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

Korea Institute of Construction Technology
Seung Un Chae

May 20, 2014
1.1 Introduction

Fire Cases in the curtain wall buildings
1.2 Introduction

Fire protection issues in the curtain wall buildings

1. Fire Code
   - Apply to the design

2. Building Code
   - Reinforced Glass Wall

Korea Fire Code
- Apply sprinkler system

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

- 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
3. Issues

- Performance Test Fail
- Approved by the expert group judgment
- Reliability, Uncertainty

Temperature Curve Problem

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 Sys.
2.2 Fire Performance Test of Curtain Wall

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

**Normal Curtain Wall**

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

- **ELEVATION**
  - Size of the specimen of glass curtain wall
  
- 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 Wall Fire Protection Sys.

Specimen of glass block

Heptane full burner and temperature measurement point

Installation of sprinkler head

Temperature measurement points and distance between specimen and burner
2.4 Fire Performance Test of Curtain Wall

Size of Fire

- Fuel Spill Volume \( (V) \): 21.1 gallons
- Fuel Spill Area or Dike Area \( (A_{\text{dike}}) \): 8.45 ft\(^2\)
- Mass Burning Rate of Fuel \( (m^\text{m}) \): 0.101 kg/m\(^2\)-sec
- Effective Heat of Combustion of Fuel \( (DH_{c,\text{eff}}) \): 44600 kJ/kg
- Fuel Density \( (r) \): 675 kg/m\(^3\)
- Empirical Constant \( (k_b) \): 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\(^3\)

Heat Release Rate Calculation

\[
Q = m^\text{m}DH_{c,\text{eff}}(1-e^{-k_bD})A_{\text{dike}}
\]

Where,
- \( Q \) = pool fire heat release rate (kW)
- \( m^\text{m} \) = mass burning rate fuel per unit surface area (kg/m\(^2\)-sec)
- \( DH_{c,\text{eff}} \) = effective heat of combustion of fuel (kJ/kg)
- \( A_{\text{dike}} \) = surface area of pool fire (area involved in vaporization) (m\(^2\))
- \( k_b \) = empirical constant (m\(^{-1}\))
- \( D \) = diameter of pool fire (diameter involved in vaporization, circular pool is assumed) (m)

Pool Fire Diameter Calculation

\[
A_{\text{dike}} = \pi D^2 / 4
\]

Where,
- \( A_{\text{dike}} \) = surface area of pool fire (m\(^2\))
- \( D \) = pool fire diameter (m)

Heat Release Rate Calculation

\[
Q = m^\text{m}DH_{c,\text{eff}}(1-e^{-k_bD})A_{\text{dike}}
\]

\[
Q = 2358.83 \text{ kW}
\]
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 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

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

**Alternative performance test method**
- Vertical heating furnace (ASTM E119)
- Building vertical exterior material furnace
- Large Scale Calorimeter

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

Sync. System

Vertical furnace

Predict glass cracking time

Bldg. vertical exterior material furnace

Predict glass Curtain wall temp.
Thank you!

Questions