SLS

FIRE PROTECTION ENGINEERING AND CODE CONSULTING

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WHO WE ARE

FIRE PROTECTION ENGINEERS

ARCHITECTS

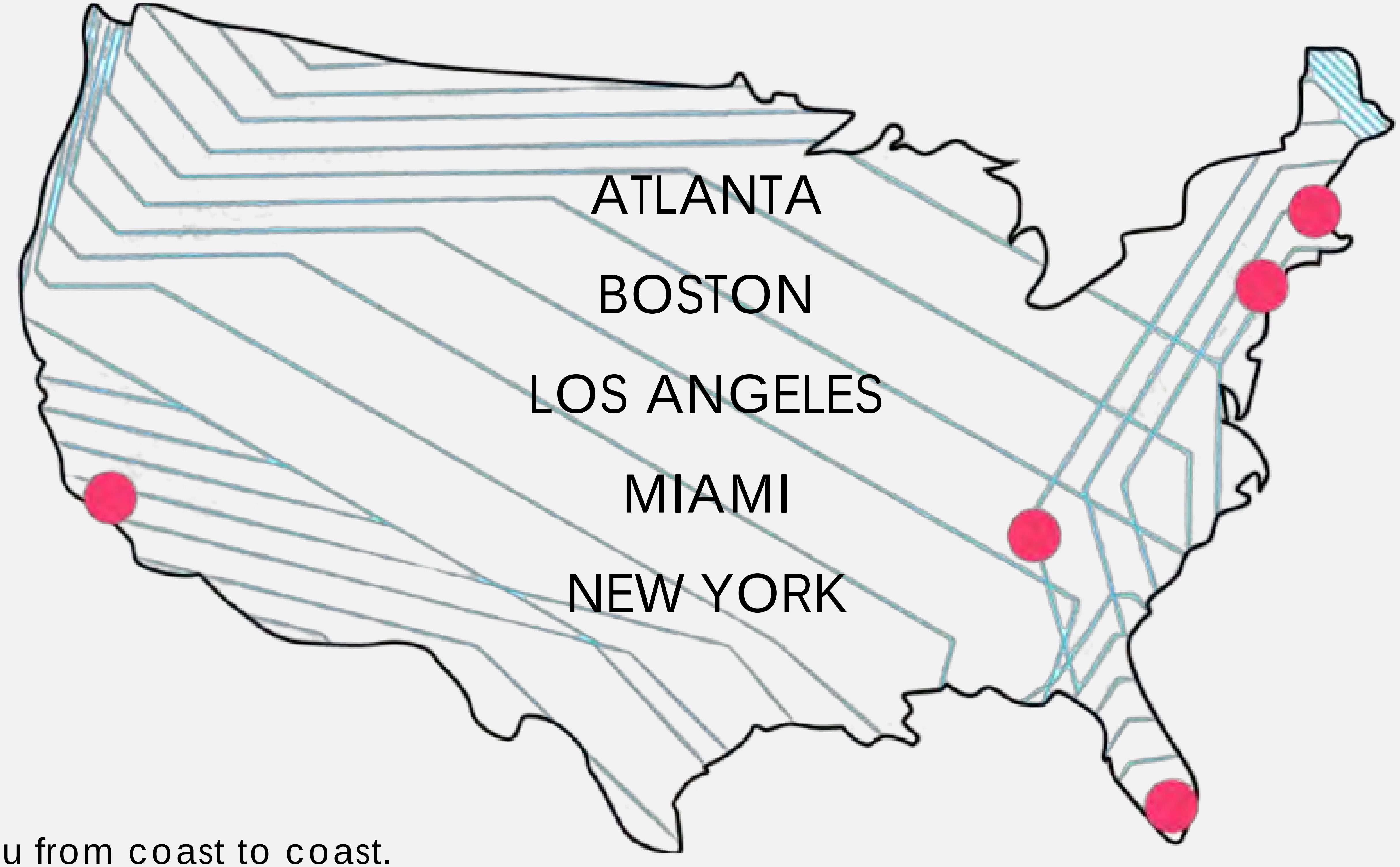
CONSTRUCTION PROFESSIONALS

DESIGN CATALYSTS

INDUSTRY EXPERTS

BUILDING CODE THERAPISTS

WHERE WE ARE



We're with you from coast to coast.

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WHAT WE DO

Design Services

- Architectural Support & Engineering
- Performance-Based Design
- Hazardous Materials & Process
- Fire Protection System Design

Construction Services

- System Testing
- Inspection & Commissioning
- Liaison Services
- Transition to Occupancy Services

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MARKET SECTORS

- Transportation
- Residential
- Commercial
- Mixed-Use
- Municipal
- DOE/Nuclear
- Education
- Food And Beverage
- Gaming And Hospitality
- Government
- Healthcare
- Industrial And Manufacturing
- Retail

SLS

Eric Montplaisir, PE

- Principal Fire Protection Engineer
- Registered Professional Fire Protection Engineer in Massachusetts
- Certified Plans Examiner (ICC)
- Certified Accessibility Plans Examiner (ICC)
- Certified Special Inspector (ICC)
- Certified Firestop Special Inspector (IFC)
- Member, National Fire Protection Association (NFPA)
- Member, Society of Fire Protection Engineers (SFPE)
- 15+ Years of Fire and Life Safety Experience
- Nuclear Experience with Rigorous Technical Reviews

Andrew Biery, PE

- Technical Director/Fire Protection Engineer
- Registered Professional Fire Protection Engineer in Massachusetts
- Member, Society of Fire Protection Engineers (SFPE)
- Member, SFPE Standing Committee on Research, Tools and Methods
- 14+ Years of Fire and Life Safety Experience
- Nuclear Experience with Rigorous Technical Reviews

SLS

THE BENEFITS OF PERFORMANCE BASED DESIGN

WORKING WITHIN THE REQUIREMENTS OF THE BUILDING CODE

Provider Number: 404108894
Course Number: 000

Eric Montplaisir, PE
Principal Fire Protection Engineer

Andrew Biery, PE
Technical Director

CONTINUING EDUCATION AIA

AIA 2020

Credit(s) earned on completion of this course will be reported to AIA CES for AIA members. Certificates of Completion for both AIA members and non-AIA members are available upon request.

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Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

Copyright Materials

COURSE DESCRIPTION

The presentation focuses on challenges encountered when utilizing performance-based aspects of the building code with respect to fire protection design. The benefits of using performance-based design as well as alternative means and methods are discussed and illustrated by case studies. Commonly accepted and sound engineering practice is detailed as well as potential pitfalls and red flags which could lead to the use of certain designs that may not align with the performance-based aspects of the building code. The process of implementing performance-based designs is also discussed in the presentation.

Topics covered by the presentation include, but are not limited to, structural fire resistance, smoke control, the use of engineering judgment, firestopping, fireproofing, and much more.

LEARNING OBJECTIVES

- Understand the requirements applicable to performance-based design
- Understand the performance-based design process and general procedure for approval
- Understand the benefits of using performance-based design
- Gain the ability to recognize situations where performance-based design may not be appropriate and/or may not meet the intent of the code

STRUCTURAL FIRE RESISTANCE

CONTINUING EDUCATION AIA

AIA 2020

MISUNDERSTANDING THE 20' RULE

Roof construction and associated secondary members (see Section 202)	$1^1/_2$ [b]	1[b,c]	1[b,c]	0[c]	1[b,c]	0	HT	1[b,c]	0

For SI: 1 foot = 304.8 mm.

a. Roof supports: Fire-resistance ratings of primary structural frame and bearing walls are permitted to be reduced by 1 hour where supporting a roof only.

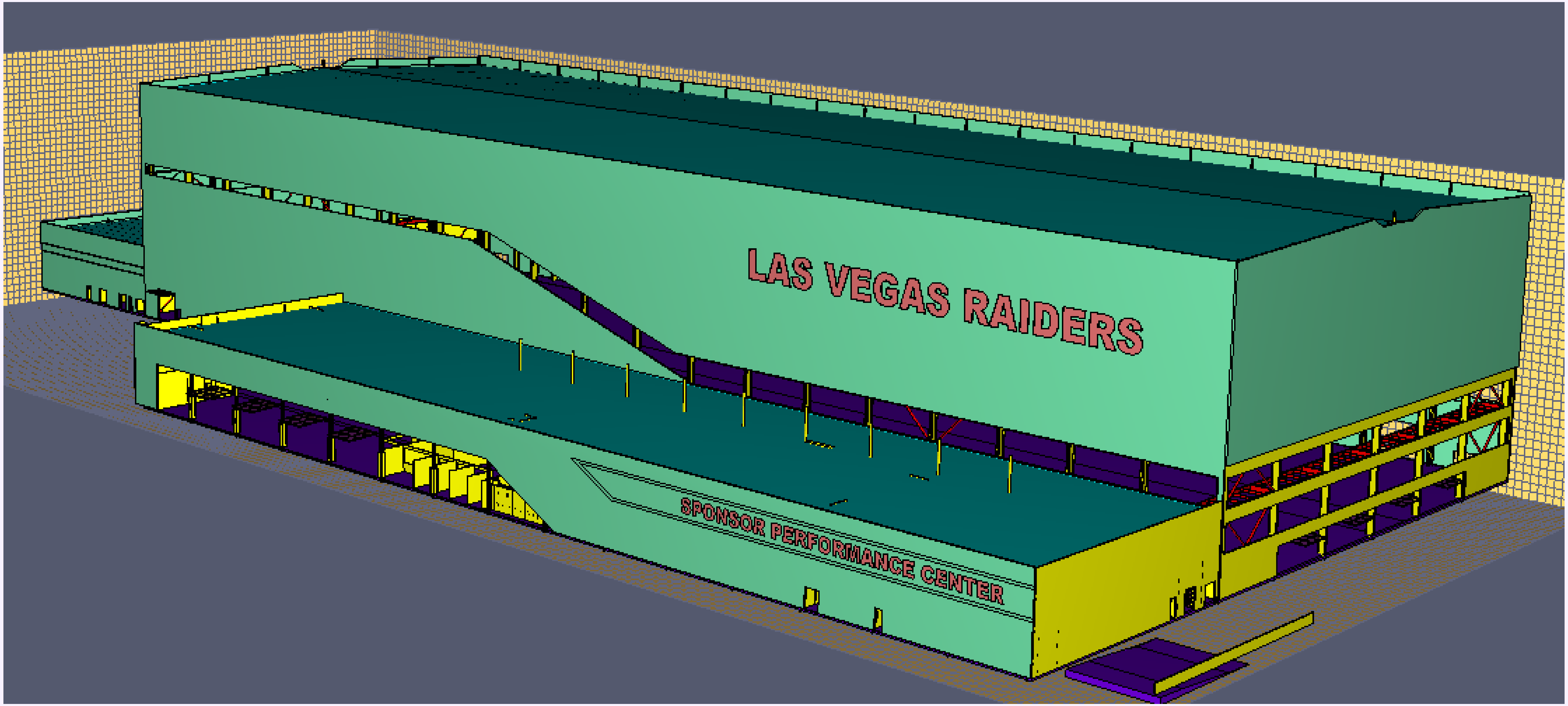
b. Except in Group F-1, H, M and S-1 occupancies, fire protection of structural members shall not be required, including protection of roof framing and decking where every part of the roof construction is 20 feet or more above any floor immediately below. Fire-retardant-treated wood members shall be allowed to be used for such unprotected members.

STRUCTURAL FIRE RESISTANCE

FIRE MODELING APPLICATIONS

- IBC, Table 6, Note b: No fire protection for structural members where every part of the roof construction is 20 feet or more above any floor immediately below.
  - Justify small portions of a floor that do not meet the 20-foot requirement.
  - Certain retail situations due to the nature of storage.

PERFORMANCE BASED-DESIGN

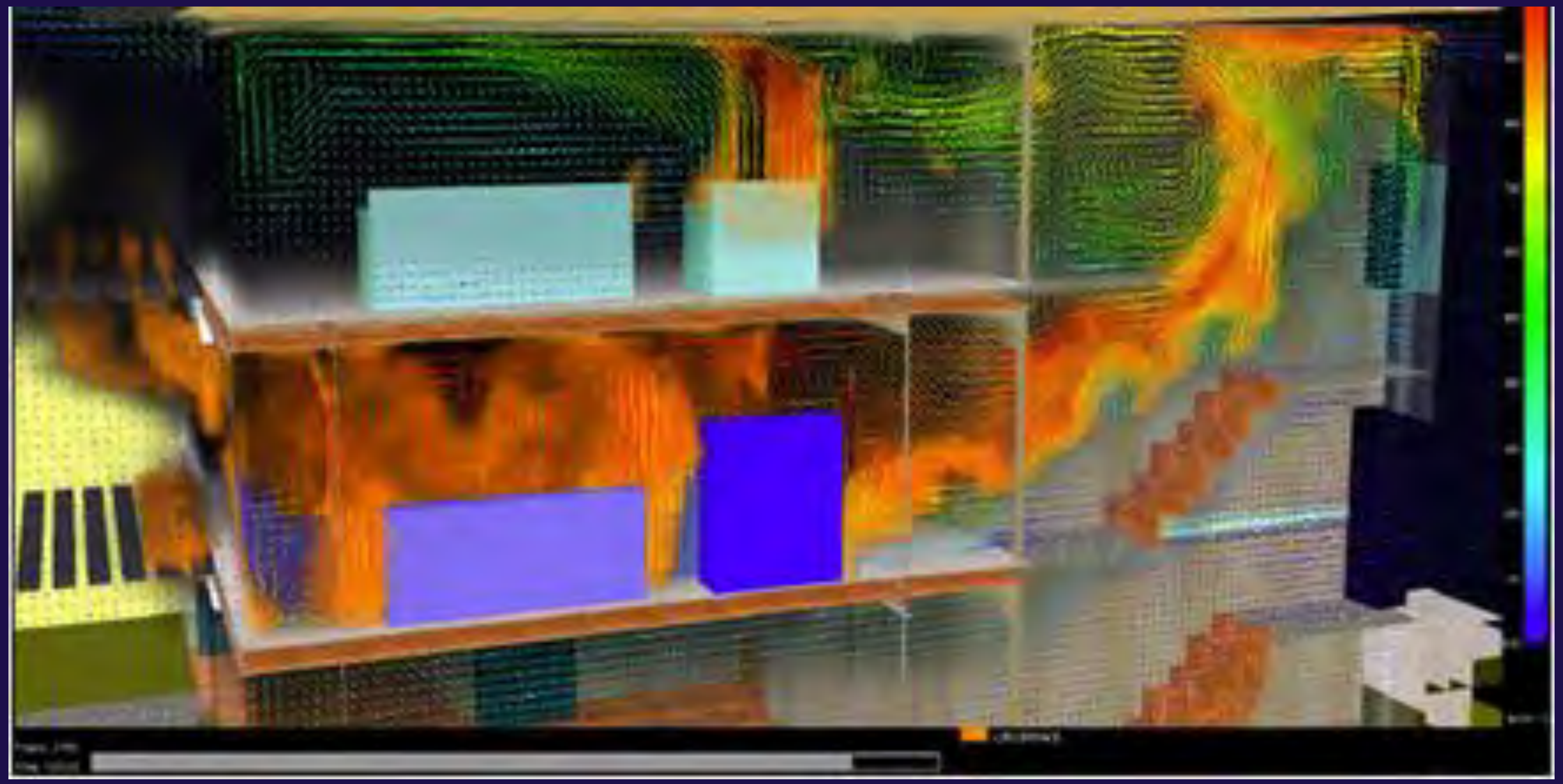


COMPUTER MODELING

PERFORMANCE ANALYSIS

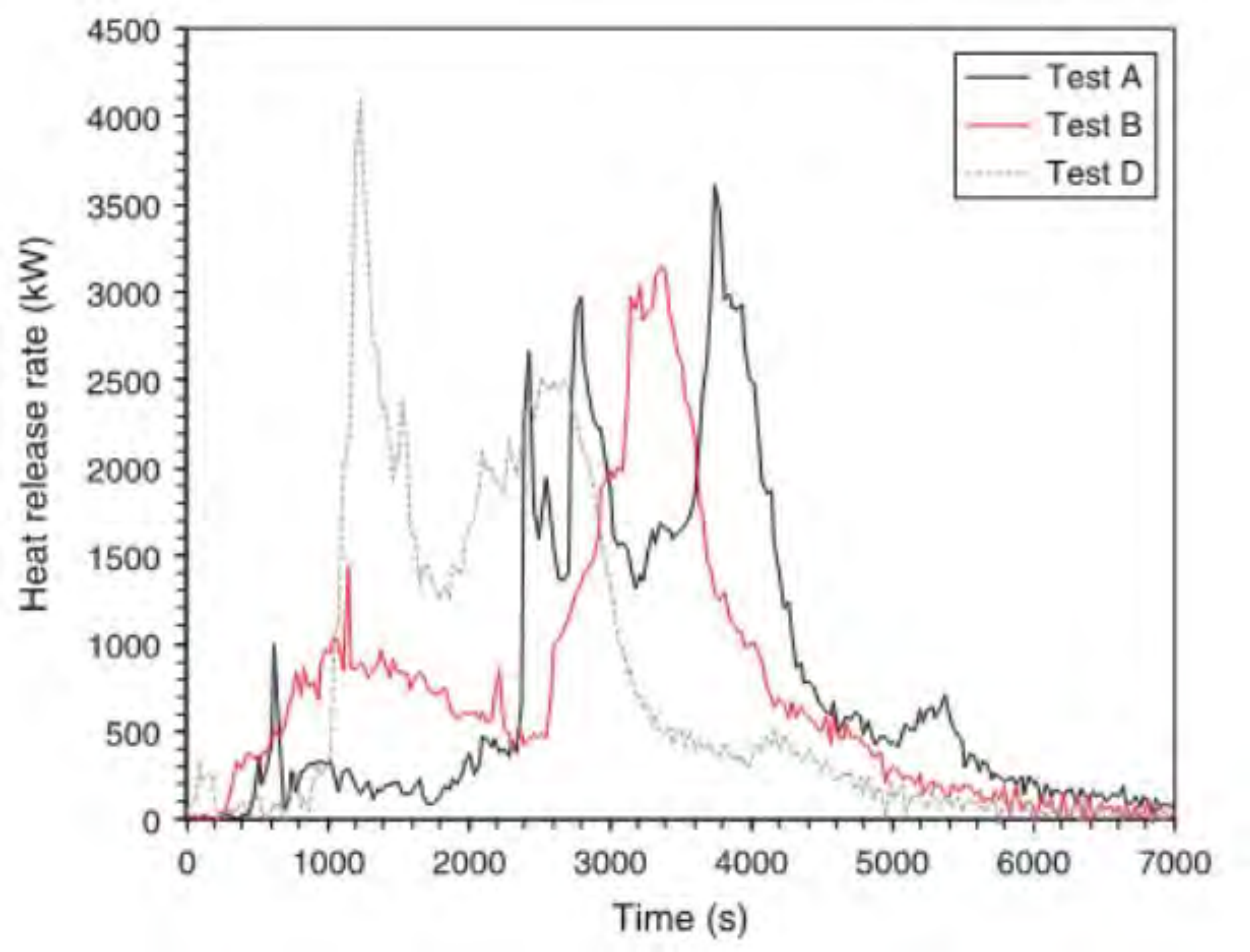
Fire Dynamics Simulator (FDS)

- Verified and Validated by the Nuclear Regulatory Commission (NRC)
- 3D model performs calculations (e.g. smoke and heat movement)
- Qualified work accepted by fire and building officials
- Third party review required (780 CMR, Section 909.2)



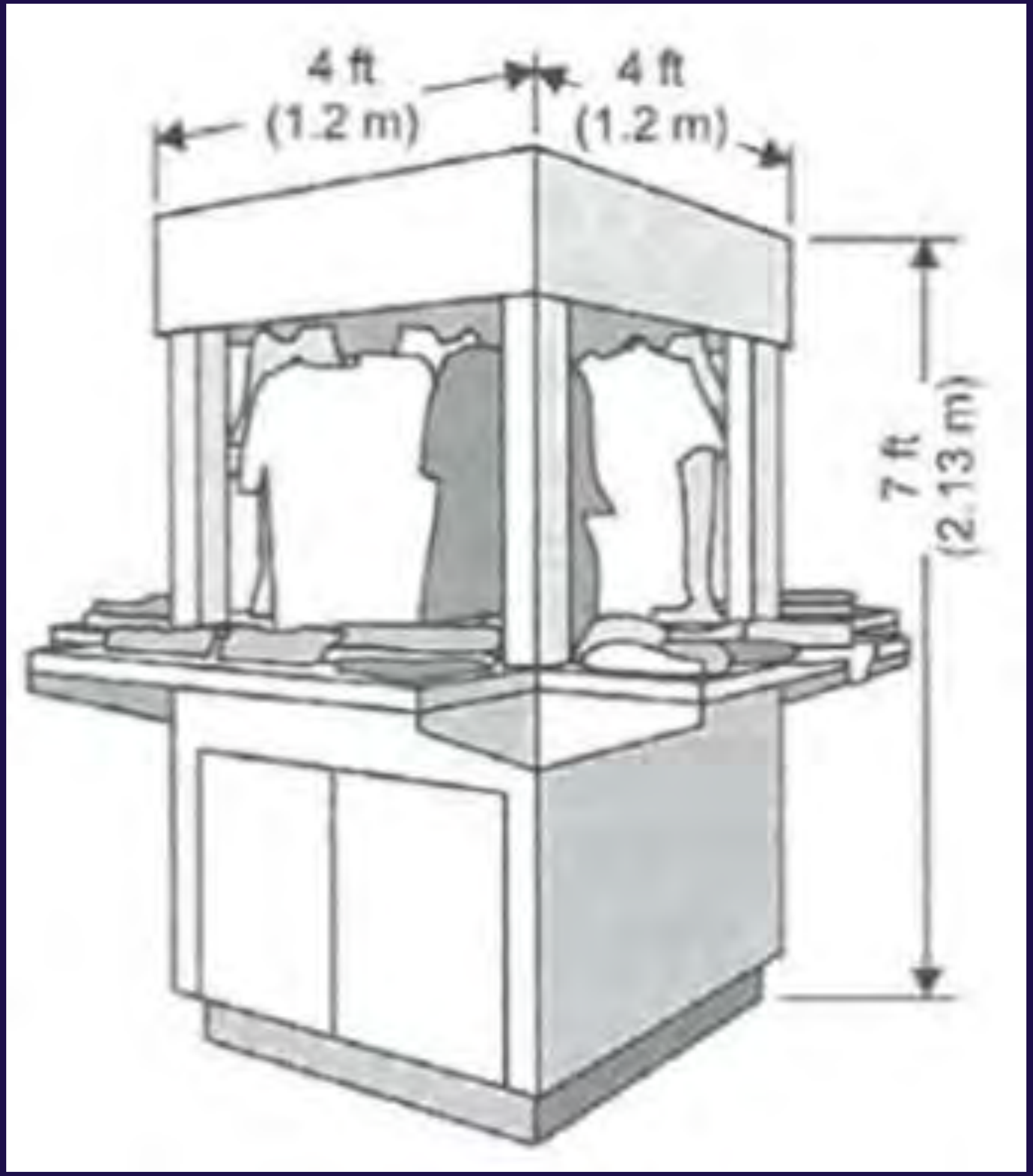
PERFORMANCE-BASED DESIGN

DESIGN FIRES



PERFORMANCE-BASED DESIGN

DESIGN FIRES



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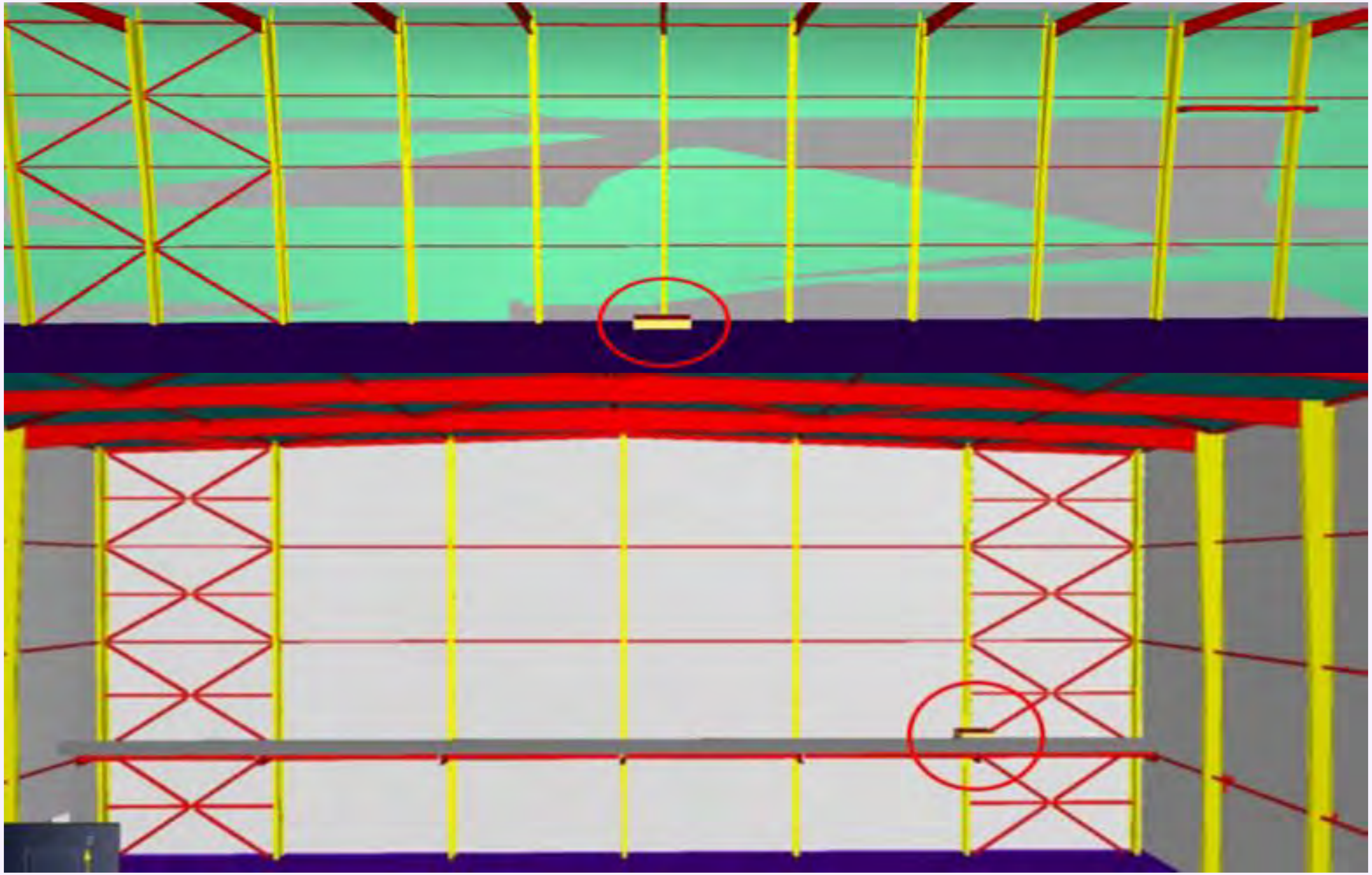

PERFORMANCE-BASED DESIGN

Table X.1 Steel Modulus of Elasticity and Yield Strength Reduction at Elevated Temperatures

Steel Temperature °F [°C]	E_m/E	F_{ym}/F_y
68 [20]	1.00	1.00
200 [93]	1.00	1.00
400 [204]	0.90	1.00
600 [316]	0.78	1.00
750 [399]	0.70	1.00
800 [427]	0.67	0.94
1,000 [538]	0.49	0.66
1,200 [649]	0.22	0.35
1,400 [760]	0.11	0.16
1,600 [871]	0.07	0.07
1,800 [982]	0.05	0.04
2,000 [1,090]	0.02	0.02
2,200 [1,200]	0.00	0.00

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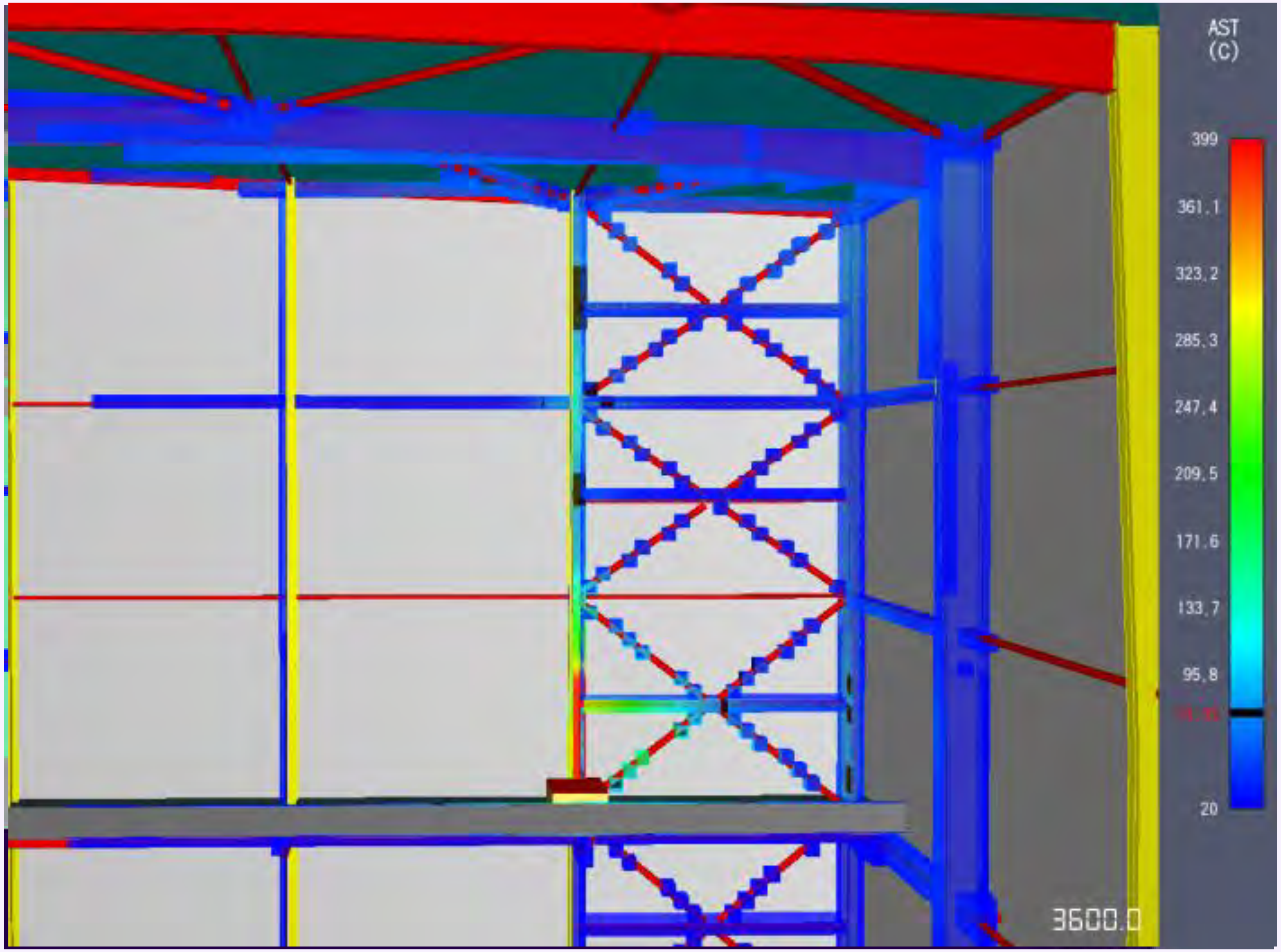

