

Quality with Integrity

ubse

April 2021

Peter Marxhausen, M.S., P.E., F. SEI

BUILDING OCCUPANCY AND FIRE SAFETY

Learning to speak Architecturalese

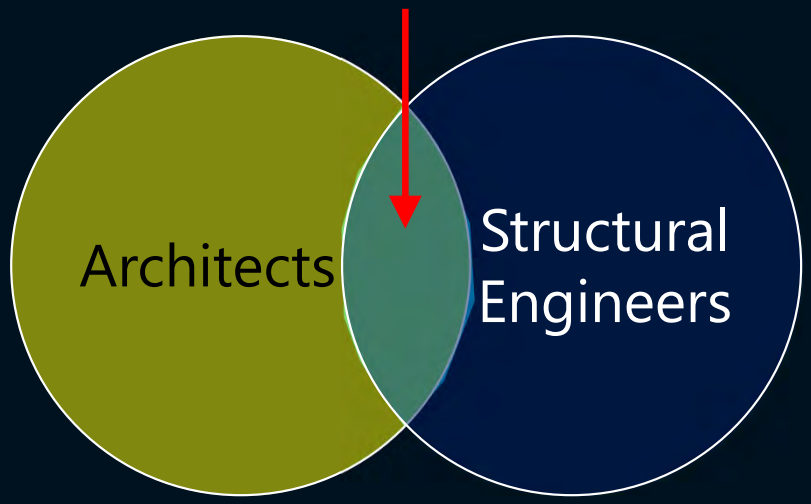
2021 Annual Conference



Broadening our Horizons

- Architects do what structural engineers don't care about
- Structural engineers do what architects don't care about

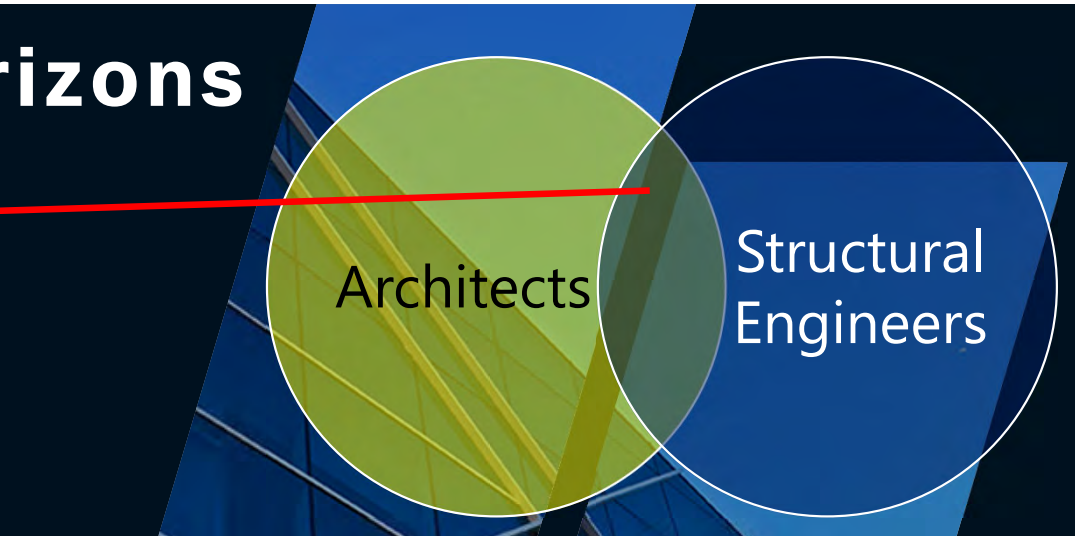
- In a Venn diagram world, we both care about structures and public safety





Broadening our Horizons

- Occupancy Types
- Construction Types
- Area limitations
- Fire Assemblies
  - Walls
  - Floors
- Sound Attenuation
- Passive fire features



Four Categories of Architects:

1. **Program management**
2. **Artistic design**
3. **Building envelope**
4. **Life safety/occupancy/fire**

- Architects do what structural engineers don't care about
- Structural engineers do what architects don't care about

What are they saying?

Most of this is like Pig Latin, it seems non-sensical until you take the time and break the code.



Credits:
Simpsons, 2003,"Marge v. Everyone" Season 15, Episode 8. Episode 321.



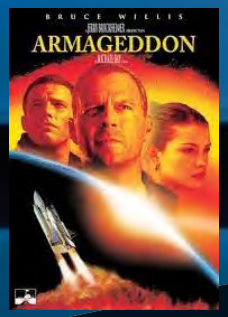
How is it learned?



O.J.T. - On the job training

F.T.V. – Fill the void

Sometimes you are just the guy beating the problem with a lead pipe because you just want to go home.



Credits:
Bay, Michael. 1998. Armageddon. United States: Buena Vista Pictures.

Breakdown



Fire Science

Fire science is the study of all aspects of fire, from fire behavior, design, rescue operations/ saving lives, and fire investigation.

- Per the FEMA U.S. Fire Administration 2019 statistics in the U.S. (which did not have large wildfire events):
  - There were 1,291,500 fires
  - Which resulted in 3,700 deaths
  - And 16,600 injuries
  - That cost $14.8 Billion in damages
  - The 2018 California wildfire was $10B alone.
- Compare this to and average of 10 U.S. deaths per year caused by structural collapse (excluding fire and construction).

Source:
https://www.usfa.fema.gov/data/statistics/

8



Occupancy Types

Defining the expected use of every vertical structure

- Classifying the use and occupancy of a building is an important part of the design process as it determines how a structure is designed and quantifies the levels of risk.
- Designating the occupancy type helps ensure a reasonable level of protection is provided to the building and its occupants.
- Once the occupancy type is determined, the analysis that follows is construction type, building height, allowable area, fire protection systems, egress requirements, and permissible finishes.

12



Types of Construction

Not all structural materials perform equally.

- The categories generally include:
  - Fire resistive
  - Mixed
  - Heavy timber
  - Combustible material

23



Area and Height Limitations

Limiting the risk by limiting the general proportions of the structure

- Limiting the duration of construction (grade of a building) occupancy and construction material type).
- Limiting the aggregate area of a building occupancy and construction material type).

30

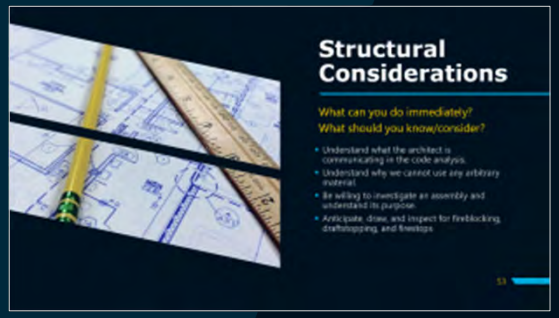


Fire Assemblies

A "fire assembly" or "assembly" is a combination of construction materials assembled in a specific way that achieves the fire resistance rating required by the applicable building code.

- Most common test is ASTM E119, the "Standard Test Methods for Fire Tests of Building Construction and Materials" or that test.
- A test assembly is exposed to fire/flames from one side under a time temperature curve.
- The assembly must not allow the passage of smoke, fire, or heat that would ignite a cotton ball.
- The assembly is then exposed to a hose stream and must retain integrity for any load-bearing application.

39



Structural Considerations

What can you do immediately?
What should you know/consider?

- Understand what the architect is communicating in the code analysis.
- Understand why we cannot use any arbitrary material.
- Be willing to investigate an assembly and understand its purpose.
- Anticipate, draw, and inspect for fireblocking, draftstopping, and firestops.

53



Fire Science

Fire science is the study of all aspects of fire, from fire behavior, design, rescue operations/ saving lives, and fire investigation.

- Per the FEMA U.S. Fire Administration 2019 statistics in the U.S. (which did not have large wildfire events):
  - There were 1,291,500 fires
  - Which resulted in 3,700 deaths
  - And 16,600 Injuries
  - That cost $14.8 Billion in damages
  - The 2018 California wildfire was $10B alone.
- Compare this to and average of 10 U.S. deaths per year caused by structural collapse (excluding fire and construction).

