
Stair Shaft
8" Masonry
Walls
Elevator Shaft
12" Masonry Walls
FORSE

about your instructor….

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Experience / Background

- Licensed Structural Engineer (SE) in the State of IL
- Professional Engineer (PE) in WI, MN, IA, KS, MI, AR
- Structural Engineering: University of Minnesota
- MBA: Marquette University

FORSE Consulting

- Team of engineers with extensive masonry design experience
- Consultant to the masonry industry since February 2010

Learning Objectives

- Develop Checklist of important items for masonry design and construction
- Review important aspect of masonry design criteria
- Discuss best practices for element design
- Consider the impact of efficient and effective designs in case studies

Available Presentations

1. What Non-Engineers need to know about Structural Masonry
2. Intro to Structural Masonry Design
3. Structural Concrete Masonry Design
4. Structural Clay Masonry Design
5. Masonry Notes, Details, and Prototypes
6. Software Review for Structural Masonry Design
7. Masonry Analysis and Design with Finite Element Software
8. Movement Joints, Structural Edition
9. Masonry Shear Wall Design
10. Lintels for Masonry Walls
11. Connection to Masonry walls
12. Storm Shelter design with Masonry
13. Cutting Edge Masonry Codes & Standards
14. Masonry Case Studies
15. Building System Selection (featuring Masonry)
16. Hybrid Masonry with PT Concrete
17. Masonry Checklist: Reviewing Struc Drawings

created in conjunction with

TEAM IMI

FORSE

Masonry Checklist

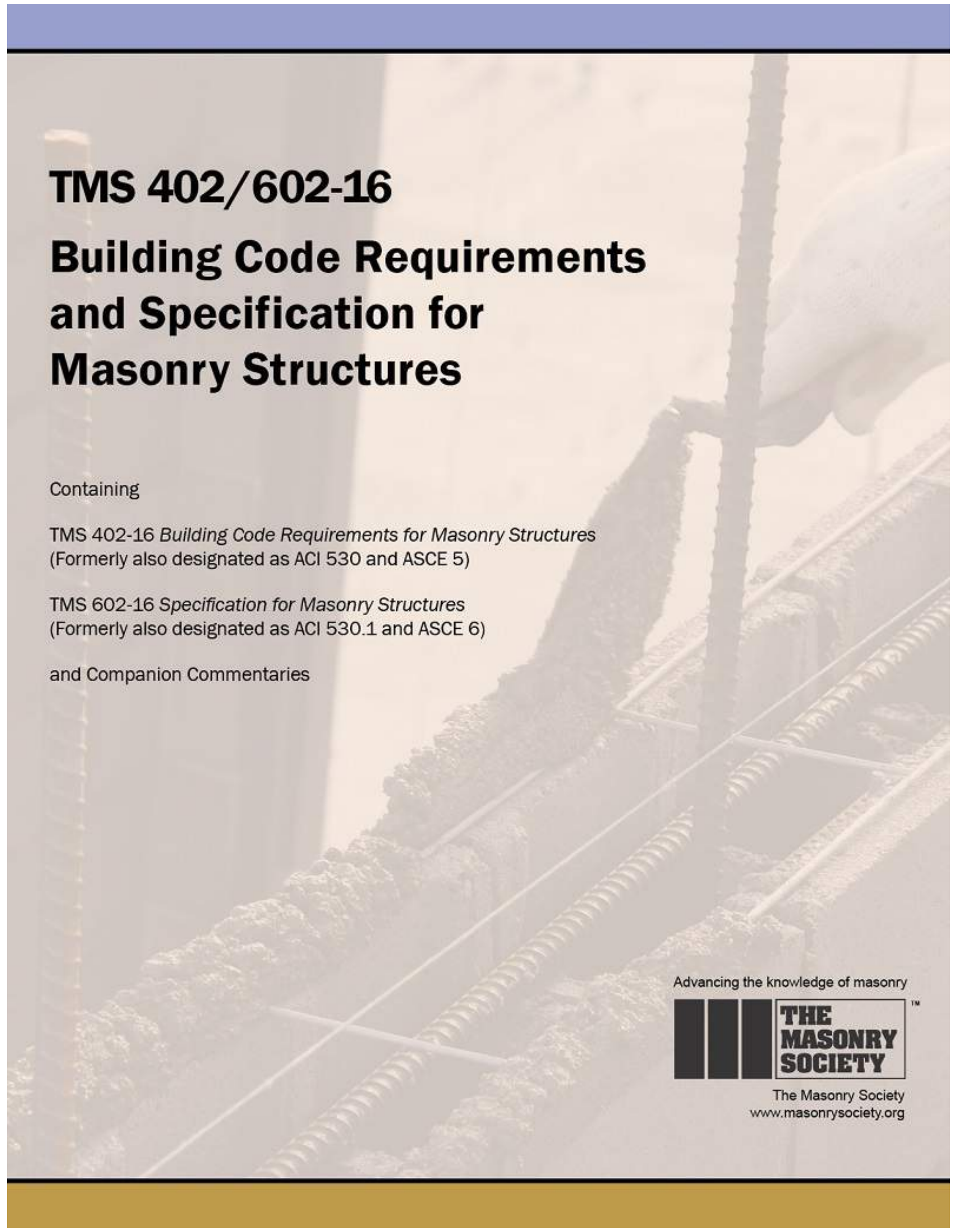
MASONRY INSIGHTS
written in conjunction with International Masonry Institute

Masonry checklist: reviewing structural plans

- ☐ f'_m (masonry assembly strength) for structural concrete or clay masonry is 2,000 psi or greater
  - ☐ concrete masonry f'_m = 2,500psi most common in Midwest, likely can be greater
  - ☐ clay masonry f'_m = commonly in the range of 3,000psi to 4,000psi
  - ☐ strengths between up to 4,000 psi are permitted in current codes for strength design[1]
- ☐ check that all components of masonry are specified:
  - ☐ block strength: check masonry.forsei.com/masonry/cmudata/ to verify based on location
  - ☐ mortar type (mortar strength need not be listed)
    - ☐ recommend Type S for structural walls
    - ☐ recommend Type N for non-structural walls (veneer and possibly partition walls)
  - ☐ grout strength
    - ☐ should be at least 2,000 psi, and equal to or greater than f'_m
  - ☐ reinforcement specified in schedule
    - ☐ typical walls have reinforcement bars of #4 thru #6, and no bars larger than #9
    - ☐ lap lengths are specified for correct f'_m and based on current TMS 402 code[1]
  - ☐ joint reinforcement specified and coordinated with CJ locations
- ☐ verify that movement joints are located - CJs are common for structural concrete masonry and MJs are common for structural clay masonry
  - ☐ CJs or MJs for structural walls must be located on structural elevations or plans[1]
  - ☐ CJs or MJs in reinforced structural walls
    - ☐ at common wall locations [2]: generally at 25 ft spacing or less, change of wall height, building corners

Checklist Items

- ☐ f'm - masonry assembly strength
- ☐ Verify all components of masonry are specified
- ☐ Consider masonry wall thickness and reinforcement
- ☐ Review masonry shear walls
- ☐ Review masonry partition walls
- ☐ Check that control joints are located on plans
- ☐ Review lintels, <u>prefer masonry lintels</u> where possible
- ☐ Review bearing plate details
- ☐ Consider conflicts between steel and masonry



<u>REFERENCES</u>

- Masonry code TMS 402/602-16
- NCMA TEK 10-2D (2019)
- NCMA TEK 10-3 (2003)

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MASONRY

MASONRY

1. MINIMUM 28-DAY COMPRESSIVE STRENGTHS FOR MASONRY CONSTRUCTION SHALL BE:

DESIGN ASSEMBLY STRENGTH, f'm	**1500 2000** PSI
INDIVIDUAL CONCRETE MASONRY UNITS	**1900 2800** PSI
MORTAR	1800 PSI
GROUT	2000 PSI

2. MASONRY MATERIALS SHALL CONFORM TO THE FOLLOWING STANDARDS:

CONCRETE MASONRY UNITS (CMU)	ASTM C90, GRADE N-1
MORTAR	ASTM C270, TYPE S
GROUT	ASTM C476
REINFORCING STEEL	ASTM A615, GR 60
PLATE AND BENT BAR ANCHORS	ASTM A36
SHEET METAL ANCHORS AND TIES	ASTM A1008
WIRE MESH TIES	ASTM A1064
WIRE TIES AND ANCHORS	ASTM A951
ANCHOR BOLTS	ASTM A307, GRADE A

these values are too low

when specifying mortar, you are not required to indicate strength, instead specify TYPE

Checklist should help reviews

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Checklist should help reviews
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LAP LENGTHS?

3. BAR SPLICES SHALL BE PROVIDED WHERE INDICATED ON THE DRAWINGS. IF SPLICE LENGTH IS NOT GIVEN ON THE DRAWINGS, PROVIDE LAP LENGTHS (IN INCHES) AS FOLLOWS EXCEPT BARS LARGER THAN #9 SHALL BE MECHANICALLY SPLICED:

wall thickness, t_w:	8 inches	reinf. spacing:	8 inches
wall strength, f'_m:	2500 psi	reinf.position:	centered
reinf. Strength, f_y:	60000 psi		

Bar	db	γ	K	development length, l_d
#3	0.375	1	3.375	**12 inches**
#4	0.5	1	3.375	**12 inches**
#5	0.625	1	3.3125	**18 inches**
#6	0.75	1.3	3.25	**35 inches**
#7	0.875	1.3	3.1875	**49 inches**
#8	1	1.5	3.125	**75 inches**
#9	1.125	1.5	3.0625	**97 inches**

OLD LAP REQ of 48db

48 * db	comment
~~18 inches~~	too long
~~24 inches~~	too long
~~30 inches~~	too long
~~36 inches~~	too long
~~42 inches~~	too short
~~48 inches~~	too short
~~54 inches~~	too short

Checklist should help reviews

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MASONRY

GOOD SCHEDULES - I WOULD SUGGEST ADDING f'm=2500 and f'm=3000

3. BAR SPLICES SHALL BE PROVIDED WHERE INDICATED ON THE DRAWINGS. IF SPLICE LENGTH IS NOT GIVEN ON THE DRAWINGS, PROVIDE LAP LENGTHS (IN INCHES) AS FOLLOWS EXCEPT BARS LARGER THAN #9 SHALL BE MECHANICALLY SPLICED:

ASD (IBC 2006/2009):

MINIMUM LAP SPLICE LENGTH	
BAR SIZE	LAP LENGTH
#3	18
#4	24
#5	30
#6	36
#7	42
#8	48
#9	54

ASD (IBC 2012/2015):

MINIMUM LAP SPLICE LENGTH						
BAR SIZE	f'm = 1500 PSI			f'm = 2000 PSI		
	8" CMU	10" CMU	12" CMU	8" CMU	10" CMU	12" CMU
#3	12	12	12	12	12	12
#4	15	12	12	13	12	12
#5	23	18	15	20	16	13
#6	43	34	28	38	29	24
#7	60	46	38	52	40	33
#8	92	71	57	70	61	50
#9	NP	90	73	NP	78	64

LRFD (IBC 2006/2009):

MINIMUM LAP SPLICE LENGTH						
BAR SIZE	f'm = 1500 PSI			f'm = 2000 PSI		
	8" CMU	10" CMU	12" CMU	8" CMU	10" CMU	12" CMU
#3	16	16	16	14	14	14
#4	21	21	21	18	18	18
#5	26	26	26	22	22	22
#6	43	40	40	38	35	35
#7	60	46	46	52	40	40
#8	72	71	61	72	61	53
#9	NP	81	73	NP	78	64

LRFD (IBC 2012/2015):

MINIMUM LAP SPLICE LENGTH						
BAR SIZE	f'm = 1500 PSI			f'm = 2000 PSI		
	8" CMU	10" CMU	12" CMU	8" CMU	10" CMU	12" CMU
#3	12	12	12	12	12	12
#4	15	12	12	13	12	12
#5	23	18	15	20	16	13
#6	43	34	28	38	29	24
#7	60	46	38	52	40	33

Checklist should help reviews
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MASONRY

4. LOAD BEARING MASONRY SHALL HAVE FULL HEIGHT 9 GAUGE MINIMUM HORIZONTAL REINFORCEMENT NOT TO EXCEED 16” OC VERTICALLY.

5. ALL LOAD BEARING MASONRY WALLS TO HAVE FULL BED, HEAD AND COLLAR JOINTS.

6. GROUT SOLID ALL JAMBS FULL HEIGHT IN LOAD BEARING MASONRY WALLS TO UNDERSIDE OF LINTEL. EXTEND GROUTED JAMB FROM FACE OF MASONRY OPENING AT LEAST EQUAL TO THE BEARING LENGTH OF THE LINTEL BEYOND THE OPENING PLUS 8 INCHES.

