

4.1 Conclusion

● Compare water curtain system

Sprinkler Protection

Foreign Product

Korea Product

Installation Standard

Foreign

NFPA13
NFPA80A

Korea

Non

- Head/Nozzle : No products(curtain wall protection) available in Korea
- Installation Standards : Not applicable for water curtains as fire barriers
- Similar Sprinkler systems, Needs optimized sprinkler systems for fire barrier

4.2 Conclusion

Water based curtain wall fire protection system in case of fire

Water based curtain wall fire
protection system:
Verified 22 min. FRR

Water based curtain wall fire
protection system

Void created between a floor and a
curtain wall required sealing to
prevent the spread of flames

4.3 Conclusion

● Compare water curtain system

Optimized water based fire protection system

- Normal (ceiling mounted) Sprinkler and curtain wall Sprinkler activation
- Minimum water capacity Window sprinkler

Sync. System

Alternative performance test method

- Vertical heating furnace (ASTM E119)
- Building vertical exterior material furnace
- Large Scale Calorimeter

Vertical furnace

Bldg. vertical exterior material furnace

Predictive or simulation model

- Verifying water curtain system based on computer modeling program
- Predictive model on curtain wall compartment area

Predict glass cracking time

Predict glass Curtain wall temp.

Thank you!

Questions