DEPARTMENT OF FIRE PROTECTION ENGINEERING

FPE4: Security & Two-Story Opening Preformance-Based Fire Protection Design Soot Happens

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Problem Definition

Project Scope Definition

The scope of this project entails a Performance-Based Design (PBD) analysis of a new two-story religious/community facility. Focus on evaluating alternative fire protection strategies for a large two-story opening. Assessment includes fire development, smoke movement, and occupant egress performance. Comparison of trial designs to determine if performance criteria are met.

Building Description

The New Hillel Building's construction; ~40,000 ft², two-story assembly-type building. It includes dining areas, meeting rooms, lounge spaces, offices, and support spaces and features a large two-story opening connecting floors. There are mixed occupant types with varying familiarity and densities.

Design Assumptions

The fire protection systems are assumed to be designed and installed per applicable codes. The automatic sprinkler and fire alarm systems function as intended during fire events. Occupants are assumed to be distributed based on typical use conditions and expected densities. Detection, notification, and pre-movement times based on literature values. Building is assumed to be maintained and inspected to ensure system reliability.

Design Criteria

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- Quantitative criteria used to evaluate overall life safety performance
- Based on maintaining tenable conditions for occupants during evacuation
- Evaluated along primary egress paths at 1.8 m above the walking surface
- Assessed using results from fire and egress modeling
- Acceptable performance requires that ASET (Available safe egress time) exceeds RSET (Required safe egress time)

Methods of Evaluation

- Fire & smoke conditions evaluated using computational fire/egress modeling softwares FDS/PyroSim
- Occupant movement and evacuation modeled to determine RSET
- Tenability conditions compared against performance criteria

Goals	Objectives	Performance Criteria
- Protect people and property during egress operations	- Maintain a tenable environment for occupants during evacuation - Prevent flashover in the room of fire origin	- Upper layer temperature ≤ 200 °C - Smoke Density ≤ 0.2 m^{-1} - Visibility along egress routes ≥ 13 m - Carbon Monoxide concentration ≤ 1400 ppm - Hydrogen cyanide concentration ≤ 90 ppm - O_2 concentration ≥ 12% - Carbon dioxide concentration ≤ 6–7%
- Maximize security without compromising life safety	- Limit unauthorized entry into the building - Ensure (ASET) exceeds (RSET)	

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Fire & Egress Modeling Results

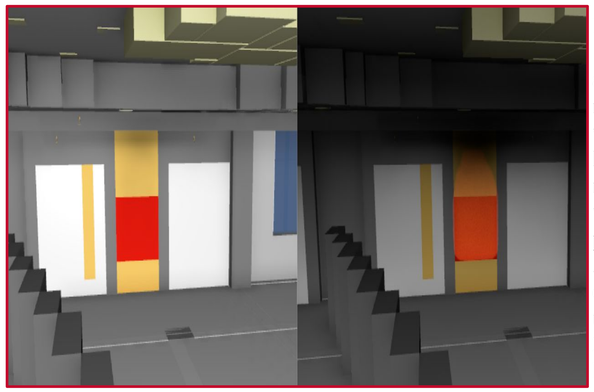


Figure 1. Large prayer room fire: 1 minute vs. 2.5 minutes. The growth of the smoke layer increase with time.

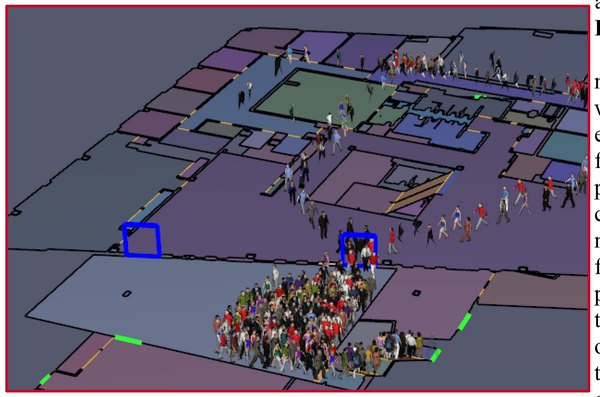


Figure 2. Second floor of pathfinder model. Queuing at the terrace shows the importance of the terrace exit. In models without the terrace stairs, egress times are higher.

FDS Results

By modeling of sprinkler activation, the heat release rate (HRR) of each scenario was capped at 710 and 290 kW respectively. Smokeview results at 1.8 m indicate that visibility is the controlling parameter for tenabilty and ASET. For the duration of evacuation, upper layer temperatures remain below 200 °C and carbon monoxide levels remain below 1400 ppm. Untenable conditions initially appear near walls and corners.

Pathfinder Results

The time for detection, notification and premovemnt was incorporated into the egress model. Occupant flow follows expected egress paths, with localized congestion observed near the north stair and terrace stair in fire scenario one and the prayer rooms in scenario two. Despite these delays, occupants reach exits prior to the onset of untenable conditions, which indicates acceptable occupant egress performance.