7. PROVIDE A MINIMUM OF 1 INCH GROUT BETWEEN MAIN REINFORCING AND/OR BOLTS AND MASONRY UNIT FACE. VERTICAL REINFORCEMENT SHALL BE CENTERED IN WALL, UNO.

standard detail showing tolerance?

8. CELLS SHALL BE IN VERTICAL ALIGNMENT. DOWELS IN FOOTINGS SHALL BE SET TO ALIGN WITH CORES CONTAINING REINFORCING STEEL.

9. ALL CELLS CONTAINING REINFORCING SHALL BE FILLED SOLID WITH GROUT, AND ALSO WHERE NOTED ON THE DRAWINGS.

10. STACK BOND LAID MASONRY SHALL HAVE VERTICAL REINFORCEMENT AT MAXIMUM ______” OC SPACING.

11. COORDINATE ANY UNIDENTIFIED PIPE OR DUCT PASSING THROUGH STRUCTURAL MASONRY WALLS, UNLESS NOTED OR DETAILED SPECIFICALLY.

12. REFER TO ARCHITECTURAL DRAWINGS FOR SURFACE AND HEIGHT OF UNITS, LAYING PATTERN AND JOINT TYPE. ALL BLOCK SHALL BE RUNNING BOND, UNO.

13. THE LOAD BEARING CONCRETE MASONRY WALLS FOR THIS PROJECT WERE DESIGNED TO SPAN VERTICALLY AND BE BRACED BY THE ROOF AND FLOOR FRAMING ELEMENTS OF THE STRUCTURE. DURING CONSTRUCTION, THE MASONRY CONTRACTOR SHALL PROVIDE LATERAL BRACING UNTIL THE ROOF STRUCTURE IS INSTALLED AS RECOMMENDED BY **ACI 530 TMS 402**/**602** AND THE “STANDARD PRACTICE FOR BRACING MASONRY WALLS UNDER CONSTRUCTION”, PREPARED BY THE COUNCIL FOR MASONRY WALL BRACING. THIS BRACING IS TO PREVENT UNNECESSARY STRESS OR DAMAGE TO THE MASONRY WALLS FROM WIND LOADS, WHICH CAN OCCUR WHILE THE WALLS ARE NOT PROPERLY BRACED BY THE ROOF AND FLOOR STRUCTURE.

14. THE MASONRY CONTRACTOR SHALL FURNISH SHOP DRAWINGS OF PRODUCT DATA, REINFORCEMENT DETAILS, AND MIX DESIGNS FOR AOR/SEOR’S REVIEW BEFORE FABRICATION.

are you successfully getting these?

MASONRY

HIGH LIFT GROUTED CONSTRUCTION

1. WHERE HIGH LIFT GROUTING IS USED, CONFORM TO THE SPECIFICATIONS AND THE CALIFORNIA BUILDING CODE.
2. CLEANOUT OPENINGS SHALL BE PROVIDED AT THE BOTTOM OF EACH POUR OF GROUT. ANY OVERHANGING MORTAR OR OTHER DEBRIS SHALL BE REMOVED FROM THE INSIDES OF CELL WALLS.
3. THE FOUNDATION OR OTHER HORIZONTAL CONSTRUCTION JOINTS SHALL BE CLEANED OF ALL LOOSE MATERIAL AND MORTAR DROPPINGS BEFORE EACH POUR.
4. THE CLEANOUTS SHALL BE SEALED BEFORE GROUTING. ALL CELLS SHALL BE FILLED.
5. AN APPROVED ADMIXTURE REDUCING EARLY WATER LOSS AND PRODUCING AN EXPANSION ACTION SHALL BE USED IN THE GROUT.

do you want to specify 12’-8” with clean outs or 24’-0” with SCG?

Checklist should help reviews

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Checklist should help reviews
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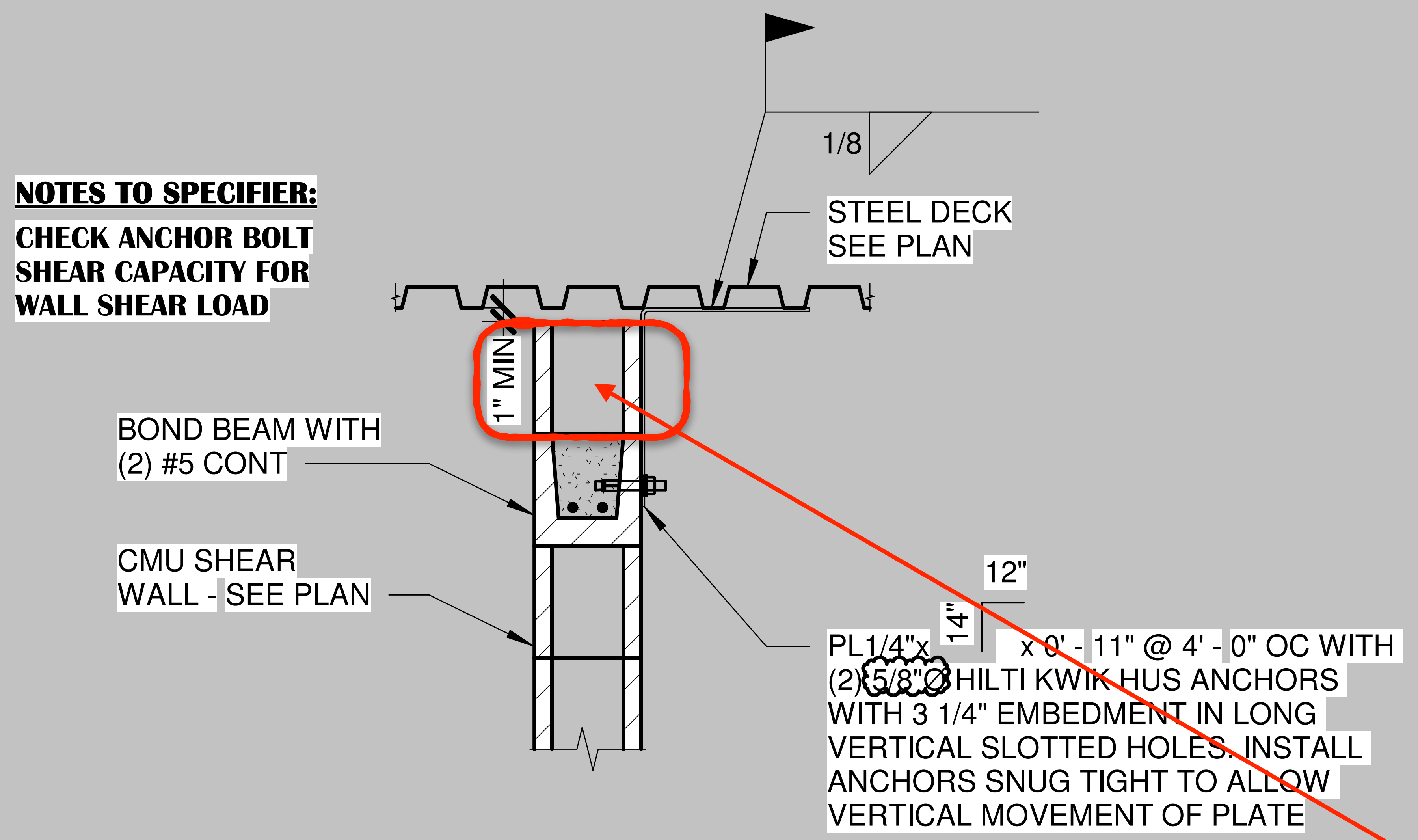
GOOD DETAIL



1 CONNECTION TO CMU SHEAR WALL DETAIL

3/4" = 1'-0"

GROUT SOLID TO INCREASE ANCHOR EDGE DISTANCE?

COMPANY ABC

CONNECTION TO CMU SHEAR WALL DETAIL_ANCHOR IN 2ND COURSE DOWN FROM ROOF DECK

M-204

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Checklist should help reviews

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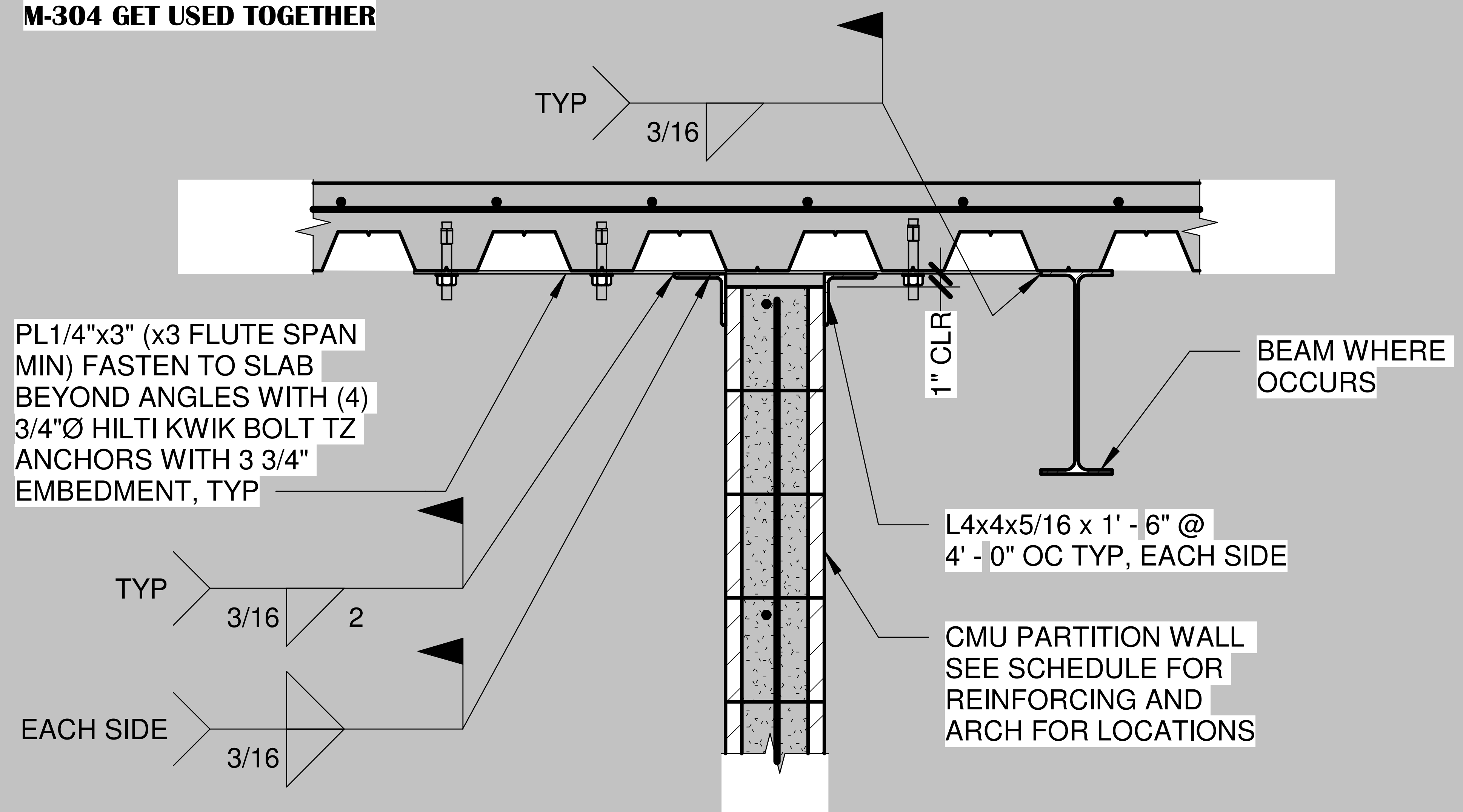
GOOD DETAIL