Source:
https://www.usfa.fema.gov/data/statistics/

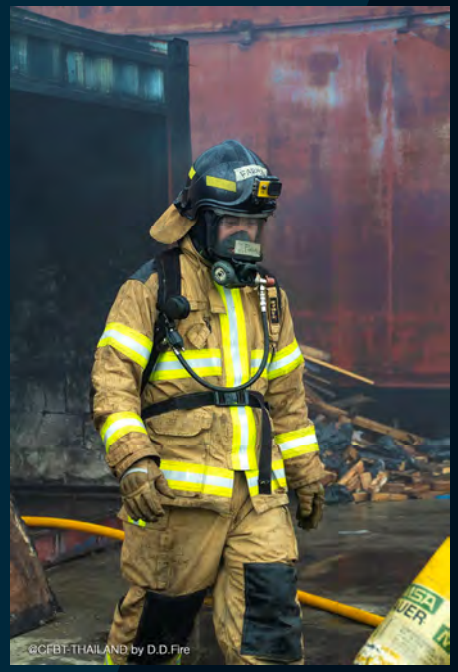
Ethics:
NCSEA Model Code of Ethics

Fundamental Principles

- "To uphold and advance the integrity, honor and dignity of the structural engineering profession by:
- 1. using their knowledge and skill for the enhancement of human welfare;"

Fundamental Tenets

- "Structural engineers: use their knowledge and skill in the performance of their professional duties to make decisions in the interest of the safety, health, and welfare of the public."



Building fires and the threat that they represent are in opposition to our ethical duties

Concept:	Methods:	System:
Save lives	Passive	Regulations (i.e. open burning/smoking ban)
		Codes regulating materials, area, heights and occupancies
		Compartmentalization (i.e. barriers, doors, stops, limited fuel)
	Active	Firemen, fire extinguishers, alarms sprinklers, etc.





Save lives

Regulations (i.e. open Burning/smoking ban)

Compartmentalization (i.e. barriers, doors, stops, limited fuel)

Codes regulating materials, area, heights and occupancies

Strategy:

1. **Don't let the fire start**
2. **If a fire starts, get people out, slow it down, and get it out**



Credit:
Seinfeld, 1994, NBC.
Episode 84, Season 5.



Occupancy Types

Defining the expected use of every vertical structure

- Classifying the use and occupancy of a building is an important part of the design process as it determines how a structure is designed and quantifies the levels of risk.
- Designating the occupancy type helps ensure a reasonable level of protection is provided to the building and its occupants.
- Once the occupancy type is determined, the analysis that follows is construction type, building height, allowable area, fire protection systems, egress requirements, and permissible finishes.

Group A: Assembly

A-1: Theatres, concert halls, TV studios

A-2: Assembly uses intended for food and/or drink consumption banquet halls, casino, nightclubs, restaurants, cafeterias, commercial kitchens, taverns, and bars

A-3: Assembly uses intended for worship, recreation or amusement including art galleries, bowling alleys, community halls, courtrooms, dance halls, exhibition halls, funeral parlors, gymnasiums, indoor swimming pools, indoor tennis courts, lecture halls, libraries, museums, churches, and transportation terminals

A-4: Assembly uses intended for viewing of indoor sporting events and activities with spectator seating like arenas, and places with bleachers

A-5: Entirely outdoor amusement park rides, bleachers, grandstands, and stadiums



Group B:
Business

"Business Group B occupancy includes, among others, the use of a building or structure, or a portion thereof, for office, professional or service-type transactions, including storage of records and accounts." Things like animal hospitals, banks, barbers, car wash, civic offices, cleaners, colleges, laboratories, showrooms, architects, engineers, dentists, doctors, and print shops.



Group E:
Education

"Educational Group E occupancy includes, among others, the use of a building or structure, or a portion thereof, by six or more persons at any one time for educational purposes through the 12th grade."

Can include schools attached to churches and day care facilities, under some circumstances.



Group F:
Factory

F-1: Moderate hazard manufacturing like vehicles, durable goods, electronics, machines, carpet, clothes, food, etc.

F-2: Low-hazard factory manufacturing of non-combustible things like brick, ceramics, glass, gypsum, ice, and metal fabrication.



Group H:
High Hazard

"High-hazard Group H occupancy includes, among others, the use of a building or structure, or a portion thereof, that involves the manufacturing, processing, generation or storage of materials that constitute a physical or health hazard in quantities in excess of those allowed in control areas complying with Section 414, based on the maximum allowable quantity limits for control areas set forth in Tables 307.1(1) and 307.1(2)."

H-1: Things that are a detonation hazard

H-2: Things that are HIGHLY flammable

H-3: Things that are MOSTLY flammable

H-4: Things that are toxic or corrosive

H-5: Semiconductor manufacturing



Group I:
Institutional

I-1: "Institutional Group I-1 occupancy shall include buildings, structures or portions thereof for more than 16 persons, excluding staff, who reside on a 24-hour basis in a supervised environment and receive custodial care." like drug centers or halfway houses

I-2: Buildings and structures used for medical care on a 24-hour basis, like hospitals, nursing homes, and detox facilities.

I-3: For housing people that are under restraint like jails, prisons, correctional facilities, etc.

I-4: Adult and some child day care facilities



Group M:
Mercantile

"Mercantile Group M occupancy includes, among others, the use of a building or structure or a portion thereof for the display and sale of merchandise, and involves stocks of goods, wares or merchandise incidental to such purposes and accessible to the public." Mercantile occupancies include things like department stores, drug stores, markets, sales-based greenhouses, motor fuel-dispensing facilities, retail or wholesale stores, and sales rooms.



Group R:
Residential

"Residential Group R includes, among others, the use of a building or structure, or a portion thereof, for sleeping purposes when not classified as an Institutional."

R-1: Hotels and motels.

R-2: Apartments, dormitories, convents, fraternities, sororities, and time shares.

R-3: Duplexes and single-family homes.

R-4: Smaller institutional facilities with less than 16 people that would otherwise be I-1.



Group S: Storage

"Storage Group S occupancy includes, among others, the use of a building or structure, or a portion thereof, for storage that is not classified as a hazardous occupancy."

S-1: Moderate-hazard storage like books, cardboard, vehicles, materials, and things that could generally burn readily.

S-2: Low-hazard storage like produce, meat, appliances, textiles, frozen food,



Group U:
Utility
(and miscellaneous)

"Buildings and structures of an accessory character and miscellaneous structures not classified in any specific occupancy shall be constructed, equipped and maintained to conform to the requirements of this code commensurate with the fire and life hazard incidental to their occupancy." Group U includes things like agricultural buildings, aircraft hangars, small sheds/barns, carports, equipment sheds, utility sheds, fences, livestock shelters, private garages, retaining walls, stables, and towers.





Types of Construction

Not all structural materials perform equally.

- The categories generally include:
  - Fire resistive
  - Mixed
  - Heavy timber
  - Combustible material

Type I

"Types I and II construction are those types of construction in which the building elements listed in Table 601 are of noncombustible materials, except as permitted in Section 603 and elsewhere in this code." (IBC, Chapter 6)

2-hour and 3-hour fire rating of the non-combustible material structural frame



Type II

"Types I and II construction are those types of construction in which the building elements listed in Table 601 are of noncombustible materials, except as permitted in Section 603 and elsewhere in this code." (IBC, Chapter 6)

1-hour and 2-hour fire rating of the non-combustible material structural frame



Type III

"Type III construction is that type of construction in which the exterior walls are of noncombustible materials and the interior building elements are of any material permitted by this code. Fire-retardant-treated wood framing and sheathing complying with Section 2303.2 shall be permitted." (IBC, Chapter 6)

0-hour and 1-hour fire rating of the structural frame



Type IV (H.T.)

"Type IV construction is that type of construction in which the exterior walls are of noncombustible materials and the interior building elements are of solid wood, laminated wood, heavy timber (HT) or structural composite lumber (SCL) without concealed spaces. The minimum dimensions for permitted materials including solid timber, glued-laminated timber, structural composite lumber (SCL), and cross-laminated timber and details of Type" (IBC, Chapter 6)

Depending upon the element and material, 4-, 6-, or 8-inch minimum width members are required – See Table 2304.11.



Type V

"Type V construction is that type of construction in which the structural elements, exterior walls and interior walls are of any materials permitted by this code." (IBC, Chapter 6)

0-hour and 1-hour fire rating of the structural frame



IBC - Table 604

TABLE 601
FIRE-RESISTANCE RATING REQUIREMENTS FOR BUILDING ELEMENTS (HOURS)

BUILDING ELEMENT	TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
	A	B	A	B	A	B	HT	A	B
Primary structural frame[f] (see Section 202)	3[a, b]	2[a, b]	1[b]	0	1[b]	0	HT	1[b]	0
Bearing walls									
Exterior[e, f]	3	2	1	0	2	2	2	1	0
Interior	3[a]	2[a]	1	0	1	0	1/HT	1	0
Nonbearing walls and partitions Exterior	See Table 602								
Nonbearing walls and partitions Interior[d]	0	0	0	0	0	0	See Section 2304.11.2	0	0
Floor construction and associated secondary members (see Section 202)	2	2	1	0	1	0	HT	1	0
Roof construction and associated secondary members (see Section 202)	$1\frac{1}{2}$[b]	1[b,c]	1[b,c]	0[c]	1[b,c]	0	HT	1[b,c]	0



Area and Height Limitations

Limiting the risk by limiting the general proportions of the structure

- Limiting the number of stories above grade of a building occupancy and construction material type.
- Limiting the aggregate area of a building occupancy and construction material type.