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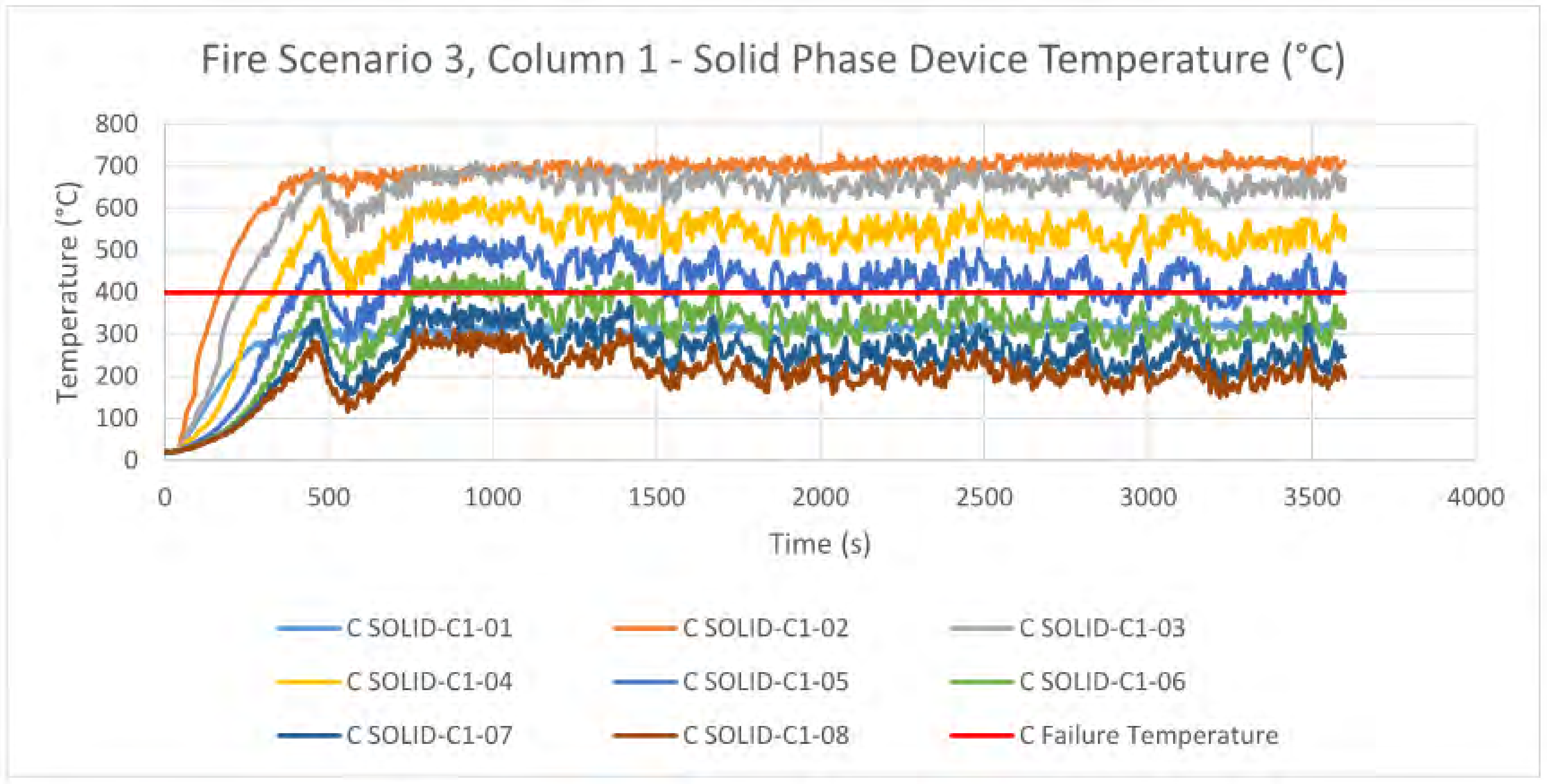

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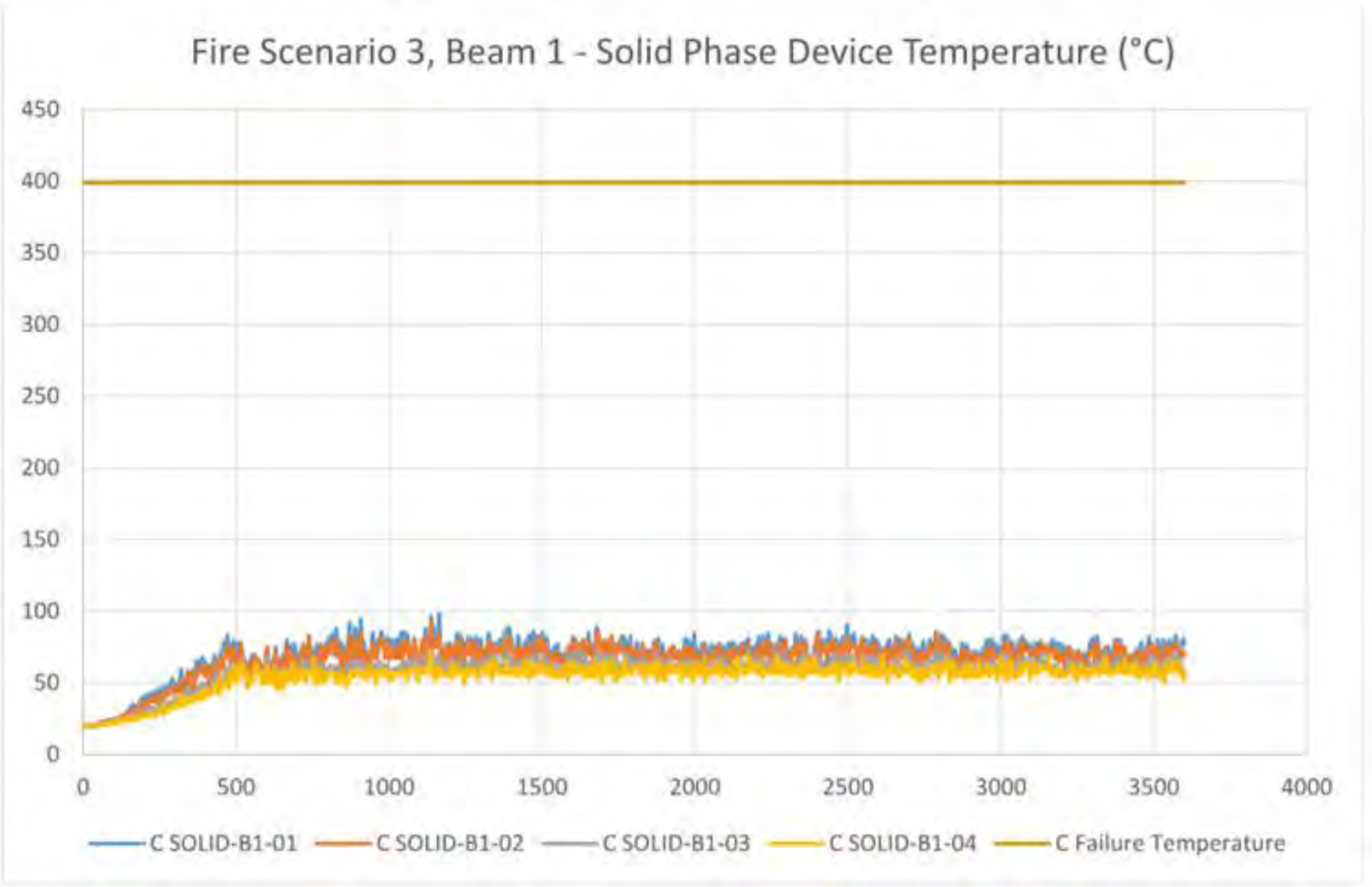

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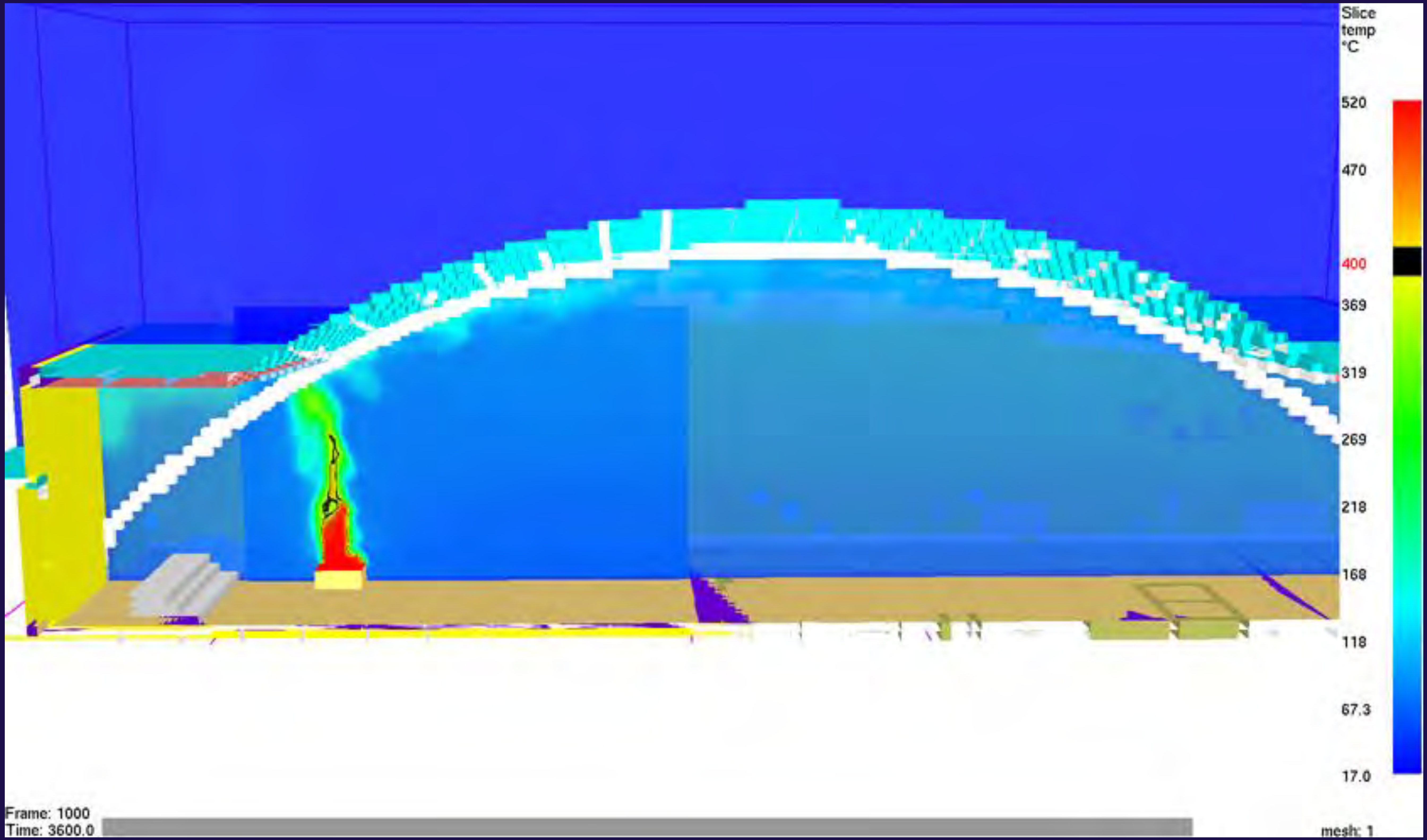

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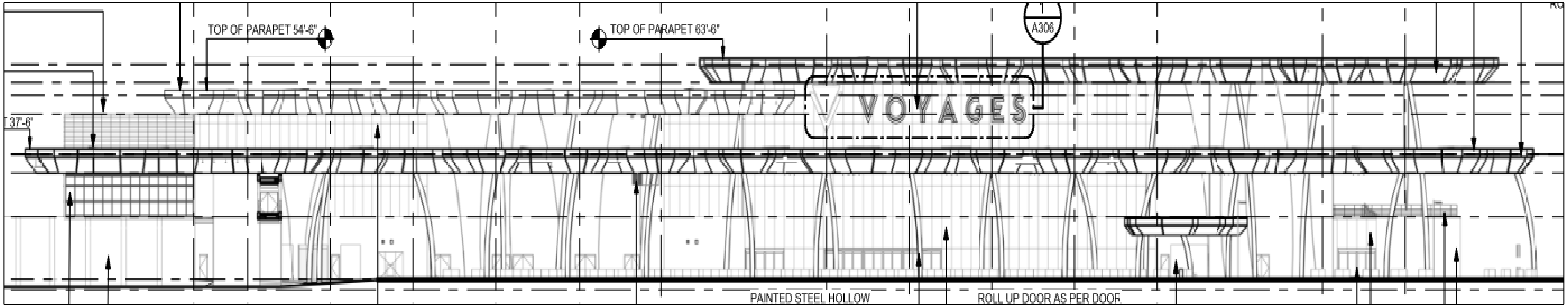

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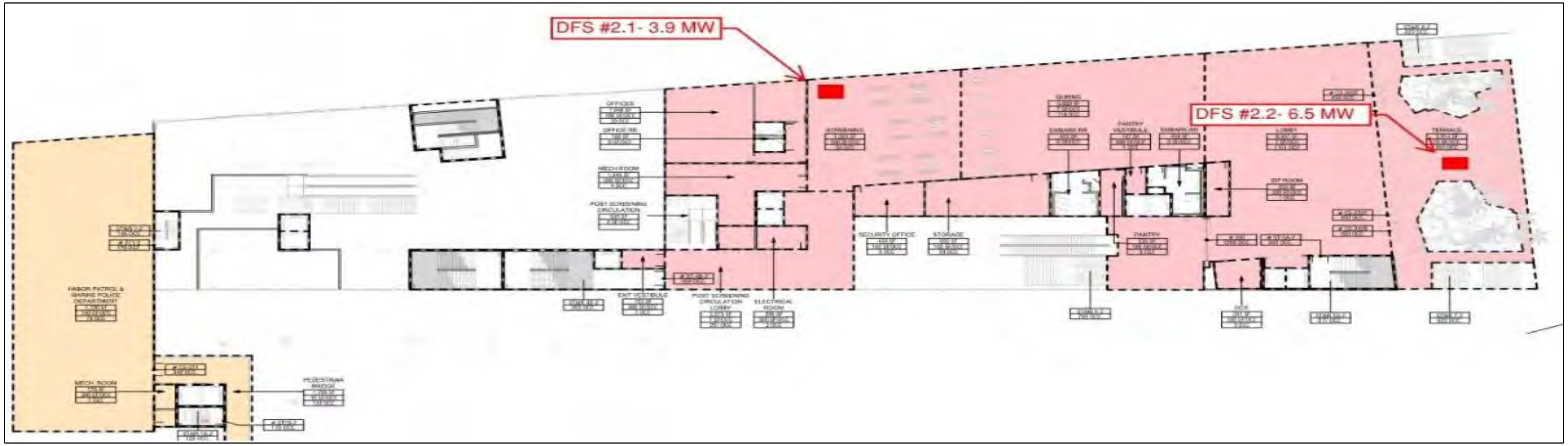

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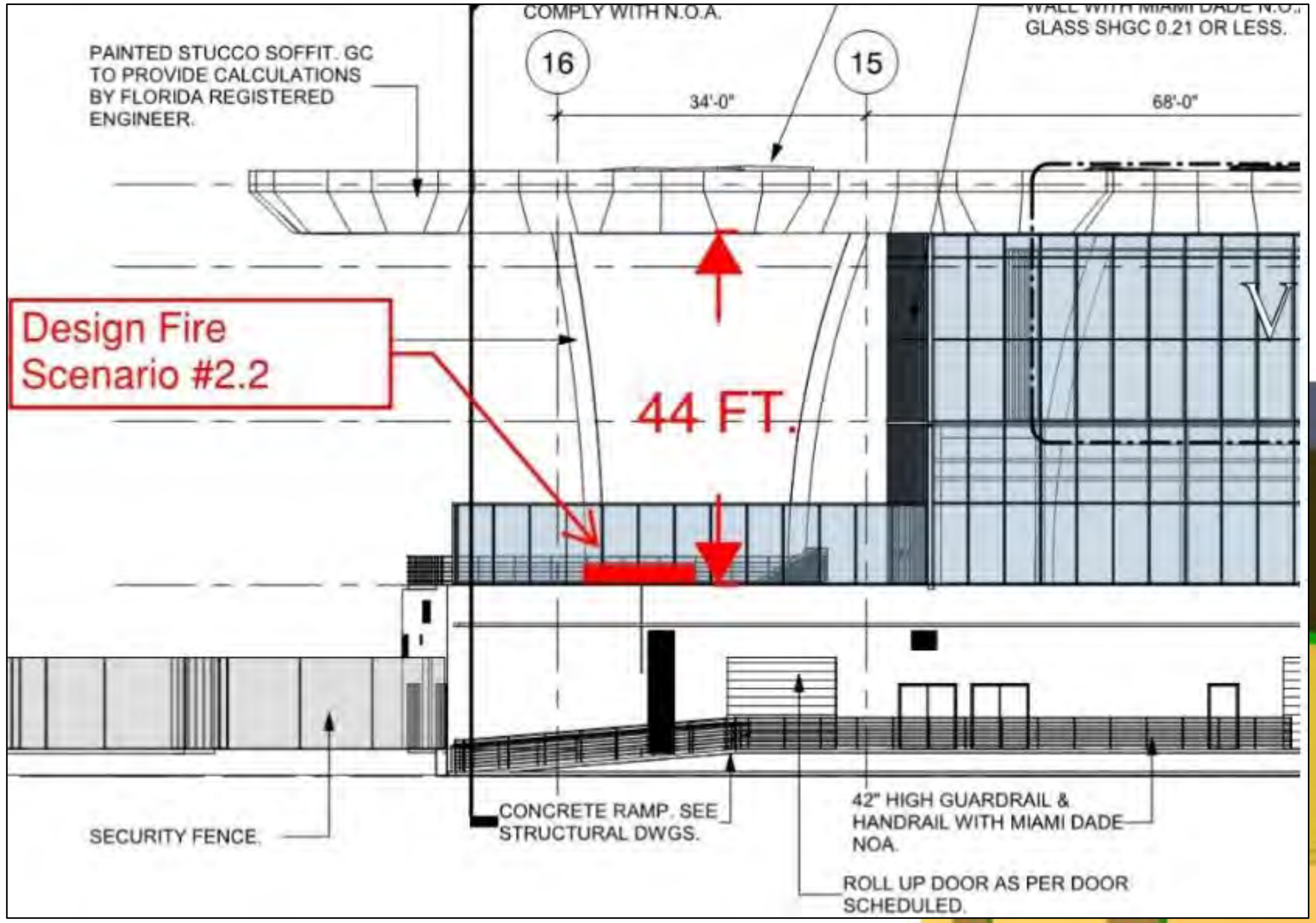

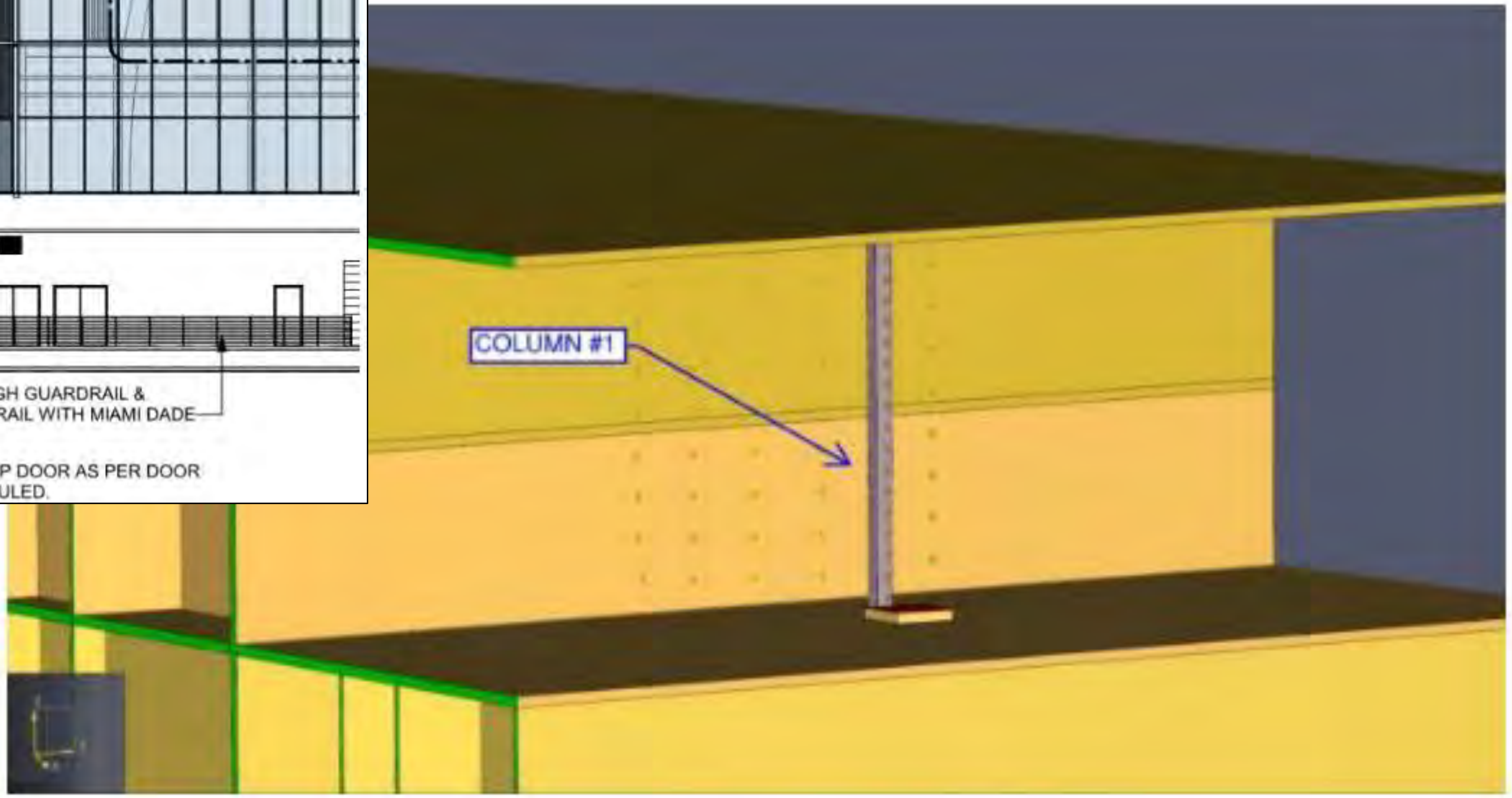

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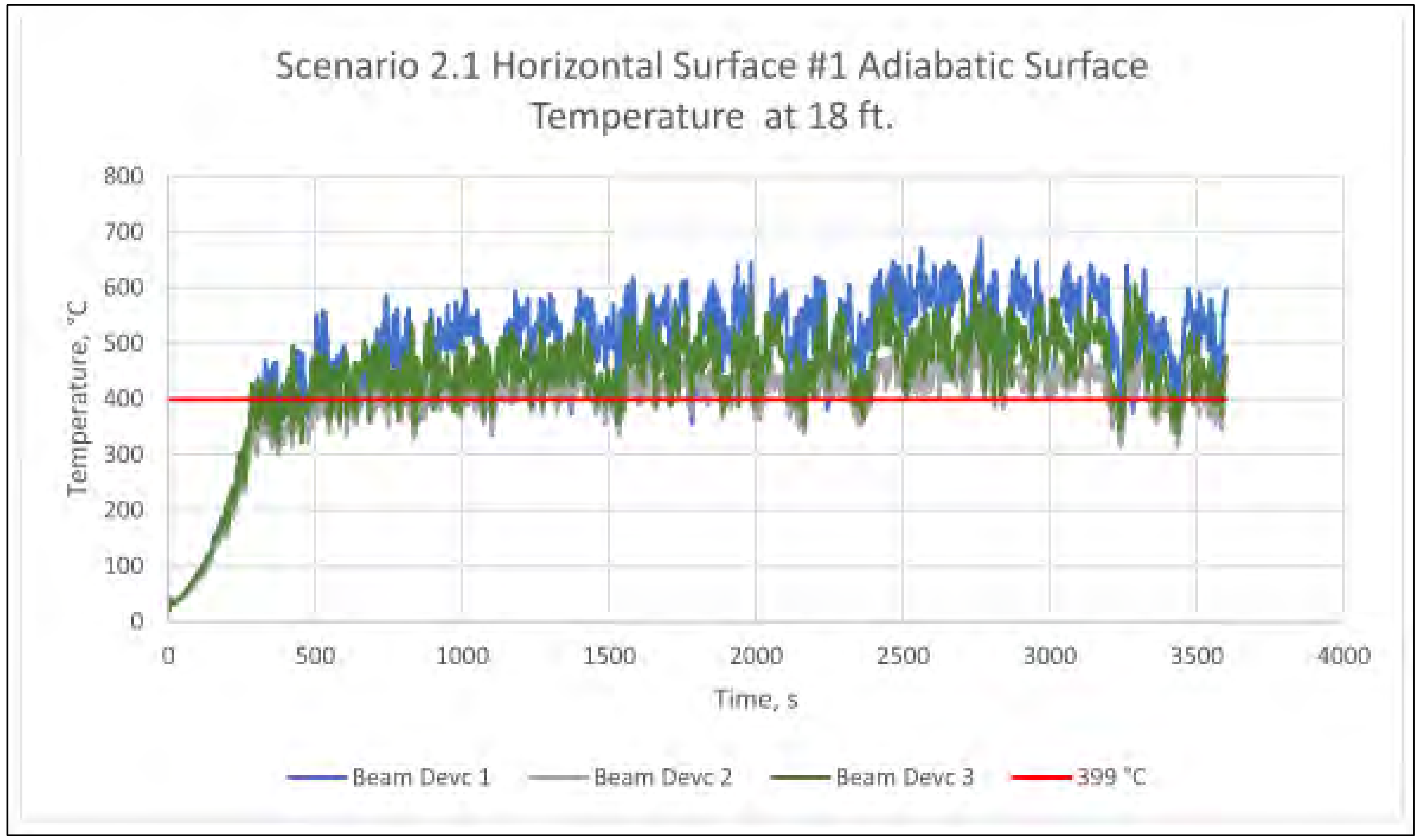

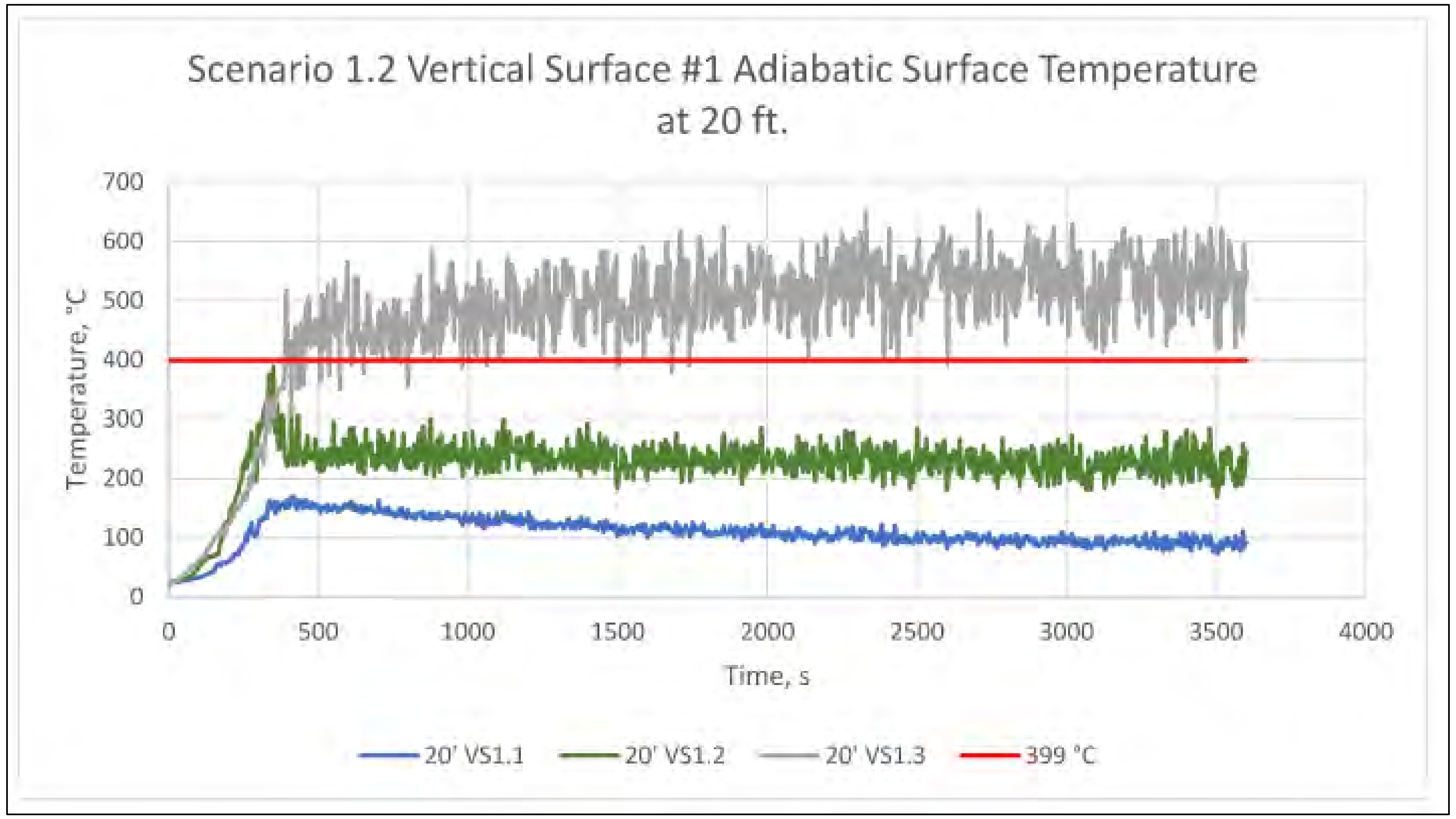

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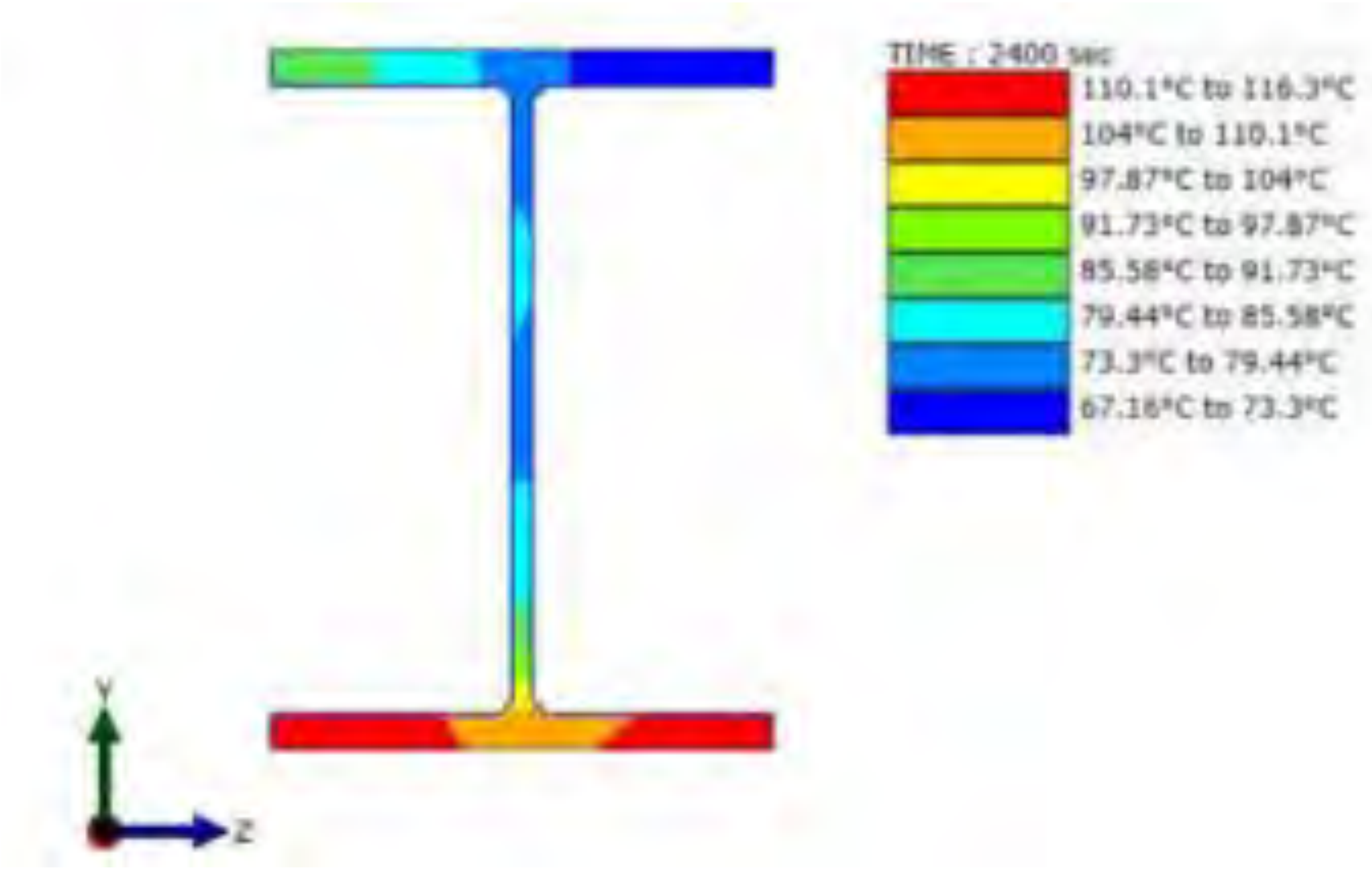