NOTES TO SPECIFIER:

M-300, M-301, M-302 AND M-304 GET USED TOGETHER



1 NON-STRUCTURAL CMU WALL BRACING TO SLAB ON DECK

3/4" = 1'-0"

COMPANY ABC	NON-STRUCTURAL CMU WALL BRACING TO SLAB ON DECK_HIGH SEISMIC WITH PLATE AND ANGLES	M-300

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Checklist should help reviews

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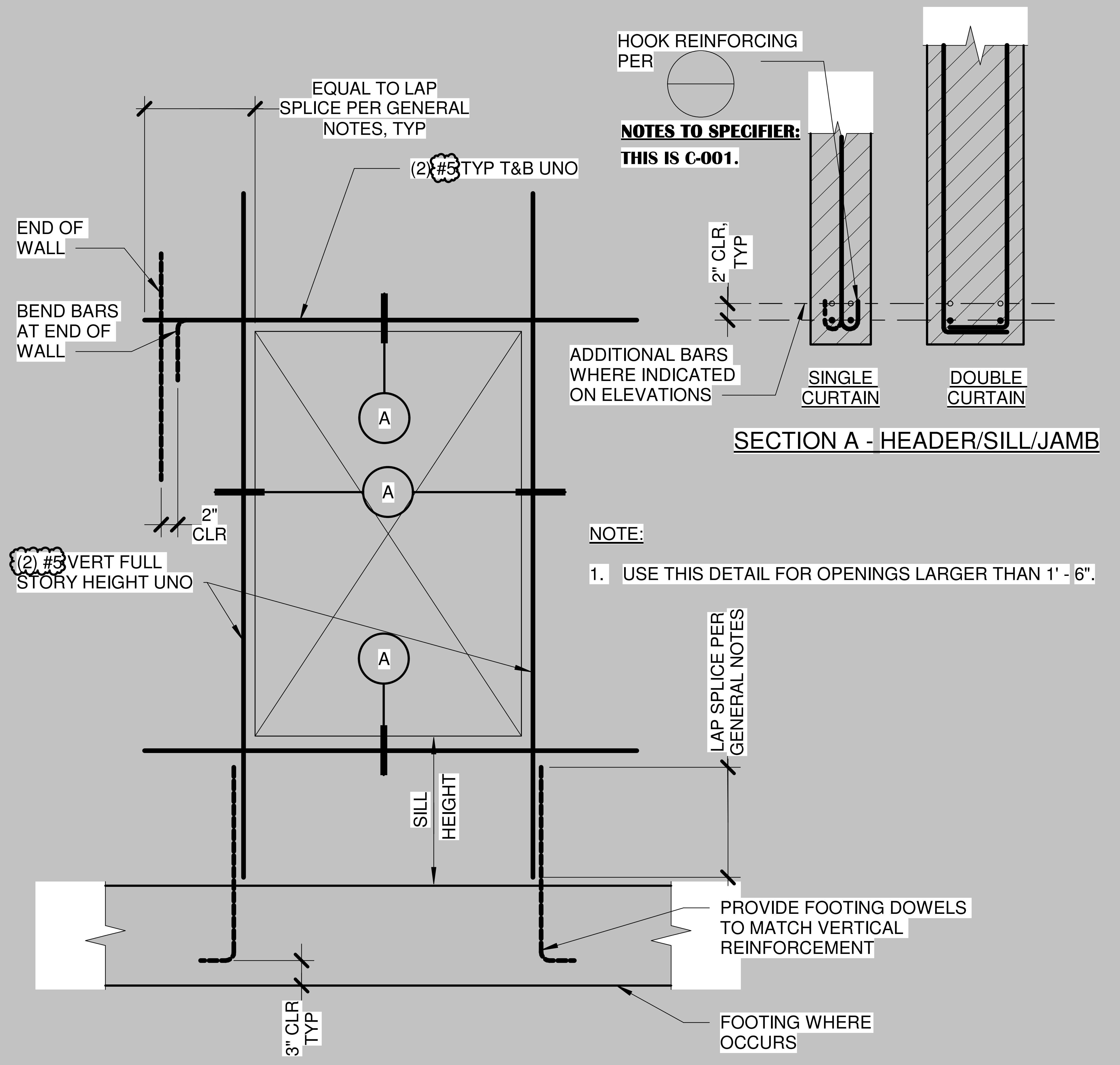

NOTE:

1. USE THIS DETAIL FOR OPENINGS LARGER THAN 1' - 6".

1 TYPICAL CMU WALL OPENING DETAIL

3/4" = 1'-0"

COMPANY ABC

TYPICAL CMU WALL OPENING DETAIL_HIGH SEISMIC

M-001

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GOOD DETAIL - SIMILAR DETAIL FOR LOW SEISMIC?

Checklist should help reviews
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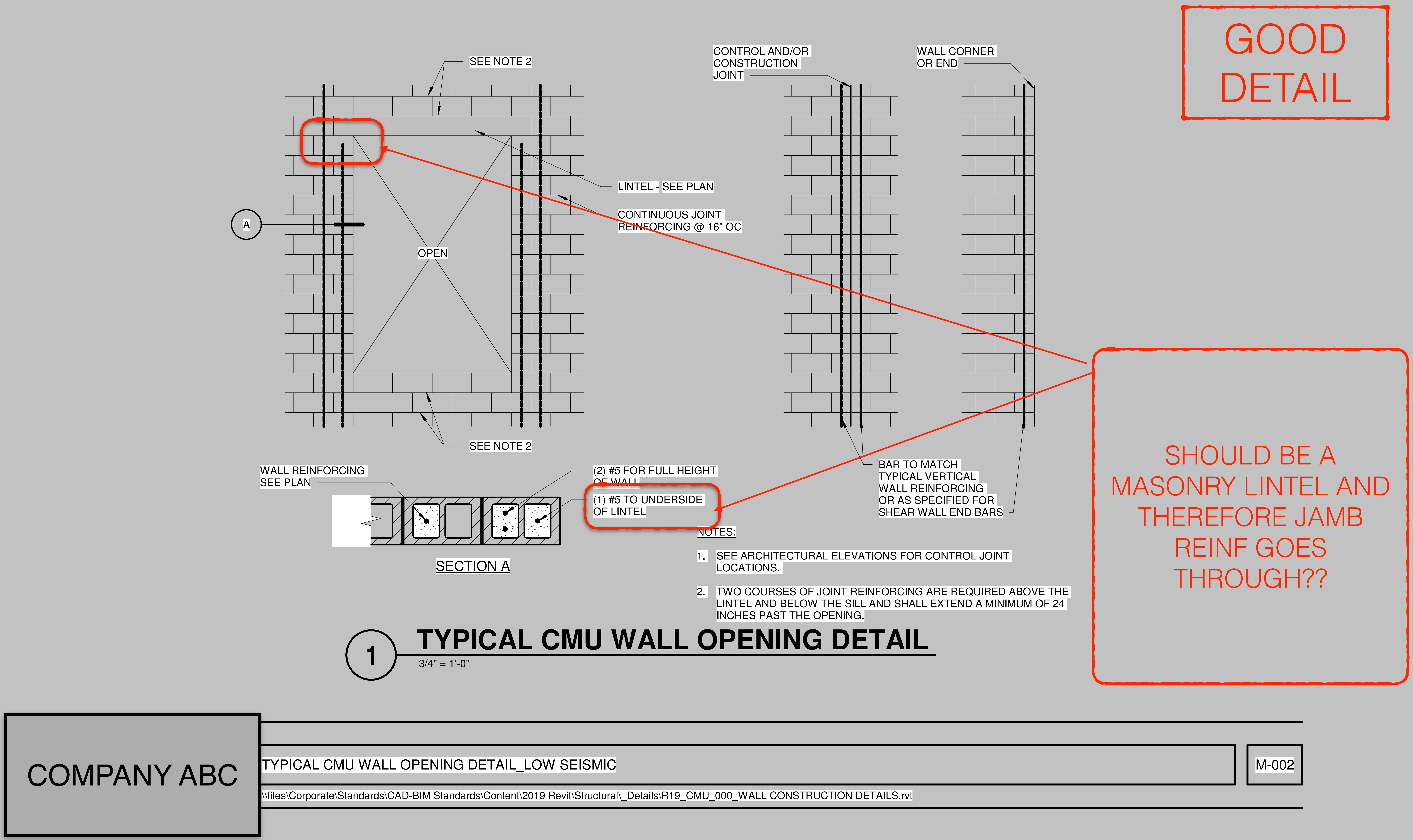