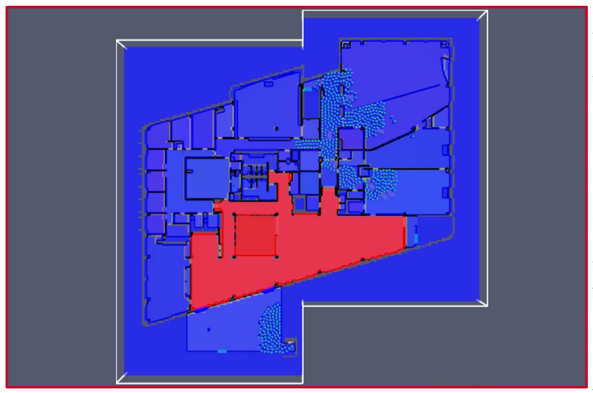


Figure 3. Visibility at 1.8 m for the second floor in the first fire scenario. Visibility less than 13 m shown in red.

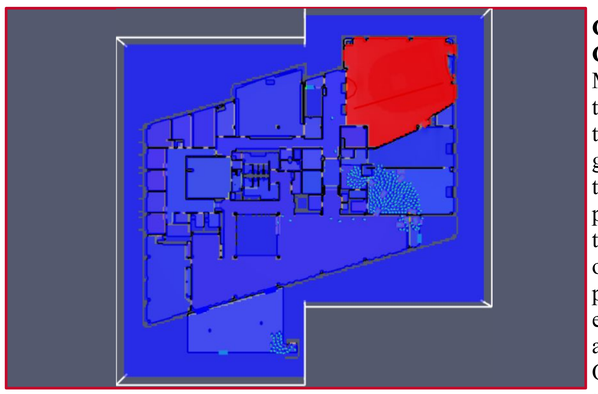


Figure 4. Visibility at 1.8 m for the second floor in the second fire scenario. Visibility less than 13 m shown in red.

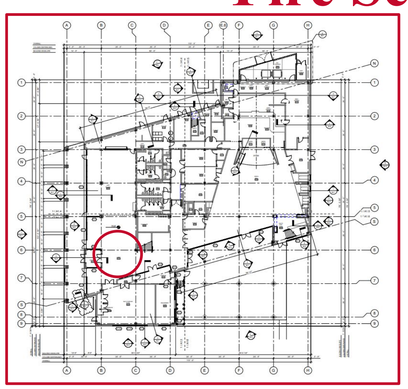
ASET vs RSET Comparison

The ASET and RSET for the two story opening space of fire scenario one shows that ASET = 336 s and RSET = 251 s. In the second fire scenario, the ASET and REST of the prayer room is 288 and 192 s, respectively. Occupants outside the bounds of these spaces do not experience untenable conditions. The condition ASET > RSET is satisfied, demonstrating that occupants can safely evacuate before tenability limits are exceeded.

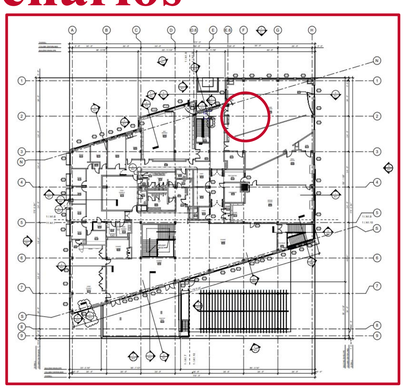
Conclusions From Computational Model

Modeling results indicate that tenability criteria for temperature, visibility, and toxic gas exposure are maintained throughout the evacuation period. The region near the two-story opening governs overall performance, but proposed design strategies effectively limit smoke spread and improve conditions. Overall, the design meets performance-based life safety objectives for the scenarios evaluated.

Fire Scenarios



Fire Scenario 1: Intentional gasoline fire in the first-floor lobby, representing rapid growth, high HRR scenario. Scenario has potential for early smoke spread to the upper level. Evaluates worst-case tenability conditions during initial egress.

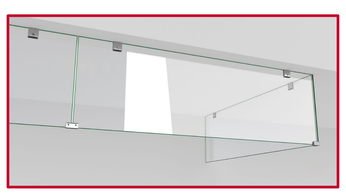


Fire Scenario 2: Candles ignite a bookshelf near exit doors the first-floor large prayer room, with the potential for high HRR in a high occupant load area. Evaluates smoke accumulation and impacts to occupant movement.

Final Design

Smoke Baffles

- Installed at two-story opening to limit vertical smoke spread
- Promote smoke layer formation and maintain tenable egress conditions
- Increase ASET by delaying smoke descent into occupied zones
- Improve visibility and reduce exposure to elevated temperatures and toxic gases
- Passive strategy with high reliability and minimal maintenance
- Cost: ~$8,000 per 20 ft



Delayed Egress Locking Doors

- 15 s delayed egress locking double doors enhance security by delaying unauthorized exit while maintaining life safety
- Immediate release upon fire alarm activation or power loss
- Integrated with fire alarm system for fail-safe operation
- Maintains ASET > RSET with no impact to egress performance
- Cost: ~$7,000–$11,000 total installed for two double-door openings