IBC - Table 504-3: Allowable Building Heights

TABLE 504.3
ALLOWABLE BUILDING HEIGHT IN FEET ABOVE GRADE PLANE[a]

OCCUPANCY CLASSIFICATION	SEE FOOTNOTES	TYPE OF CONSTRUCTION								
		TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
		A	B	A	B	A	B	HT	A	B
A, B, E, F, M, S, U	NS[b]	UL	160	65	55	65	55	65	50	40
	S	UL	180	85	75	85	75	85	70	60
H-1, H-2, H-3, H-5	NS[c, d]	UL	160	65	55	65	55	65	50	40
	S									
H-4	NS[c, d]	UL	160	65	55	65	55	65	50	40
	S	UL	180	85	75	85	75	85	70	60
I-1 Condition 1, I-3	NS[d, e]	UL	160	65	55	65	55	65	50	40
	S	UL	180	85	75	85	75	85	70	60
I-1 Condition 2, I-2	NS[d, e, f]	UL	160	65	55	65	55	65	50	40
	S	UL	180	85						
I-4	NS[d, g]	UL	160	65	55	65	55	65	50	40
	S	UL	180	85	75	85	75	85	70	60
R[h]	NS[d]	UL	160	65	55	65	55	65	50	40
	S13D	60	60	60	60	60	60	60	50	40
	S13R	60	60	60	60	60	60	60	60	60
	S	UL	180	85	75	85	75	85	70	60

IBC - Table 504-4: Allowable Stories

TABLE 504.4
ALLOWABLE NUMBER OF STORIES ABOVE GRADE PLANE[a, b]

OCCUPANCY CLASSIFICATION	SEE FOOTNOTES	TYPE OF CONSTRUCTION								
		TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
		A	B	A	B	A	B	HT	A	B
A-1	NS	UL	5	3	2	3	2	3	2	1
	S	UL	6	4	3	4	3	4	3	2
A-2	NS	UL	11	3	2	3	2	3	2	1
	S	UL	12	4	3	4	3	4	3	2
A-3	NS	UL	11	3	2	3	2	3	2	1
	S	UL	12	4	3	4	3	4	3	2
A-4	NS	UL	11	3	2	3	2	3	2	1
	S	UL	12	4	3	4	3	4	3	2
A-5	NS	UL	UL	UL	UL	UL	UL	UL	UL	UL
	S	UL	UL	UL	UL	UL	UL	UL	UL	UL
B	NS	UL	11	5	3	5	3	5	3	2
	S	UL	12	6	4	6	4	6	4	3
E	NS	UL	5	3	2	3	2	3	1	1
	S	UL	6	4	3	4	3	4	2	2
F-1	NS	UL	11	4	2	3	2	4	2	1
	S	UL	12	5	3	4	3	5	3	2
F-2	NS	UL	11	5	3	4	3	5	3	2
	S	UL	12	6	4	5	4	6	4	3

IBC - Table 506-2: Allowable Area (per floor) 1

TABLE 506.2
ALLOWABLE AREA FACTOR (A_t = NS, S1, S13R, S13D or SM, as applicable) IN SQUARE FEET[a, b]

OCCUPANCY CLASSIFICATION	SEE FOOTNOTES	TYPE OF CONSTRUCTION								
		TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
		A	B	A	B	A	B	HT	A	B
A-1	NS	UL	UL	15,500	8,500	14,000	8,500	15,000	11,500	5,500
	S1	UL	UL	62,000	34,000	56,000	34,000	60,000	46,000	22,000
	SM	UL	UL	46,500	25,500	42,000	25,500	45,000	34,500	16,500
A-2	NS	UL	UL	15,500	9,500	14,000	9,500	15,000	11,500	6,000
	S1	UL	UL	62,000	38,000	56,000	38,000	60,000	46,000	24,000
	SM	UL	UL	46,500	28,500	42,000	28,500	45,000	34,500	18,000
A-3	NS	UL	UL	15,500	9,500	14,000	9,500	15,000	11,500	6,000
	S1	UL	UL	62,000	38,000	56,000	38,000	60,000	46,000	24,000
	SM	UL	UL	46,500	28,500	42,000	28,500	45,000	34,500	18,000
A-4	NS	UL	UL	15,500	9,500	14,000	9,500	15,000	11,500	6,000
	S1	UL	UL	62,000	38,000	56,000	38,000	60,000	46,000	24,000
	SM	UL	UL	46,500	28,500	42,000	28,500	45,000	34,500	18,000
A-5	NS	UL	UL	UL	UL	UL	UL	UL	UL	UL
	S1									
	SM									

IBC - Table 506-2: Allowable Area (per floor) 2

B	NS	UL	UL	37,500	23,000	28,500	19,000	36,000	18,000	9,000
	S1	UL	UL	150,000	92,000	114,000	76,000	144,000	72,000	36,000
	SM	UL	UL	112,500	69,000	85,500	57,000	108,000	54,000	27,000
E	NS	UL	UL	26,500	14,500	23,500	14,500	25,500	18,500	9,500
	S1	UL	UL	106,000	58,000	94,000	58,000	102,000	74,000	38,000
	SM	UL	UL	79,500	43,500	70,500	43,500	76,500	55,500	28,500
F-1	NS	UL	UL	25,000	15,500	19,000	12,000	33,500	14,000	8,500
	S1	UL	UL	100,000	62,000	76,000	48,000	134,000	56,000	34,000
	SM	UL	UL	75,000	46,500	57,000	36,000	100,500	42,000	25,500
F-2	NS	UL	UL	37,500	23,000	28,500	18,000	50,500	21,000	13,000
	S1	UL	UL	150,000	92,000	114,000	72,000	202,000	84,000	52,000
	SM	UL	UL	112,500	69,000	85,500	54,000	151,500	63,000	39,000
H-1	NS[c]	21,000	16,500	11,000	7,000	9,500	7,000	10,500	7,500	NP
	S1									

IBC - Table 506-2: Allowable Area (per floor) 3

R-1[h]	NS[d]	UL	UL	24,000	16,000	24,000	16,000	20,500	12,000	7,000
	S13R									
	S1	UL	UL	96,000	64,000	96,000	64,000	82,000	48,000	28,000
	SM	UL	UL	72,000	48,000	72,000	48,000	61,500	36,000	21,000
R-2[h]	NS[d]	UL	UL	24,000	16,000	24,000	16,000	20,500	12,000	7,000
	S13R									
	S1	UL	UL	96,000	64,000	96,000	64,000	82,000	48,000	28,000
	SM	UL	UL	72,000	48,000	72,000	48,000	61,500	36,000	21,000
R-3[h]	NS[d]	UL	UL	UL	UL	UL	UL	UL	UL	UL
	S13D									
	S13R									
	S1									
	SM									
R-4[h]	NS[d]	UL	UL	24,000	16,000	24,000	16,000	20,500	12,000	7,000
	S13D									
	S13R									
	S1	UL	UL	96,000	64,000	96,000	64,000	82,000	48,000	28,000
	SM	UL	UL	72,000	48,000	72,000	48,000	61,500	36,000	21,000
S-1	NS	UL	48,000	26,000	17,500	26,000	17,500	25,500	14,000	9,000
	S1	UL	192,000	104,000	70,000	104,000	70,000	102,000	56,000	36,000
	SM	UL	144,000	78,000	52,500	78,000	52,500	76,500	42,000	27,000
S-2	NS	UL	79,000	39,000	26,000	39,000	26,000	38,500	21,000	13,500
	S1	UL	316,000	156,000	104,000	156,000	104,000	154,000	84,000	54,000
	SM	UL	237,000	117,000	78,000	117,000	78,000	115,500	63,000	40,500
U	NS[i]	UL	35,500	19,000	8,500	14,000	8,500	18,000	9,000	5,500
	S1	UL	142,000	76,000	34,000	56,000	34,000	72,000	36,000	22,000
	SM	UL	106,500	57,000	25,500	42,000	25,500	54,000	27,000	16,500

IBC – Equation 5-2: Allowable Area

506.2.3 Single-occupancy, multistory buildings. The allowable area of a single-occupancy building with more than one *story above grade plane* shall be determined in accordance with Equation 5-2:

$$A_a = [A_t + (NS \times I_f)] \times S_a \qquad \textbf{(Equation 5-2)}$$

- S_a — Number of stories
- I_f — Frontage increase
- NS — Non-sprinkled allowable area
- A_t — Allowable area per story
- A_a — Total Building area allowed

Mixed Occupancies

509.3 Area limitations. Incidental uses shall not occupy more than 10 percent of the *building area* of the *story* in which they are located.