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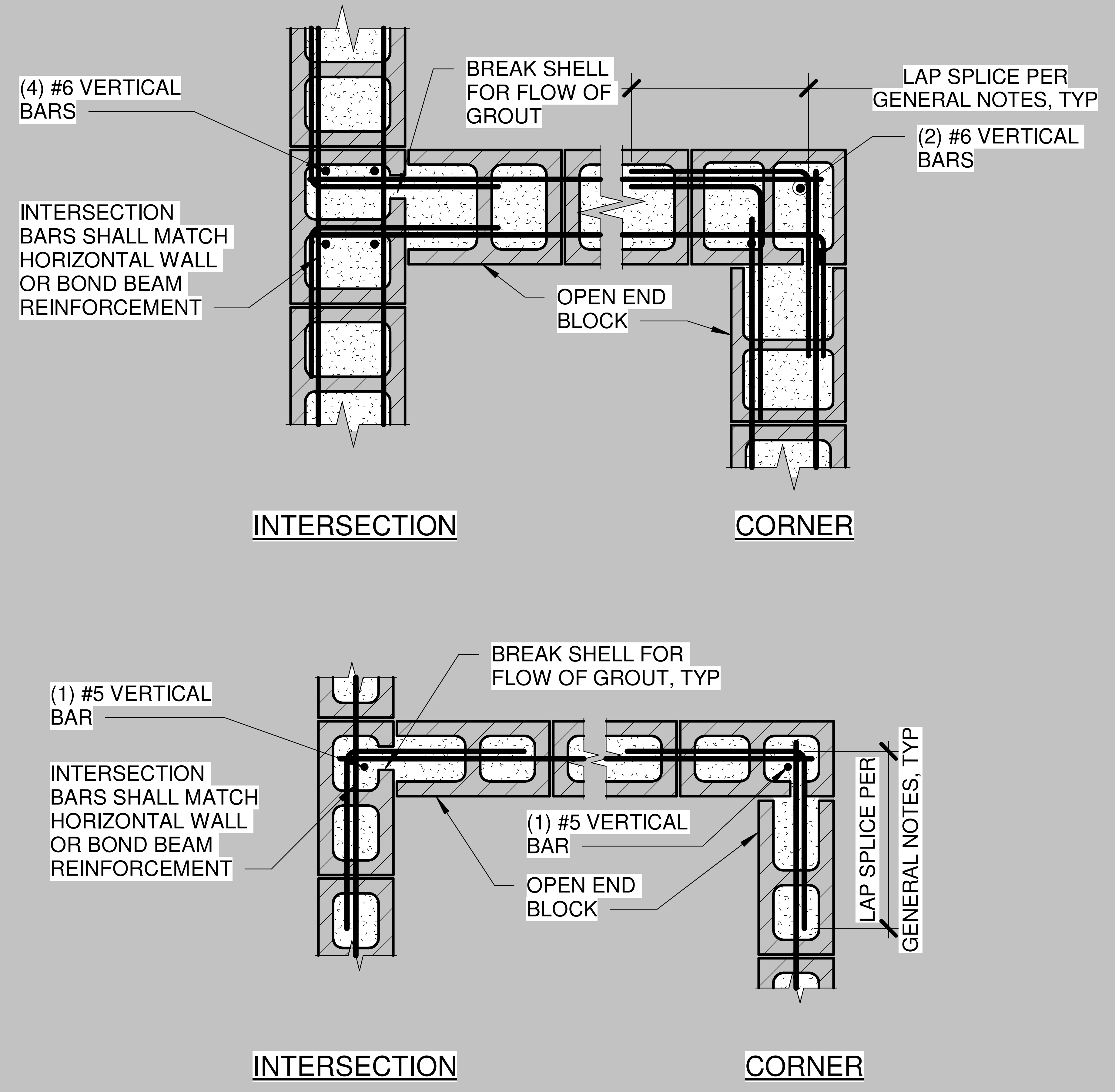
GOOD DETAIL



1 **CMU WALL INTERSECTION DETAILS**
3/4" = 1'-0"

COMPANY ABC	CMU WALL INTERSECTION DETAILS	M-003

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Checklist should help reviews

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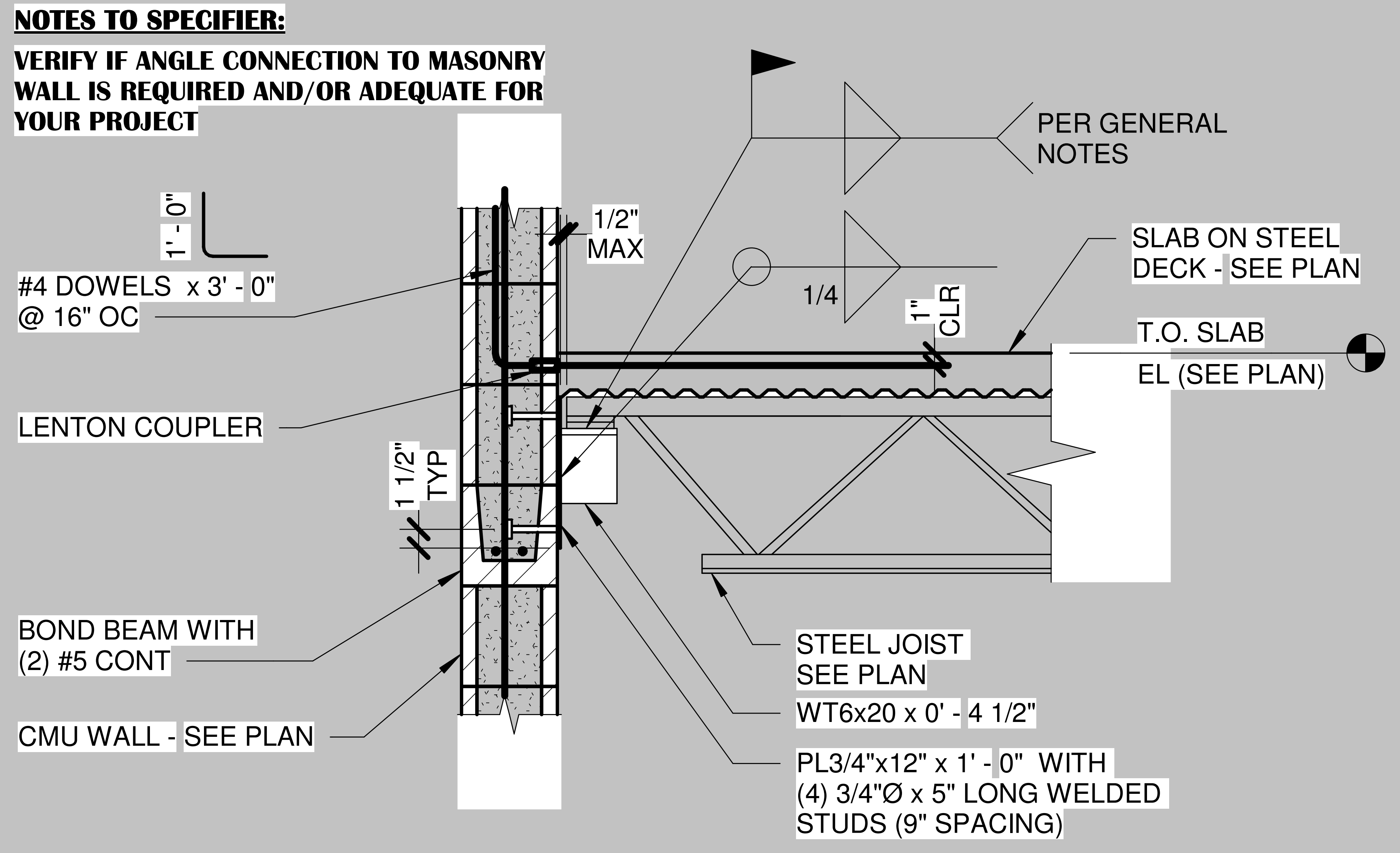
ASSUME JOIST/BEAM POCKET NOT POSSIBLE? …



TYPICAL FLOOR JOIST BEARING ON CMU

1

3/4" = 1'-0"

COMPANY ABC

TYPICAL FLOOR JOIST BEARING ON CMU_HIGH SEISMIC WITH HAUNCH

M-104

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Checklist should help reviews
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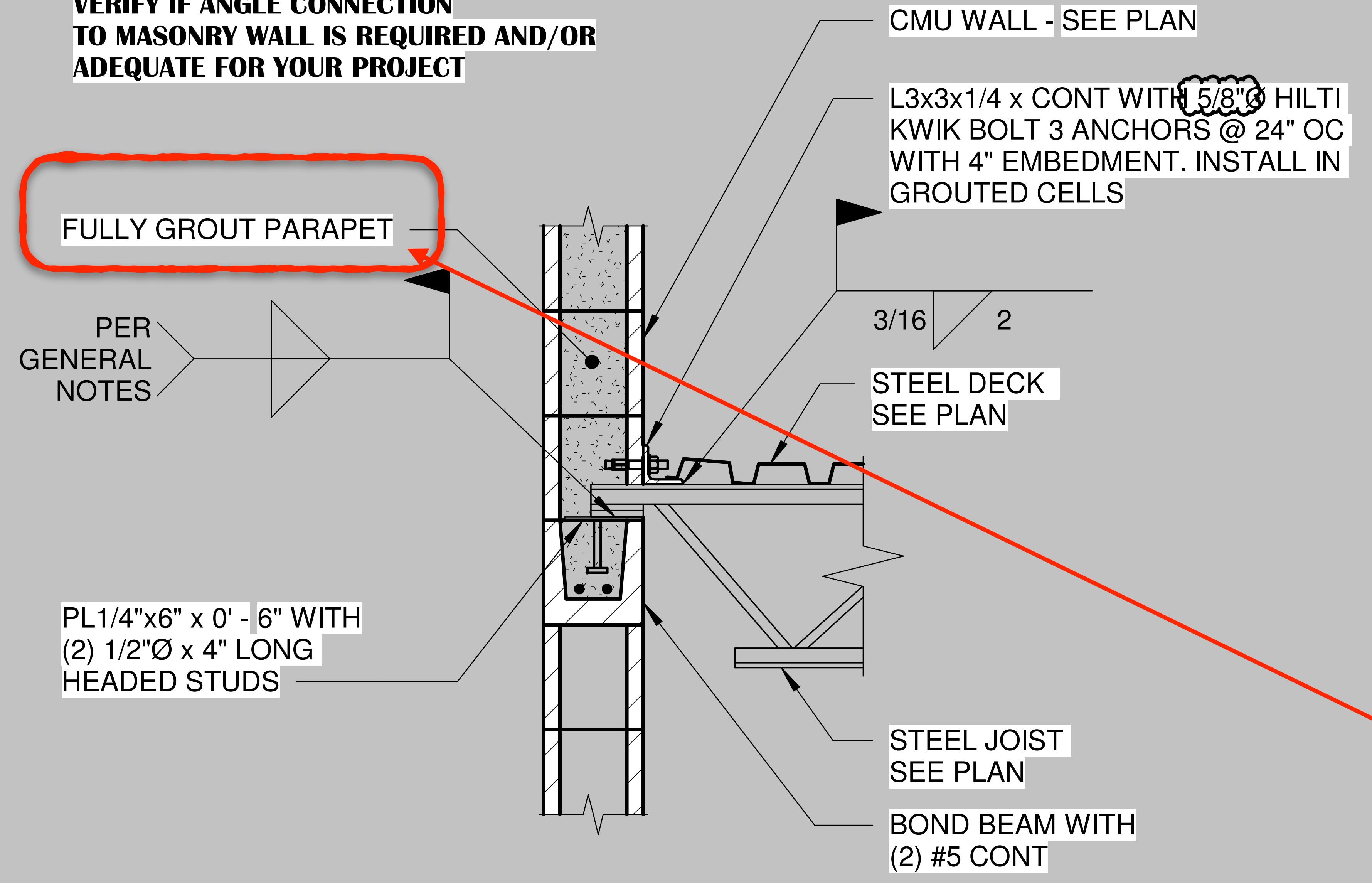
GOOD DETAIL

NOTES TO SPECIFIER:

VERIFY IF ANGLE CONNECTION TO MASONRY WALL IS REQUIRED AND/OR ADEQUATE FOR YOUR PROJECT



1 TYPICAL ROOF JOIST BEARING ON EXTERIOR CMU WALL

3/4" = 1'-0"