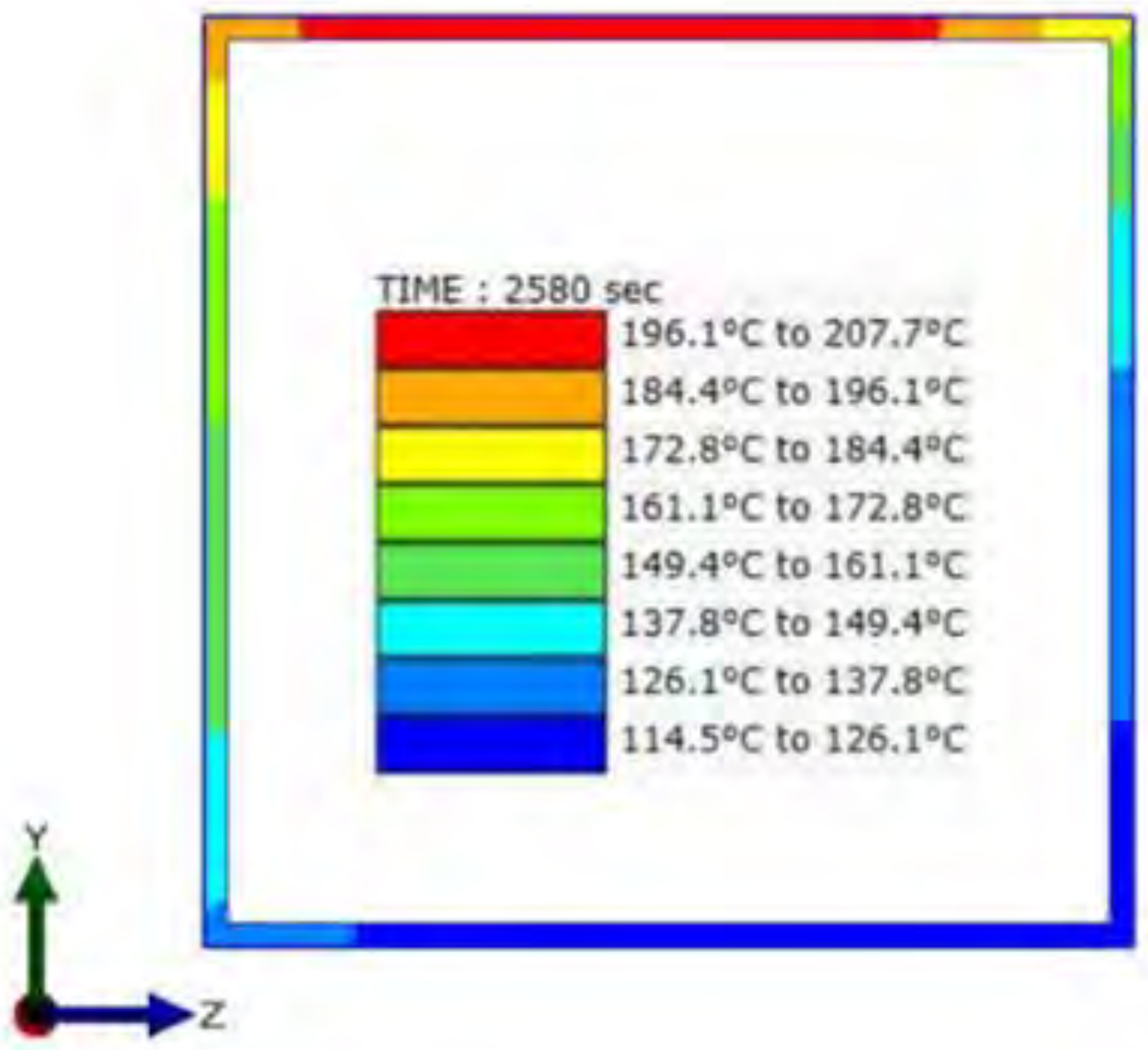

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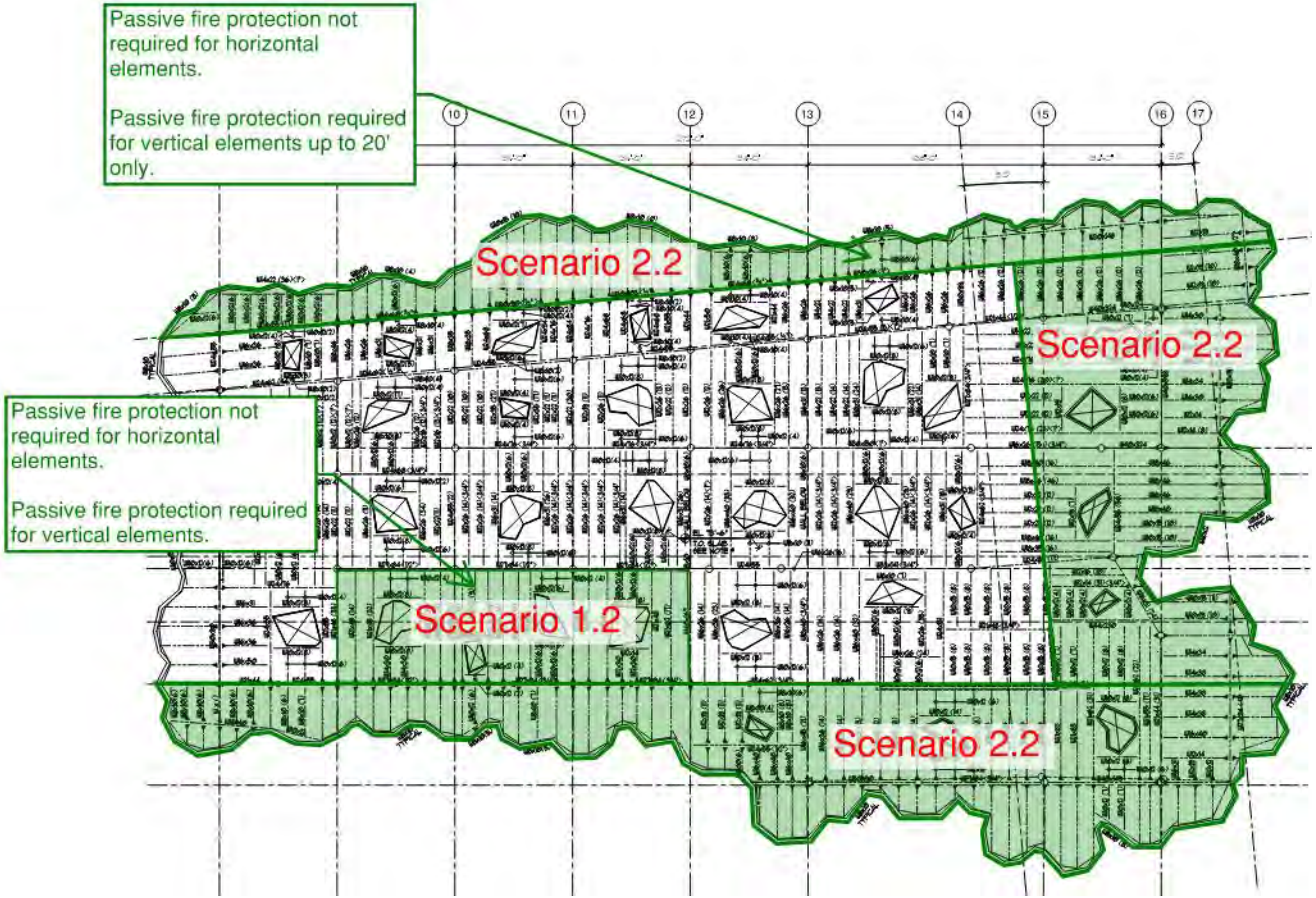

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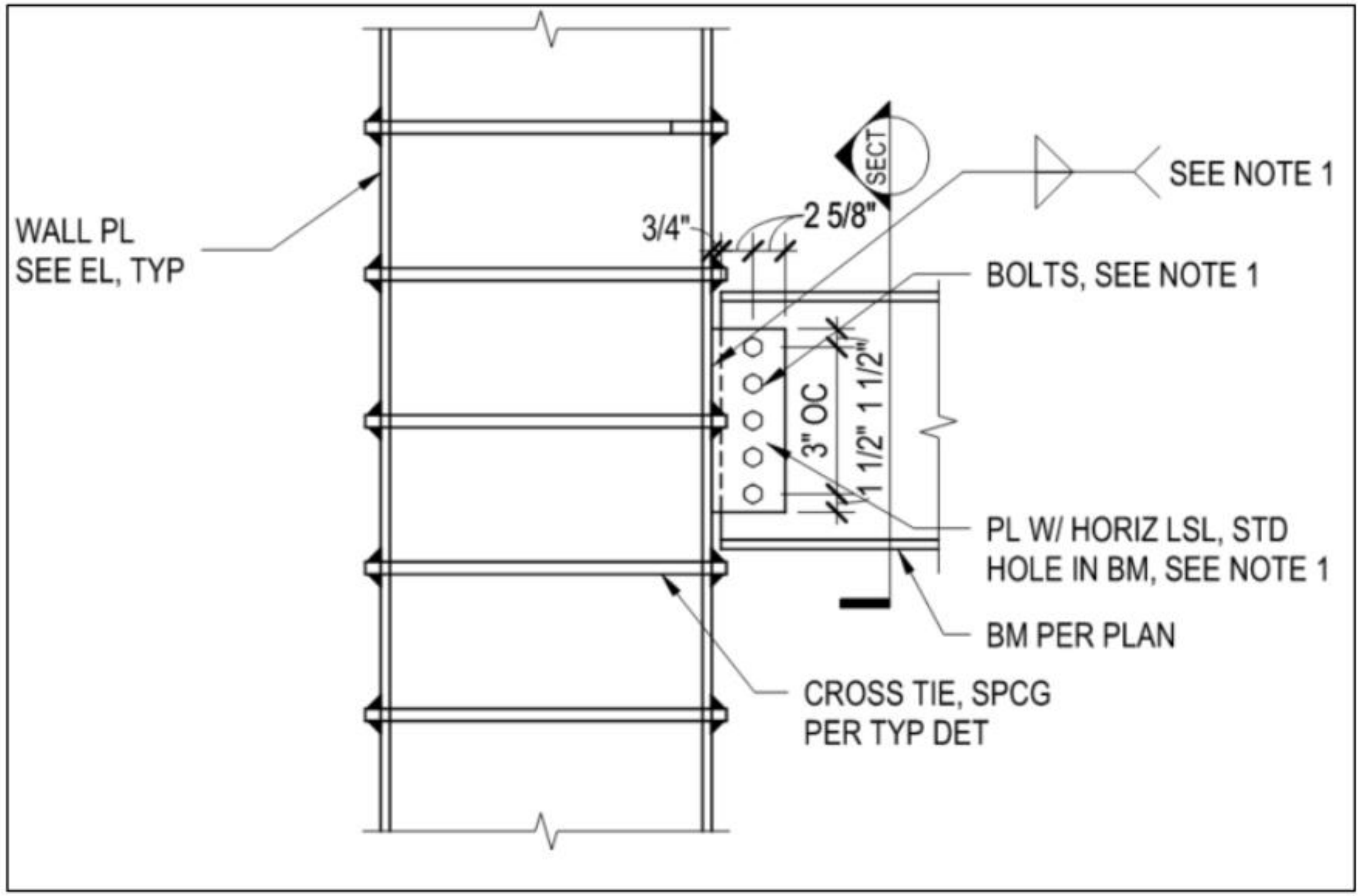

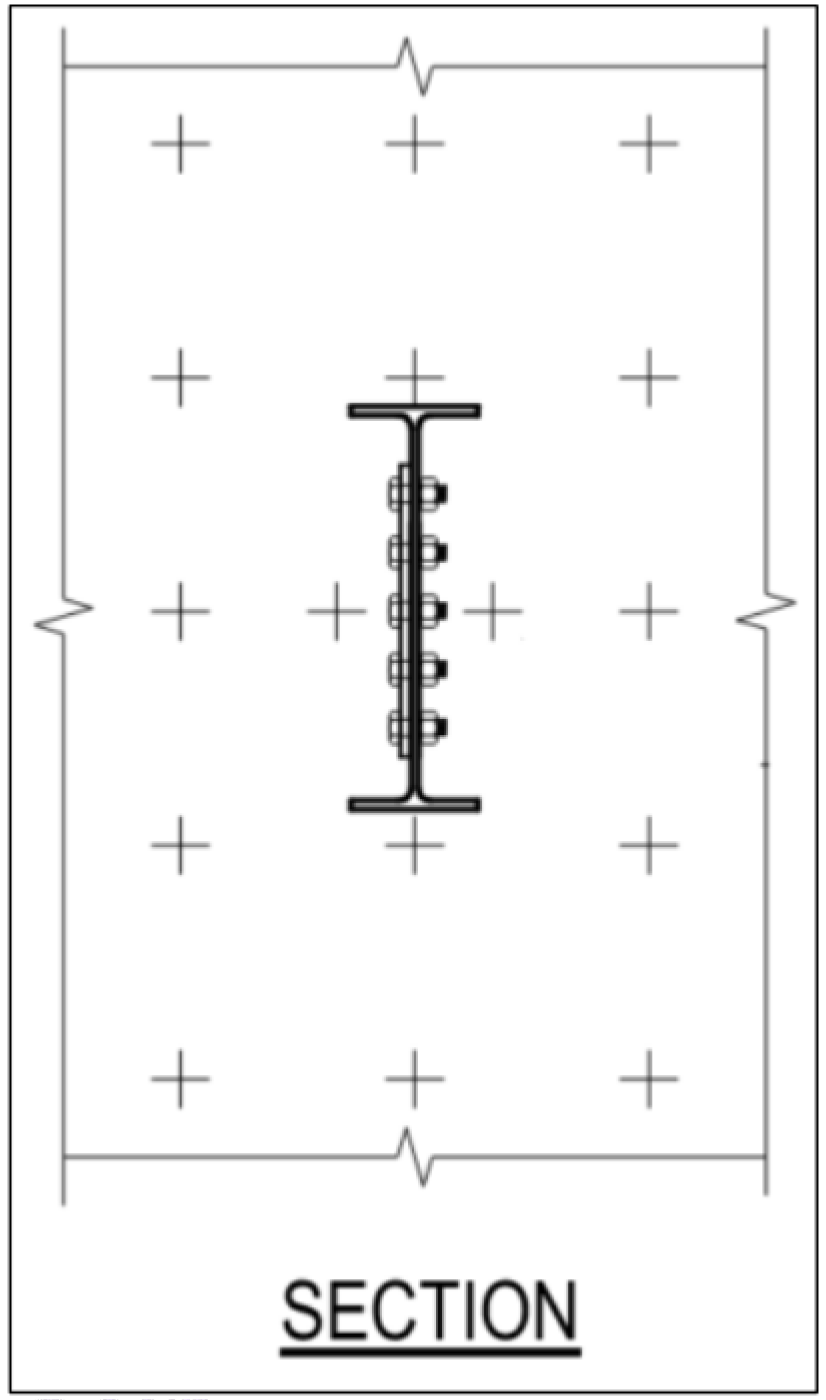

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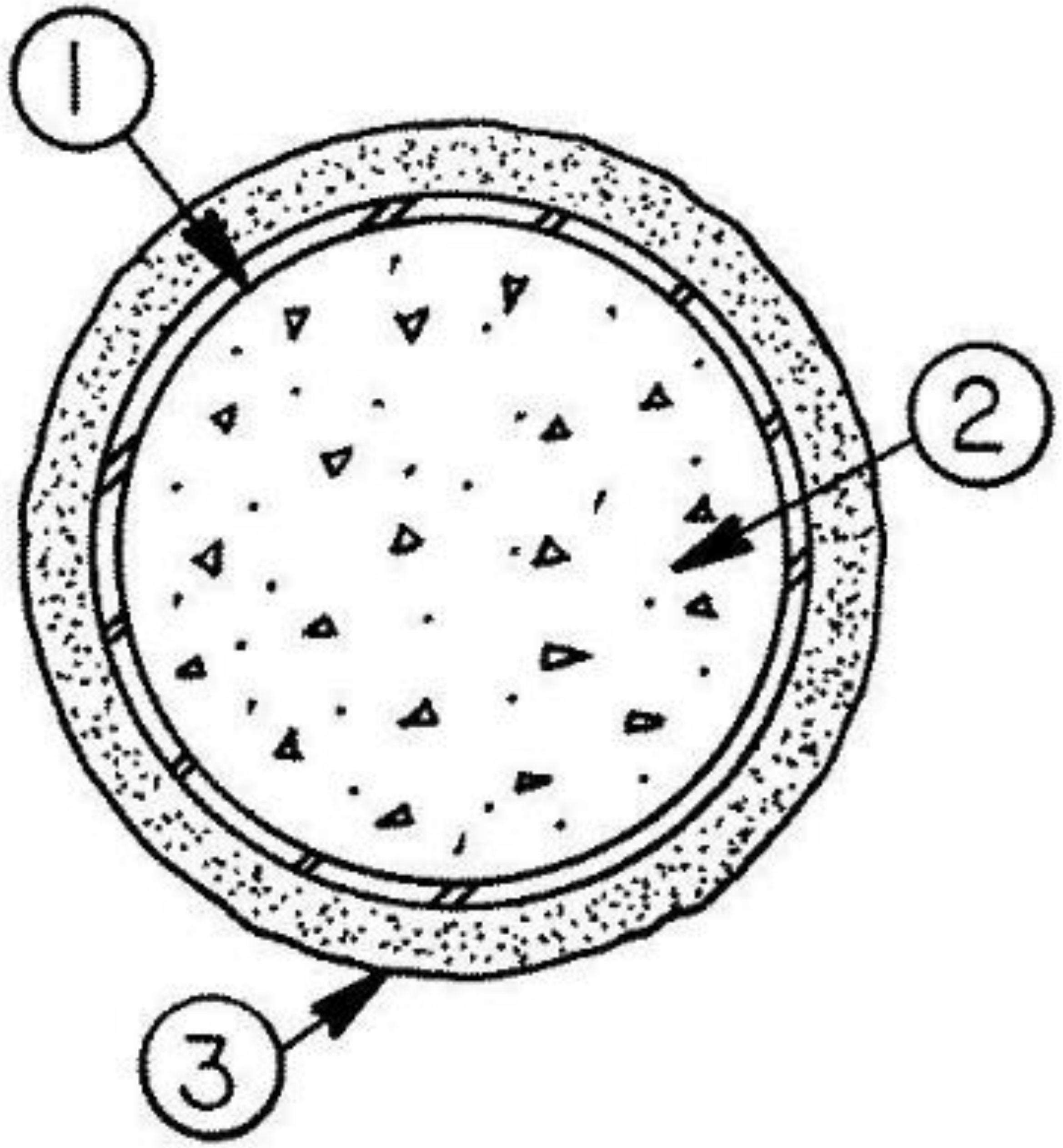

Rating Hr	Min Thkns In.
1	3/8
1-1/2	7/16
2	9/16
3	13/16
4	1-1/8

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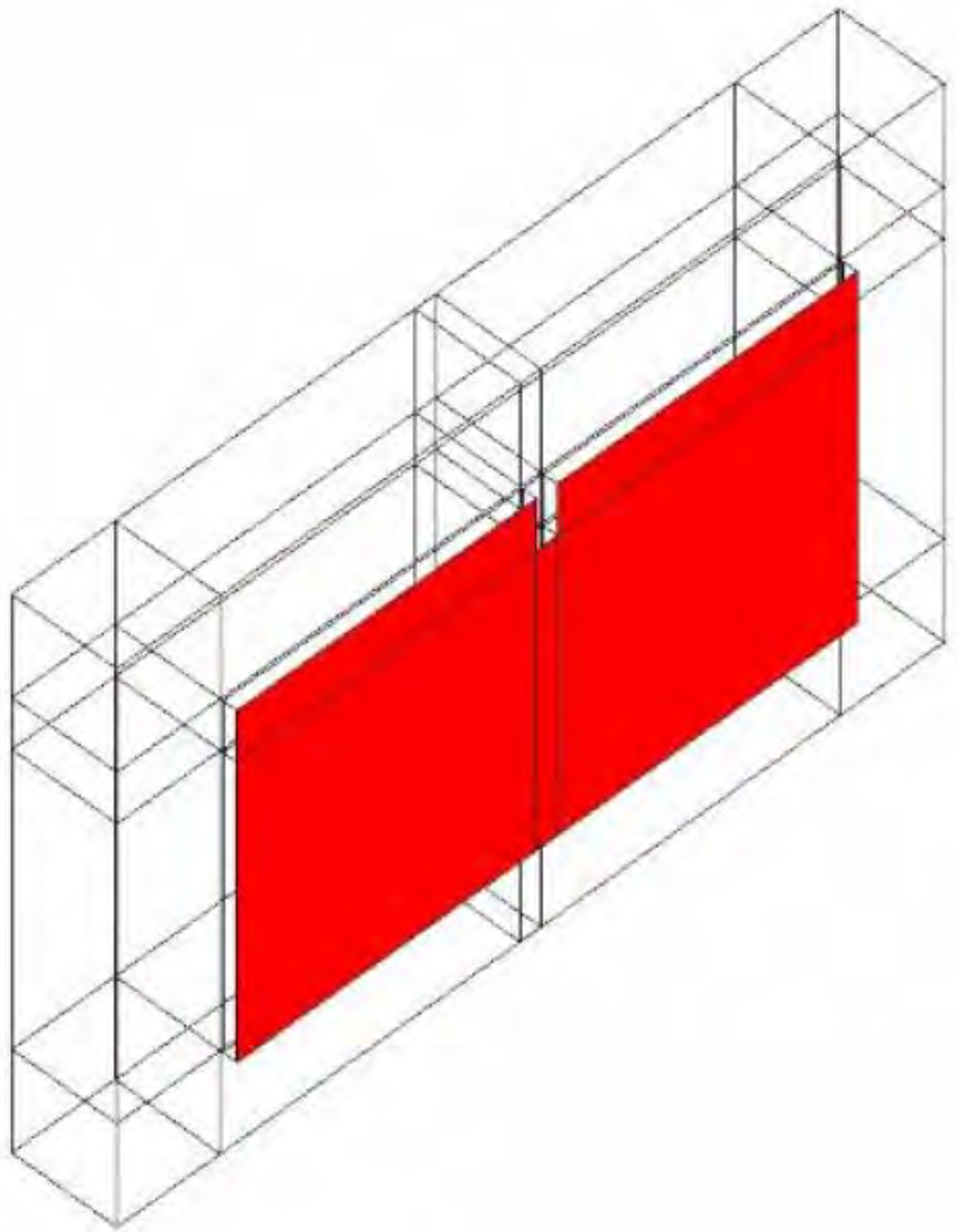

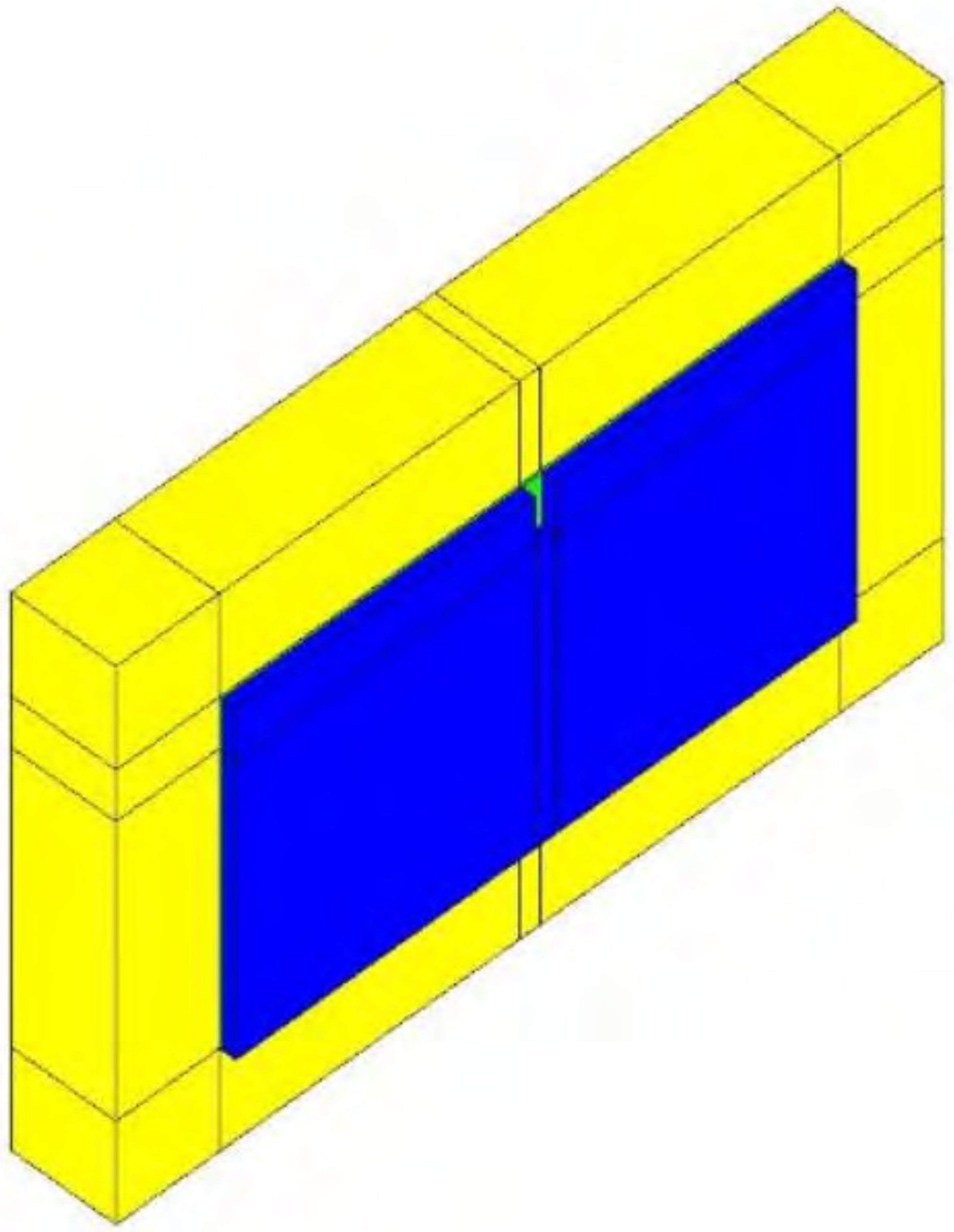

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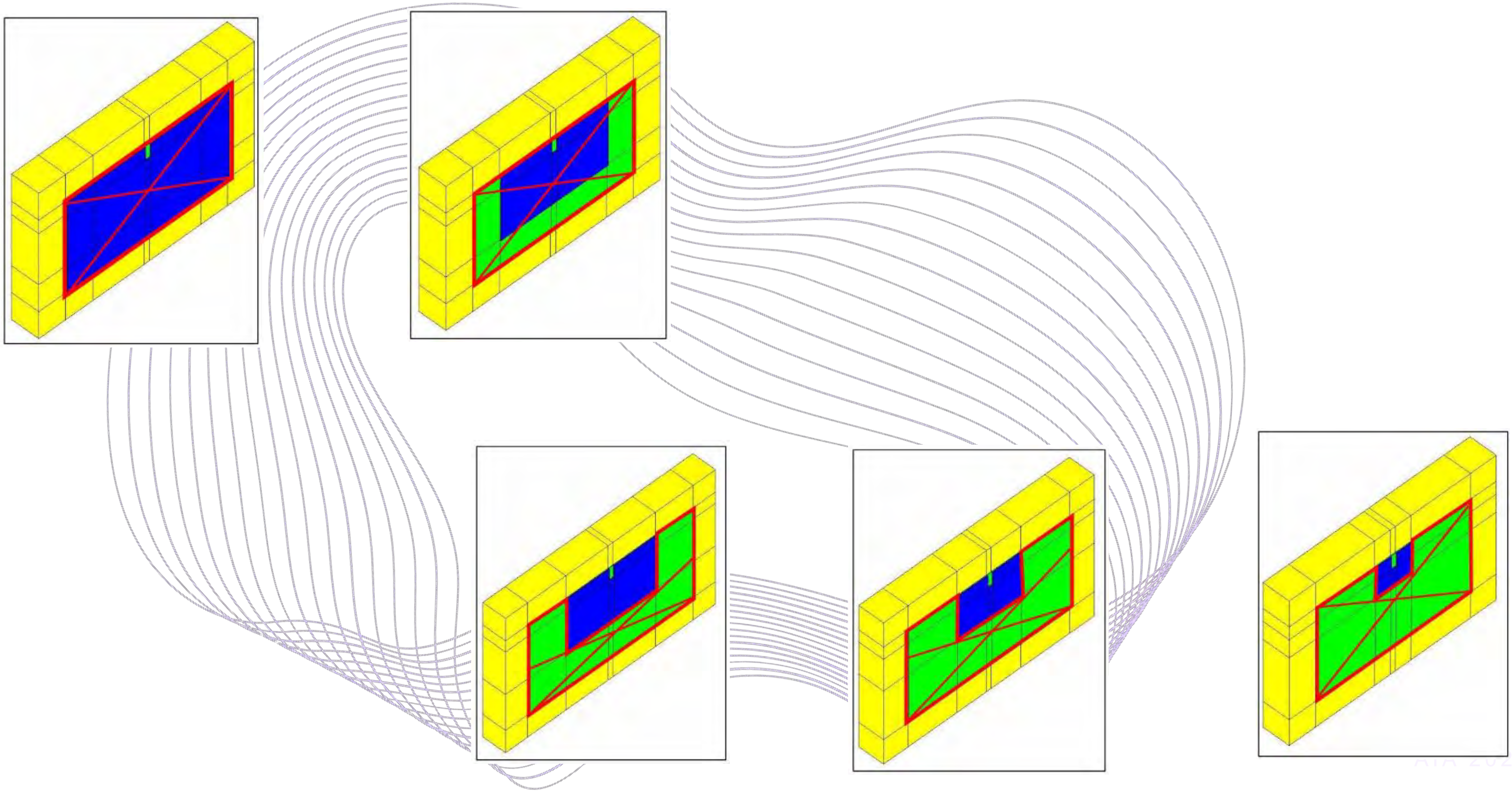

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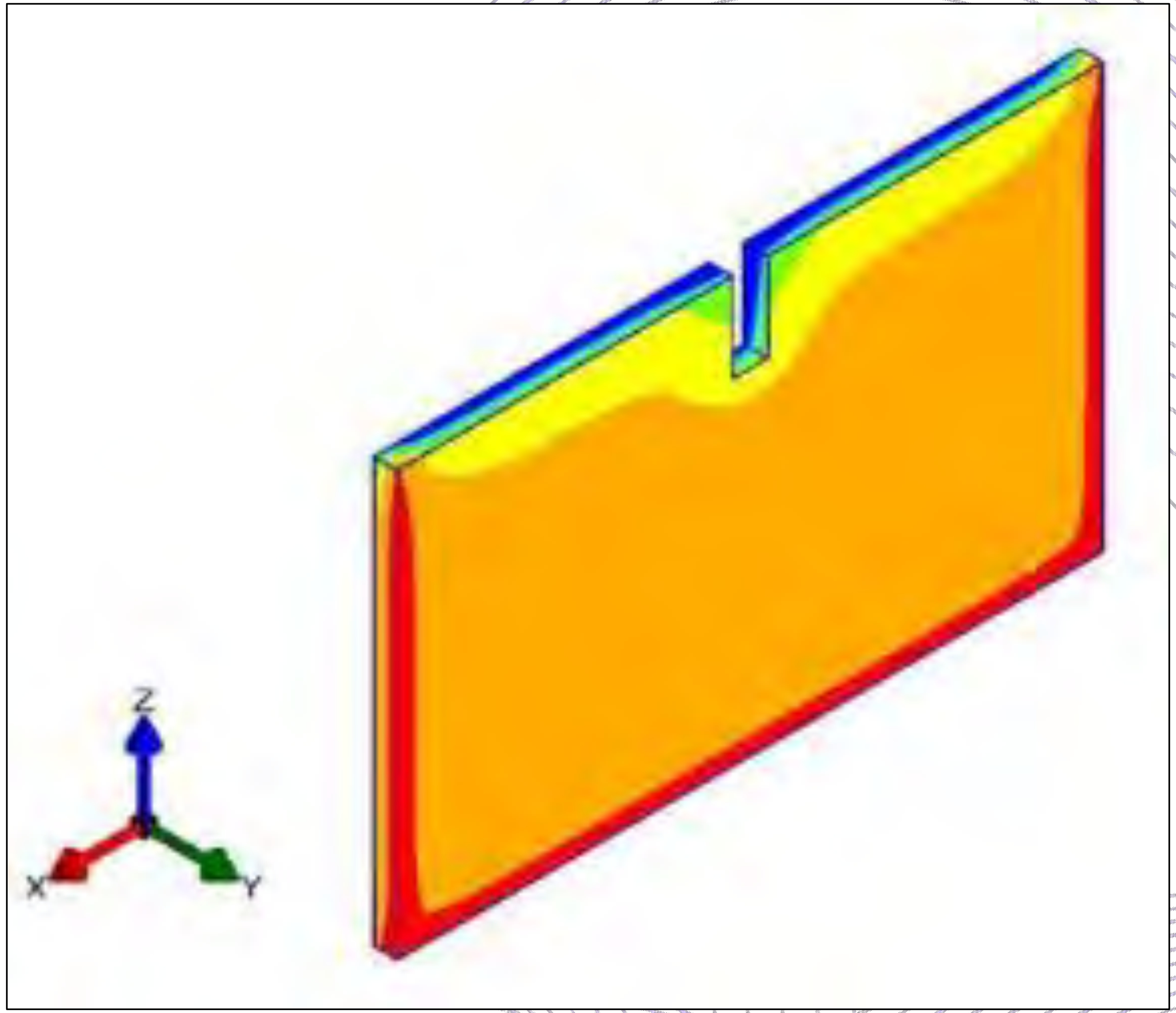