508.1 General. Each portion of a building shall be individually classified in accordance with Section 302.1. Where a building contains more than one occupancy group, the building or portion thereof shall comply with the applicable provisions of Section 508.2, 508.3 or 508.4, or a combination of these sections.

508.2 Accessory occupancies. Accessory occupancies are those occupancies that are ancillary to the main occupancy of the building or portion thereof. Accessory occupancies shall comply with the provisions of Sections 508.2.1 through 508.2.4.

508.3.2 Allowable building area, height and number of stories. The allowable *building area, height* and number of *stories* of the building or portion thereof shall be based on the most restrictive allowances for the occupancy groups under consideration for the type of construction of the building in accordance with Section 503.1.

IBC – Table 508.4: Separated Occupancies

TABLE 508.4
REQUIRED SEPARATION OF OCCUPANCIES (HOURS)[f]

OCCUPANCY	A, E		I-1[a], I-3, I-4		I-2		R[a]		F-2, S-2[b], U		B[e], F-1, M, S-1		H-1		H-2		H-3, H-4		H-5	
	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS
A, E	N	N	1	2	2	NP	1	2	N	1	1	2	NP	NP	3	4	2	3	2	NP
I-1[a], I-3, I-4	—	—	N	N	2	NP	1	NP	1	2	1	2	NP	NP	3	NP	2	NP	2	NP
I-2	—	—	—	—	N	N	2	NP	2	NP	2	NP	NP	NP	3	NP	2	NP	2	NP
R[a]	—	—	—	—	—	—	N	N	1[c]	2[c]	1	2	NP	NP	3	NP	2	NP	2	NP
F-2, S-2[b], U	—	—	—	—	—	—	—	—	N	N	1	2	NP	NP	3	4	2	3	2	NP
B[e], F-1, M, S-1	—	—	—	—	—	—	—	—	—	—	N	N	NP	NP	2	3	1	2	1	NP
H-1	—	—	—	—	—	—	—	—	—	—	—	—	N	NP	NP	NP	NP	NP	NP	NP
H-2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	NP	1	NP	1	NP
H-3, H-4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1[d]	NP	1	NP
H-5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	NP

S = Buildings equipped throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.1.
NS = Buildings not equipped throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.1.
N = No separation requirement.
NP = Not Permitted.



Fire Assemblies

A “fire assembly” or “assembly” is a combination of construction materials assembled in a specific way that achieves the fire resistance rating required by the applicable building code.

- Most common test is ASTM E119, the “Standard Test Methods for Fire Tests of Building Construction and Materials.” In that test:
- A test assembly is exposed to fire/flames from one side under a time temperature curve.
- The assembly must not allow the passage of smoke, fire, or heat that would ignite a cotton ball.
- The assembly is then exposed to a hose stream and must retain integrity for any load-bearing application.

ASTM E119

- Invent a product
- Design it
- Built it
- Burn it
- Note the time
- Blast it with water



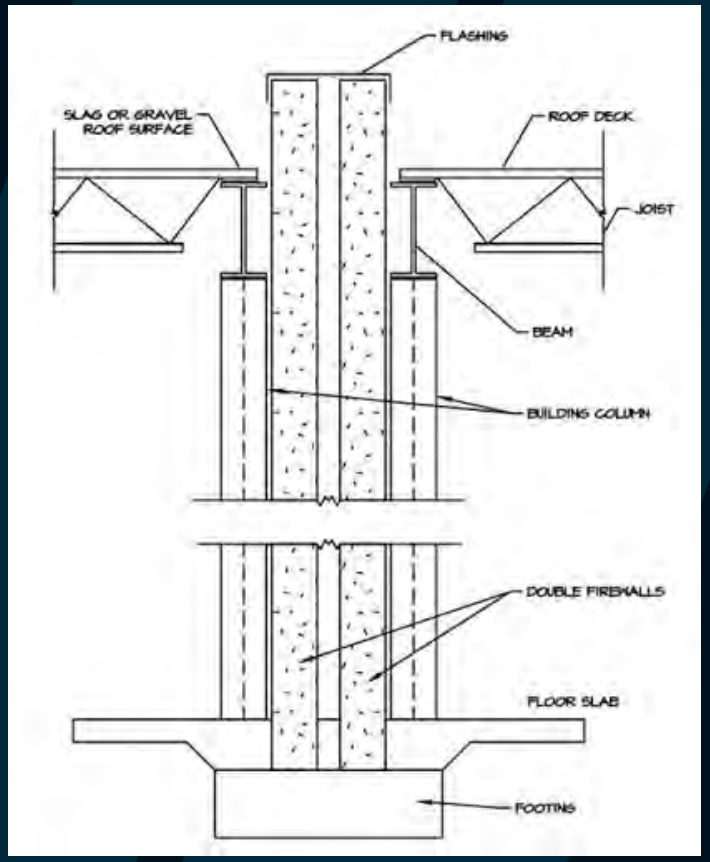
Credits:
https://www.youtube.com/watch?v=IgqDx646s-U
National Gypsum Corporation
https://www.nationalgypsum.com/

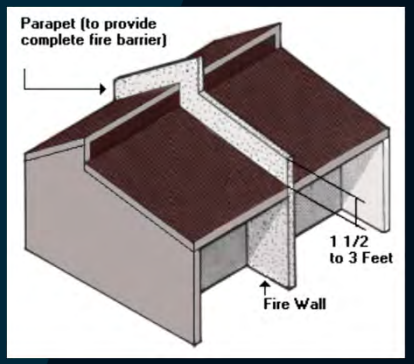
FIRE WALLS

"A fire-resistance-rated wall having protected openings, which restricts the spread of fire and extends continuously from the foundation to or through the roof, with sufficient structural stability under fire conditions to allow collapse of construction on either side without collapse of the wall."

CHARACTERISTICS:

- Governed by IBC 706
- Creates two buildings (IBC 706.1.1)
- Used at a lot line (IBC 706.1.1)
- 2- to 4-hour rating depending upon what is separated (IBC Table 706.4)
- Non-combustible material (IBC 706.3)
- Structural stability – will stand if there is a collapse of the structure on either side (IBC 706.2)
- Must extend 18 inches beyond wall and roof (IBC 706.5)



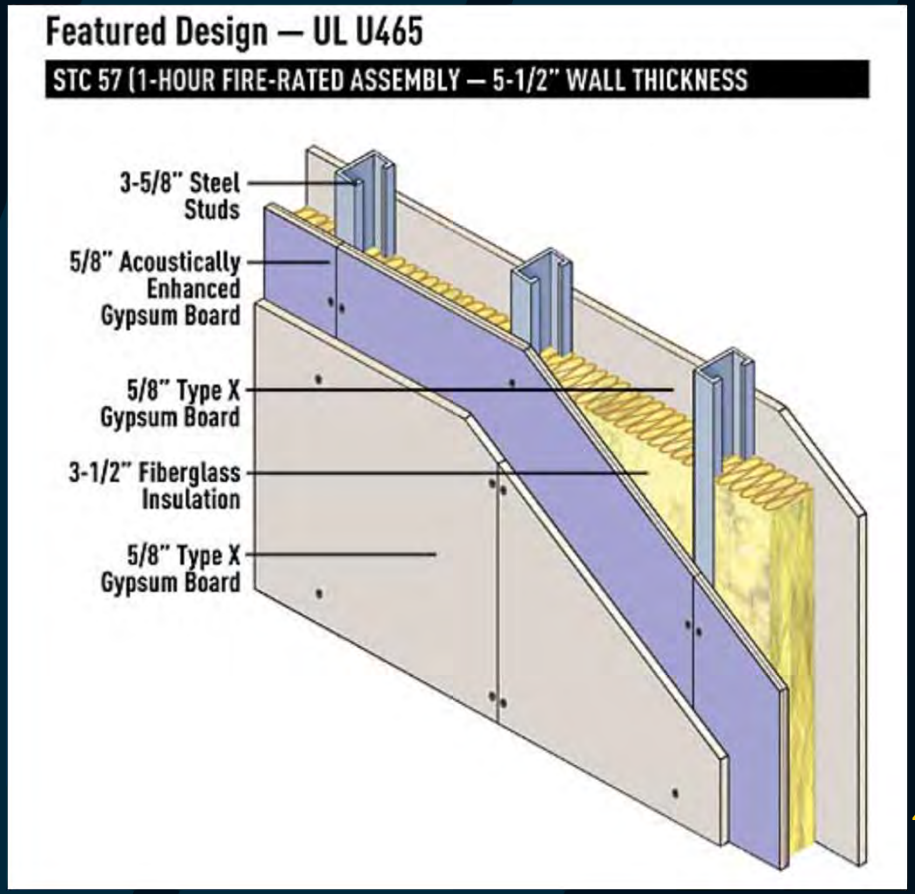


FIRE BARRIERS

"A fire-resistance-rated wall assembly of materials designed to restrict the spread of fire in which continuity is maintained."