NECESSARY? COULD BE COSTLY LITTLE NOTE, AND NOT BE NEEDED

COMPANY ABC	TYPICAL ROOF JOIST BEARING ON EXTERIOR CMU WALL	M-109

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Checklist should help reviews
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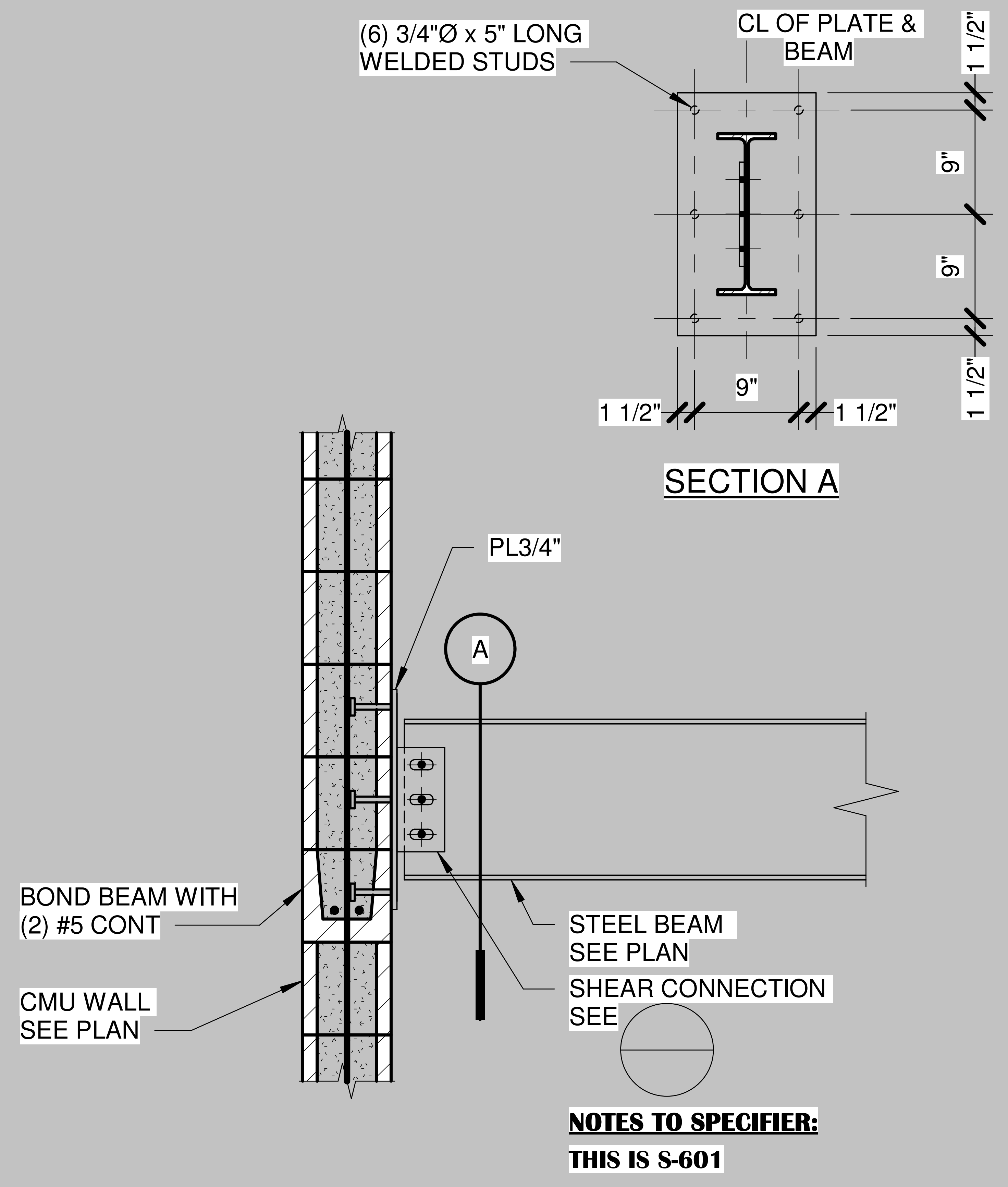
ASSUME BEAM POCKET NOT POSSIBLE? …



1 **BEAM CONNECTION AT CMU**

3/4" = 1'-0"

COMPANY ABC

BEAM CONNECTION AT CMU

M-113

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Checklist should help reviews
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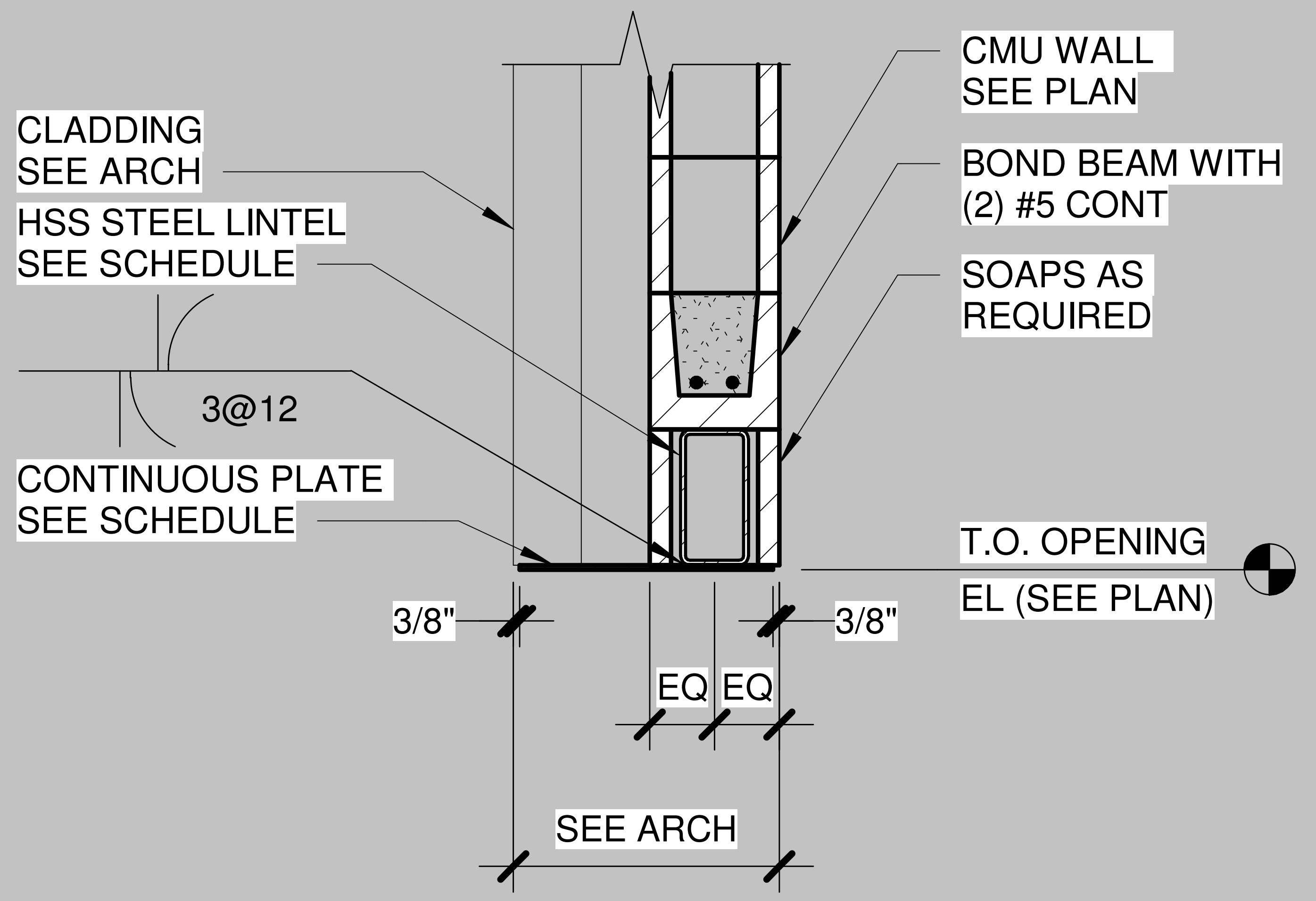
GOAL TO ELIMINATE THE NEED FOR THIS TYPE OF DETAIL - CONCERN AT BEARING CONDITION

NOTES TO SPECIFIER:

VERIFY WALL CAN SPAN HORIZONTALLY OVER OPENING. IF NOT, TRANSFER LOAD TO LINTEL USING STUDS. HOOK WALL BARS IF REQUIRED FOR DEVELOPMENT

NOTES TO SPECIFIER:

USE THE FOLLOWING HSS WIDTHS WHEN POSSIBLE TO ALLOW ENOUGH ROOM FOR MASONRY SOAPS:
8" WIDE MASONRY = 4" HSS WIDTH
10" WIDE MASONRY = 6" HSS WIDTH
12" WIDE MASONRY = 8" HSS WIDTH



NOTE:

1. SEE ARCHITECTURAL DRAWINGS FOR INSULATION, THROUGH-WALL FLASHING, AND WEEP HOLES.

1 HSS LINTEL DETAIL

3/4" = 1'-0"

COMPANY ABC

HSS LINTEL DETAIL_CAVITY WALL

M-400

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Checklist should help reviews
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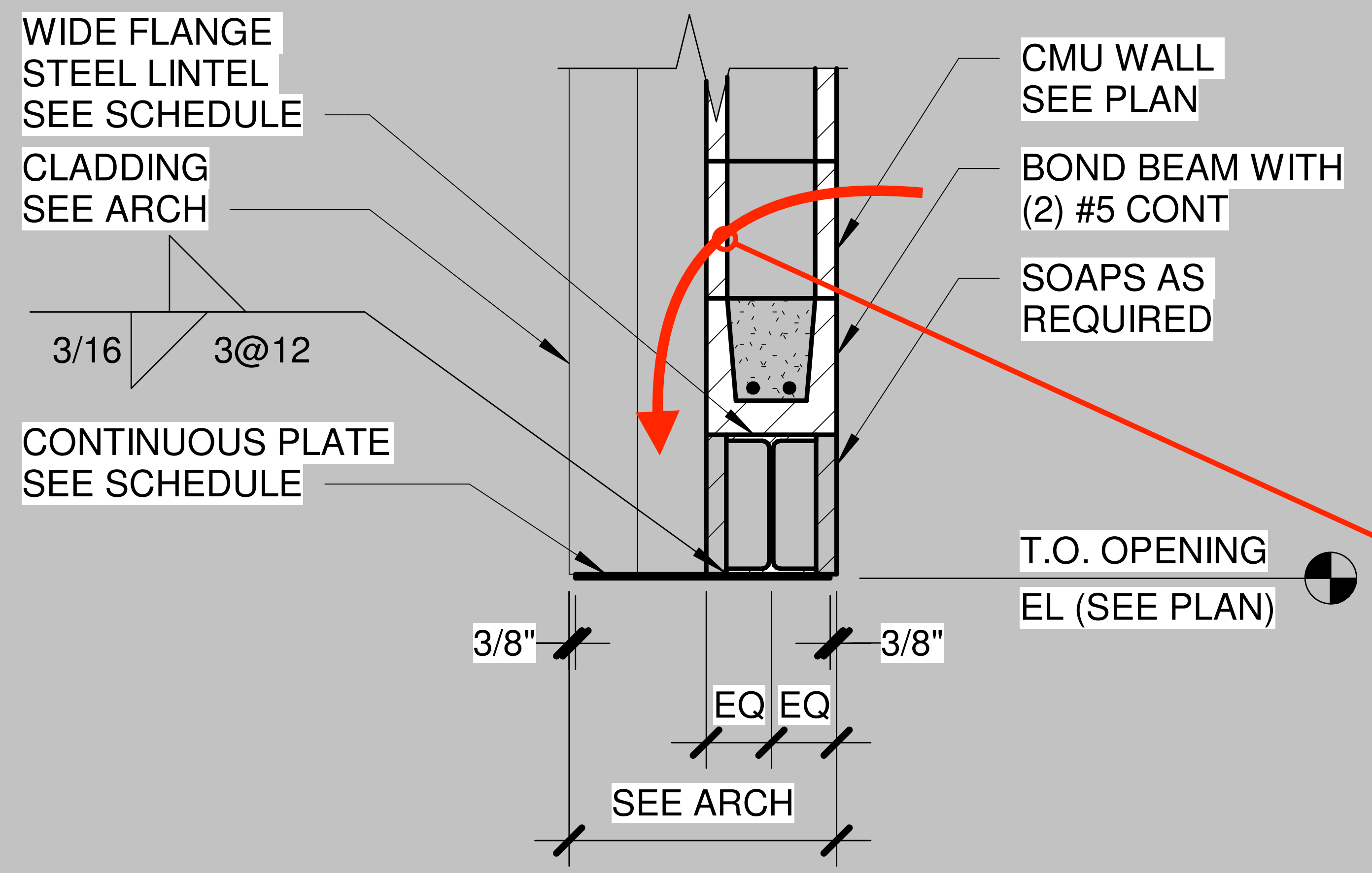
NOTES TO SPECIFIER:

PLATE MAY BE REQUIRED ON TOP OF WIDE FLANGE IF FLANGE WIDTH IS NOT WIDE ENOUGH TO REACH THE FACE SHELL.

NOTES TO SPECIFIER:

VERIFY WALL CAN SPAN HORIZONTALLY OVER OPENING. IF NOT, TRANSFER LOAD TO LINTEL USING STUDS. HOOK WALL BARS IF REQUIRED FOR DEVELOPMENT

GOAL TO ELIMINATE THE NEED FOR THIS TYPE OF DETAIL - CONCERN AT BEARING CONDITION



THERE IS A TORSIONAL ISSUE HERE

NOTE:

1. SEE ARCHITECTURAL DRAWINGS FOR INSULATION, THROUGH-WALL FLASHING, AND WEEP HOLES.

1 WIDE FLANGE LINTEL DETAIL

3/4" = 1'-0"

COMPANY ABC	WIDE FLANGE LINTEL DETAIL_CAVITY WALL	M-401

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Checklist should help reviews
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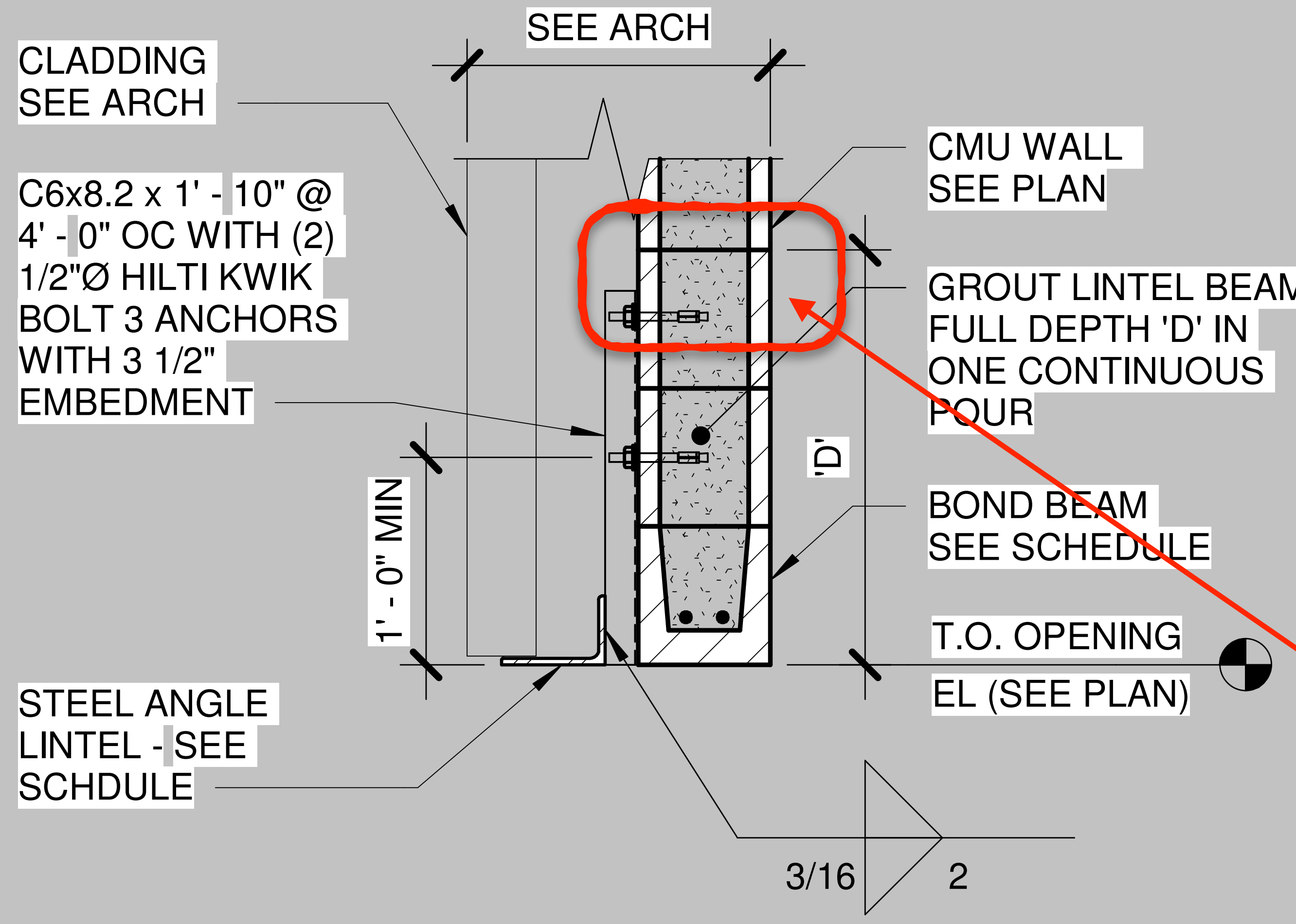
GOOD DETAIL

NOTES TO SPECIFIER:

VERIFY WALL CAN SPAN HORIZONTALLY OVER OPENING. IF NOT, CONSIDER A DIFFERENT SHAPE. HOOK WALL BARS IF REQUIRED FOR DEVELOPMENT



NOTES:

1. SEE ARCHITECTURAL DRAWINGS FOR INSULATION, THROUGH-WALL FLASHING, AND WEEP HOLES.
2. SHORE UNTIL GROUT FOR LINTEL HAS REACHED ITS SPECIFIED STRENGTH.

1 BOND BEAM LINTEL DETAIL

3/4" = 1'-0"

TOP REINFORCEMENT GOOD FOR MASONRY LINTELS, AND ESP GOOD AT THIS CONDITION

COMPANY ABC

BOND BEAM LINTEL DETAIL_CAVITY WALL WITH BRICK RELIEF

M-404

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Checklist should help reviews

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NOTES TO SPECIFIER:

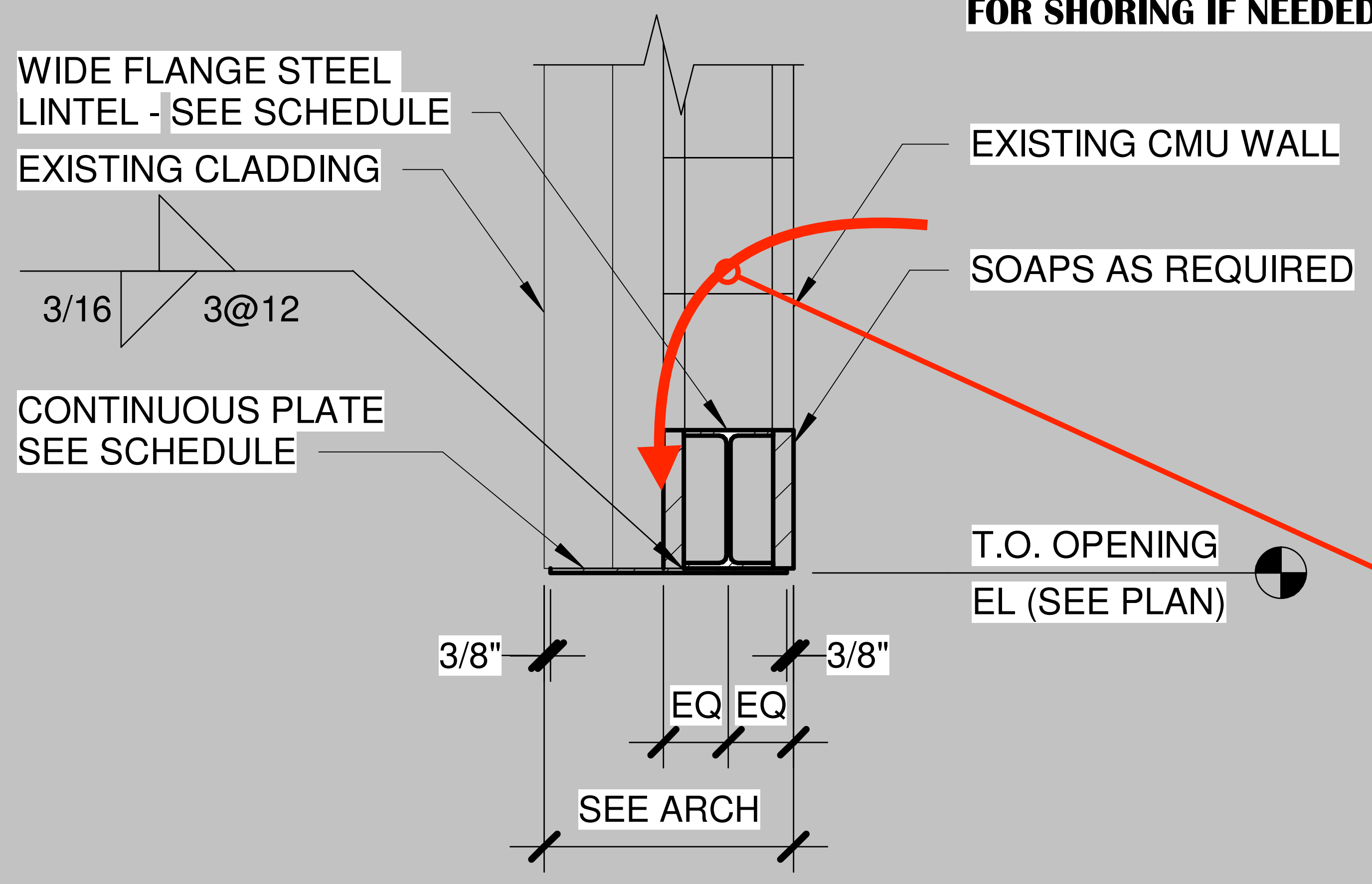
VERIFY WALL CAN SPAN HORIZONTALLY OVER OPENING. IF NOT, TRANSFER LOAD TO LINTEL USING STUDS. HOOK WALL BARS IF REQUIRED FOR DEVELOPMENT

NOTES TO SPECIFIER:

PLATE MAY BE REQUIRED ON TOP OF WIDE FLANGE IF FLANGE WIDTH IS NOT WIDE ENOUGH TO REACH THE FACE SHELL.