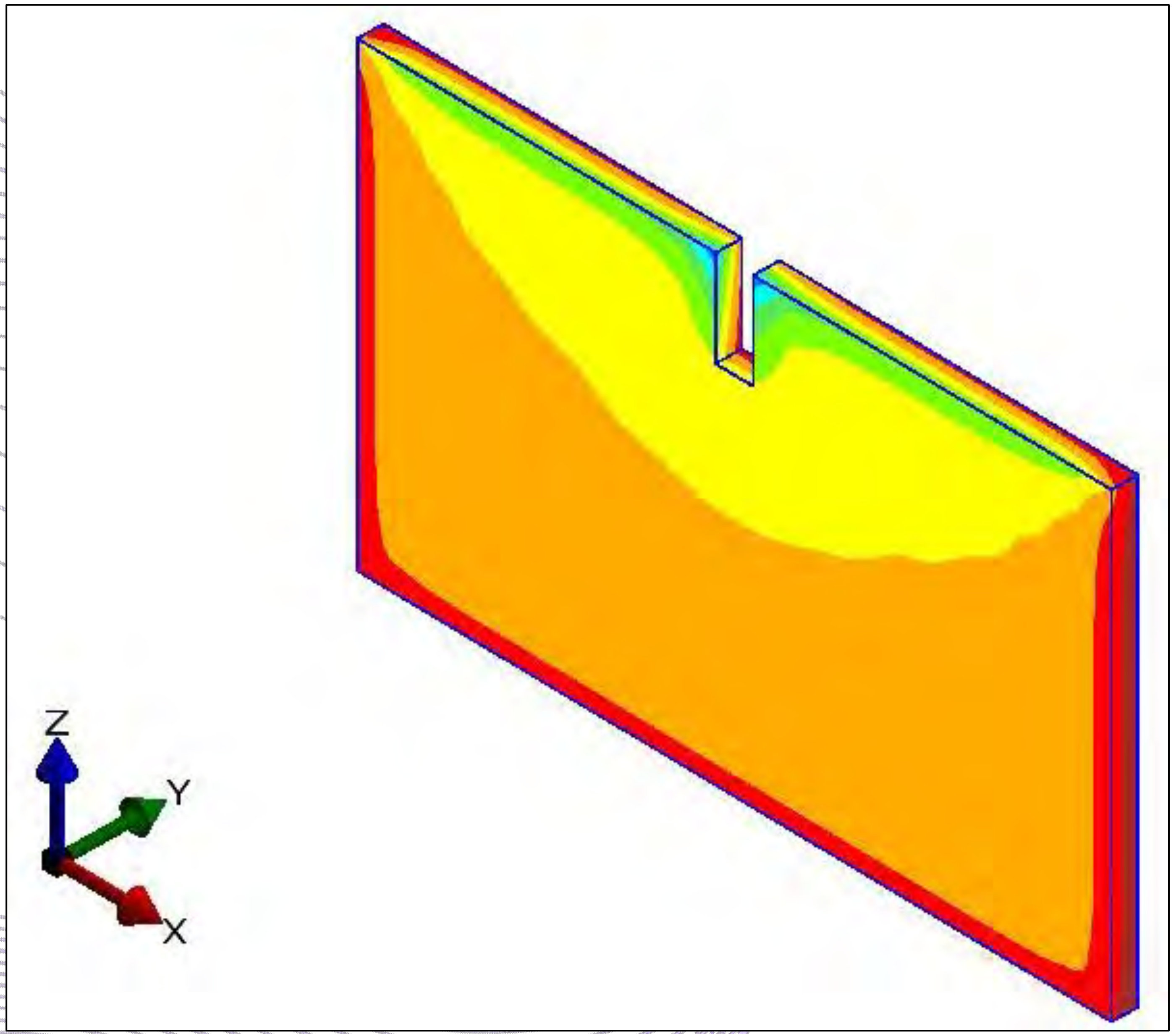

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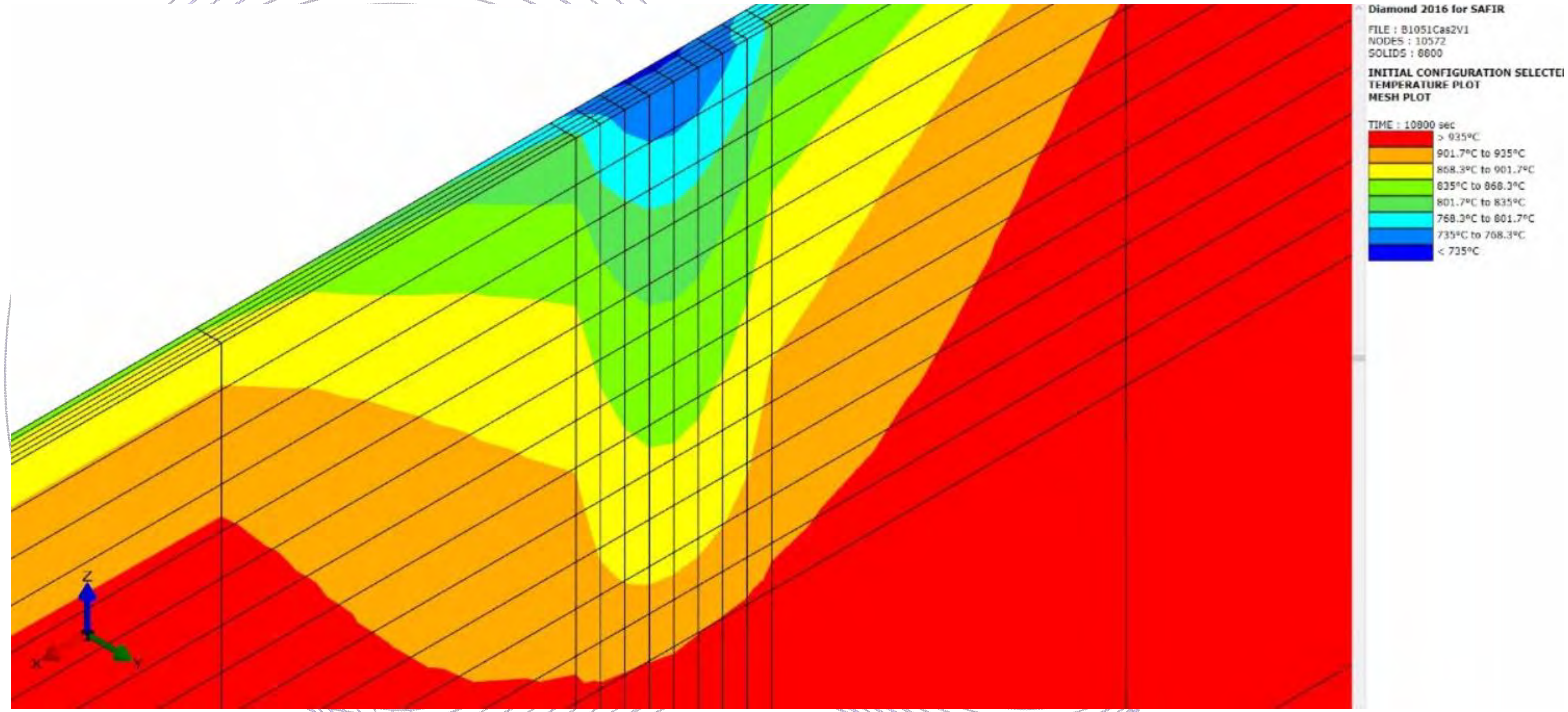

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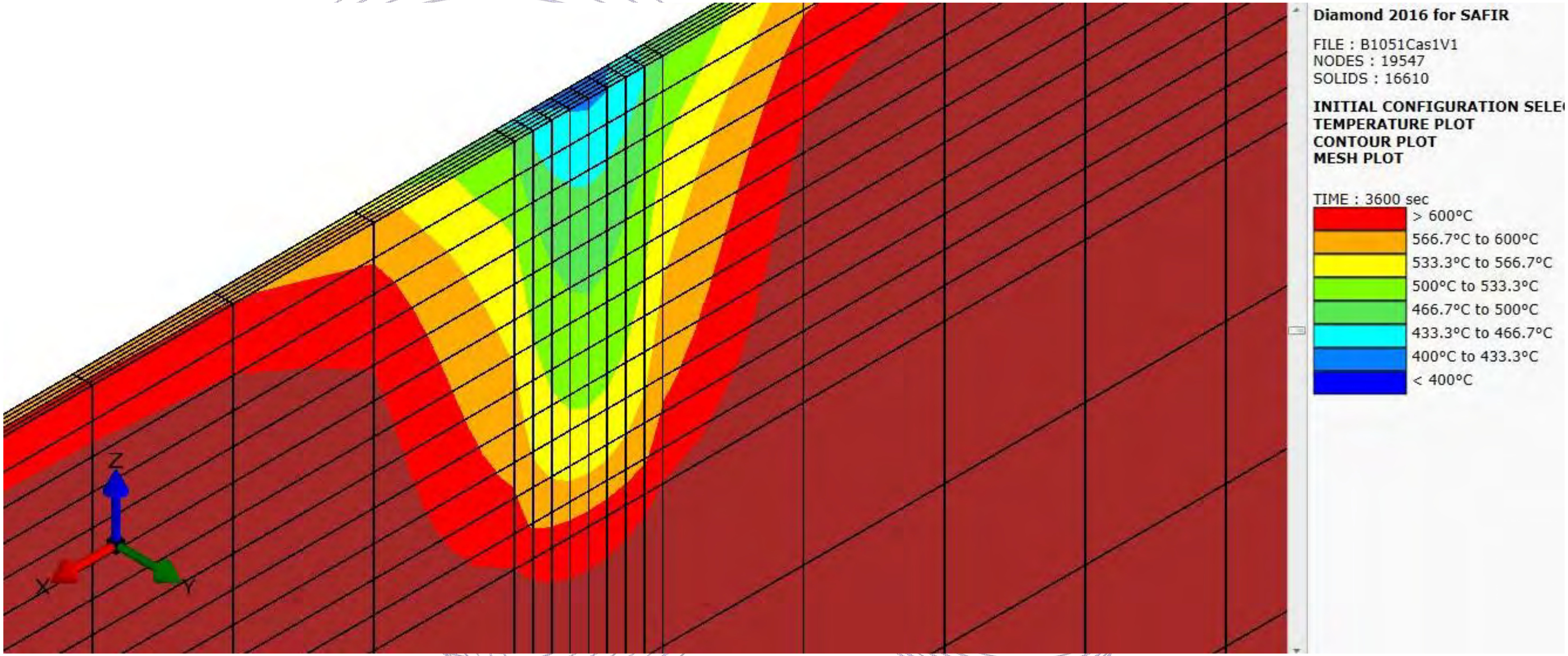

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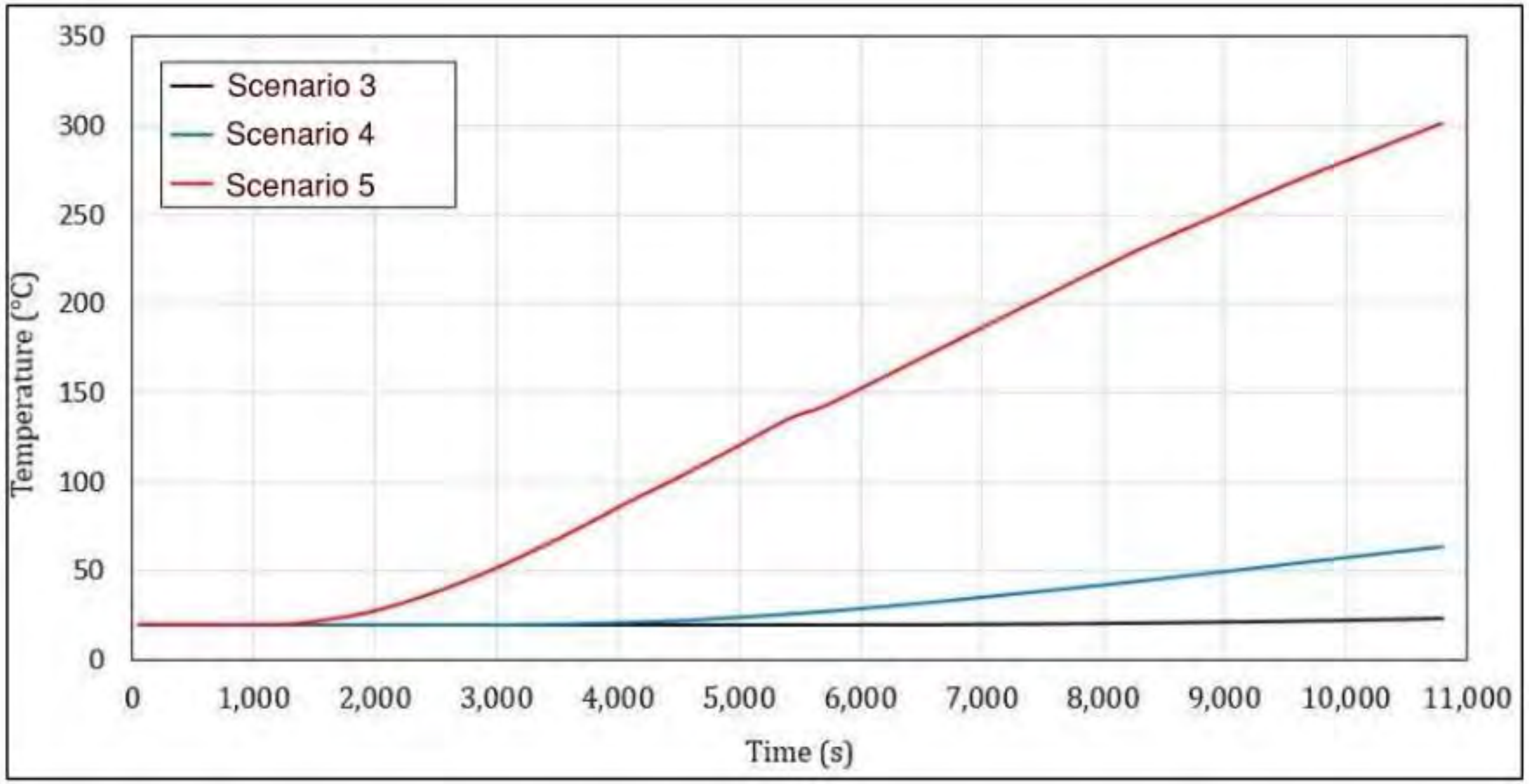

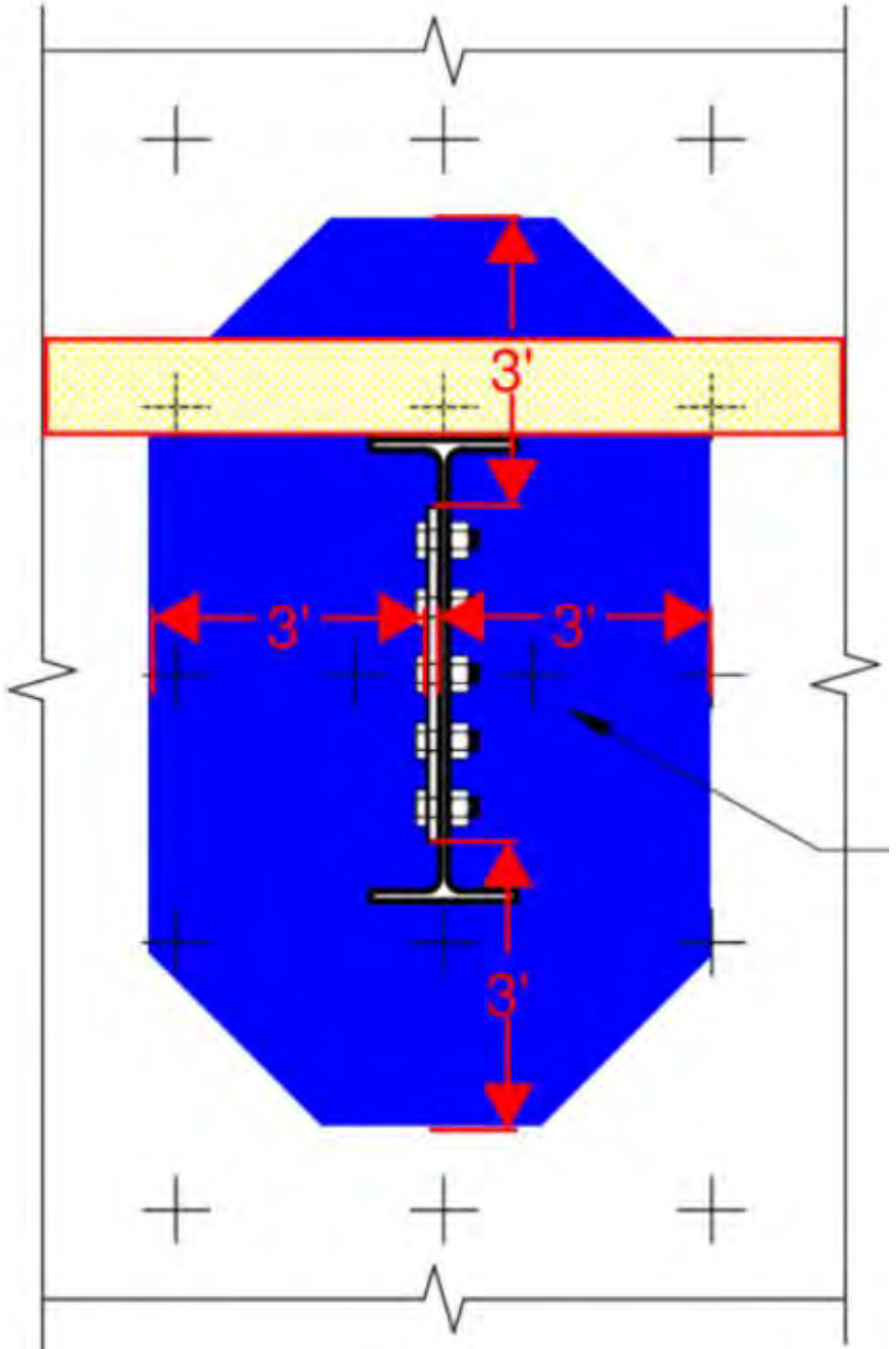

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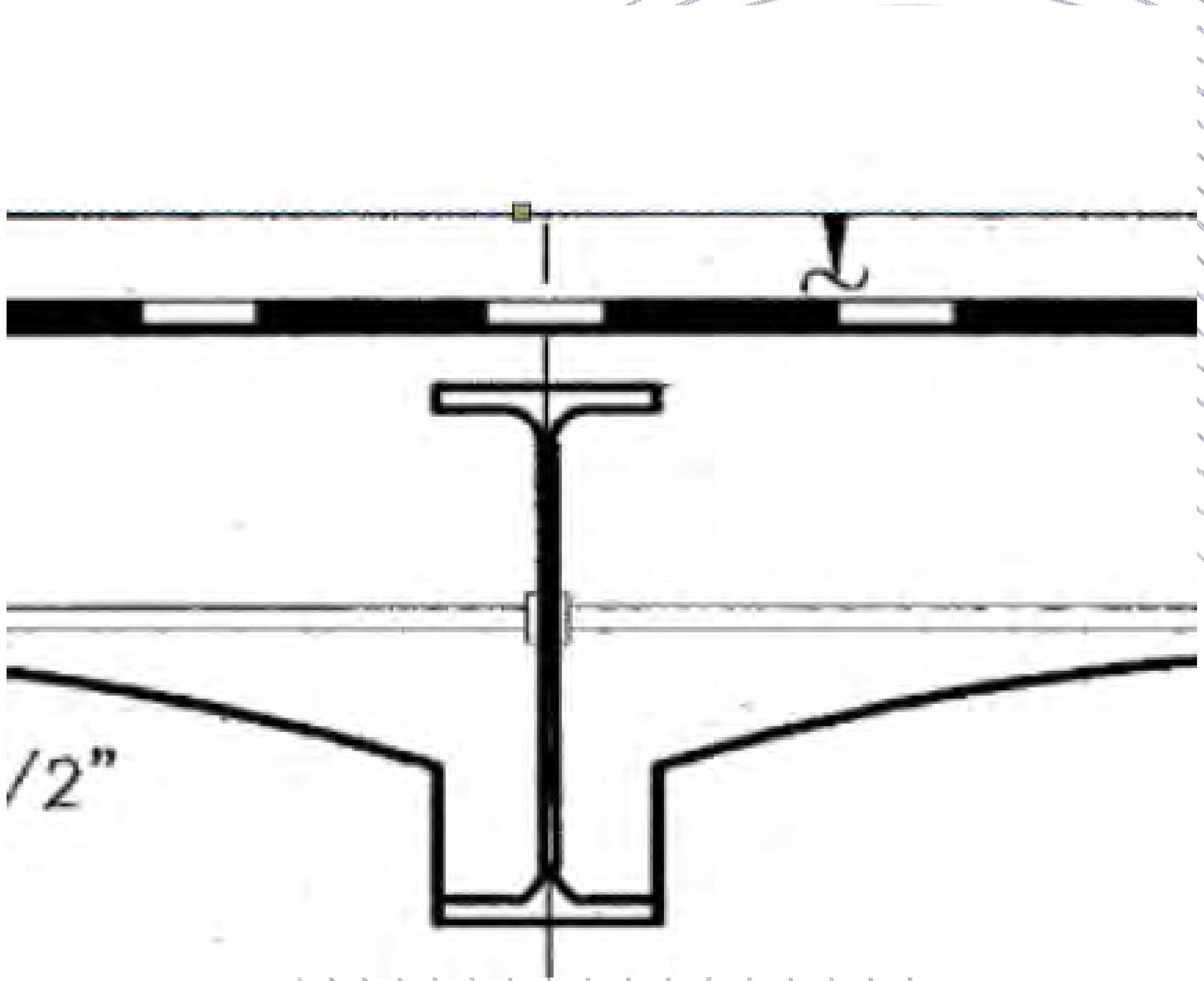

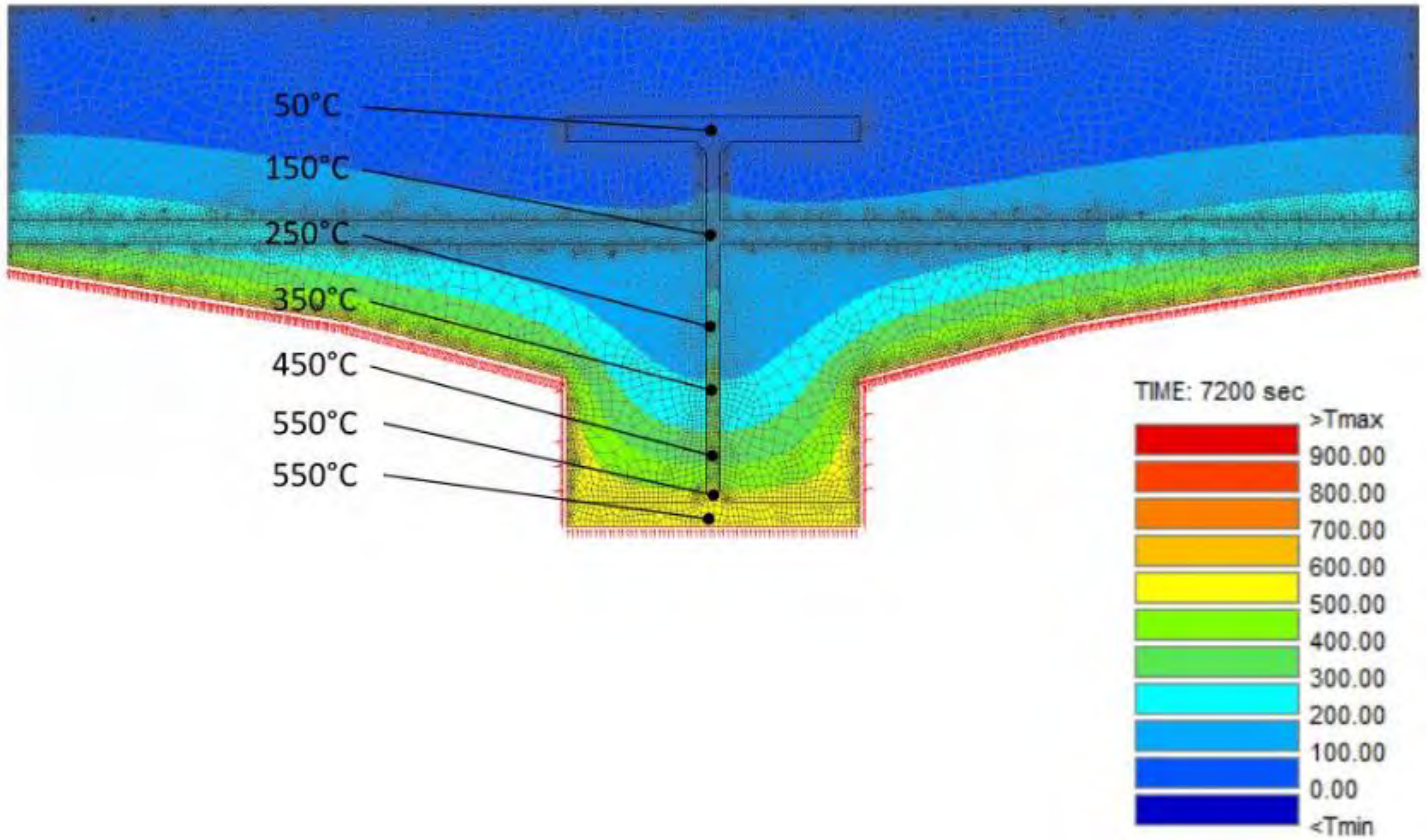

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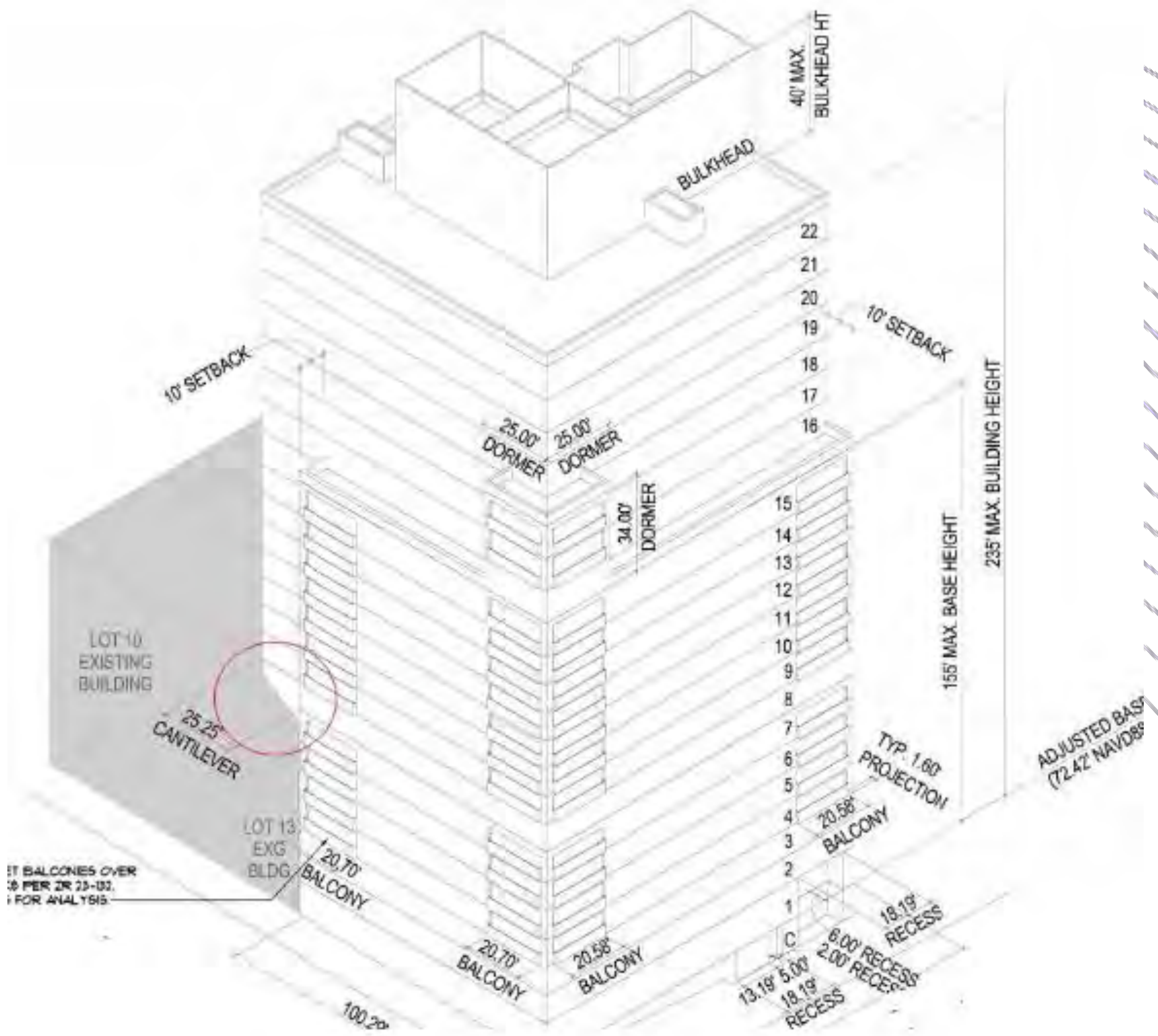
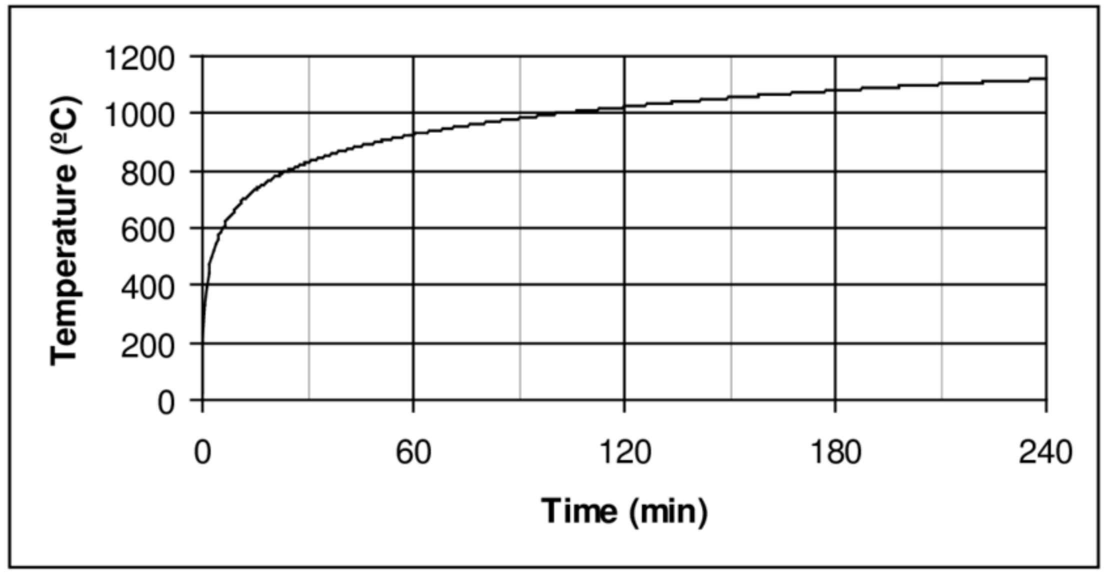
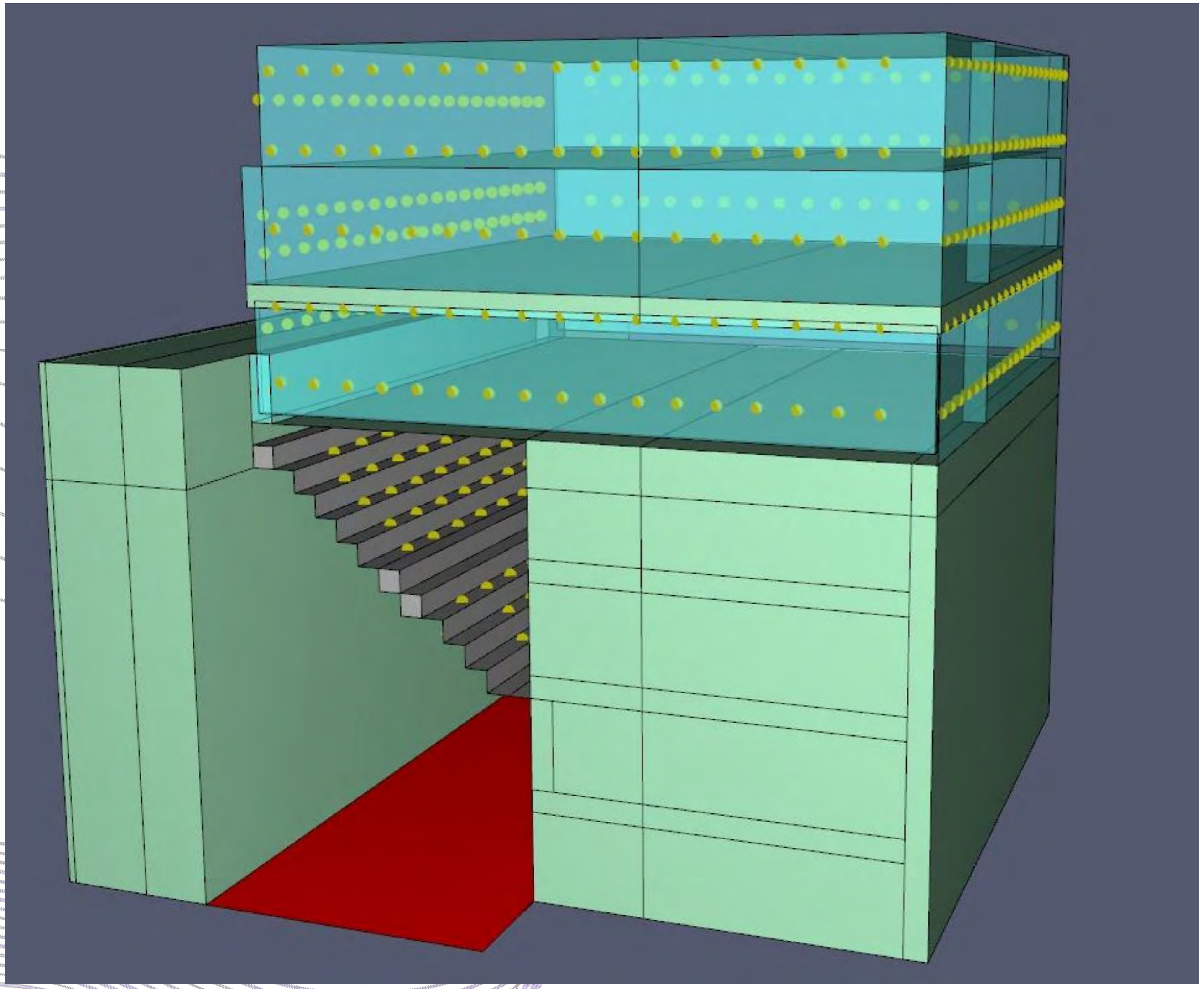






EGRESS ANALYSIS

PERFORMANCE-BASED DESIGN

104.11 Alternative Materials, Design and Methods of Construction and Equipment. The provisions of 780 CMR are not intended to prevent the installation of any material or to prohibit any design or method of construction not specifically prescribed by 780 CMR, provided that any such alternative has been approved. An alternative material, design or method of construction shall be approved where the building official finds that the proposed design is satisfactory and complies with the intent of the provisions of 780 CMR, and that the material, method or work offered is, for the purpose intended, at least the equivalent of that prescribed in 780 CMR in quality, strength, effectiveness, fire resistance, durability and safety.