CHARACTERISTICS:

- Governed by IBC 707
- Separates stairways, shafts, exit passageways, and areas of incidental usages (IBC 707.3.1-707.3.8)
- Compartmentalizes occupancies that require separation (IBC 707.3.9)
- Can be a wall or a floor assembly (IBC Table 707.3.10)
- Combustible material allowed (IBC 707.2)
- Must extend to inside of wall and roof sheathing/material (IBC 707.5)

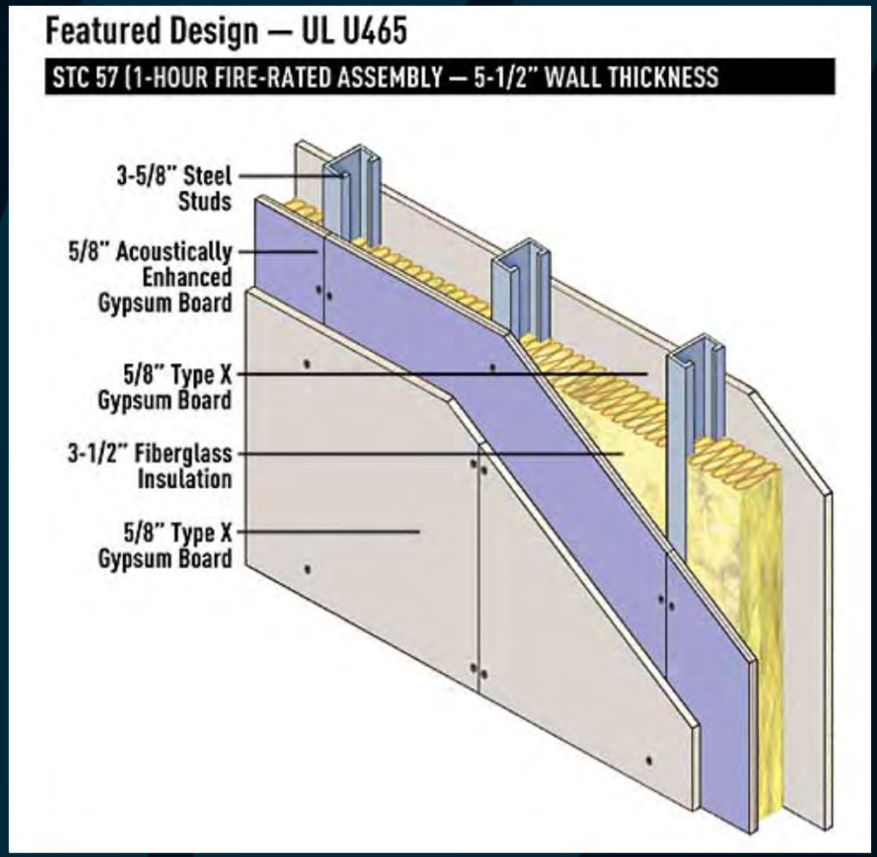


FIRE PARTITIONS

"A vertical assembly of material designed to restrict the spread of fire in which openings are protected."

CHARACTERISTICS:

- Governed by IBC 708
- Less rigorous than a fire barrier but used to separate apartments, tenants, occupancies, lobby areas, and corridors (IBC 708.1)
- Combustible material permitted (IBC 708.2)
- Typically, a 1-hour rating (IBC 708.3)
- Must extend to inside of wall and roof sheathing/material (IBC 708.4)



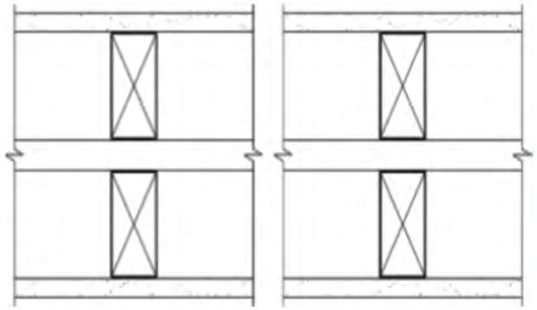
EXAMPLE WALL ASSEMBLY 1

GA FILE NO. WP 3370	GENERIC	1 HOUR FIRE	45 to 49 STC SOUND

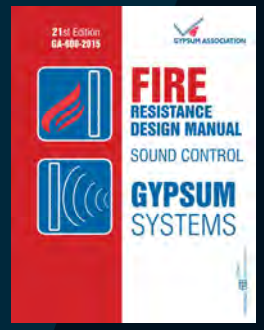
GYPSUM WALLBOARD, WOOD STUDS

One layer 5/8" type X gypsum wallboard or gypsum veneer base applied parallel or at right angles to each side of double row of 2 x 4 wood studs 16" o.c. on separate plates 1" apart with 6d coated nails, 1 7/8" long, 0.0915" shank, 1/4" heads, 7" o.c.

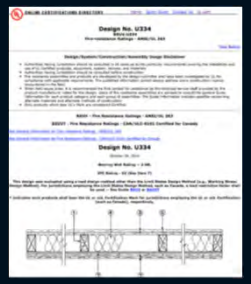
Joints staggered 16" on opposite sides. Horizontal bracing required at mid-height. **(LOAD-BEARING)**



Thickness:	9½"
Approx. Weight:	8 psf
Fire Test:	See WP 3605 (UL R1319-4, 6, 6-17-52; UL R2717-39, 1-20-66; UL R3501-52, 3-15-66, UL Design U305; ULC Design W301); UL R4024, 10-31-68
Sound Test:	NRCC TL-93-261, IRC-IR-761, 3/98







EXAMPLE WALL ASSEMBLY 2



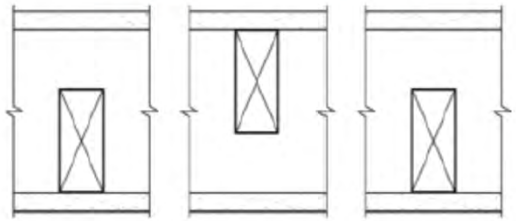
WALLS AND INTERIOR PARTITIONS, WOOD FRAMED

GA FILE NO. WP 3380	GENERIC	1 HOUR FIRE	40 to 44 STC SOUND

GYPSUM WALLBOARD, WOOD STUDS

One layer 5/8" type X gypsum wallboard or gypsum veneer base applied parallel or at right angles to each side of 2 x 4 wood studs 16" o.c. staggered 8" o.c. on 2 x 6 wood plates with 6d coated nails, 1 7/8" long, 0.0915" shank, 1/4" heads, 7" o.c.

Joints staggered 24" on opposite sides. Horizontal bracing required at mid-height. **(LOAD-BEARING)**



Thickness:	7 3/4"
Approx. Weight:	8 psf
Fire Test:	See WP 3605 (UL R1319-4, -6, 6-17-52; UL R2717-39, 1-20-66; UL R3501-52, 3-15-66, UL Design U305; ULC Design W301); UL R4024, 10-31-68
Sound Test:	NRCC TL-93-254, IRC-IR-761, 3/98

EXAMPLE FLOOR ASSEMBLY 1



FLOOR-CEILING SYSTEMS, WOOD FRAMED

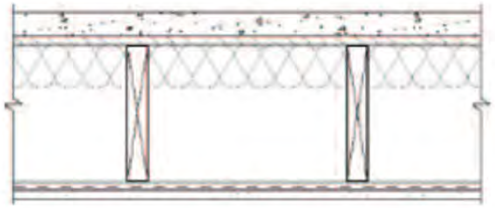
GA FILE NO. FC 5116	PROPRIETARY*	1 HOUR FIRE	50 to 54 STC SOUND

WOOD JOISTS, GYPSUM WALLBOARD, RESILIENT CHANNELS, GLASS FIBER INSULATION

One layer 5/8" proprietary type X gypsum wallboard or gypsum veneer base applied at right angles to resilient furring channels 24" o.c. with 1" Type S drywall screws 12" o.c. Gypsum board end joints located midway between continuous channels and attached to additional pieces of channel 54" long with screws at 12" o.c. Resilient furring channels applied at right angles to 2 x 10 wood joists 16" o.c. with 1 1/4" Type W drywall screws. Wood joists supporting 5/8" interior plywood with exterior glue subfloor and 1 5/8" perlite-sand concrete reinforced with No. 19 SWG galvanized hexagonal wire mesh. 3" glass fiber insulation 0.90 pcf in joist space stapled to subfloor.