NOTES TO SPECIFIER:

ENGINEER TO PROVIDE LOADING FOR SHORING IF NEEDED.



NOTE:

1. EXISTING WALL TO BE SHORED AS REQUIRED FOR INSTALLATION OF NEW LINTEL.

WIDE FLANGE LINTEL DETAIL AT EXISTING

1

3/4" = 1'-0"

GOAL TO ELIMINATE THE NEED FOR THIS TYPE OF DETAIL - CONCERN AT BEARING CONDITION

THERE IS A TORSIONAL ISSUE HERE

COMPANY ABC

WIDE FLANGE LINTEL DETAIL AT EXISTING_CAVITY WALL

M-406

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Checklist should help reviews
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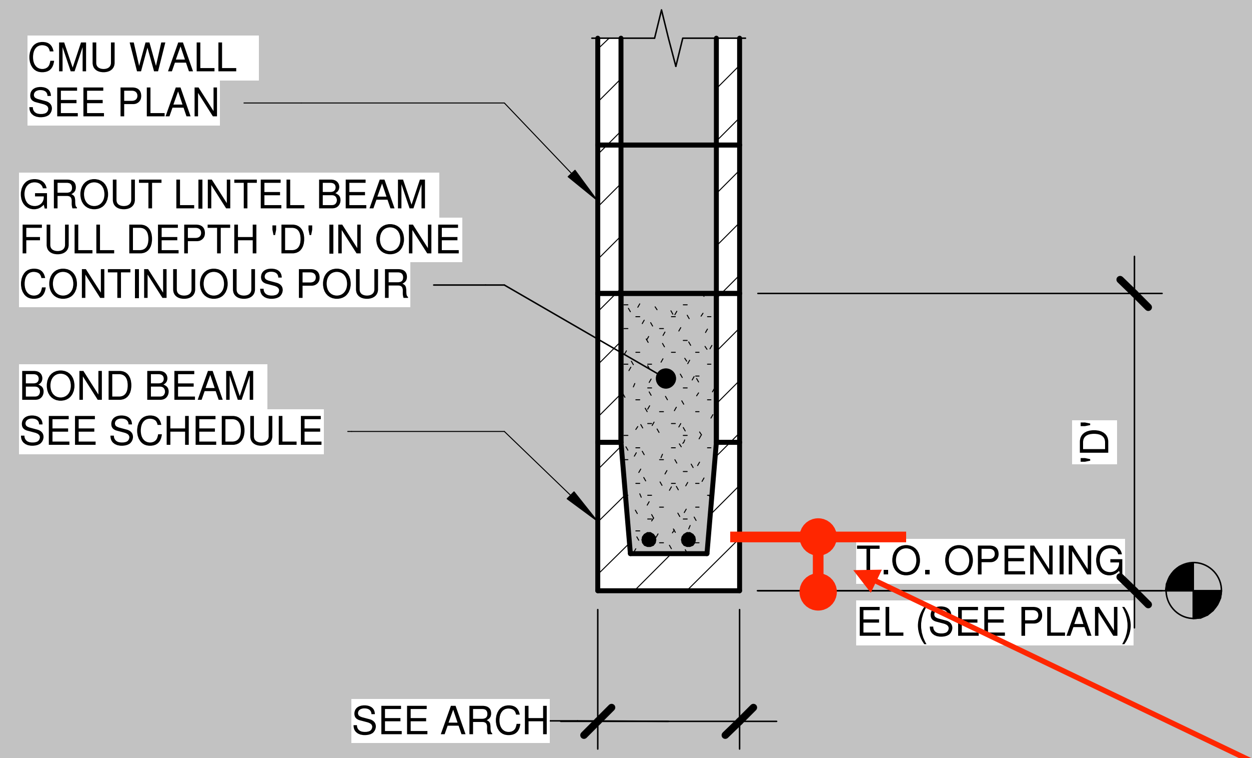
GOOD DETAIL

NOTES TO SPECIFIER:

VERIFY WALL CAN SPAN HORIZONTALLY OVER OPENING. IF NOT, CONSIDER A DIFFERENT SHAPE. HOOK WALL BARS IF REQUIRED FOR DEVELOPMENT.



NOTE:

1. SHORE UNTIL GROUT FOR LINTEL HAS REACHED ITS SPECIFIED STRENGTH.

1 BOND BEAM LINTEL DETAIL

3/4" = 1'-0"

COVER??, NEEDS TO INCLUDE BLOCK AND CLEARANCE OF 1", GENERALLY THIS IS 3" TO 4"

COMPANY ABC

BOND BEAM LINTEL DETAIL_CMU ONLY

M-412

3/

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Checklist should help reviews

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GOOD SCHEDULE

NOTES TO SPECIFIER:

THIS SCHEDULE TO BE USED WHEN ALL LINTELS ARE STEEL OR LINTELS OF MIXED MATERIALS. USE M-419 WHEN ALL LINTELS ARE REINFORCED CMU.

NOTES TO SPECIFIER:

SCHEDULE SHOULD BE DONE AS A LINK THROUGH SCHEDULE XL WHEREVER POSSIBLE.

LINTEL SCHEDULE

MARK	MEMBER SIZE	REFERENCE DETAIL	REMARKS
L1	8" DEEP BOND BEAM WITH (2) #5	-	-
L2	16" DEEP BOND BEAM WITH (2) #5 + L6x4x5/16 (LLV)	-	-
L3	W8x28 + 3/8" PL	-	-
L4	-	-	-
L5	-	-	-
L6	-	-	-
L7	-	-	-
L8	-	-	-
L9	-	-	-
L10	-	-	-

NOTE:

1. BEARING LENGTH EACH END = 8" UNO.

STILL NOT A FAN

1 **LINTEL SCHEDULE**

12" = 1'-0"

COMPANY ABC

LINTEL SCHEDULE

M-418

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Checklist should help reviews
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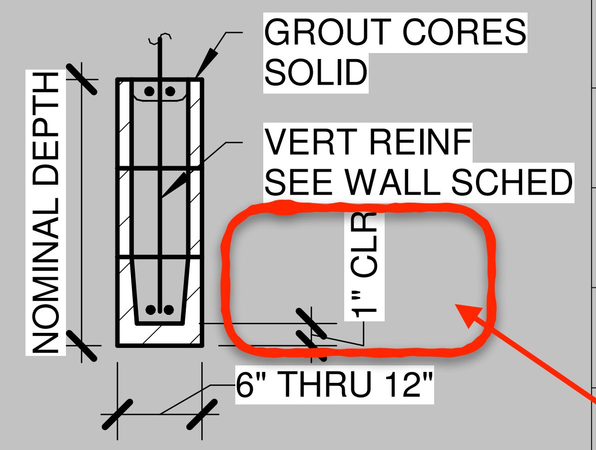
GOOD SCHEDULE

NOTES TO SPECIFIER:
THIS SCHEDULE TO BE USED WHEN ALL LINTELS ARE REINFORCED CMU.
USE M-418 WHEN ALL LINTELS ARE STEEL OR MIXED MATERIALS.

NOTES TO SPECIFIER:
SCHEDULE SHOULD BE DONE AS A LINK THROUGH SCHEDULE XL WHEREVER POSSIBLE.

REINFORCED CMU LINTEL SCHEDULE

MARK	CLEAR SPAN	DEPTH	REINF	TYPICAL DETAIL	REMARKS
A	0' - 0" TO 4' - 0"	8"	(2) #4 BOTT		-
B	OVER 4' - 0" TO 6' - 8"	16"	(2) #4 T & B		-
C	OVER 6' - 8" TO 8' - 8"	16"	(2) #5 T & B		-
D	OVER 8' - 8" TO 10' - 8"	24"	(2) #5 T & B		-
E	OVER 10' - 8" TO 12' - 8"	32"	(2) #6 T & B		-
F	OVER 12' - 8" TO 14' - 8"	40"	(2) #6 T & B		-



NOTES:

1. ALL LINTELS TYPE 'A', UNO. SEE ARCHITECTURAL DRAWINGS FOR LOCATION AND CLEAR SPAN.
2. LINTELS SHALL SPAN CONTINUOUS BETWEEN BEARING EACH SIDE.
3. PROVIDE 8" MIN BEARING FOR CLEAR SPAN 8' - 8" OR LESS AND 16" MIN BEARING FOR SPANS GREATER THAN 8' - 8".
4. EXTEND BOTTOM REINFORCING TO END OF BEARING EACH SIDE. EXTEND TOP REINFORCING, WHERE POSSIBLE, 40 BAR DIAMETERS INTO WALL EACH SIDE. TERMINATE TOP REINFORCING WITH STANDARD HOOK AT CONTROL JOINTS OR FREE EDGES.
5. PROVIDE SOLID GROUTED OR SOLID MASONRY JAMB UNDER LINTEL EACH SIDE OF OPENING FOR CLEAR SPAN GREATER THAN 6' - 0".

TOO SMALL, NEEDS TO INCLUDE BLOCK AND CLEARANCE OF 1", GENERALLY THIS IS 3" TO 4"

1 **REINFORCED CMU LINTEL SCHEDULE**
12" = 1'-0"