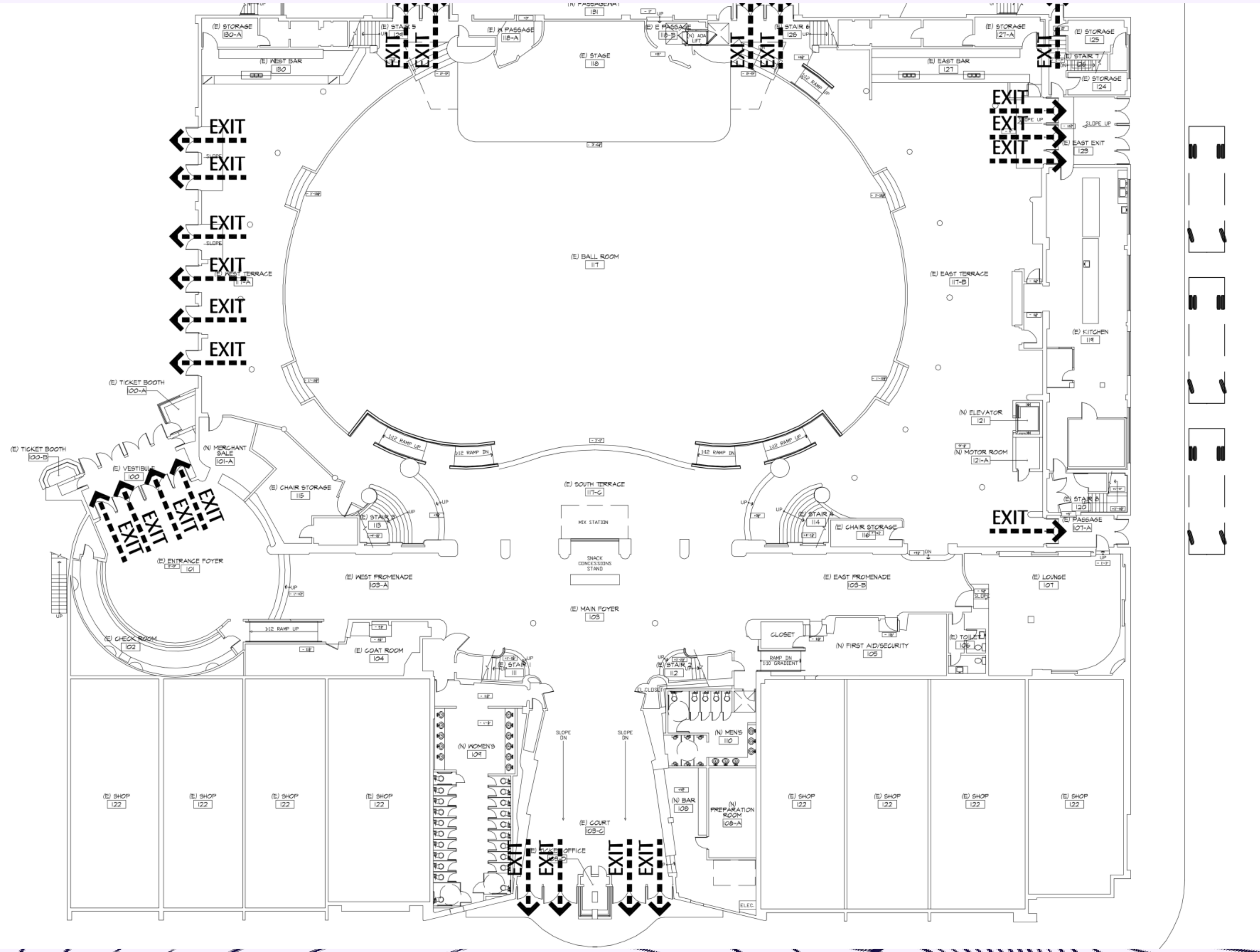
104.11.1 Research Reports. Supporting data, where necessary to assist in the approval of materials or assemblies not specifically provided for in 780 CMR, shall consist of valid research reports from approved sources.

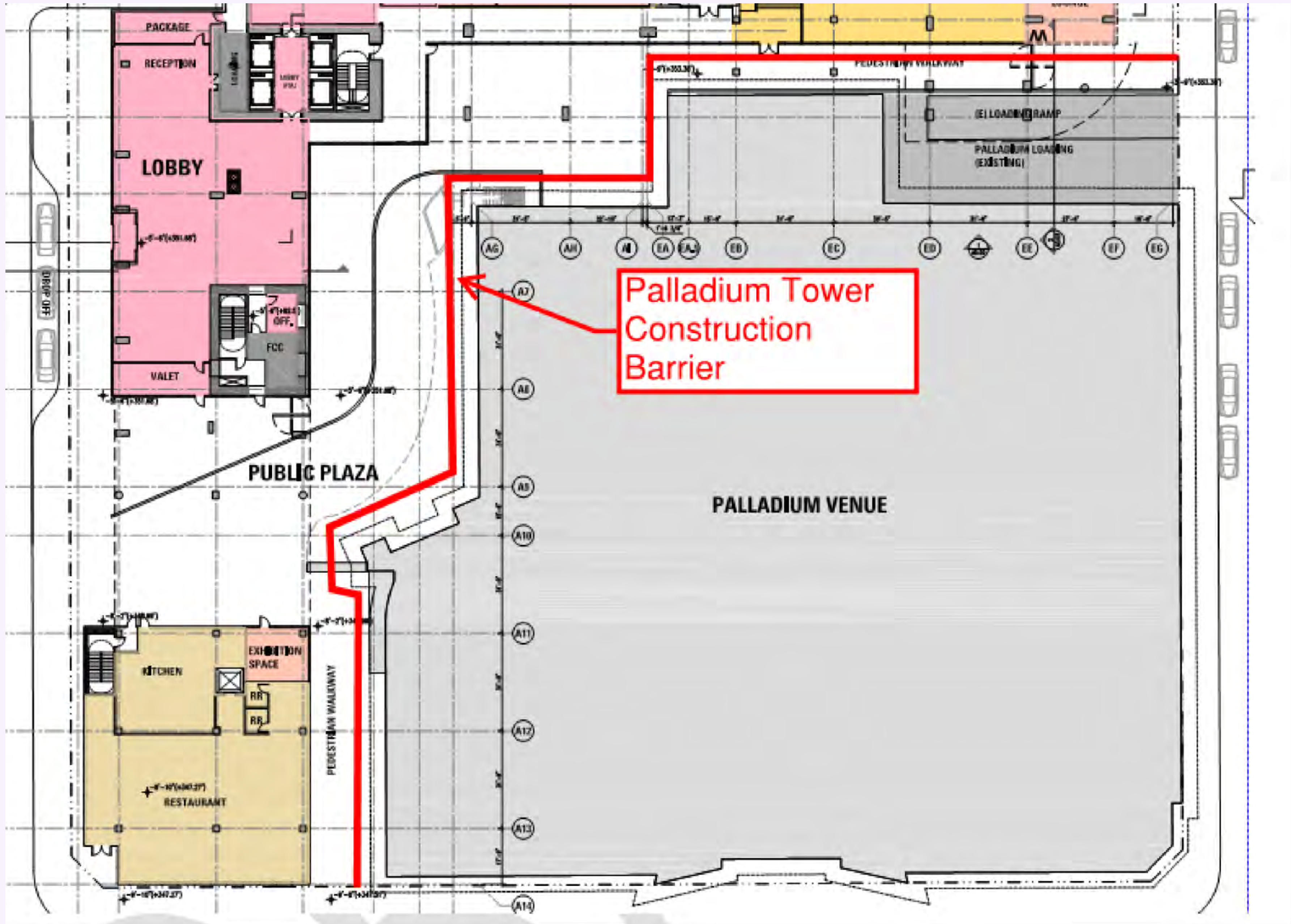
104.11.2 Tests. Whenever there is insufficient evidence of compliance with the provisions of 780 CMR, or evidence that a material or method does not conform to the requirements of 780 CMR, or in order to substantiate claims for alternative materials or methods, the building official shall have the authority to require tests as evidence of compliance to be made at no expense to the enforcement authority. Test methods shall be as specified in 780 CMR or by other recognized test standards. In the absence of recognized and accepted test methods, the building official shall approve the testing procedures. Tests shall be performed by an approved agency. Reports of such tests shall be retained by the building official for the period required for retention of public records.

104.12 Matters Not Provided For. In recognition of the inherent difficulty of drafting a functional code that contemplates every situation that may arise in the area of building safety, this section provides the building official, the Building Code Appeals Board, or the BBRS itself, with reasonable discretion to ensure that all life safety issues that may arise in the enforcement of 780 CMR may be appropriately addressed. Matters not specifically provided for in 780 CMR regarding structural, egress, fire, energy, sanitary or other requirements essential to occupant safety shall be determined by the building official or, in the case of an appeal, the Building Code Appeals Board. The details of action granting modifications shall be recorded and entered in the files of the building official. For highly specialized buildings and structures that conform to unique code requirements or nationally recognized standards not required in 780 CMR, registered design professionals shall provide sufficient information to the building official to support their approval.

PERFORMANCE-BASED DESIGN

HOLLYWOOD PALLADIUM

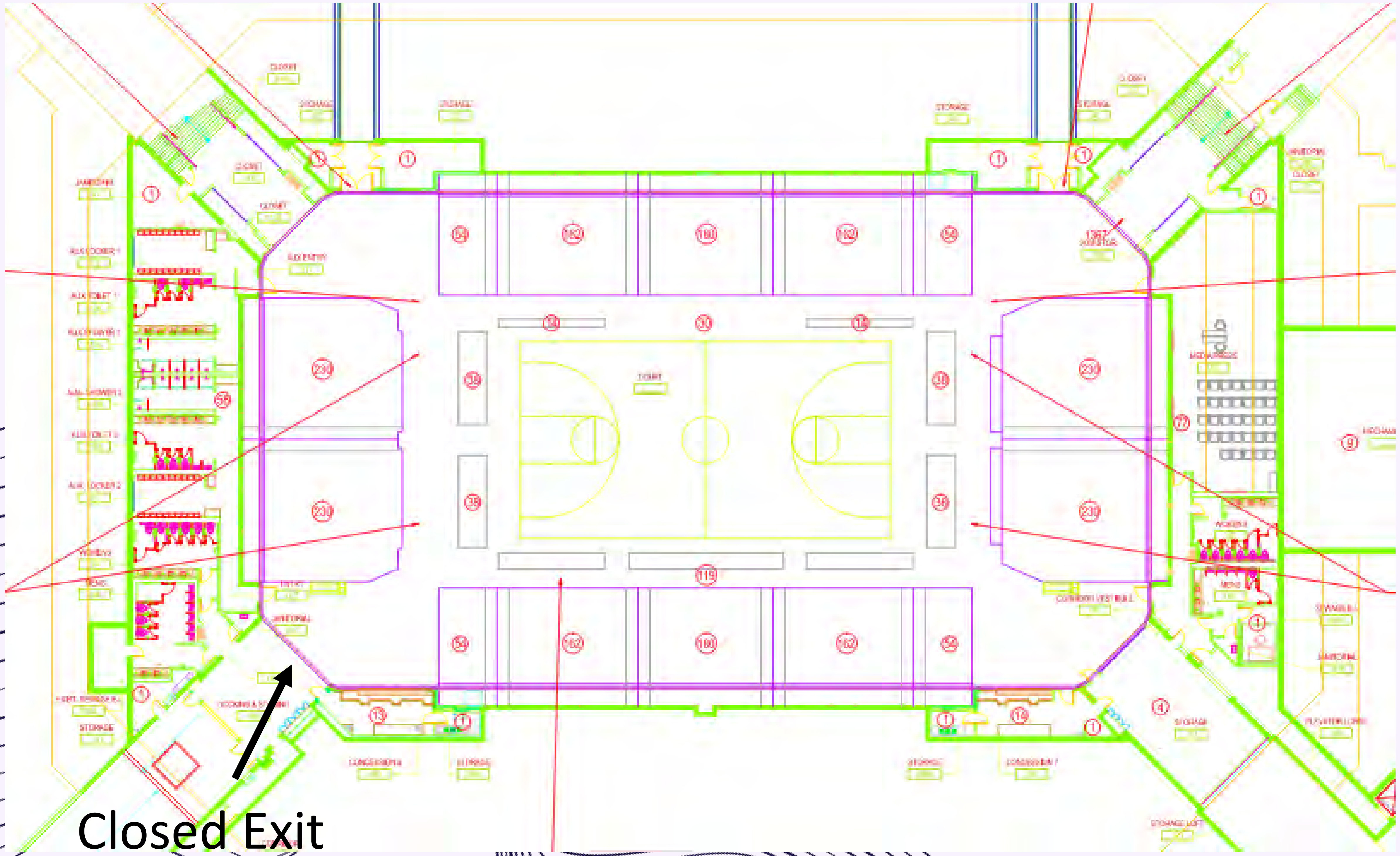




PERFORMANCE-BASED DESIGN

PERFORMANCE-BASED DESIGN

PAULEY PAVALION - UCLA

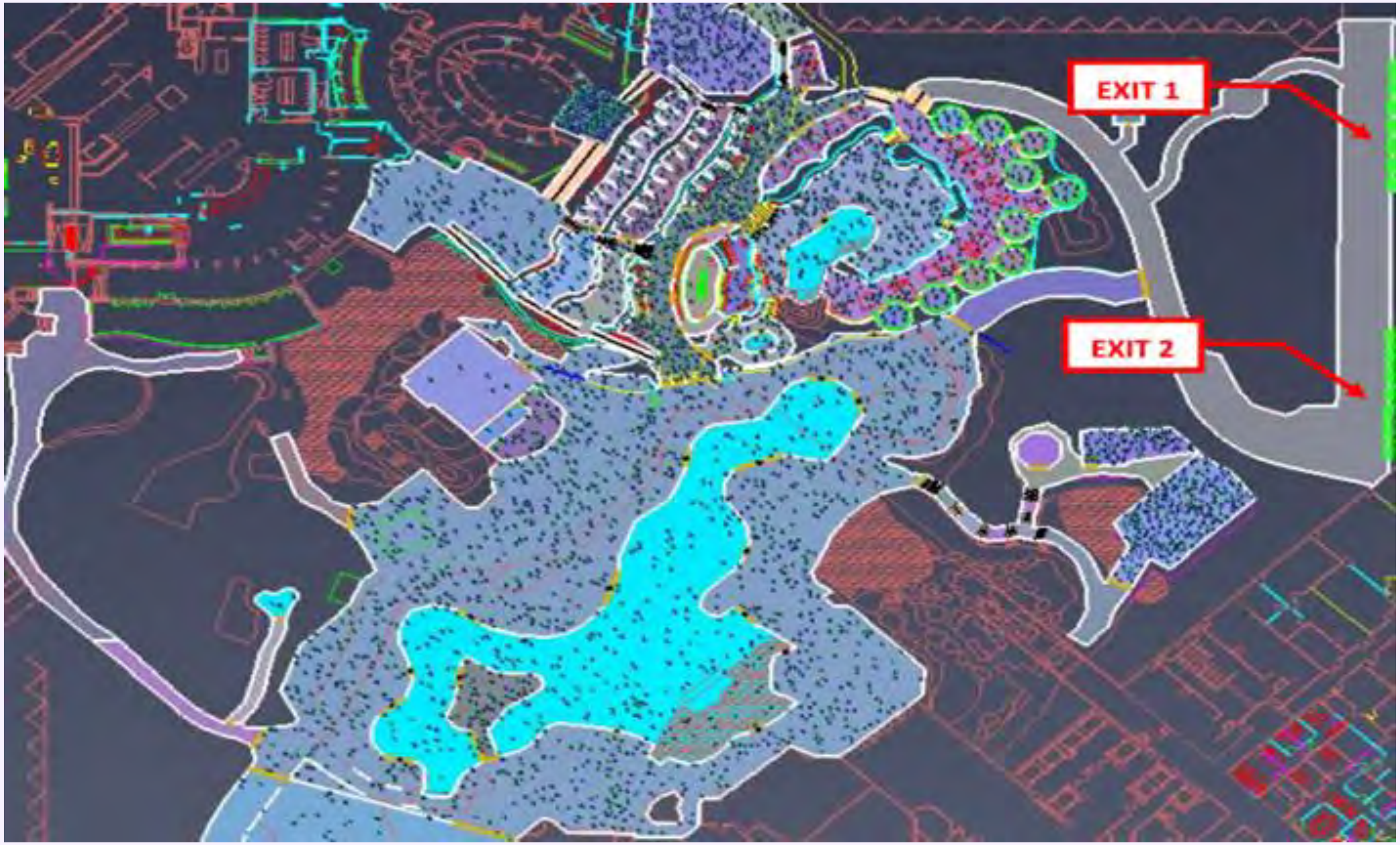


PERFORMANCE-BASED DESIGN

Closed Exit

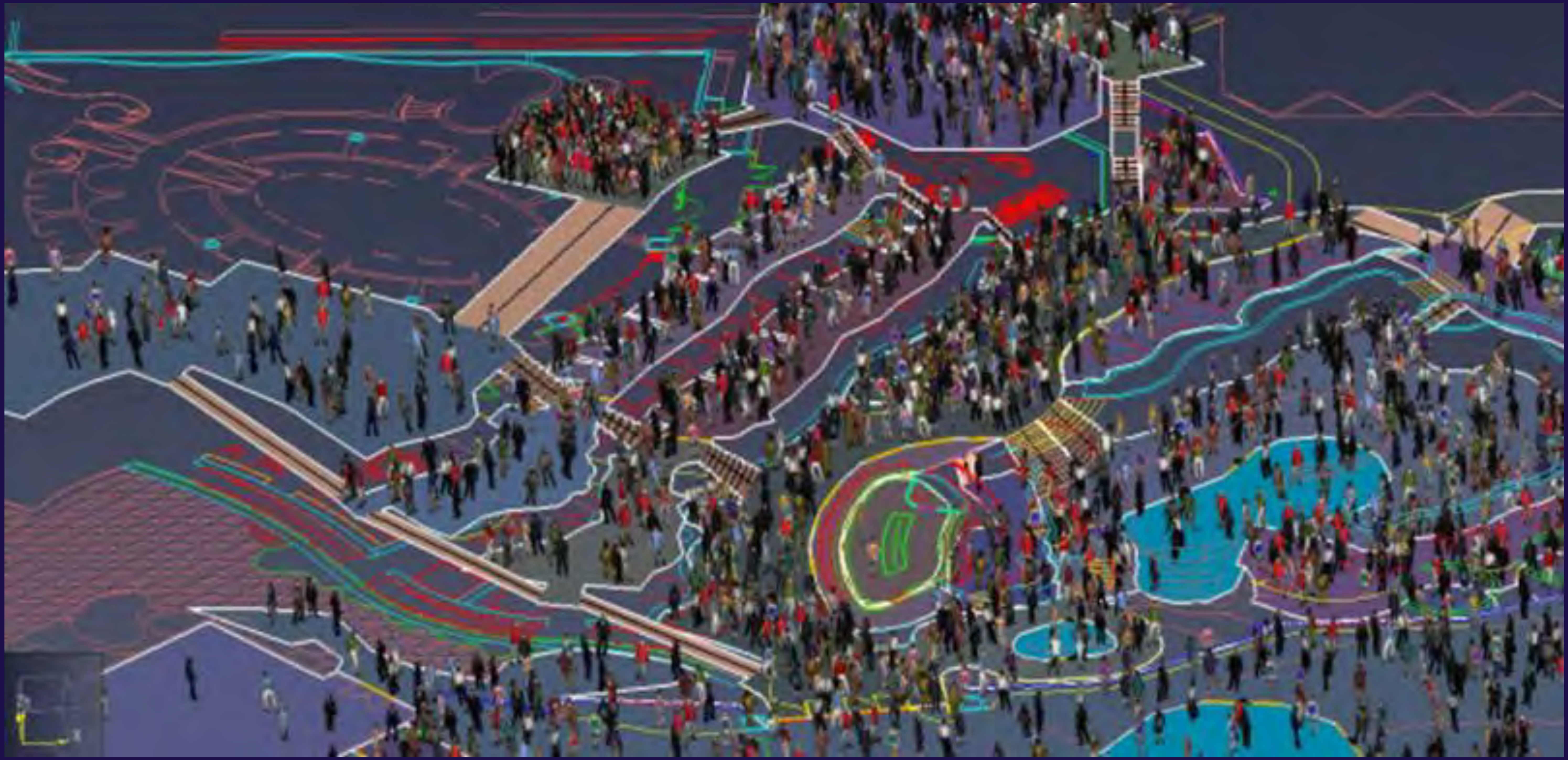
PERFORMANCE-BASED DESIGN

POOL AT THE TROPICANA



PERFORMANCE-BASED DESIGN

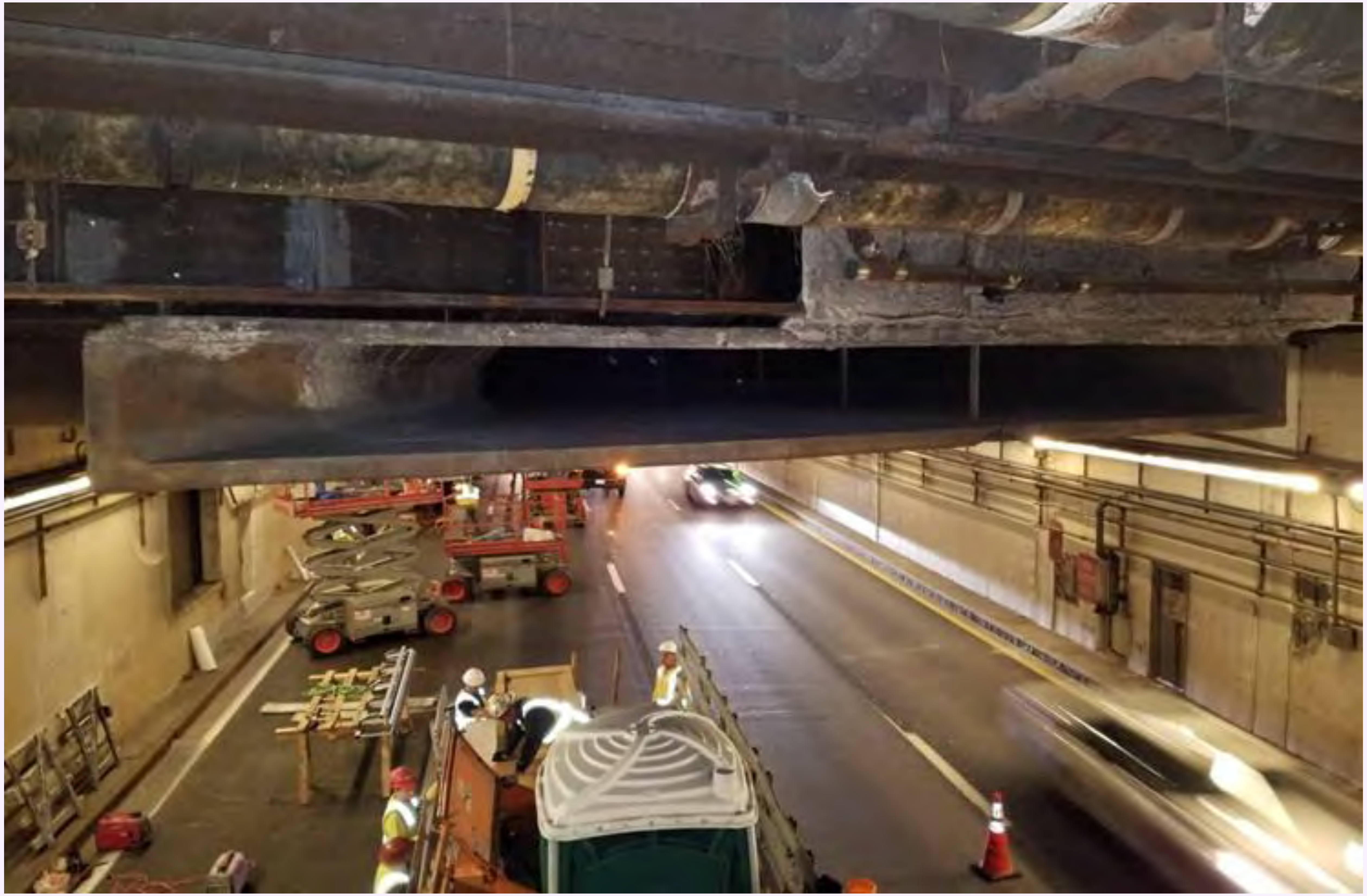
POOL AT THE TROPICANA



FIRE RESISTANCE RATINGS

AIA 2020

ENGINEERING JUDGMENT



FIRE RATING REQUIREMENTS

- 780 CMR (2015 IBC) Chapter 7 – Unamended (TYP)
- 703.2 FRR. Ratings must be determined in accordance with ASTM E 119 (UL 263).

UNLESS:

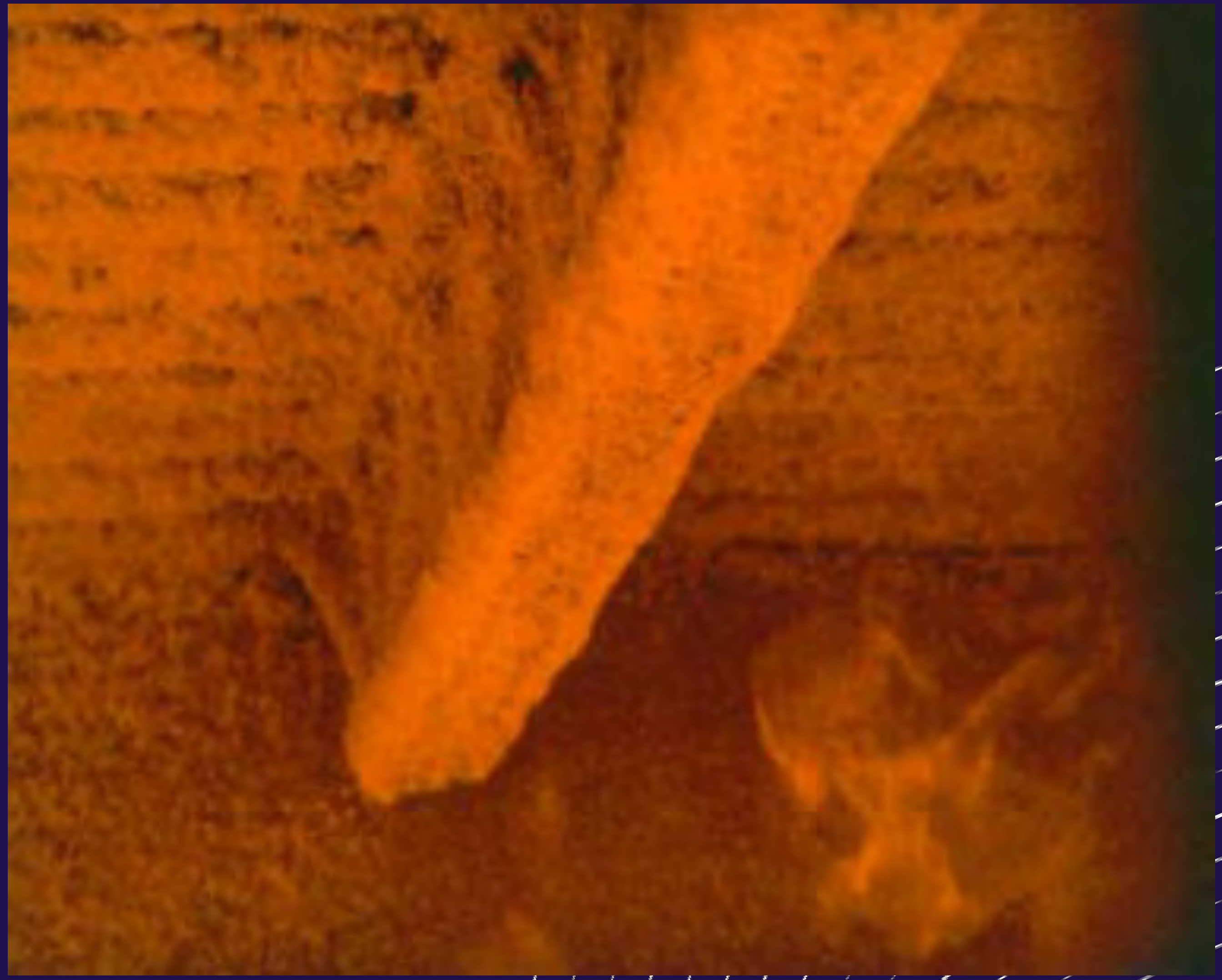
- 703.3 Alternative methods for determining FRR. Five methods available.

FIRE RATING REQUIREMENTS

- Designs documented in approved sources (e.g. SFPE handbook)
- Prescriptive designs outlined in Section 721
- Calculations in accordance with Section 722
- Engineering analysis based on comparative design tested under ASTM E 119
- Alternative methods allowed by the AHJ.
  - 104.11: The code doesn't intend to prevent the installation certain materials or prohibit any design that isn't specifically prescribed. The building official has the authority to approve an alternative which is satisfactory and meets the intent of the code.
- Certified by approved agencies (e.g. UL, ICC ESR)

FIRE RATING REQUIREMENTS

- ASTM E119
- Furnace test
- Success criteria varies
- Beam v. column v. wall v. floor ceiling



FIRE RATING REQUIREMENTS

E 119 ACCEPTANCE CRITERIA

UNREST. BEAM

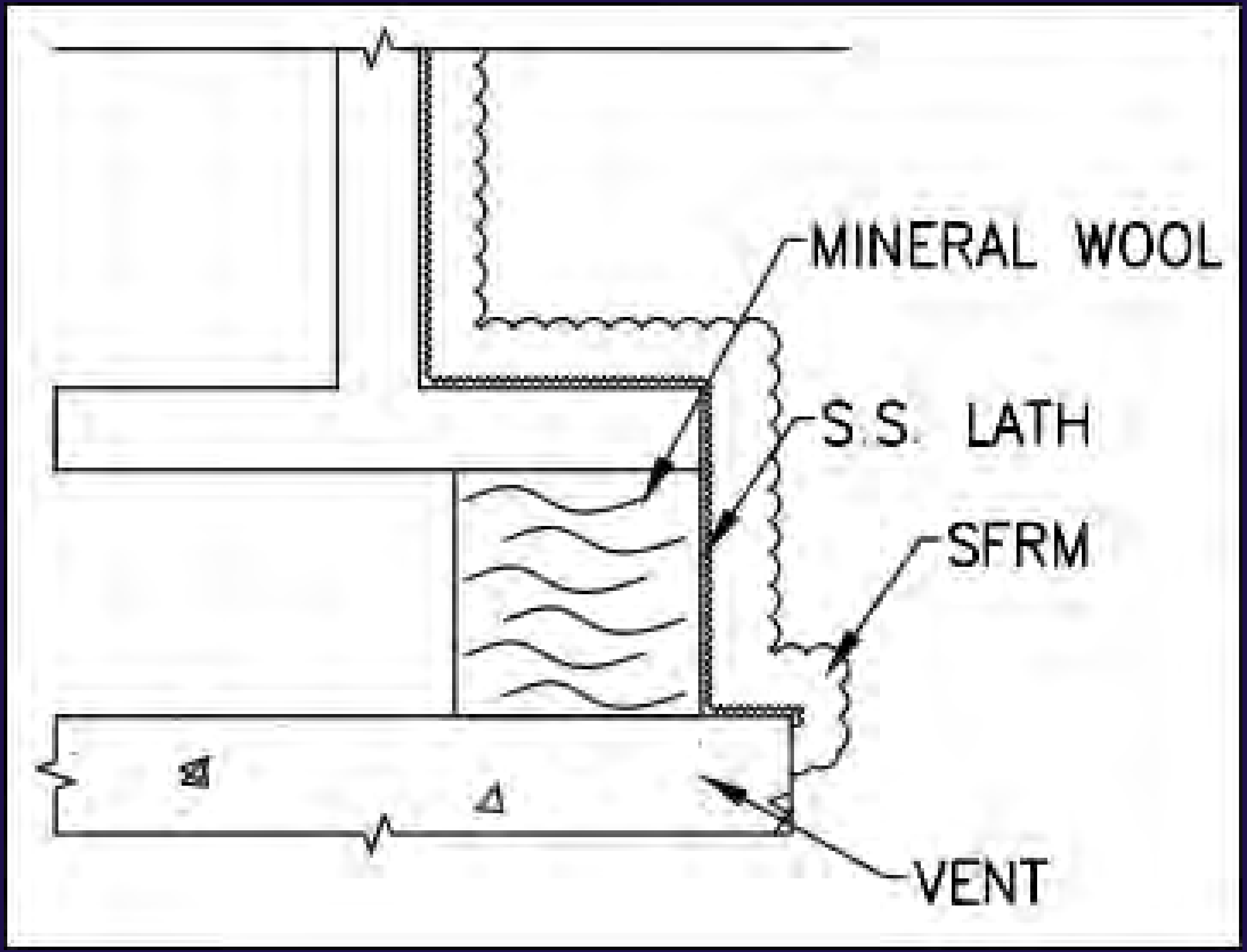
32.1.3 For specimens employing steel structural members (beams, open-web steel joists, etc.), spaced more than 4 ft (1.2 m) on centers, the temperature of the steel shall not have exceeded 1300°F (704°C) at any location during the classification period nor shall the average temperature recorded by four thermocouples at any section have exceeded 1100°F (593°C) during the classification period.