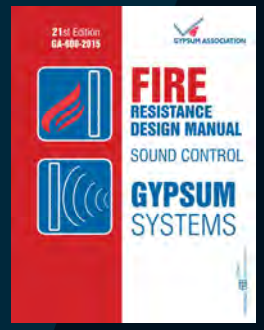
PROPRIETARY GYPSUM BOARD

American Gypsum Company LLC	-	5/8" FireBloc® Type C
CertainTeed Gypsum Inc.	-	5/8" ProRoc® Type C Gypsum Panels
CertainTeed Gypsum Canada Inc.	-	5/8" ProRoc® Type C Gypsum Panels
Georgia-Pacific Gypsum LLC	-	5/8" ToughRock® Fireguard C™
Lafarge North America Inc.	-	5/8" Firecheck® Type C
National Gypsum Company	-	5/8" Gold Bond® Brand FIRE-SHIELD C™ Gypsum Board
PABCO Gypsum	-	5/8" FLAME CURB® Super 'C'™
Temple-Inland	-	5/8" TG-C



Approx. Ceiling Weight:	2 psf
Fire Test:	UL R3453-7, 5-1-70; Based on UL R3660-7, -8, 11-12-87; R2717-61, 8-18-87; Based on UL R7094, 90NK10635, 10-24-90; Based on UL R8742, 88NK22591, 10-6-88; UL Design L516
Sound Test: IIC & Test:	KAL L 224-28-65, 3-30-65 (74 C & P) KAL L 224-27-65, 3-30-65

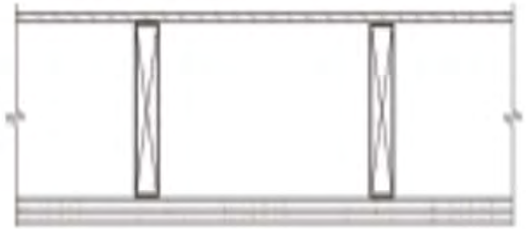
EXAMPLE FLOOR ASSEMBLY 2



GA FILE NO. RC 2601	GENERIC	1 HOUR FIRE

GYPSUM WALLBOARD, WOOD JOISTS, ROOF COVERING

Base layer 5/8" type X gypsum wallboard applied at right angles to 2 x 10 wood joists 24" o.c. with 1¼" Type W or S drywall screws 24" o.c. **Face** layer 5/8" type X gypsum wallboard or gypsum veneer base applied at right angles to joists with 1⅞" Type W or S drywall screws 12" o.c. at joints and intermediate joists and 1½" Type G drywall screws 12" o.c. placed 2" back on either side of end joints. Joints offset 24" from base layer joints. Wood joists supporting ½" plywood with exterior glue applied at right angles to joists with 8d nails. Appropriate roof covering. **Ceiling provides one hour fire resistance protection for framing, including trusses.**



Approx. Ceiling Weight: 5 psf

Fire Test: FM FC 172, 2-25-72; ITS, 8-6-98

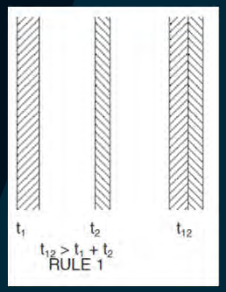
Harmathy's 10 Rules of Fire Endurance

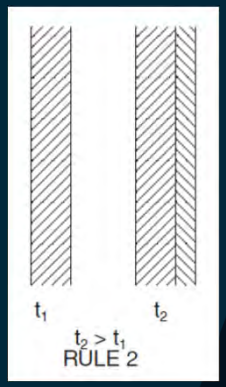
Source: May 1965 Edition of Fire Technology promulgated by the 2018 IEBC

RULES:

- Rule 1: The "thermal"1 fire endurance of a construction consisting of a number of parallel layers is greater than the sum of the "thermal" fire endurance's characteristic of the individual layers when exposed separately to fire.

- Rule 2: The fire endurance of a construction does not decrease with the addition of further layers.





MEANING:

- The value of the whole can be greater than the sum of the parts.

- More does not hurt

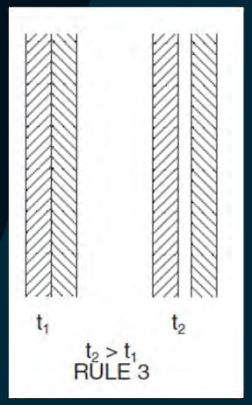


Harmathy's 10 Rules of Fire Endurance

Source: May 1965 Edition of Fire Technology promulgated by the 2018 IEBC

RULES:

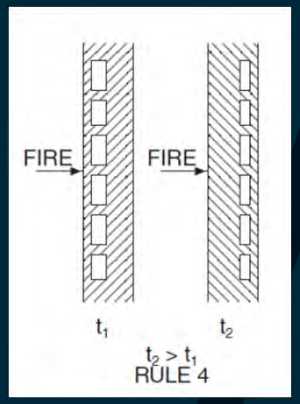
- Rule 3: The fire endurance of constructions containing continuous air gaps or cavities is greater than the fire endurance of similar constructions of the same weight, but containing no air gaps or cavities.



MEANING:

- Air gaps (with appropriate firestopping) are beneficial.

- Rule 4: The farther an air gap or cavity is located from the exposed surface, the more beneficial is its effect on the fire endurance.



- Place the air gap further from the fire for better performance



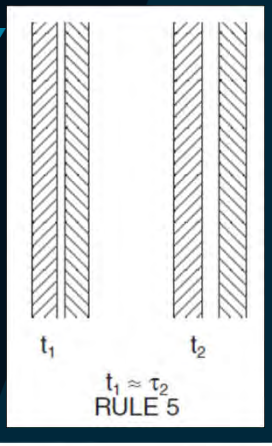
Harmathy's 10 Rules of Fire Endurance

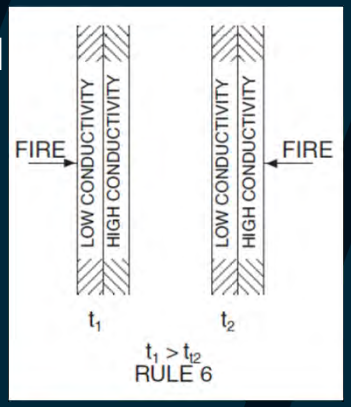
Source: May 1965 Edition of Fire Technology promulgated by the 2018 IEBC

RULES:

- Rule 5: Increasing the thickness of a completely enclosed air layer cannot increase the fire endurance of a construction.

- Rule 6: Layers of materials of low thermal conductivity are better utilized on that side of the construction on which fire is more likely to happen.





MEANING:

- An increase in the size of the air gap is not helpful.

- Think of the barrier as Captain America's shield – place it toward the expected hazard.

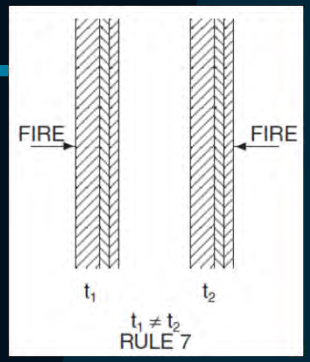


Harmathy's 10 Rules of Fire Endurance

Source: May 1965 Edition of Fire Technology promulgated by the 2018 IEBC

RULES:

- Rule 7: The fire endurance of asymmetrical constructions depends on the direction of heat flow.

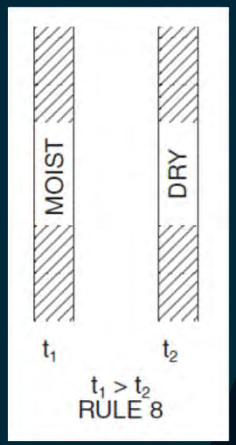


MEANING:

- Again, consider the orientation of the threat.

- Rule 8: The presence of moisture, if it does not result in explosive spalling, increases the fire endurance.





- There is no need to eliminate the moisture that is naturally part of the manufacturing process.

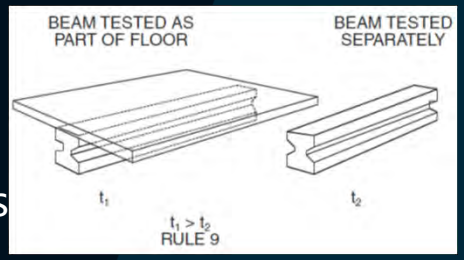
Harmathy's 10 Rules of Fire Endurance

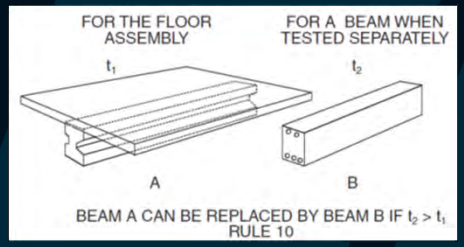
Source: May 1965 Edition of Fire Technology promulgated by the 2018 IEBC



RULES:

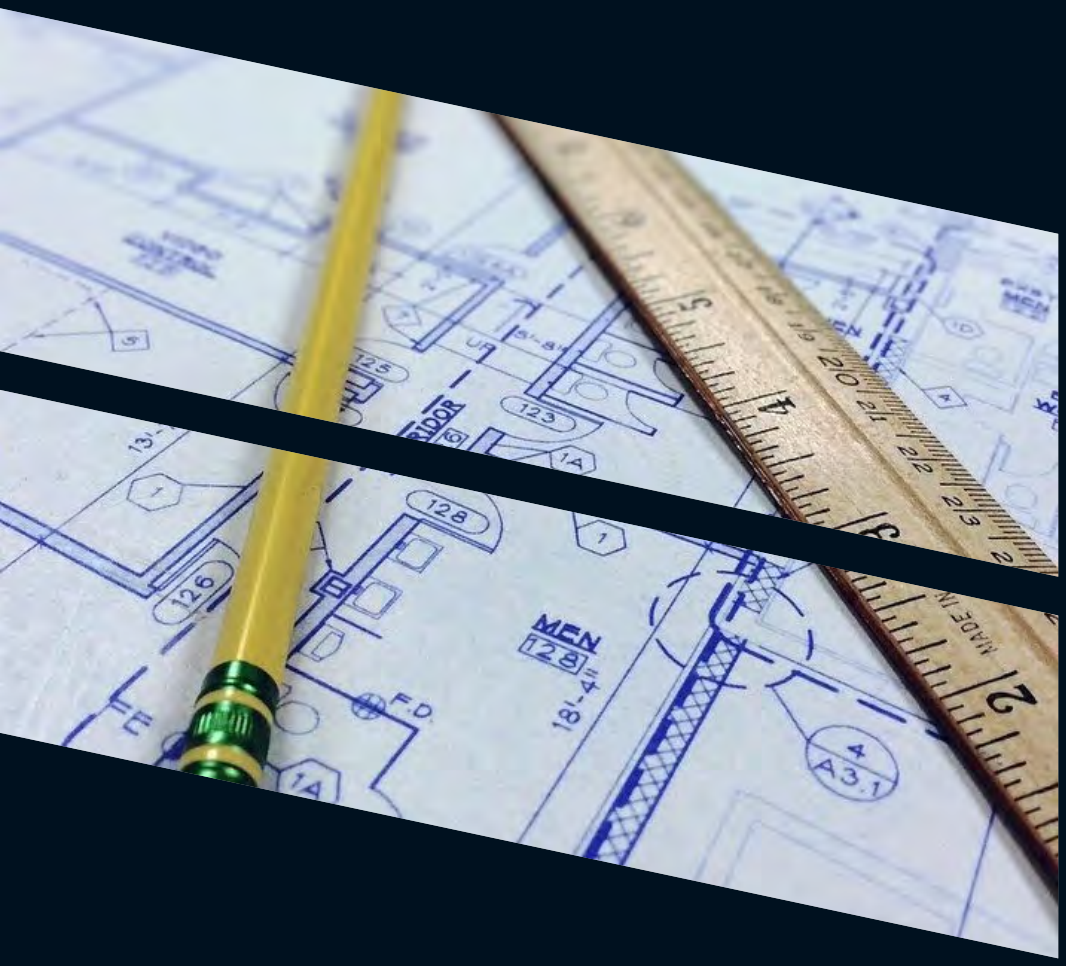
- Rule 9: Load-supporting elements, such as beams, girders and joists, yield higher fire endurance's when subjected to fire endurance tests as parts of floor, roof, or ceiling assemblies than they would when tested separately.
- Rule 10: The load-supporting elements (beams, girders, joists, etc.) of a floor, roof, or ceiling assembly can be replaced by such other load-supporting elements which, when tested separately, yielded fire endurance's not less than that of the assembly.





MEANING:

- Failure is dictated by the breaking or excessive deflection of members. Due to load-sharing of an assembly, the actual performance of structural members is better than a test of a single member would indicate.
- The introduction of a fire-rated beam into a compatible assembly is likely to increase the performance, not hinder it.



Structural Considerations

What can you do immediately?

What should you know/consider?

- Understand what the architect is communicating in the code analysis.
- Understand why we cannot use any arbitrary material.
- Be willing to investigate an assembly and understand its purpose.
- Anticipate, draw, and inspect for fireblocking, draftstopping, and firestops

FIREBLOCKING & DRAFTSTOPPING

Fireblocking

- "FIREBLOCKING. Building materials, or materials approved for use as fireblocking, installed to resist the free passage of flame to other areas of the building through concealed spaces." (IBC definition)

Draftstopping

- "DRAFTSTOP. A material, device or construction installed to restrict the movement of air within open spaces of concealed areas of building components such as crawl spaces, floor/ceiling assemblies, roof/ceiling assemblies and attics." (IBC definition)

FIREBLOCKING & DRAFTSTOPPING

Fireblocking

- "718.2 Fireblocking. In combustible construction, fireblocking shall be installed to cut off concealed draft openings (both vertical and horizontal) and shall form an effective barrier between floors, between a top story and a roof or attic space. Fireblocking shall be installed in the locations specified in Sections 718.2.2 through 718.2.7."

Draftstopping

- "718.3 Draftstopping in floors. Draftstopping shall be installed to subdivide floor/ceiling assemblies where required by Section 708.4.2. In other than Group R occupancies, draftstopping shall be installed to subdivide combustible floor/ceiling assemblies so that horizontal floor areas do not exceed 1,000 square feet (93 m2)."

FIREBLOCKING & DRAFTSTOPPING MATERIALS

Fireblocking

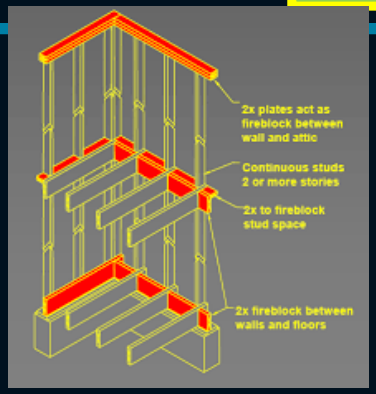
- 1. Two-inch (51 mm) nominal lumber.
- 2. Two thicknesses of 1-inch (25 mm) nominal lumber with broken lap joints.
- 3. One thickness of 0.719-inch (18.3 mm) wood structural panels with joints backed by 0.719-inch (18.3 mm) wood structural panels.
- 4. One thickness of 0.75-inch (19.1 mm) particleboard with joints backed by 0.75-inch (19 mm) particleboard.
- 5. One-half-inch (12.7 mm) gypsum board.
- 6. One-fourth-inch (6.4 mm) cement-based millboard.
- 7. Batts or blankets of mineral wool, mineral fiber or other approved materials installed in such a manner as to be securely retained in place.
- 8. Cellulose insulation installed as tested for the specific application.

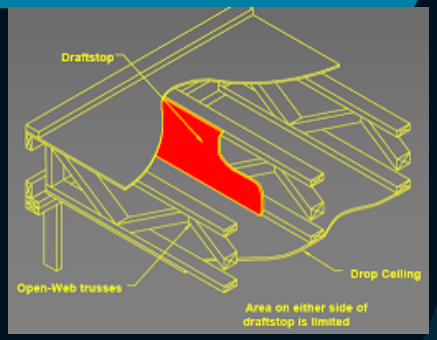
Draftstopping

- 1/2-inch (12.7 mm) gypsum board,
- 3/8-inch (9.5 mm) wood structural panel,
- 3/8-inch (9.5 mm) particleboard,
- 1-inch (25-mm) nominal lumber,
- cement fiberboard,
- batts or blankets of mineral wool or glass fiber,
- Or other approved materials adequately supported.