WALL

48.1.1 The average temperature rise of any set of thermocouples for each class of element being protected is more than 250°F (139°C) above the initial temperature, or

48.1.2 The temperature rise of any one thermocouple of the set for each class of element being protected is more than 325°F (181°C) above the initial temperature.

CHAPTER 7: Field Conditions/EJ



CHAPTER 7: Field Conditions/EJ

UL Fire Resistive Directory, Section CHPX.R4339:
Spanning gaps between a beam or column and a rated concrete block wall – Guidance provided.

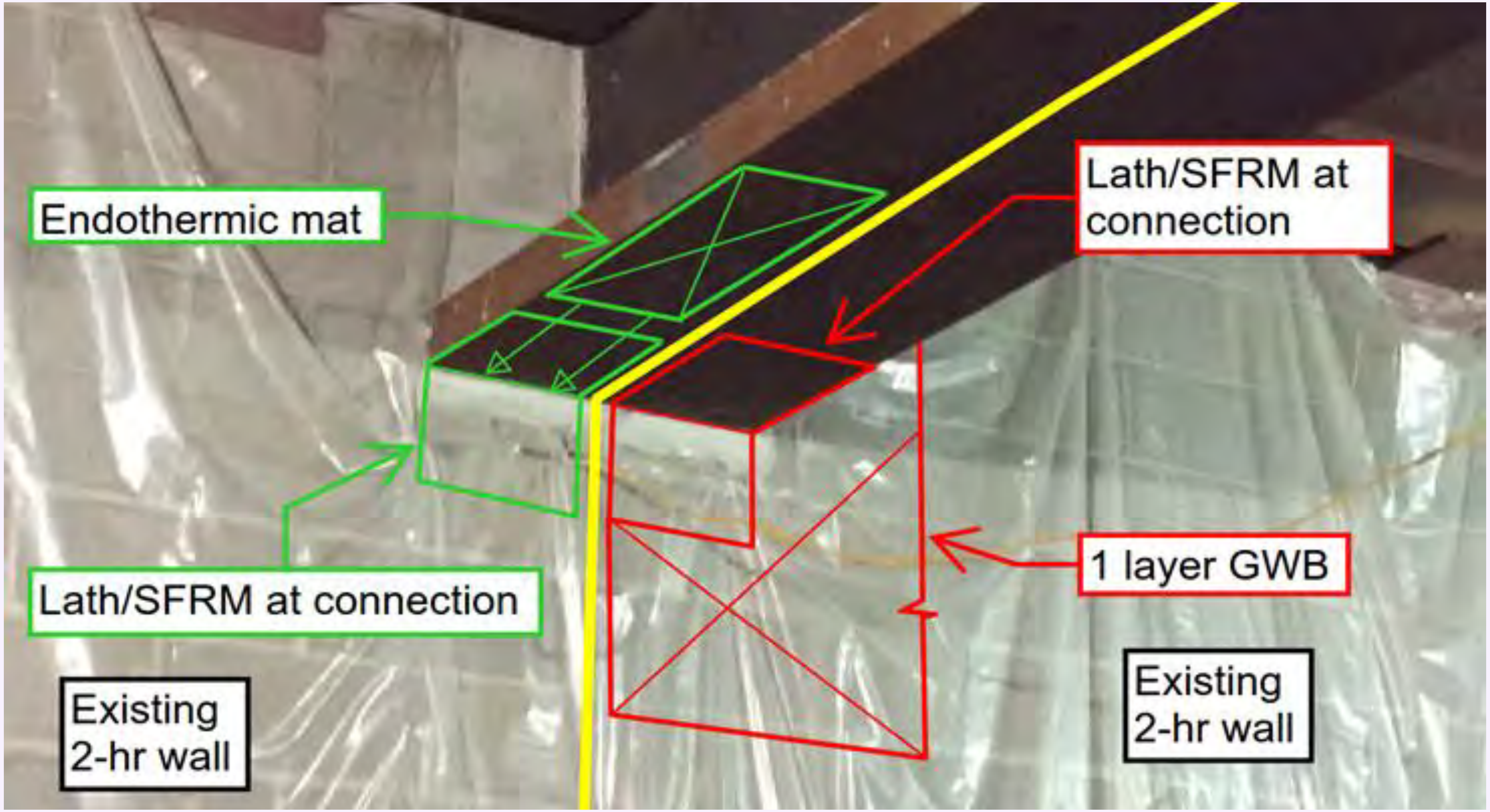
4. Spanning Gaps Between a Wide Flange Steel Beam and a Rated Concrete Block Wall

When the wide flange steel beam in a floor-or-roof ceiling assembly is in close proximity and parallel to a rated concrete block wall, preventing the entire perimeter of the beam from being properly protected with Spray-Applied Fire Resistive Material (SFRM), the following method may be used to maintain the fire resistance rating of the floor-or-roof ceiling assembly. Minimum 3.4 lb/sq yd galvanized or painted expanded steel lath shall be used to bridge the gap between the beam and the masonry wall. The lath shall be mechanically attached by welds, screws or powder-actuated fasteners to the lower flange of the beam and the masonry facade. The SFRM shall be applied to the entire metal lath surface at the thickness specified for the steel beam in the chosen design for the desired rating. The steel beam, lath and masonry wall shall be clean and free of dirt, loose scale and oil. The gap may not be greater than 18 in. The concrete block wall must have an hourly rating equal to or greater than the restrained assembly rating. The steel floor units between the beam and masonry wall need not be sprayed due to the protection provided by the box enclosure formed by the metal lath and the SFRM.

5. Spanning Gaps Between a Vertical Column and a Rated Concrete Block Wall

Where a vertical column is in close proximity to a rated concrete block wall, preventing the entire perimeter of the column from being properly protected with Spray-Applied Fire Resistive Material (SFRM), one of the following methods may be used to maintain the fire resistance rating of the column assembly, depending on the depth of the gap. The protection on the remaining sides of the column shall be in accordance with the requirements in the specified column design. The concrete block wall must have an hourly rating equal to or greater than the column rating. a) For gaps greater than 2 in. and up to 18 in., minimum 3.4 lb/sq yd galvanized or painted expanded steel lath shall be used to bridge the gap between the column and the masonry wall. The lath shall be mechanically attached by welds, screws or powder-actuated fasteners to both flanges of the column and the masonry facade. The SFRM shall be applied to the entire metal lath surface at the thickness specified for the column in the chosen design for the desired rating. The column, lath and masonry wall shall be clean and free of dirt, loose scale and oil. b) For gaps 2 in. or less, no metal lath is required to bridge the gap. The gap shall be completely filled with the SFRM.

CHAPTER 7: Field Conditions/EJ



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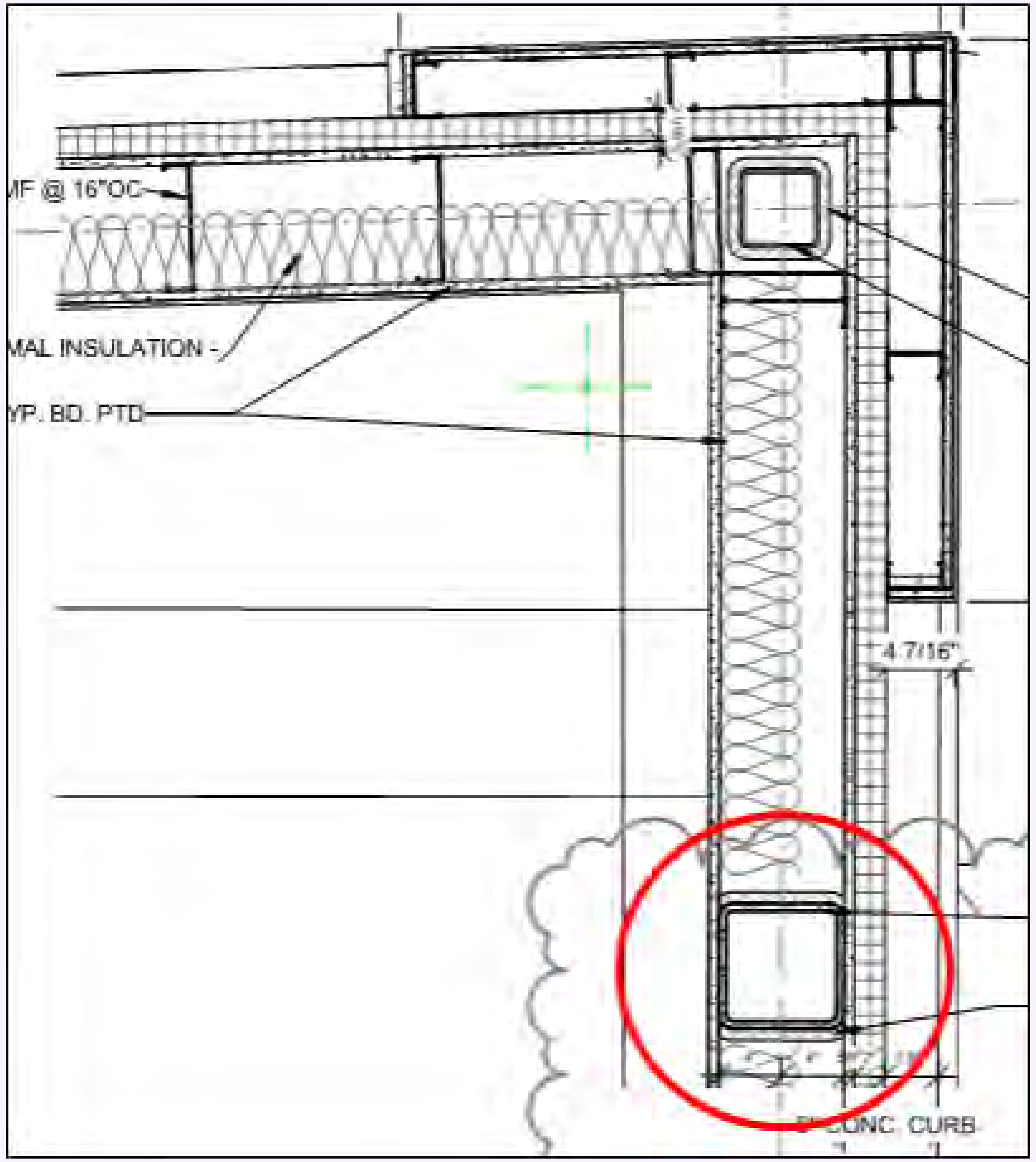
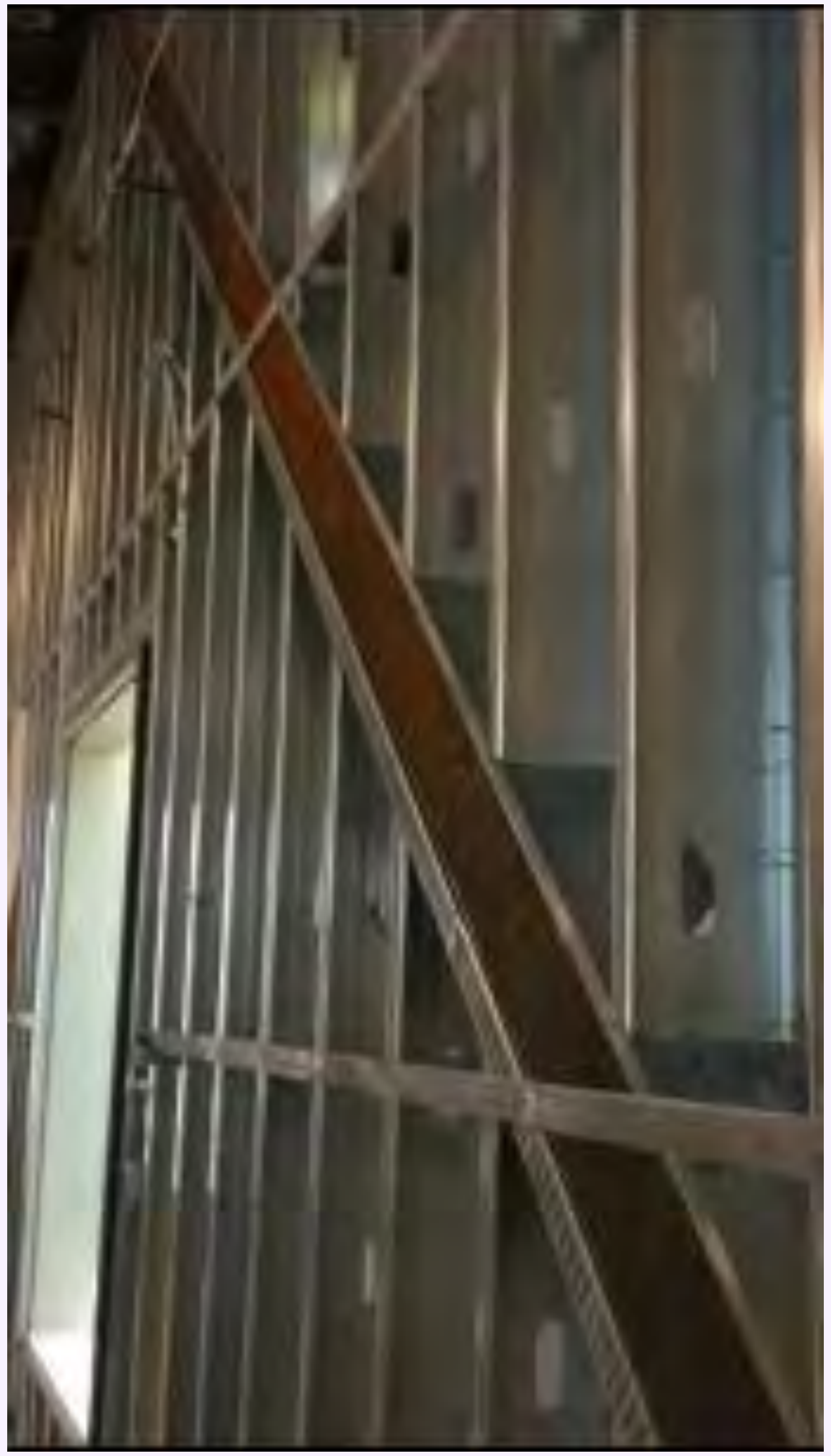
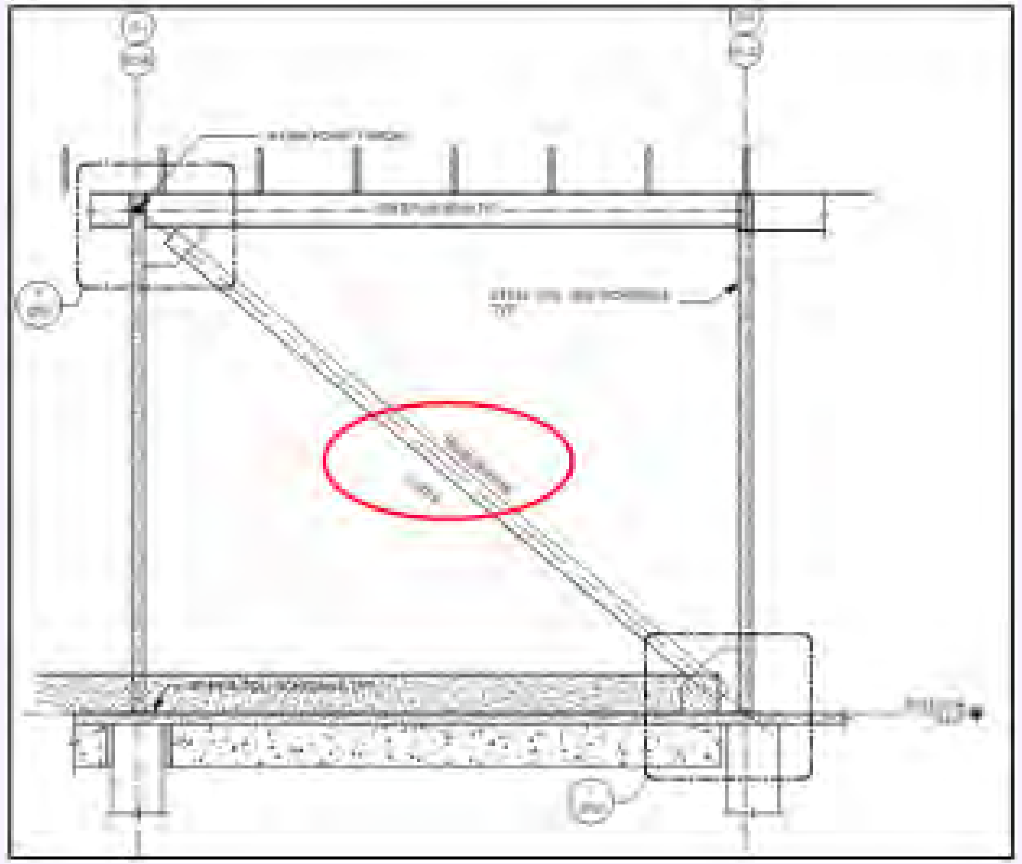






CHAPTER 7: Field Conditions/EJ

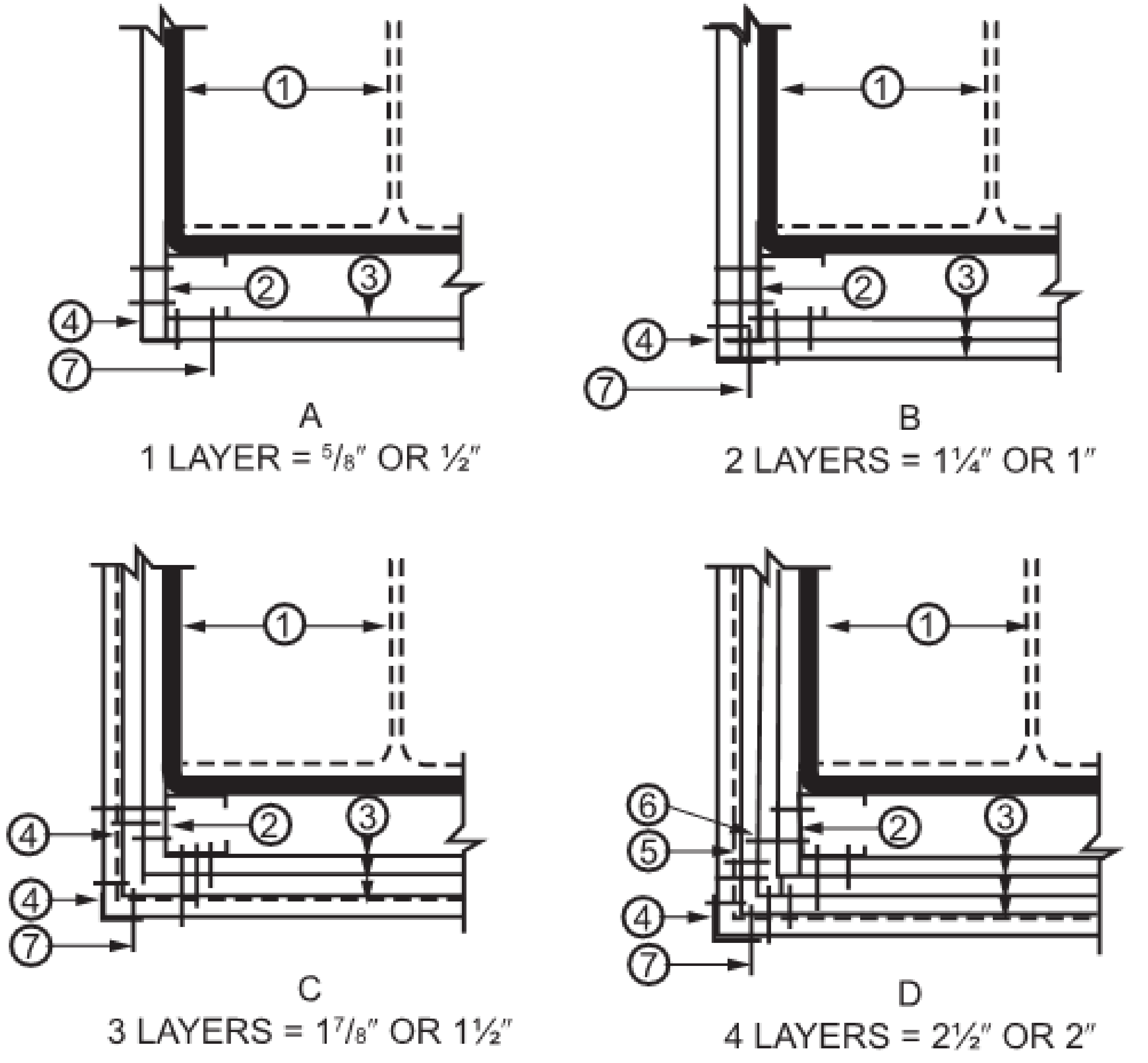
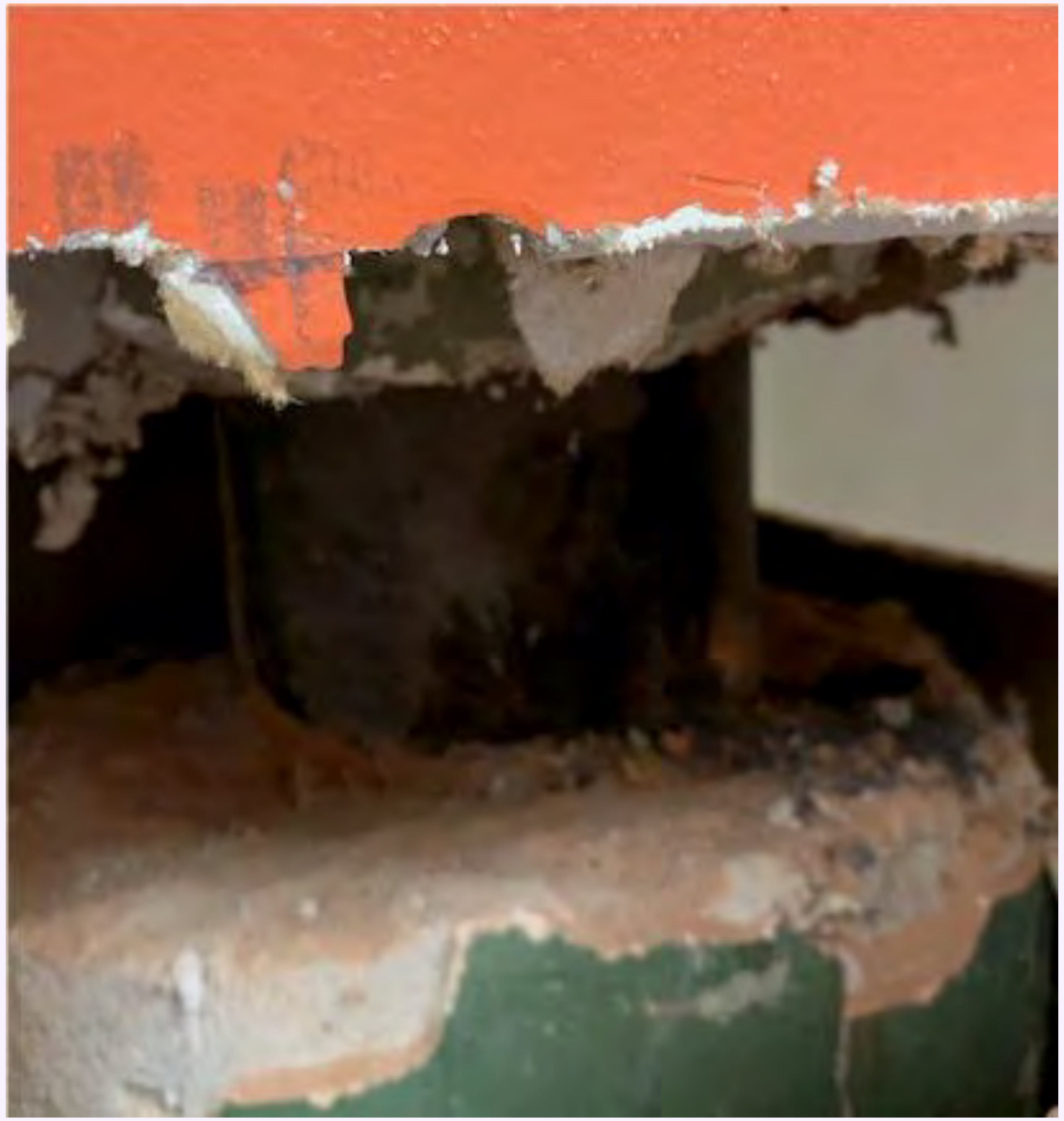


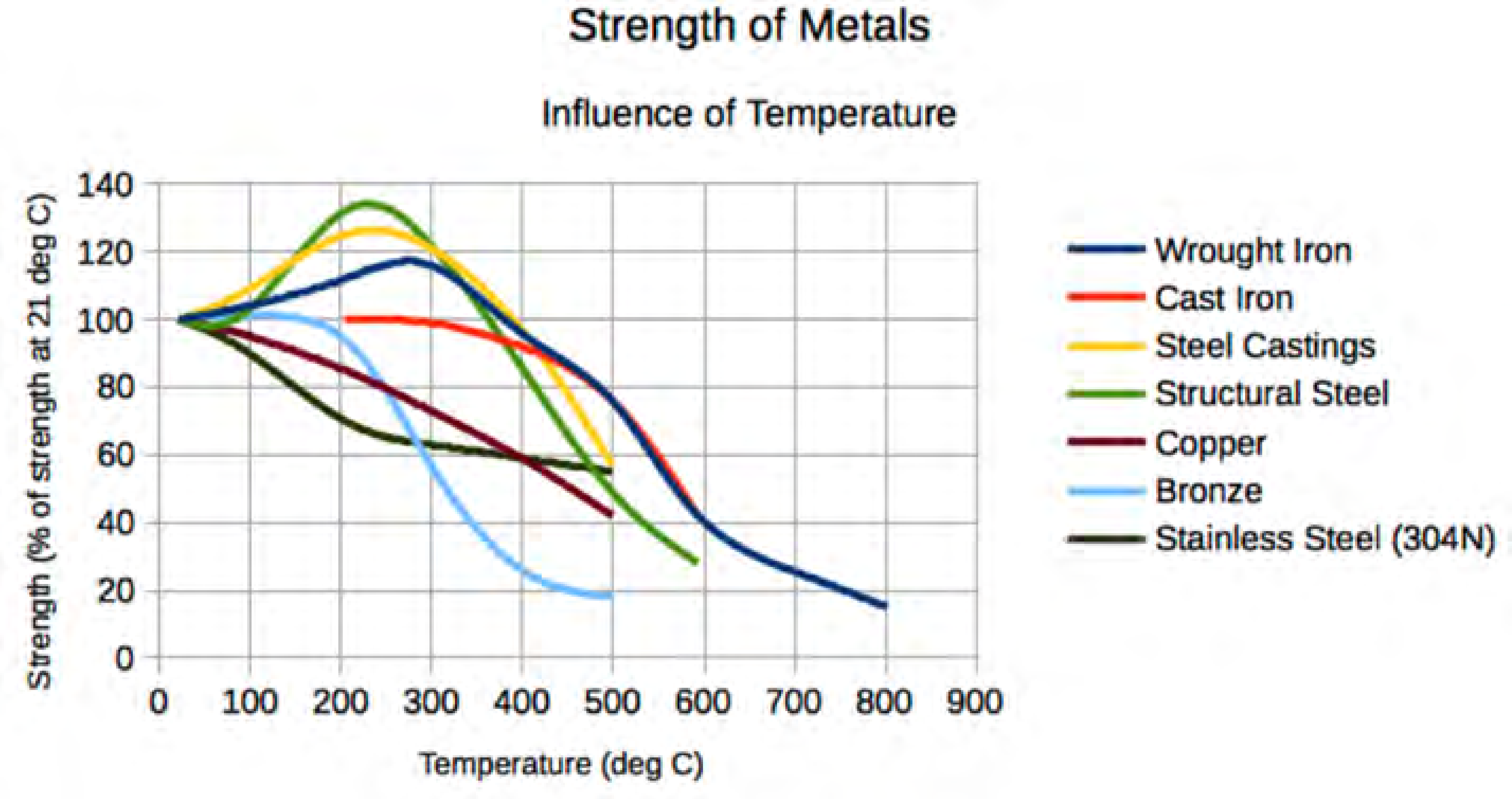
FIGURE 722.5.1(3)
GYPSUM-PROTECTED STRUCTURAL STEEL COLUMNS WITH STEEL STUD/SCREW ATTACHMENT SYSTEM

CHAPTER 7: Field Conditions/EJ

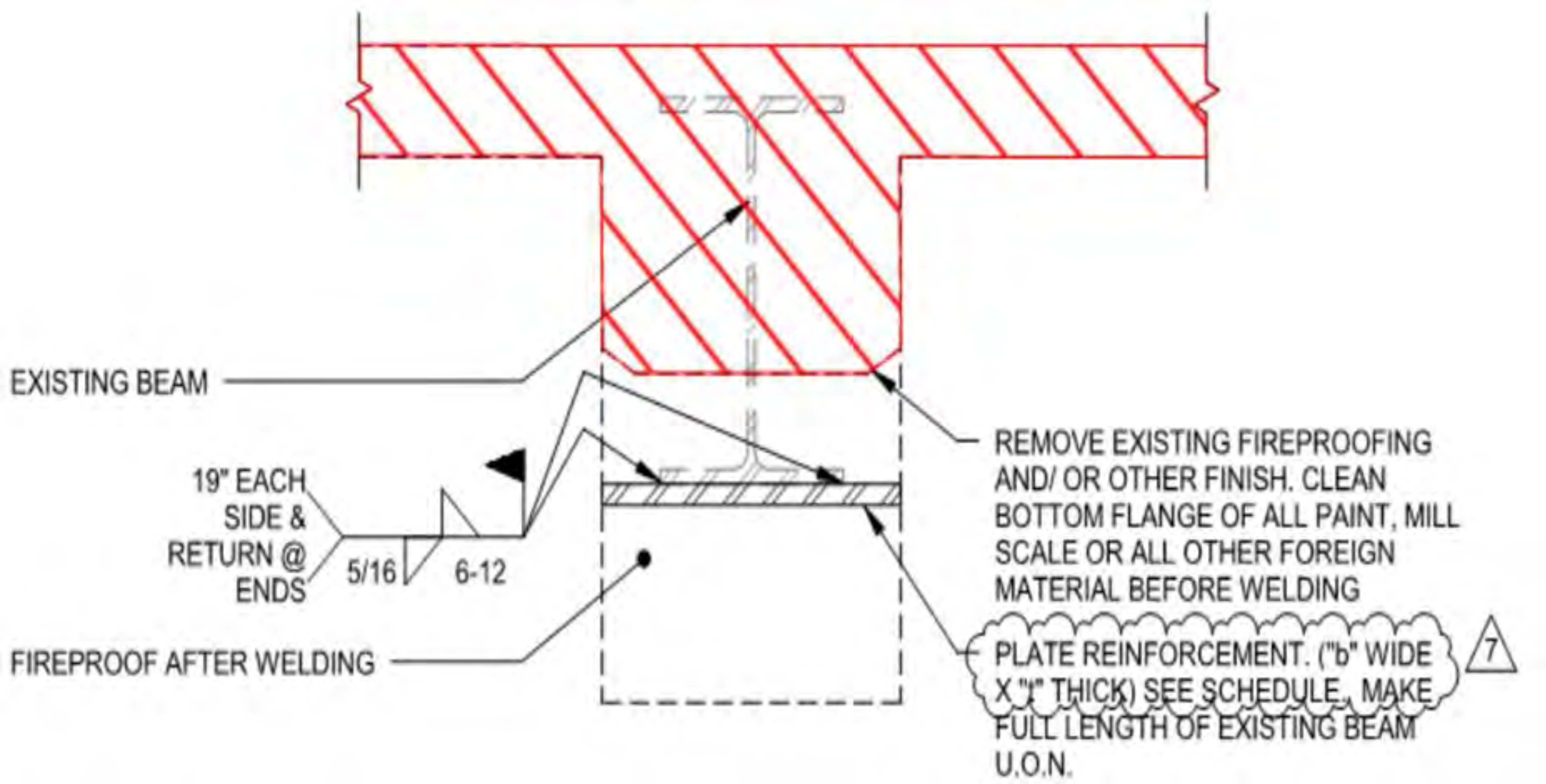


CHAPTER 7: Field Conditions/EJ

Material	Thermal Conductivity (W/m.K)	Specific Heat Capacity (J/kg^{0}C)	Coefficient of Linear Expansion at 20^{0}C
0.5% Carbon Steel	54	465	11.1
Cast Iron	55	460.5	9.0



CHAPTER 7: Field Conditions/EJ



CHAPTER 7: Field Conditions/EJ

CHAPTER 7: Field Conditions/EJ

Thickness when applied over expanded metal lath					
Density	Minimum Thickness (inches)				
	1 Hr.	1 1/2 Hr.	2 Hr.	3 Hr.	4 Hr.
Low	1 1/2	2 1/16	2 5/8	3 3/4	4 7/8
Medium	1 1/2	2 1/16	2 5/8	3 3/4	4 7/8
High	1 1/2	1 15/16	2 3/8	3 1/4	4 5/16

CHAPTER 7: Field Conditions/EJ

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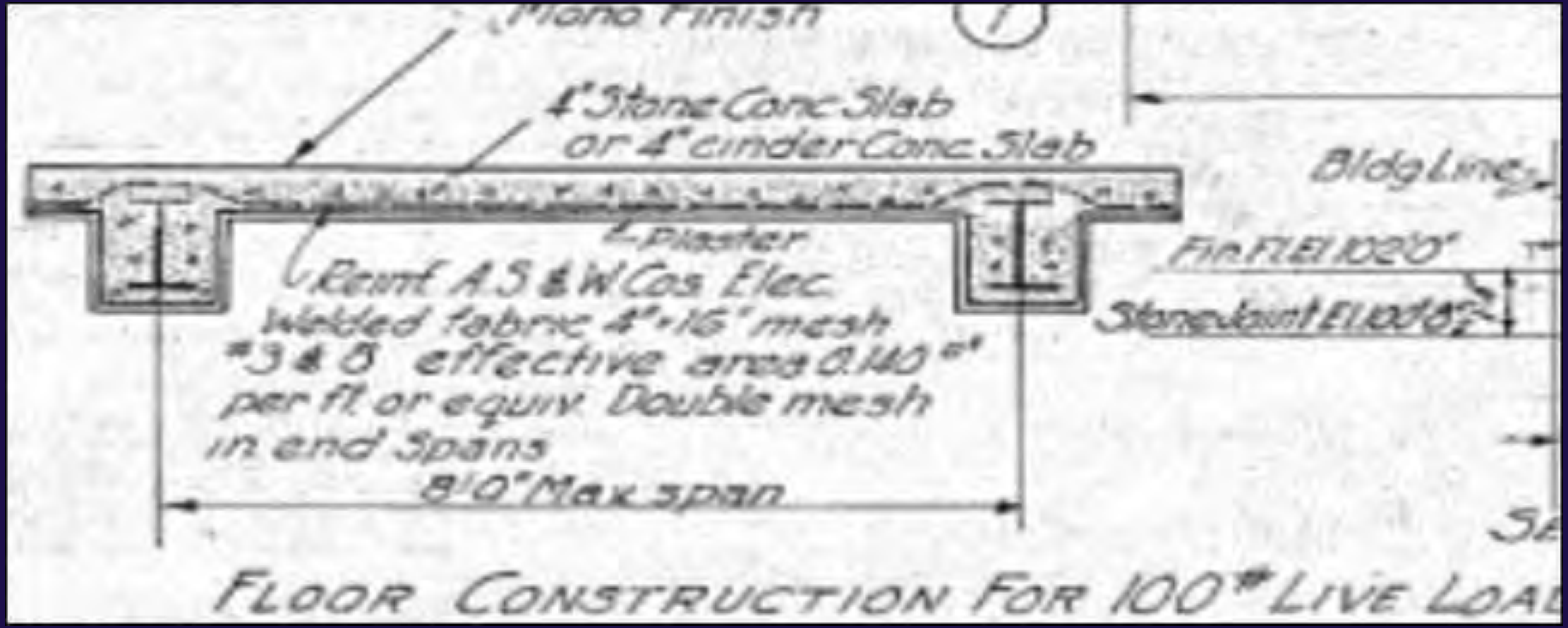
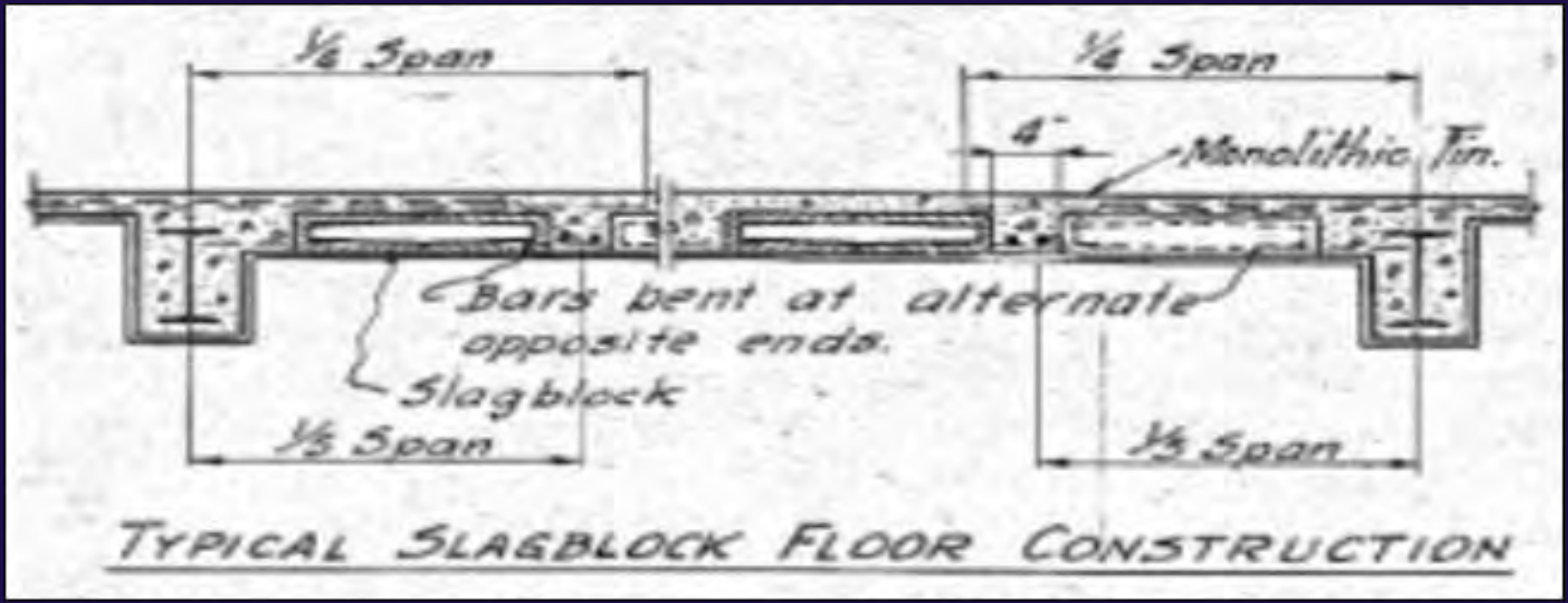
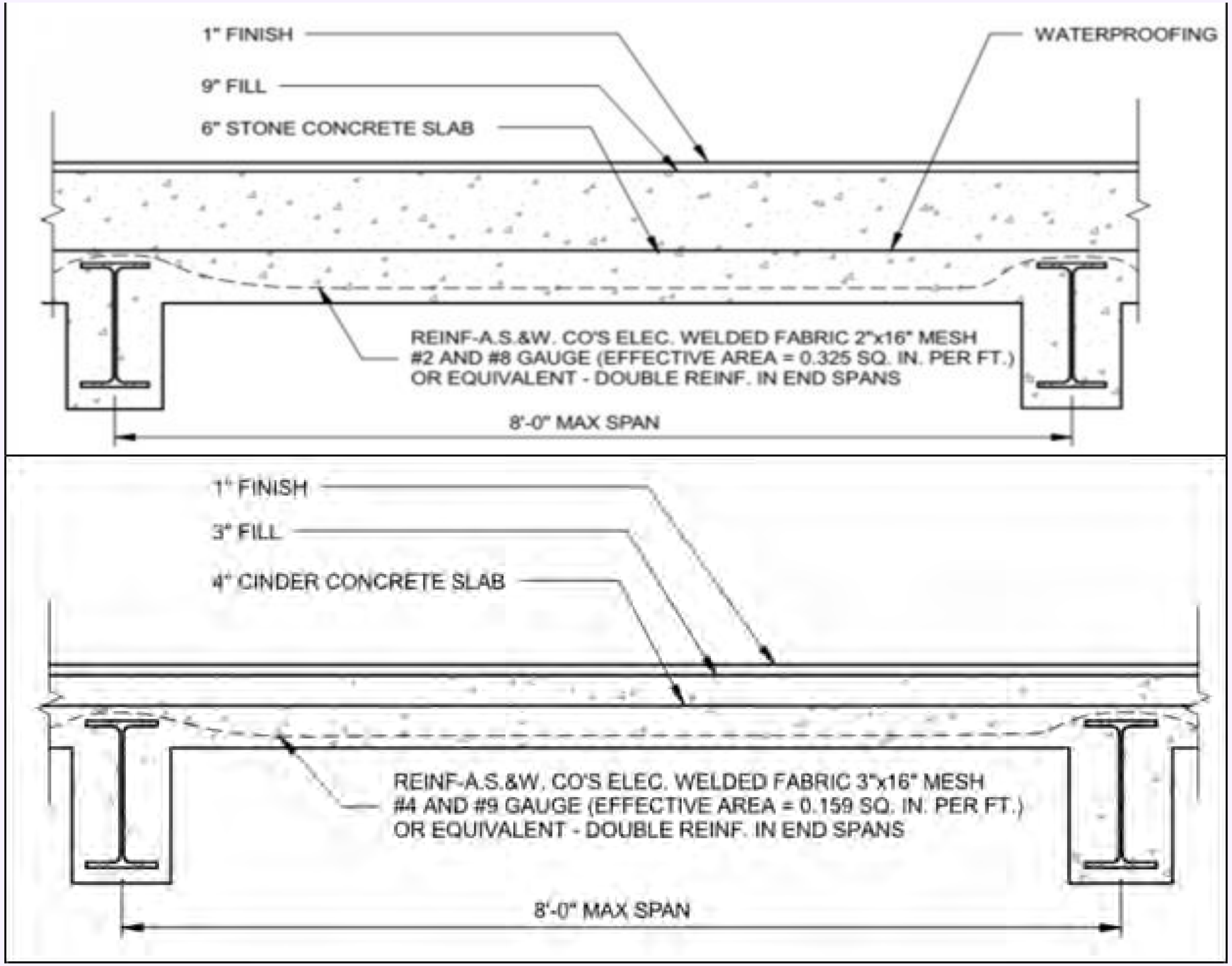




CHAPTER 7: Field Conditions/EJ



CHAPTER 7: Field Conditions/EJ

TABLE 722.2.2.1
MINIMUM SLAB THICKNESS (inches)

CONCRETE TYPE	FIRE-RESISTANCE RATING (hours)				
	1	$1^1/_2$	2	3	4
Siliceous	3.5	4.3	5	6.2	7
Carbonate	3.2	4	4.6	5.7	6.6
Sand-lightweight	2.7	3.3	3.8	4.6	5.4
Lightweight	2.5	3.1	3.6	4.4	5.1

CHAPTER 7: Field Conditions/EJ

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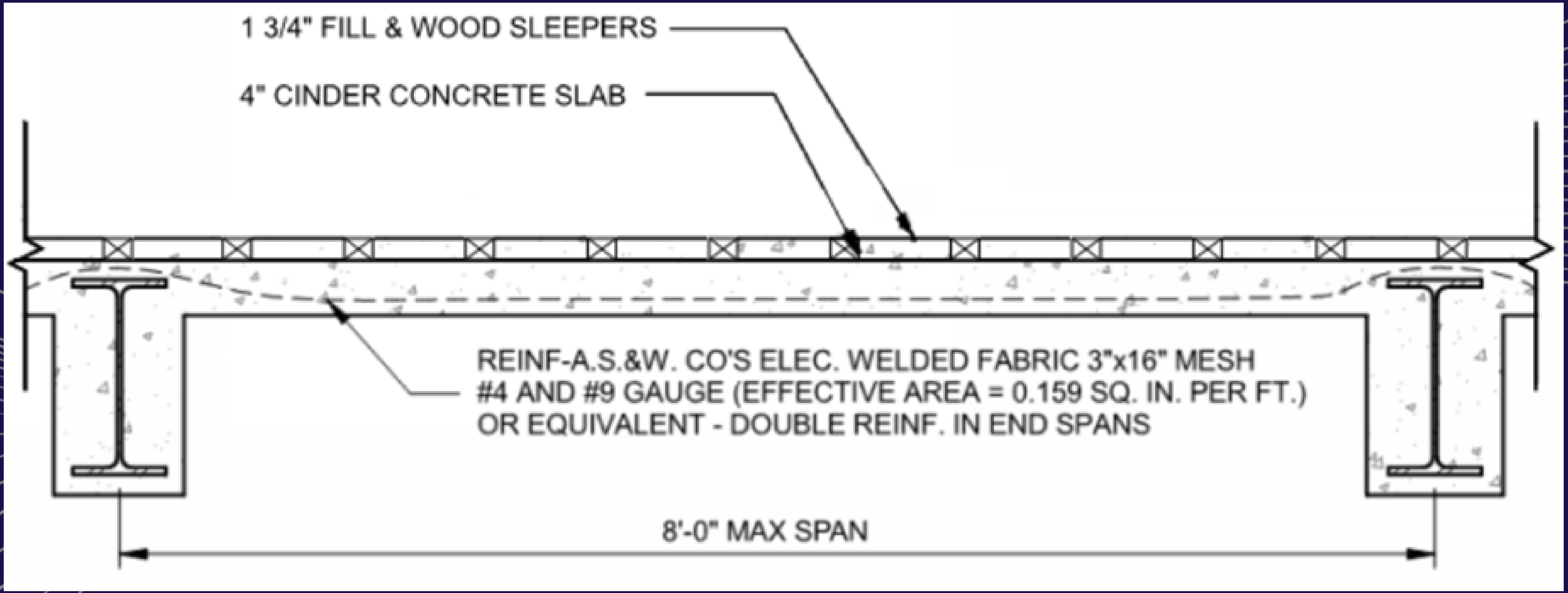

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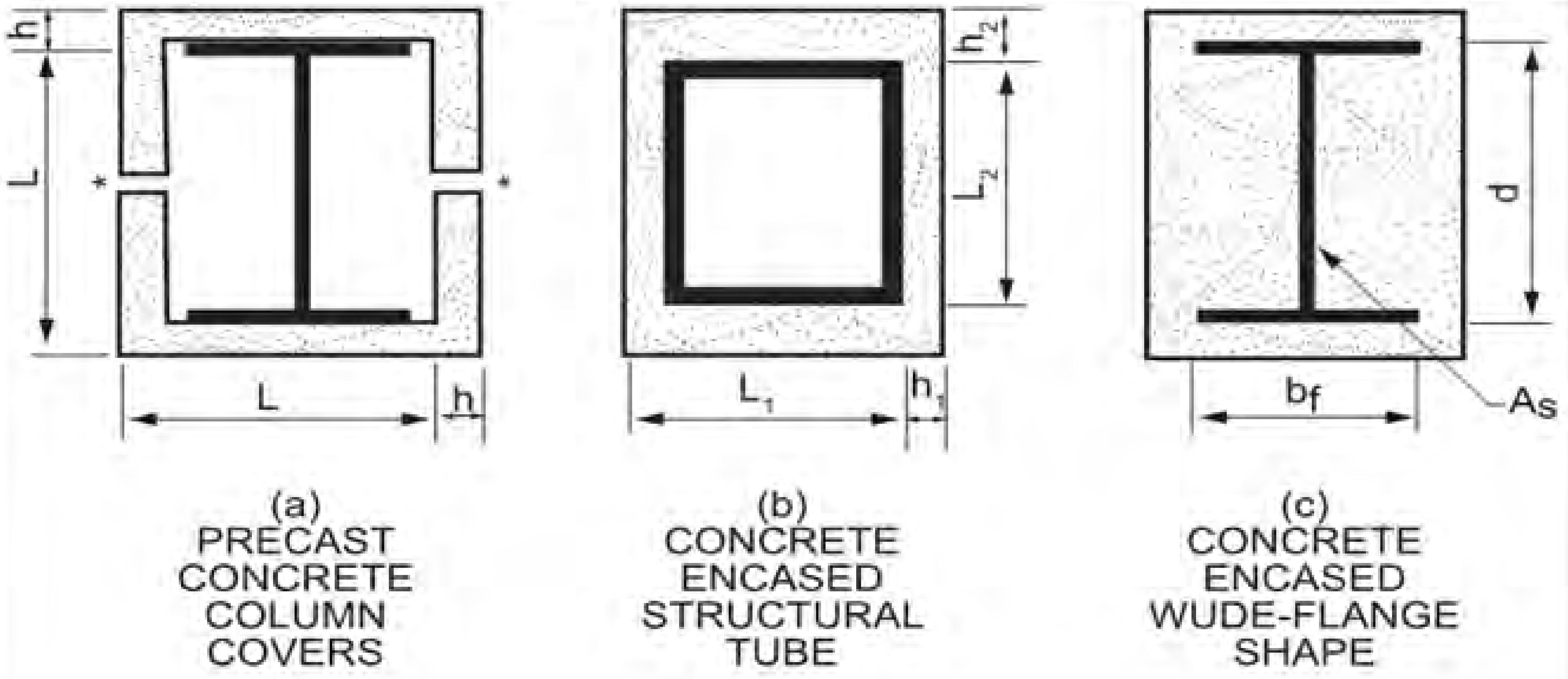
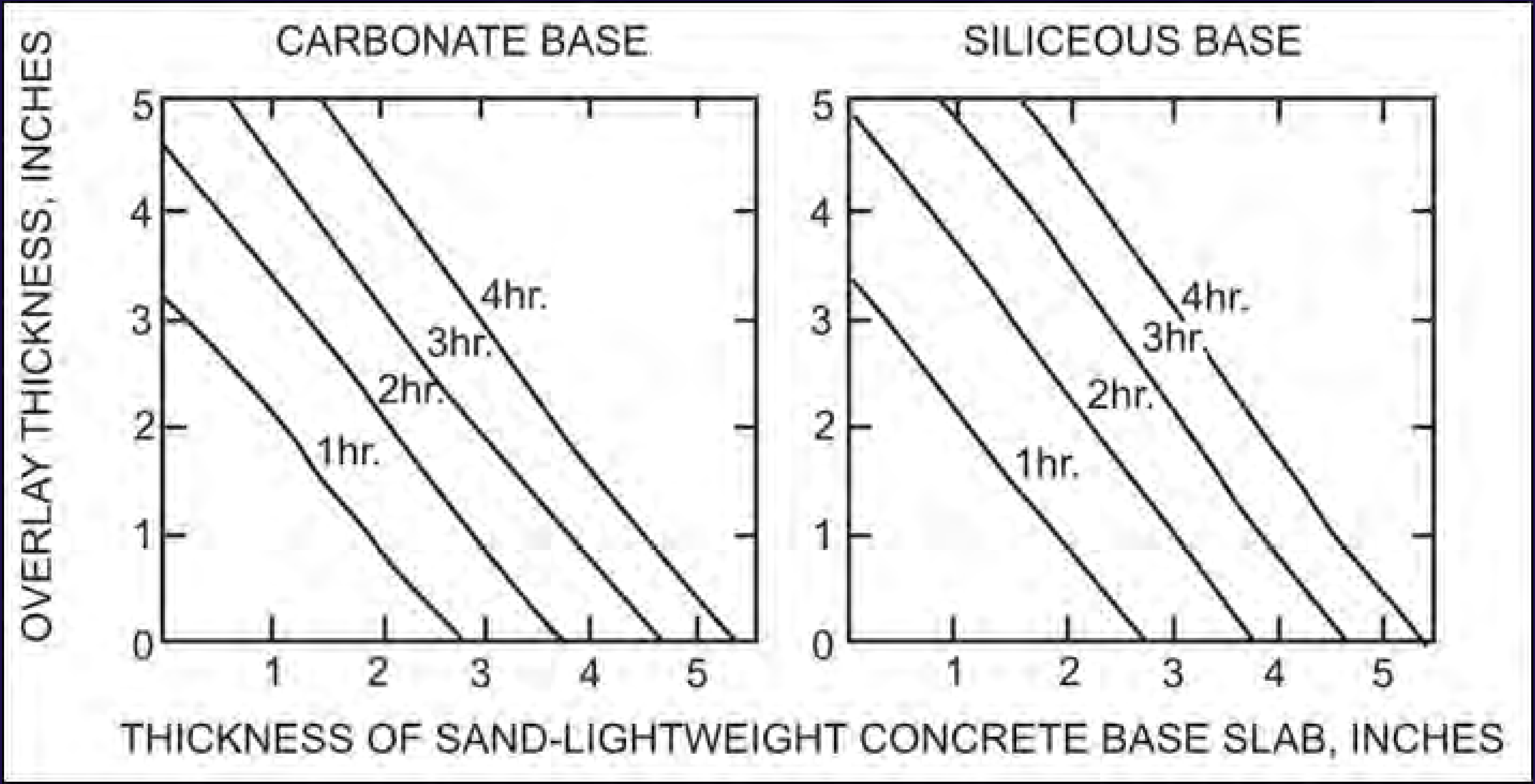


FIGURE 722.5.1(6)
CONCRETE PROTECTED STRUCTURAL STEEL COLUMNS[a,b]

CHAPTER 7: Field Conditions/EJ

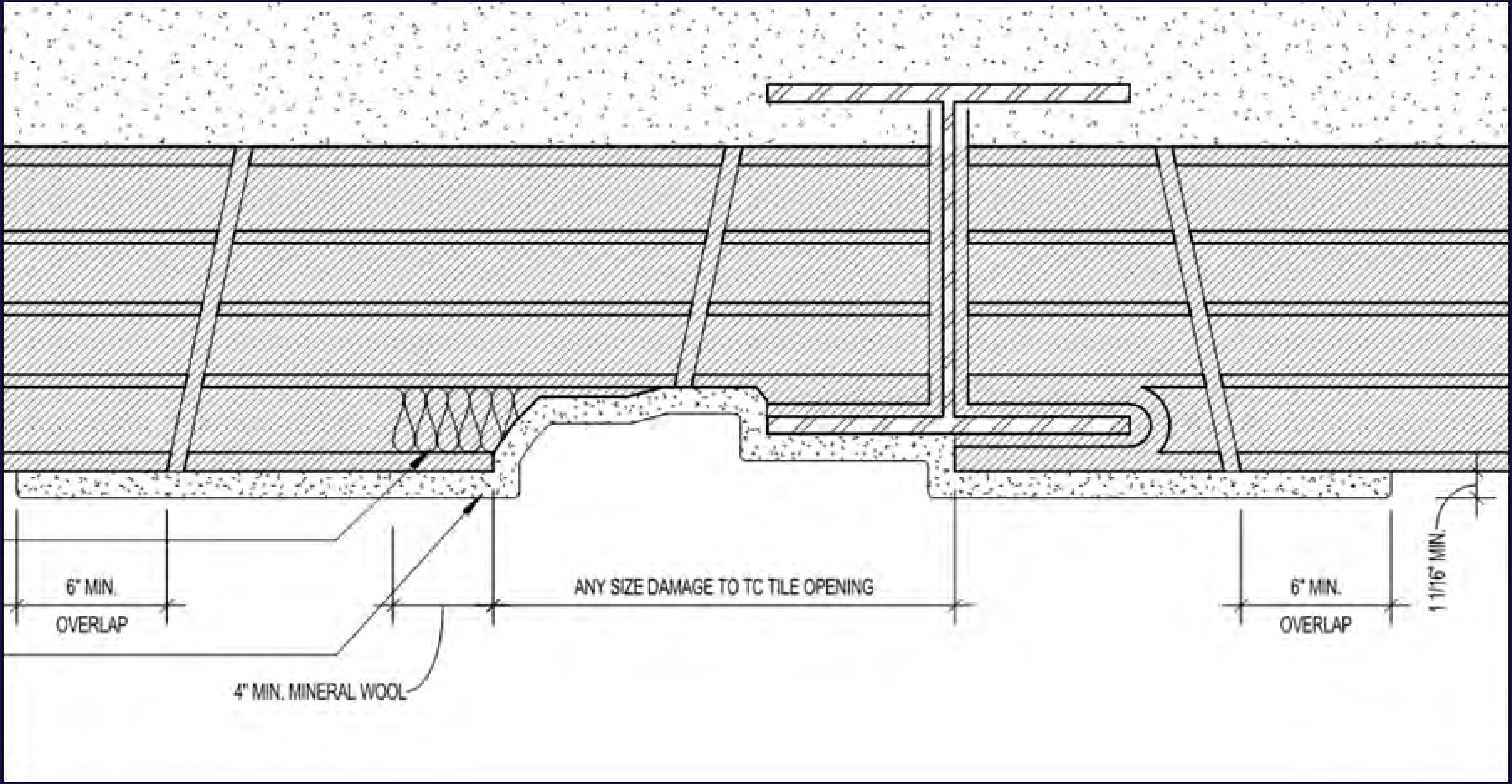


CHAPTER 7: Field Conditions/EJ

ENCAPSULANT DEBONDING

Figure 1: Photos of Damage to Condition Passive Fire Resistance Features

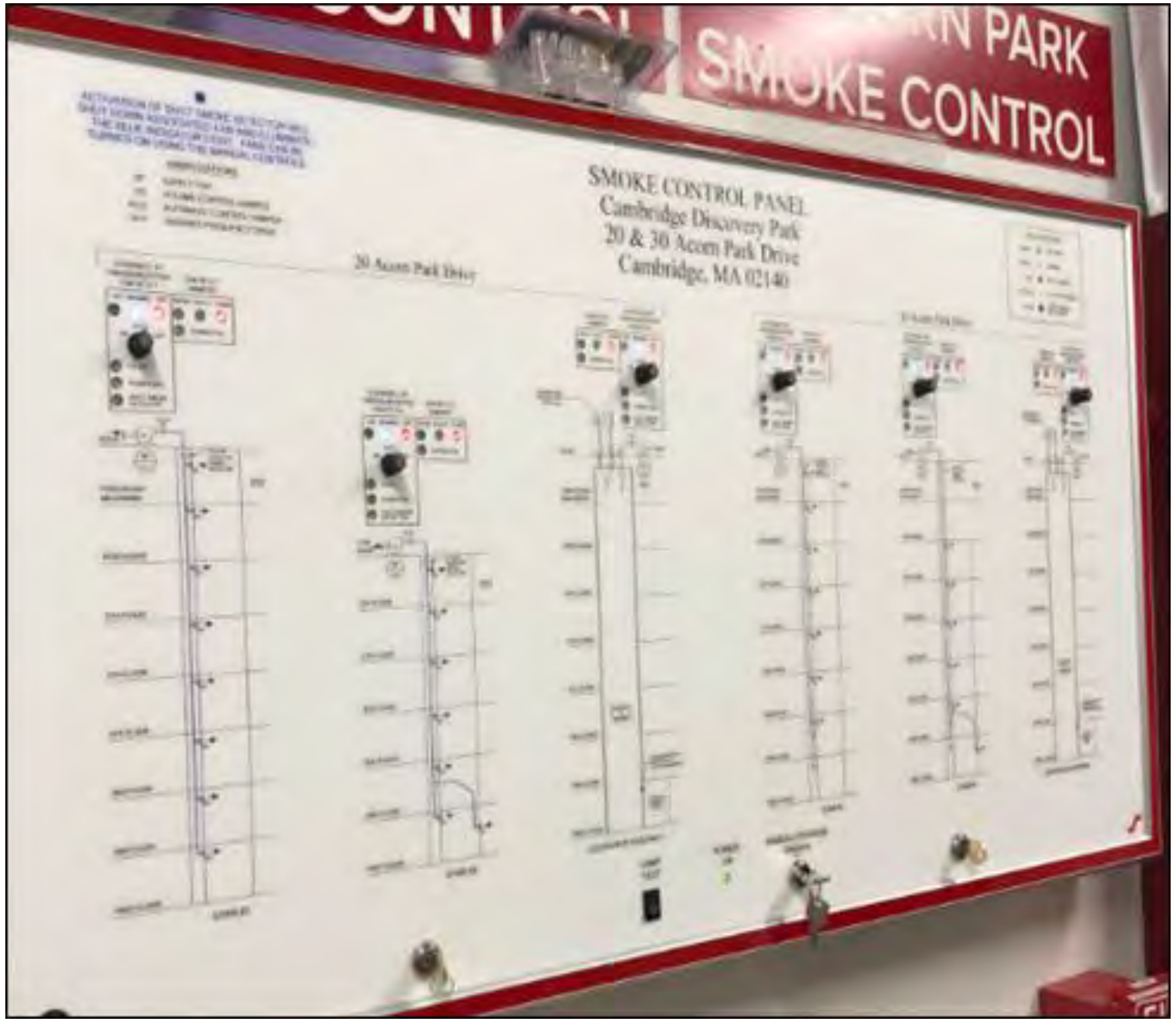

5
4
3
2


6" MIN.
OVERLAP
ANY SIZE DAMAGE TO TC TILE OPENING
6" MIN.
OVERLAP
1 1/16" MIN.
4" MIN. MINERAL WOOL

SMOKE CONTROL


SF-4-2
STAIR PRESSURIZATION
STAIR# 4

SMOKE CONTROL



APPLICABLE CODES AND STANDARDS

INTERNATIONAL BUILDING CODE (IBC)

- 404.5 Smoke Control. A smoke control system shall be installed in accordance with IBC Section 909.
- 909.8 Exhaust Method. When approved by the fire code official, mechanical smoke control for large enclosed volumes, such as in atriums or malls, shall be permitted to utilize the exhaust method. Smoke control systems using the exhaust method shall be designed in accordance with NFPA 92.
- 909.8.1 Smoke layer. The height of the lowest horizontal surface of the smoke layer interface shall be maintained at least 6 feet above any walking surface that forms a portion of a required egress system within the smoke zone.
- 909.4.6. Smoke control system must be capable of continued operation for 1.5 times the calculated egress time or 20 minutes (whichever is GREATER).