FIREBLOCKING & DRAFTSTOPPING DETAILS

Fireblocking







Draftstopping



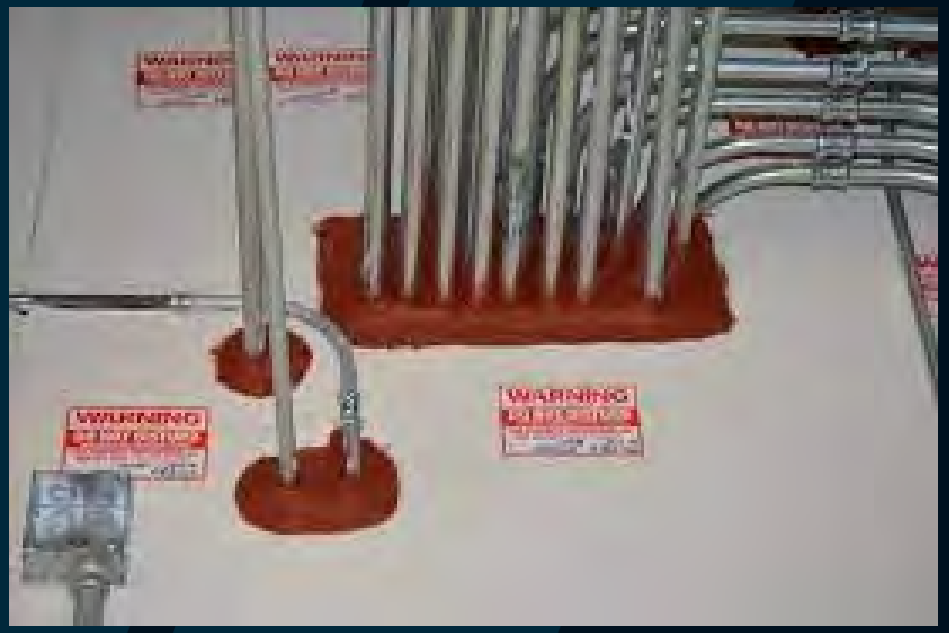




MEMBRANE-PENETRATION FIRESTOP

Firestop

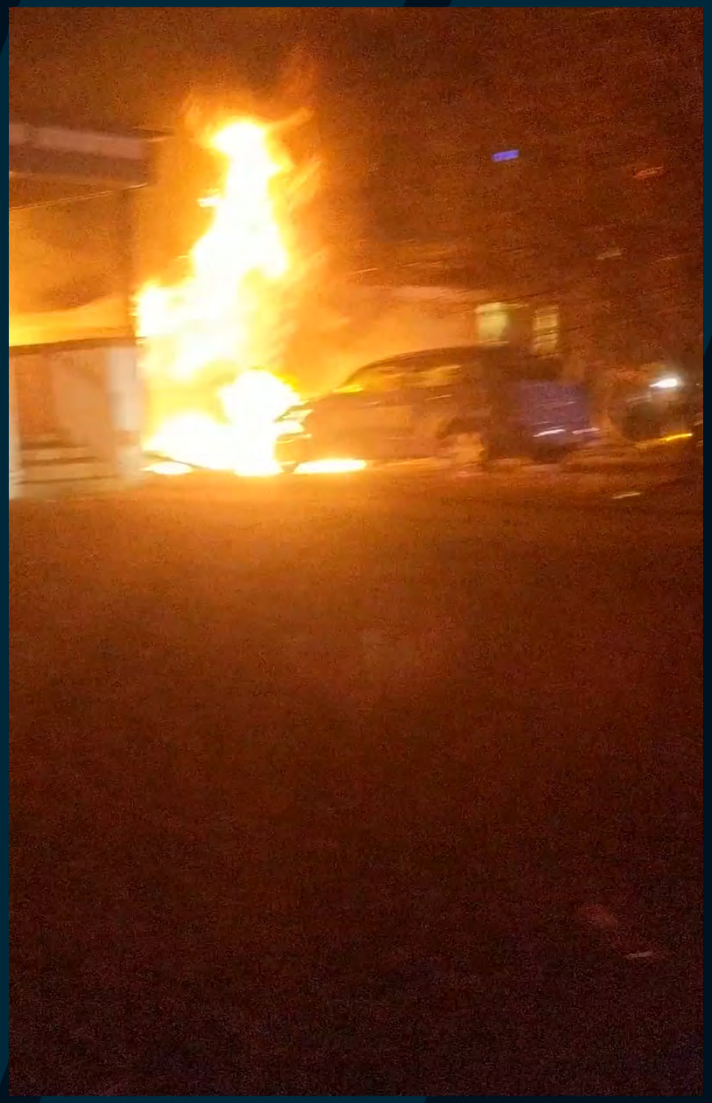
- "MEMBRANE-PENETRATION FIRESTOP. A material, device or construction installed to resist for a prescribed time period the passage of flame and heat through openings in a protective membrane in order to accommodate cables, cable trays, conduit, tubing, pipes or similar items.(IBC definition)
- i.e. fire caulk, See IBC 714



EXAMPLE 1

This fire was well fed with air and fuel and spread to the roof framing rapidly





EXAMPLE 2

This fire was cut-off and sealed to the garage. It burned so hot, it melted the chassis, but did not enter the home









EXAMPLE 3

Flames crawled from the origin in the basement and climbed stud cavities unimpeded









POP QUIZ

What is the code analysis telling us?

International Building Code - 2006

Section 310 - Use and Occupancy Classification
Group R-2 - Apartment Houses

Section 311 - Use and Occupancy Classification
Group S-2 - Open or enclosed parking garages.

Table 503 - Allowable Height and Building Areas
Group R-2 Type VA
Maximum 3 stories and 50' in height, 12,000 sf per floor plate. Number of stories (local height restriction remains at 50 feet)

Group S-2 Type VA (revised by Section 509.2 below)
Maximum 4 stories and 50' in height, 21,000 sf per floor plate.

Section 504.2 - Automatic sprinkler system increase
Increase number of stories by one and height by 20 feet.

1) Code Year / Type (Building, Residential, Electrical, Energy, Fire, Mechanical, Plumbing, Swimming Pool & Spa, Existing Building)		
2) Occupancy Classification		
3) Type of Construction (For "T.I." only, show type of construction for both the existing shell building and the proposed "T.I.")		
4) Fire Sprinklers	Yes / No _____ If Yes: New____ Existing____	Type NFPA_____
5) Fire Alarm	Yes / No _____ If Yes: New____ Existing____	
6) Height	Allowable _____	Actual _____
7) Stories	Allowable _____	Actual _____
8) Area	Allowable _____	Actual _____
(Include allowable area calculations per IBC 506) (Include mixed occupancy calculations if applicable)		
9) Occupant Load per Floor (Identify the use of Fixed or Movable Seats)		
10) Number of Exits	Required _____ (If (2) or more exits required Egress Plan Required)	Provided _____
11) Fire-Resistance Rating Requirements for Building Elements (Specify areas receiving spray applied fire protection)		
12) Fire-Resistance Rating of Exterior Walls Due to Location on Property (Specify fire separation distances on site plans)		
13) Fire-Resistance Protection of Openings Due to Location on Property and Maximum Area of Exterior Wall Openings (Provide calculations)		
14) Fire Resistance Rating of Specific Spaces and/or Design (Specify spaces requiring separation and hourly fire resistance rating)		
15) Fire Resistance Rating of Non-separated or Separated Occupancies (Provide mixed occupancy calculations if applicable)		
16) Roof Covering Material Class	Allowable _____	Actual _____
17) Required Plumbing Fixtures (Provide calculations for the number of water closets, urinals, lavatories, drinking fountains, and service sinks)		
18) Special Inspection(s) Required (Provide table specific to the project)		

DISCLAIMER

This was an introduction and summary only…

- **There are frequently exceptions within the code, that for the purpose of brevity, were not highlighted in this presentation.**
- **Read the entire IBC code sections (and sometimes the commentary) for proper context.**
- **The IBC has provisions that are in opposition and conflicted. When in doubt, err on the side of being conservative.**
- **The intent of sharing this information is to allow you to better coordinate the various building disciplines.**
- **Use the knowledge to offer better design development and field inspection guidance.**

MENTAL RESET…

WE ARE STILL STRUCTURAL ENGINEERS



Credits:
https://www.youtube.com/watch?v=5rCpsAnydYs
Written, Performed, Directed & Edited: Steve Mah.
www.stevemah.com



THANK YOU!

Peter Marxhausen

Phone
720-618-6473

Email
pmarxhausen@ubse.com

Credits:
https://www.youtube.com/watch?v=gJup5i2zikw&t=5s
Wall Street Journal
Filmed in Houston, Texas, March 26, 2014

Quality with Integrity ubse

University of Colorado Denver
CU IN THE CITY