CODE SOLUTIONS

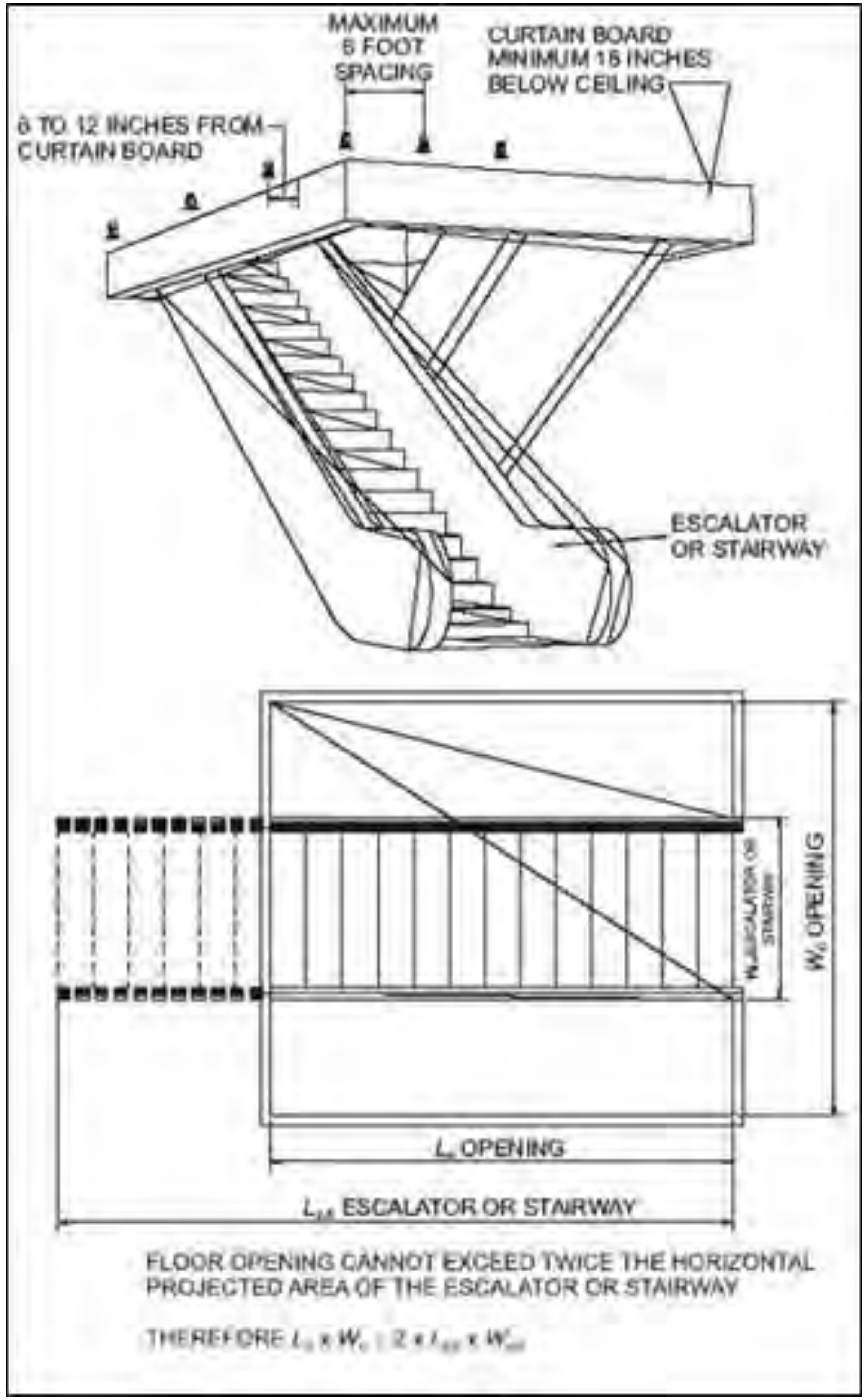
The Building Code is used to screen the need for a shaft enclosure

- Provides many individual exceptions (2015 IBC, Section 712)

- Floor opening analysis exceptions:
  - Residential dwelling unit
  - Escalator opening
  - Penetrations
  - Duct penetrations
  - Two-story openings
  - Parking garages
  - Mezzanines
  - Atrium
- Not all floor openings require smoke control

CODE SOLUTIONS

- Code options for floor openings:
  - Escalator opening with sprinkler protected draft curtain (IBC, Section 712.1.3.1)
- Not limited to escalators



CODE SOLUTIONS

CODE SOLUTIONS

- Code options for floor openings:
  - Two-story opening justification
  - Shaft enclosure (i.e. fire doors and shutters) (IBC, Section 713.11)
  - Lightwell

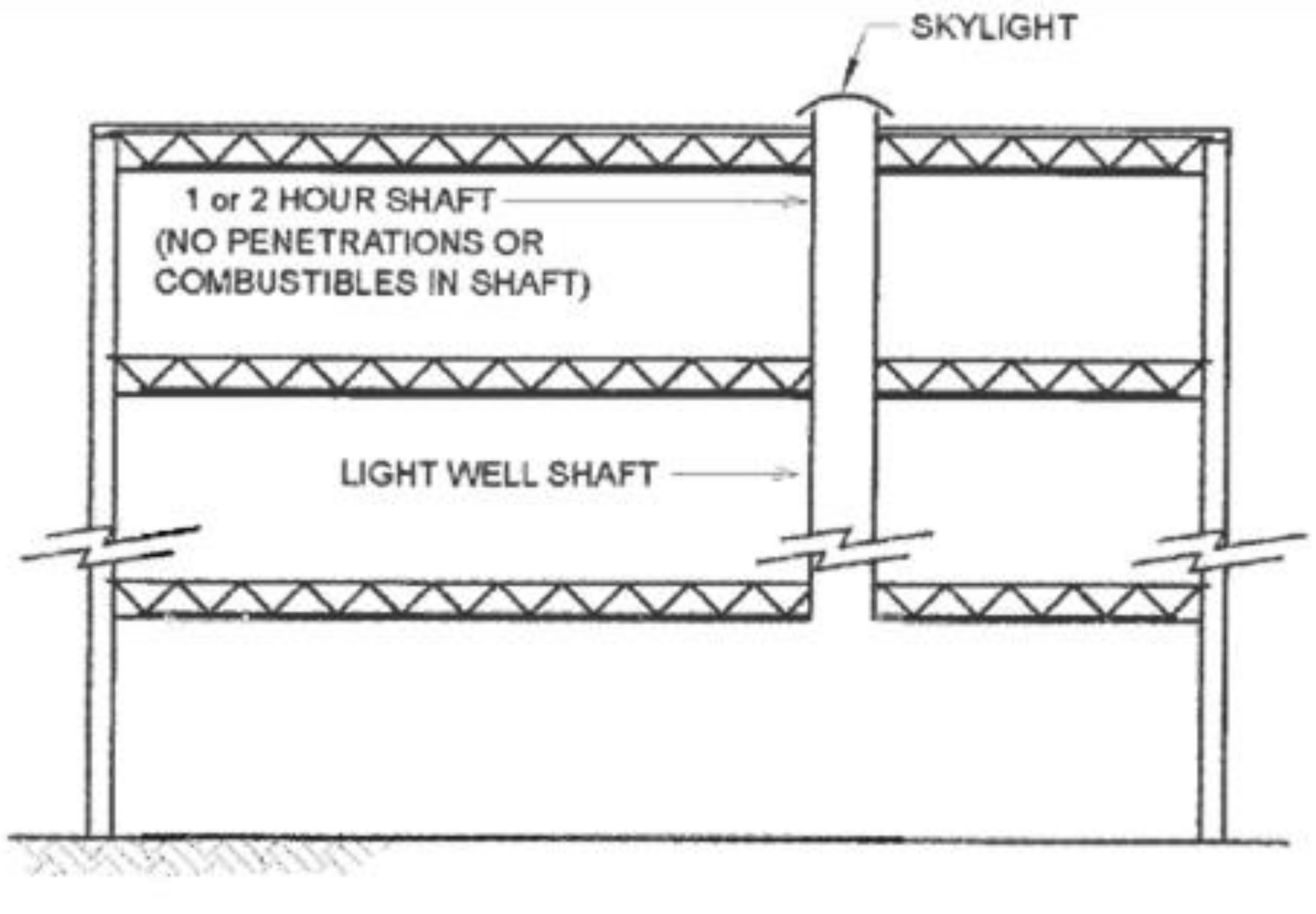
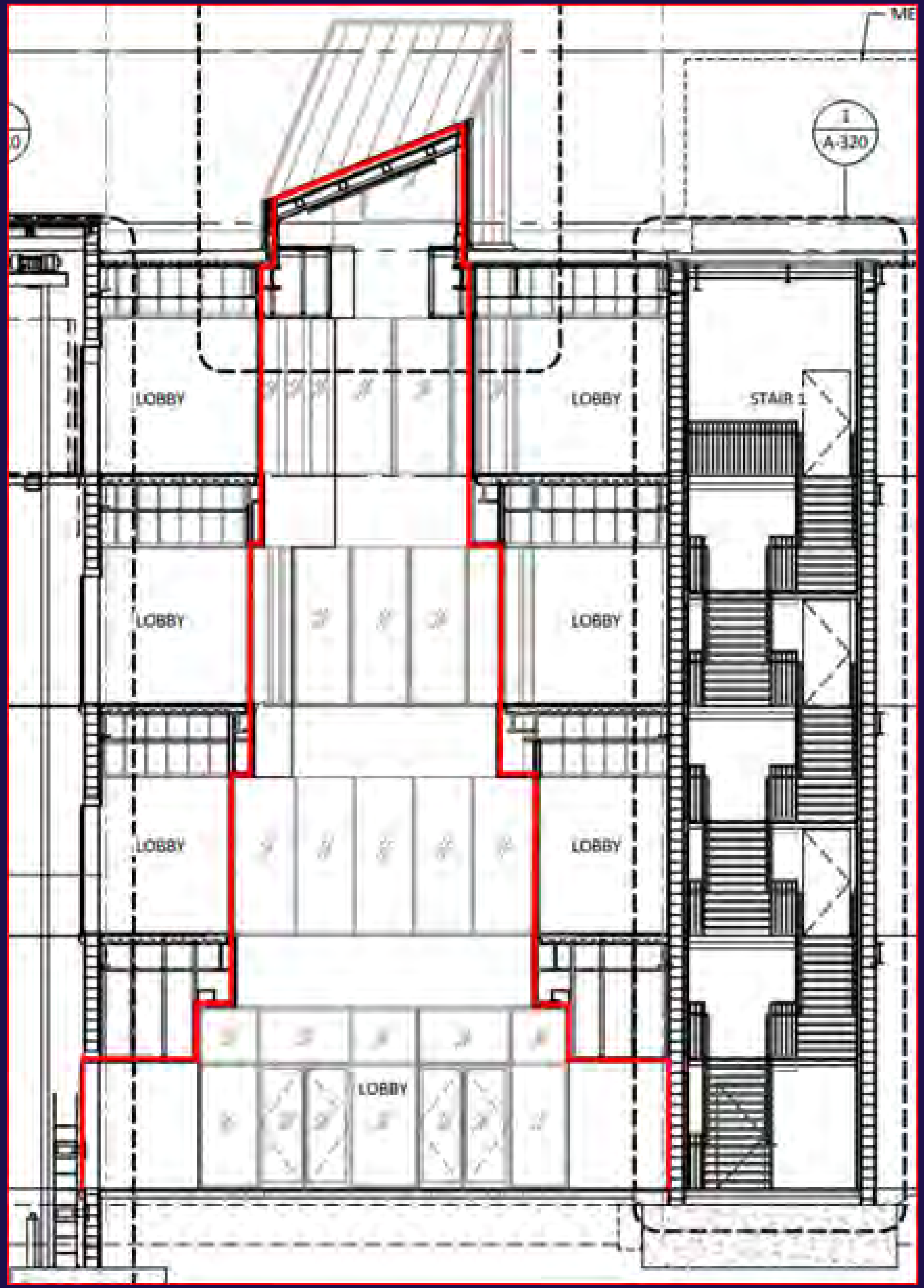


Figure 713.11(5)
VERTICAL SHAFTS—BOTTOM ENCLOSURE EXCEPTION 3

CODE SOLUTIONS

LIGHT WELL SHAFT



COMPUTER SMOKE MODELING

PERFORMANCE ANALYSIS

Goals of smoke modeling:

- Minimize design impact
- Enable complex architecturals
- Minimum exhaust rate while maintaining tenable conditions
- Right-size the smoke control system to fit the application
- Reduce project cost

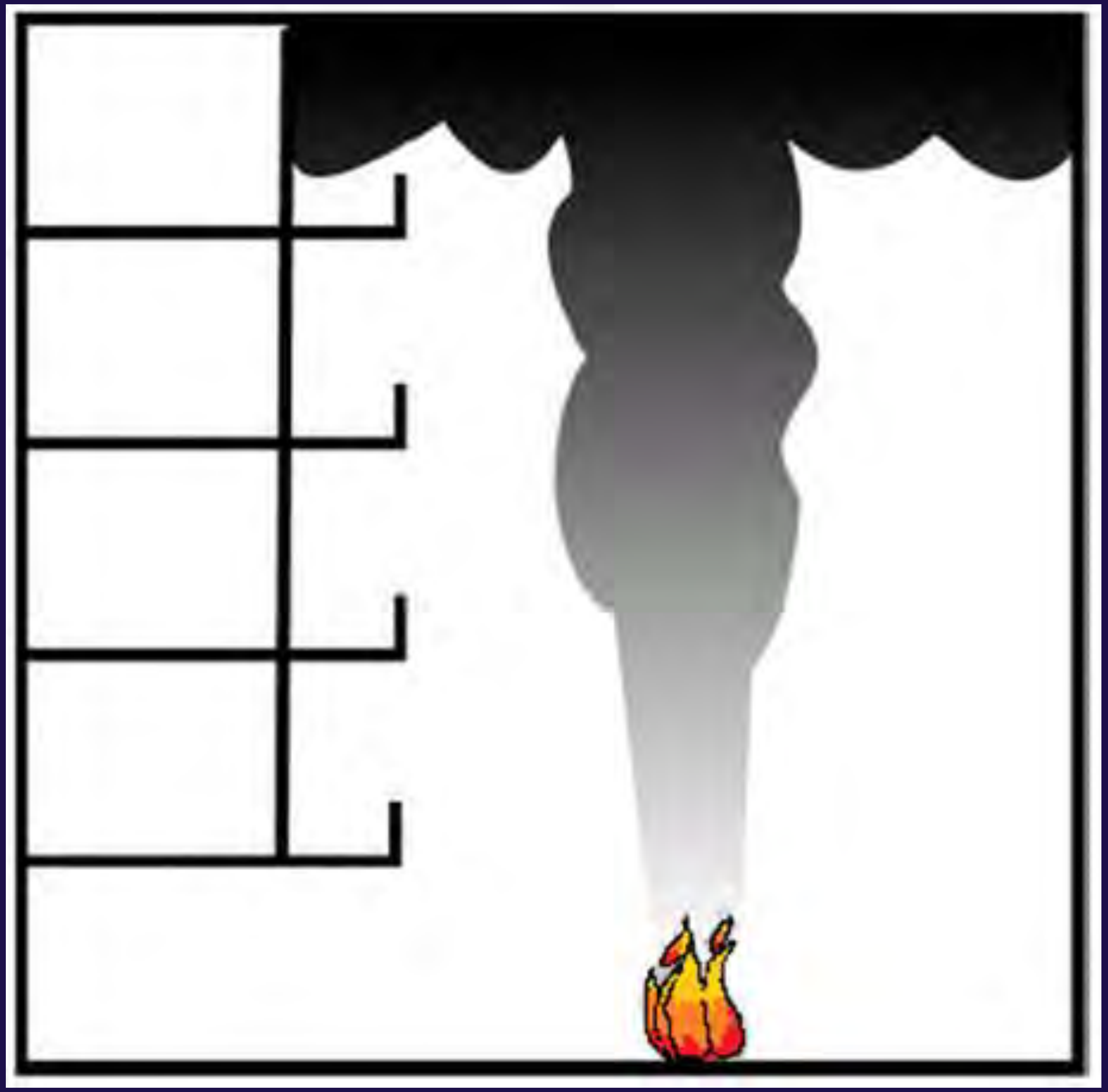
Not subject to limiting makeup air speed (200 ft/minute)

Complexity of model considers effects of IBC, Section 909.4

NFPA 92

AXISYMMETRIC PLUME:

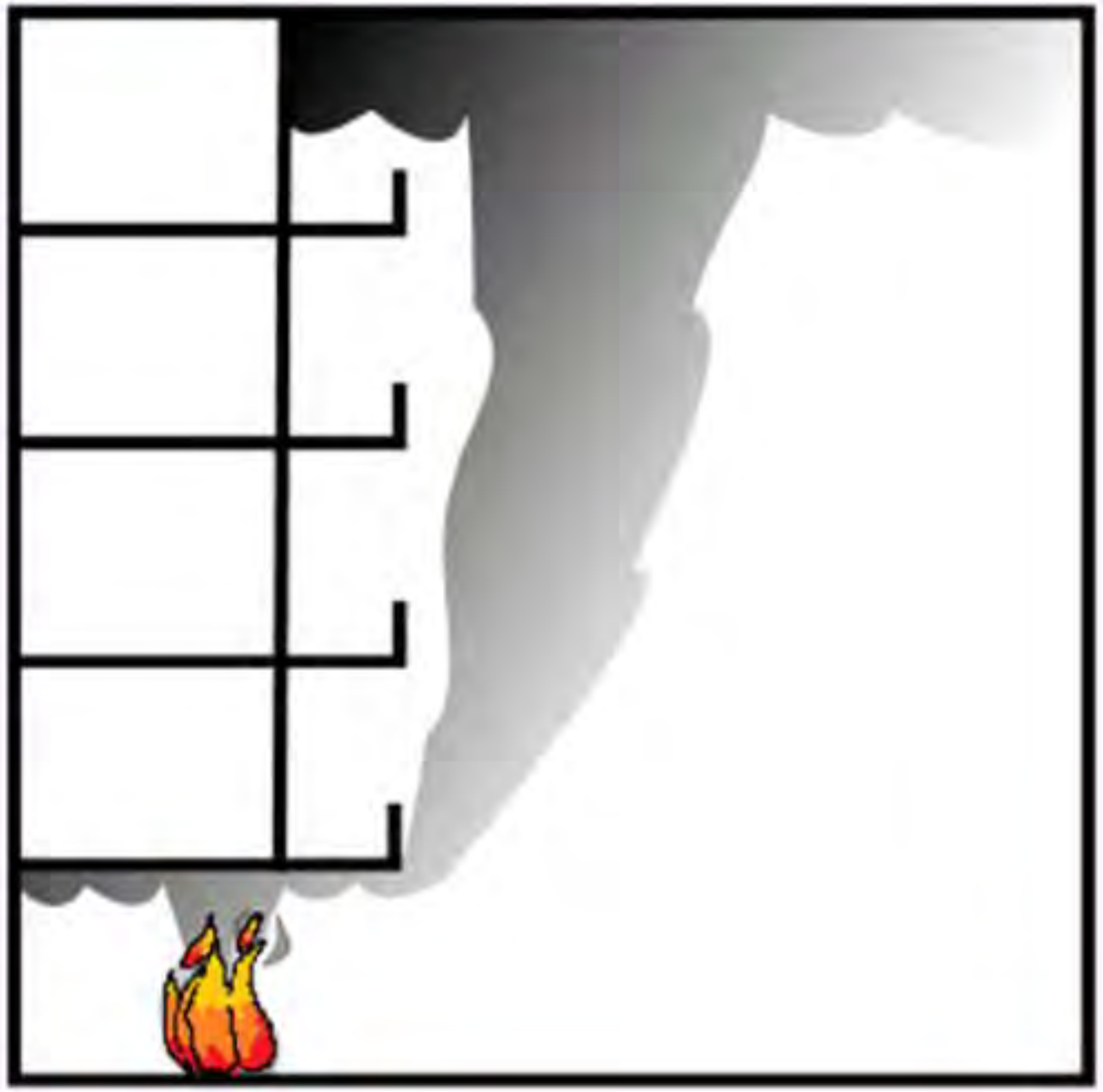
- Maximum design fire
- Away from walls
- Sprinkler activation not credited due to height of sprinklers



NFPA 92

BALCONY SPILL PLUME

- Usually sprinkler controlled
- Under balcony
- Often times limiting exhaust rates



COMPUTER SMOKE MODELING

PERFORMANCE ANALYSIS

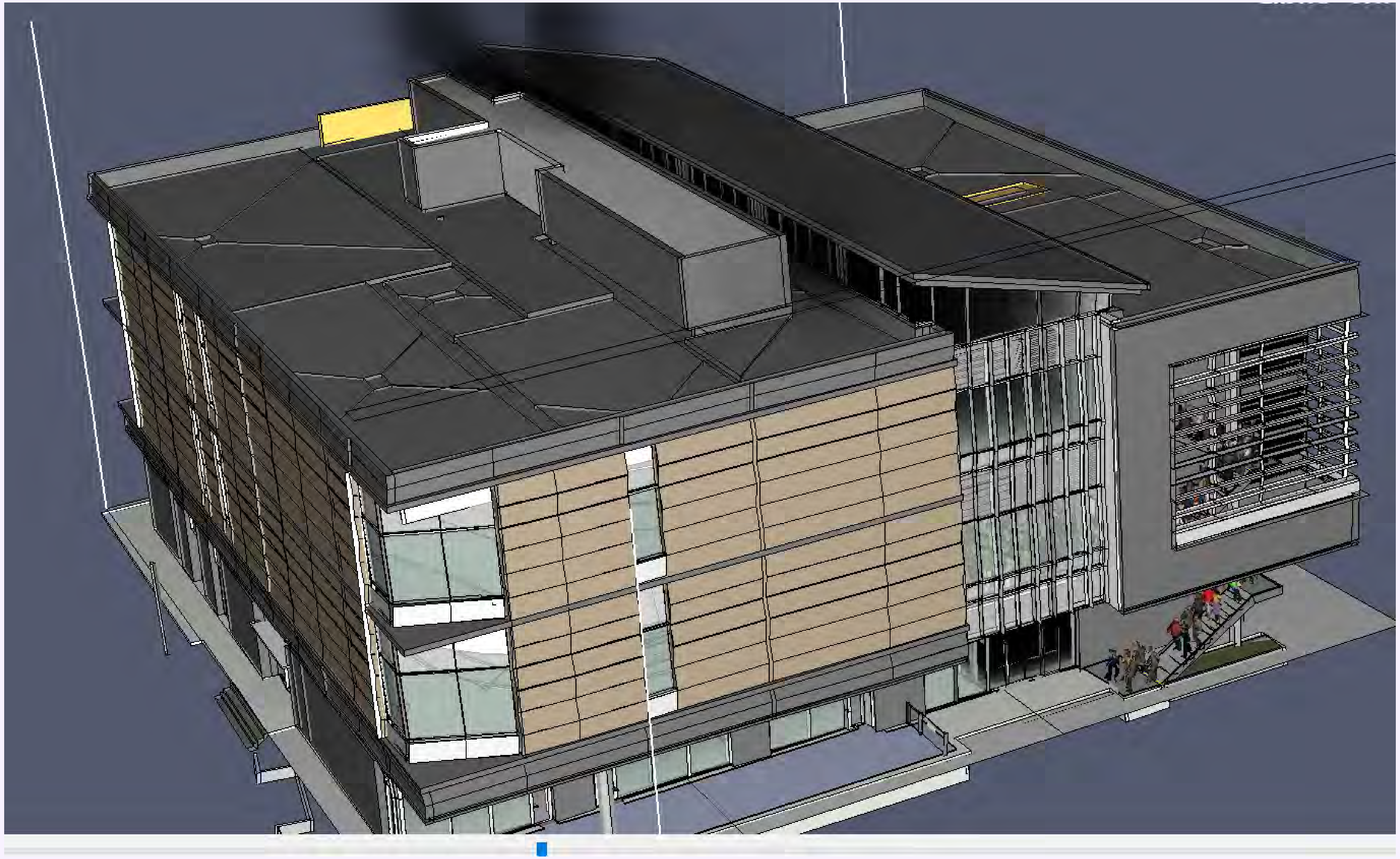
Tenable Environment – 6 ft. above walking surface part of egress (IBC, Section 909.8.1):

- Temperature
- Visibility
- Oxygen concentration
- Carbon dioxide concentration
- Carbon monoxide concentration

Tenability Criteria	
Maximum temperature	150°F (65°C)
Minimum visibility	35 feet (10 m)
Minimum Oxygen concentration	15%
Maximum Carbon Dioxide concentration	6%
Maximum Carbon Monoxide concentration	1,500 ppm

CHAPTER 9: Smoke Control

CHAPTER 9: Smoke Control

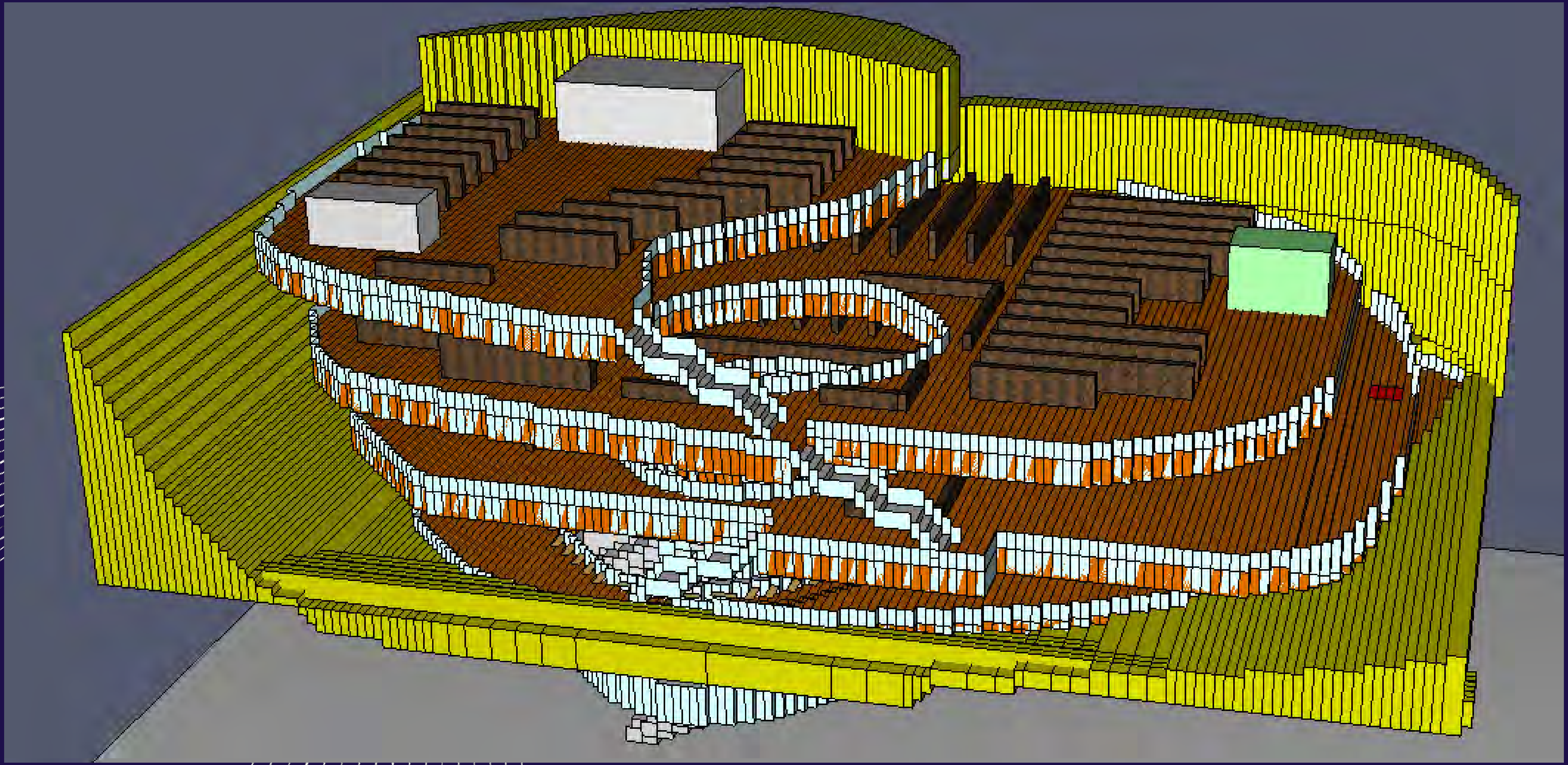


CHAPTER 9: Smoke Control

CHAPTER 9: Smoke Control

COMPUTER SMOKE MODELING

PERFORMANCE ANALYSIS



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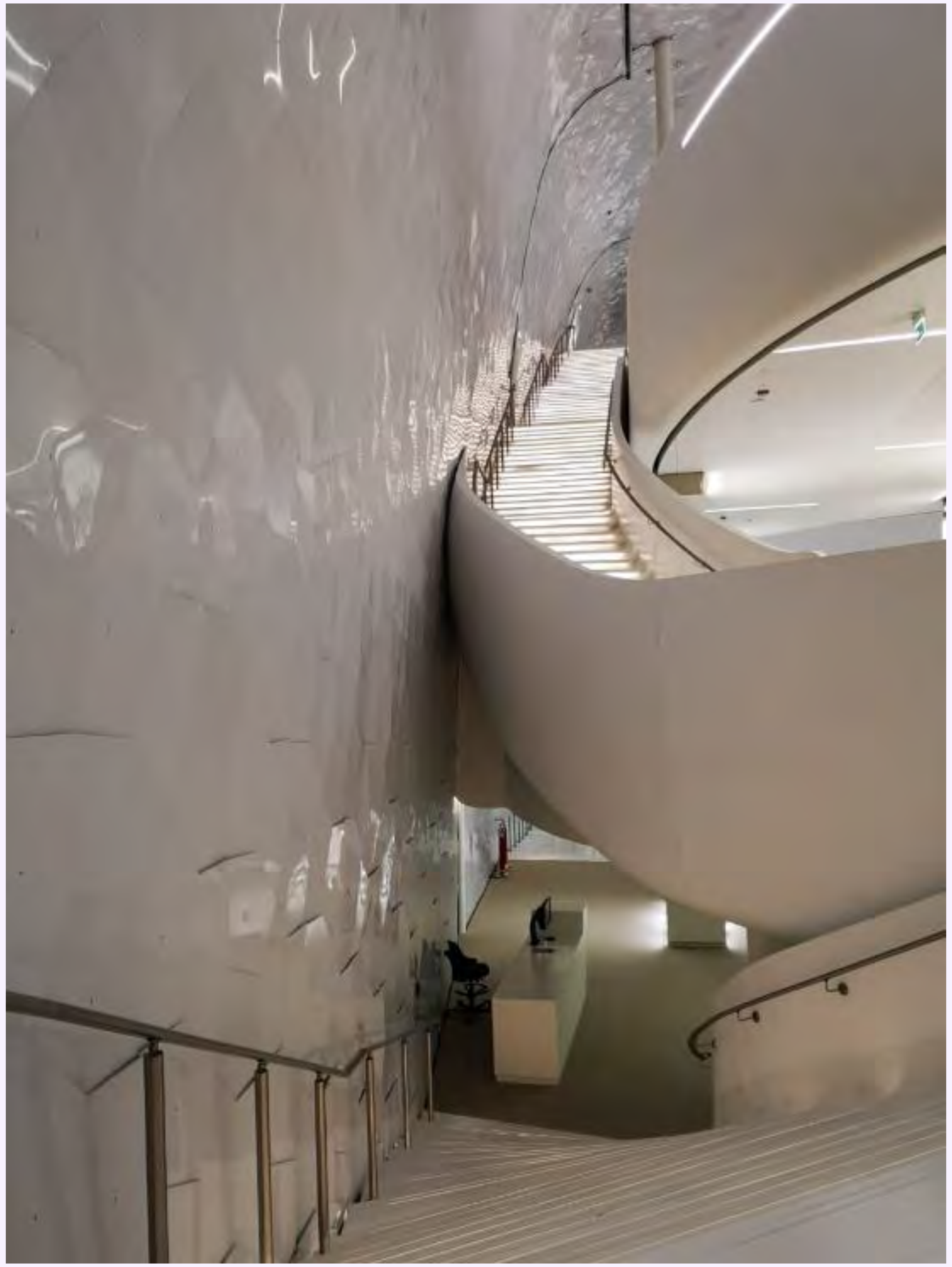
CHAPTER9 : Smoke Control



CHAPTER 9: Smoke Control

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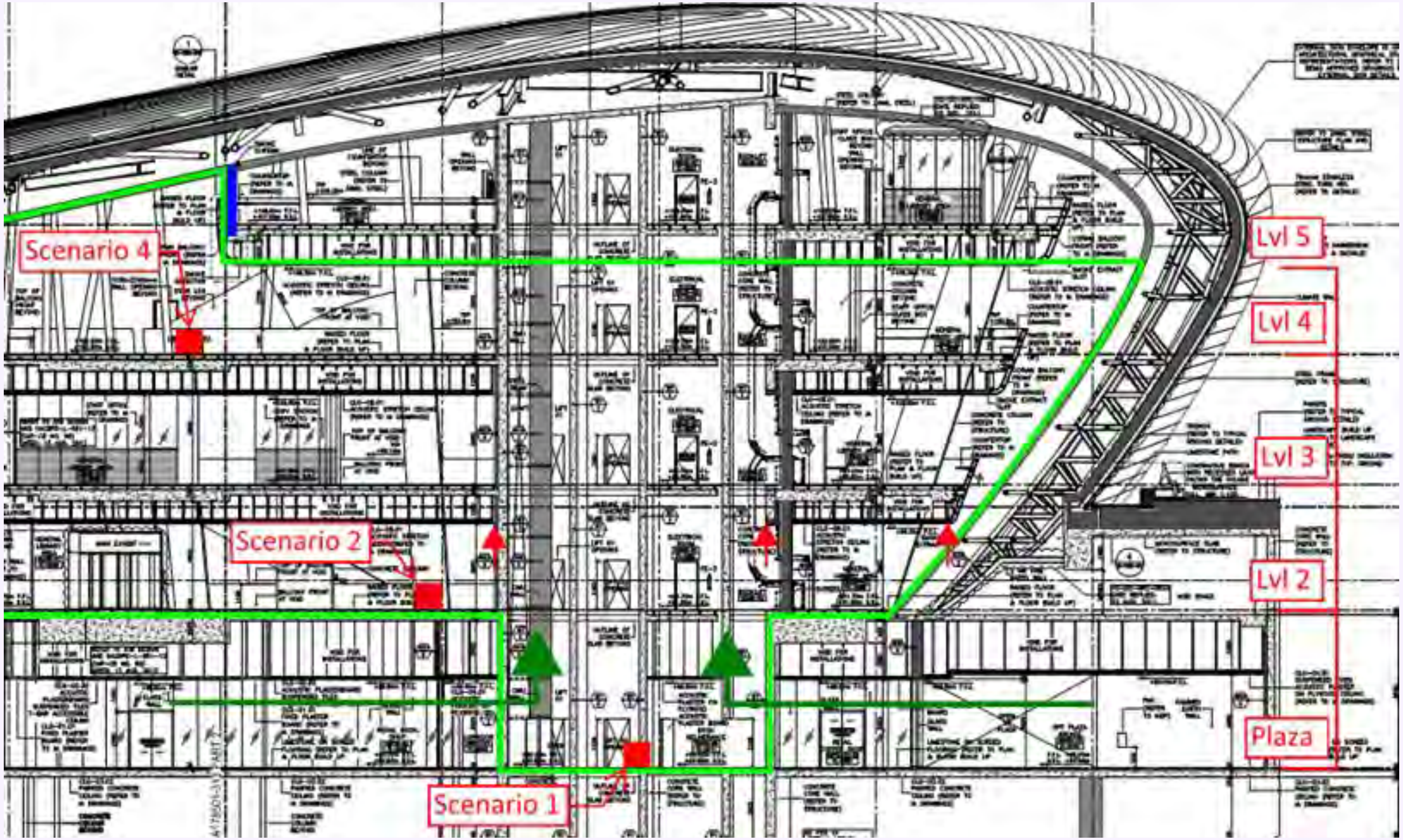

CHAPTER 9: Smoke Control

Table 7: Egress Summary – Critical Egress Times

Level	Detection Time [s]	Transmission Relay Delay [s]	Pre-Movement Time [s]	Egress Time [s]	1.5x Egress Time [s]	Total RSET [s]
2	120	10	60	102	153	343
3				186	279	469
4				103	155	345
5				58	87	277

ANY QUESTIONS?

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