COMPANY ABC

REINFORCED CMU LINTEL SCHEDULE

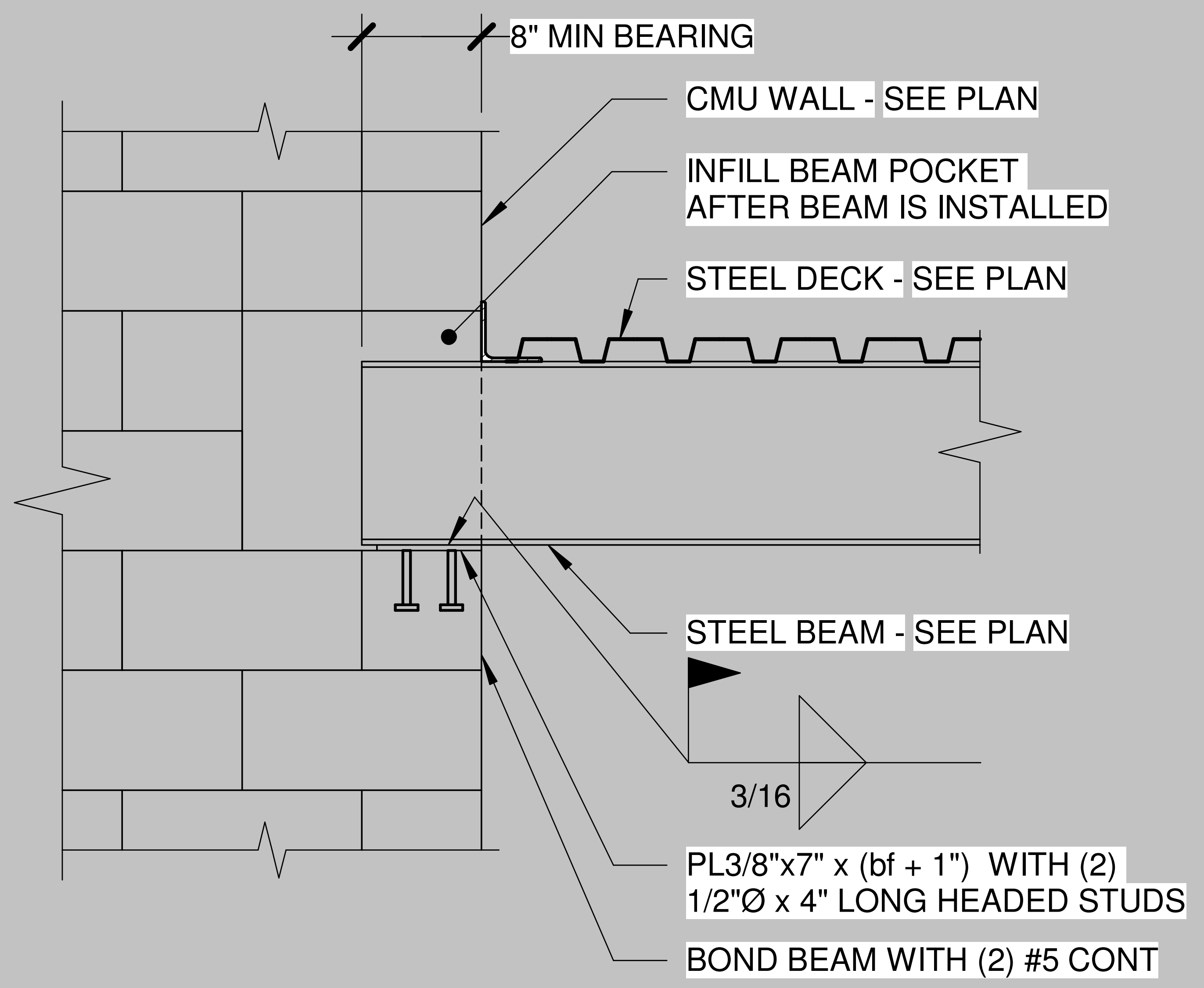
M-419

\\files\Corporate\Standards\CAD-BIM Standards\Content\2019 Revit\Structural_Details\R19_CMU_400_LINTEL DETAILS.rvt

Checklist should help reviews
- Slide not in Handout -

NOTES TO SPECIFIER:
REMOVE TABLE FROM DRAWINGS AS IT IS INFORMATIONAL ONLY

	MAXIMUM SHEAR COLLECTED (IN LBS)	
f'm (PSI)	**ASD**	**LRFD**
1500	1450	2170
2000	1550	2330
2800	1690	2540
3000	1720	2580



NOTE:

1. BEAM CENTERLINE TO BE LOCATED AT WALL CENTERLINE, UNO ON PLANS.

1 COLLECTOR BEAM BEARING ON CMU

3/4" = 1'-0"

CAUTION NEEDS REINF TO PREVENT COMPROMISED BEARING

COMPANY ABC

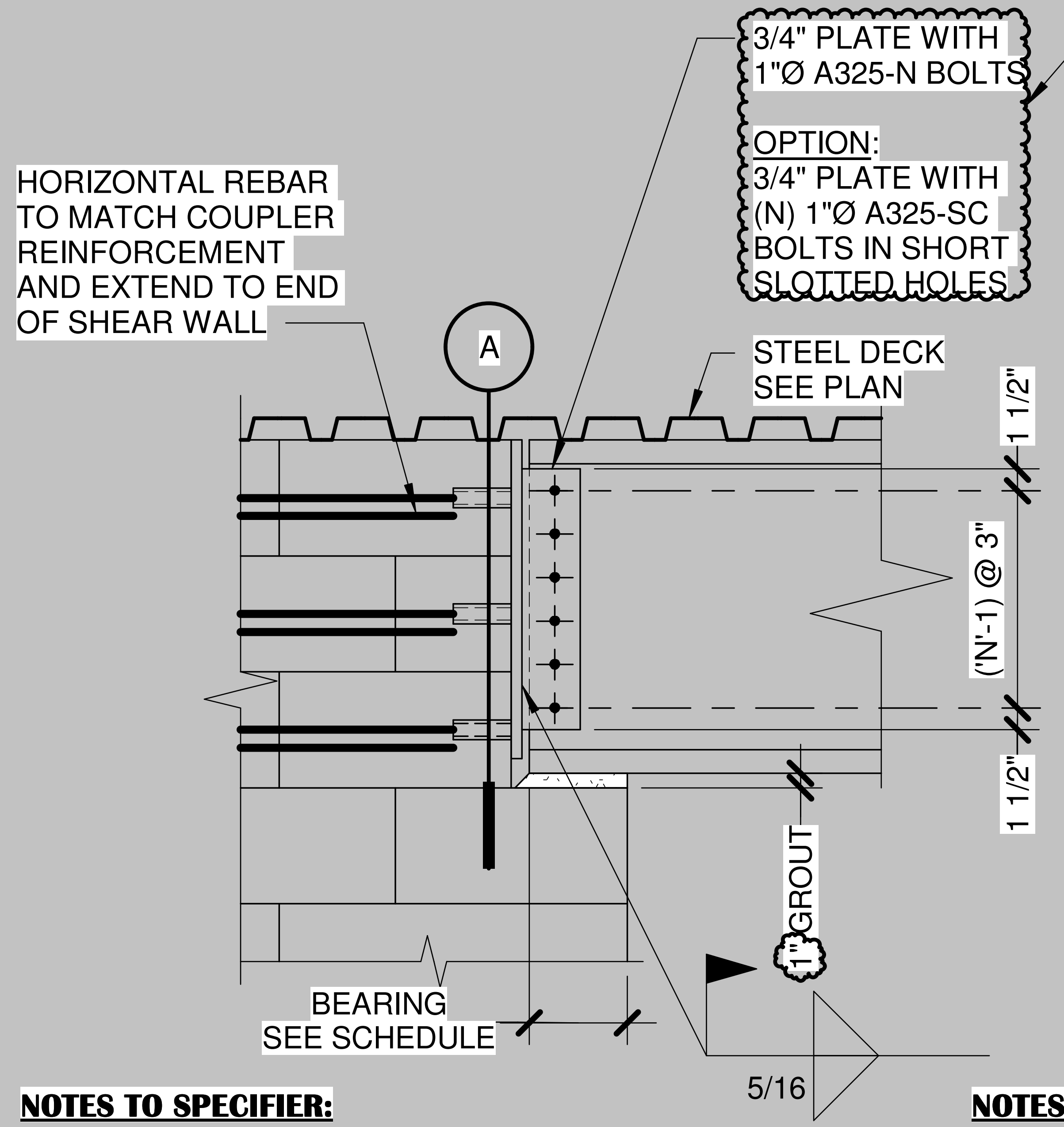
COLLECTOR BEAM BEARING ON CMU_LOW DRAG LOAD

M-200

\\files\Corporate\Standards\CAD-BIM Standards\Content\2019 Revit\Structural_Details\R19_CMU_200_LATERAL CONNECTIONS TO CMU.rvt

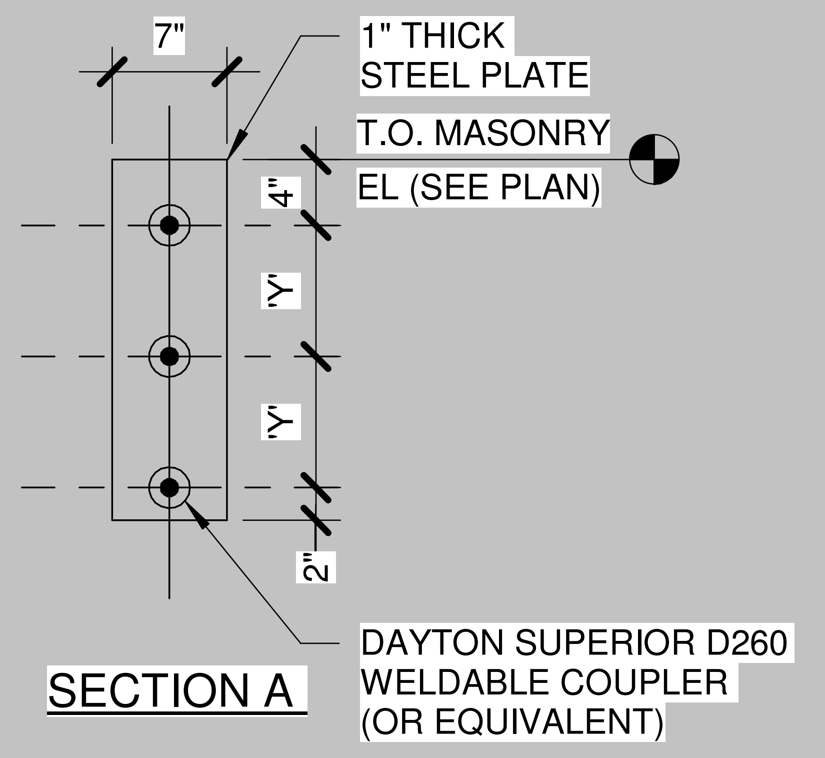
Checklist should help reviews
- Slide not in Handout -

IMPRESSIVE



NOTES TO SPECIFIER:

1. IN LOWER SEISMIC REGIONS, THIS CONNECTION MAY BE ABLE TO HAVE SHORT SLOTTED HOLES AND SLIP CRITICAL BOLTS.
2. REVIEW OPPOSITE END CONNECTION TO PROVIDE FIELD TOLERANCE.



SECTION A

NOTES TO SPECIFIER:

SCHEDULE SHOULD BE DONE AS A LINK THROUGH SCHEDULE XL WHEREVER POSSIBLE.

NOTES TO SPECIFIER:

DELETE - THIS IS INFORMATION ONLY

'N' BOLTS	COUPLERS	REBAR	SPACING 'Y'	BEARING	CAPACITY (KIPS)	SC BOLT OPTION: (KIPS)
2	(1) #7L	(1) #7 x 3' - 10"	-	8"	32	32
3	(2) #7L	(2) #7 x 3' - 10"	8"	8"	64	51
4	(2) #8L	(2) #8 x 5' - 0"	8"	8"	85	69
5	(3) #8L	(3) #8 x 5' - 0"	8"	8"	111	86

NOTES TO SPECIFIER:

EDIT TABLE AS REQUIRED FOR PROJECT CONDITIONS

NOTES TO SPECIFIER:

1. ANY CASE THAT FALLS OUTSIDE THIS TABLE SHOULD BE DESIGNED BY THE SPECIFIER.
2. LENGTHS SHOWN FOR REBAR ARE THE NECESSARY LENGTH TO GET FULL CAPACITY. IF A SHORTER REBAR LENGTH IS DESIRED, THE CAPACITY OF THE CONNECTION SHOULD BE REDUCED BY THE SAME PERCENTAGE THE REBAR LENGTH IS REDUCED.
3. CAPACITIES ARE LRFD VALUES.
4. SPECIFIER TO CHOOSE IF SC BOLTS OR NORMAL BOLTS ARE TO BE USED.

1 COLLECTOR BEAM BEARING ON CMU

3/4" = 1'-0"

COMPANY ABC

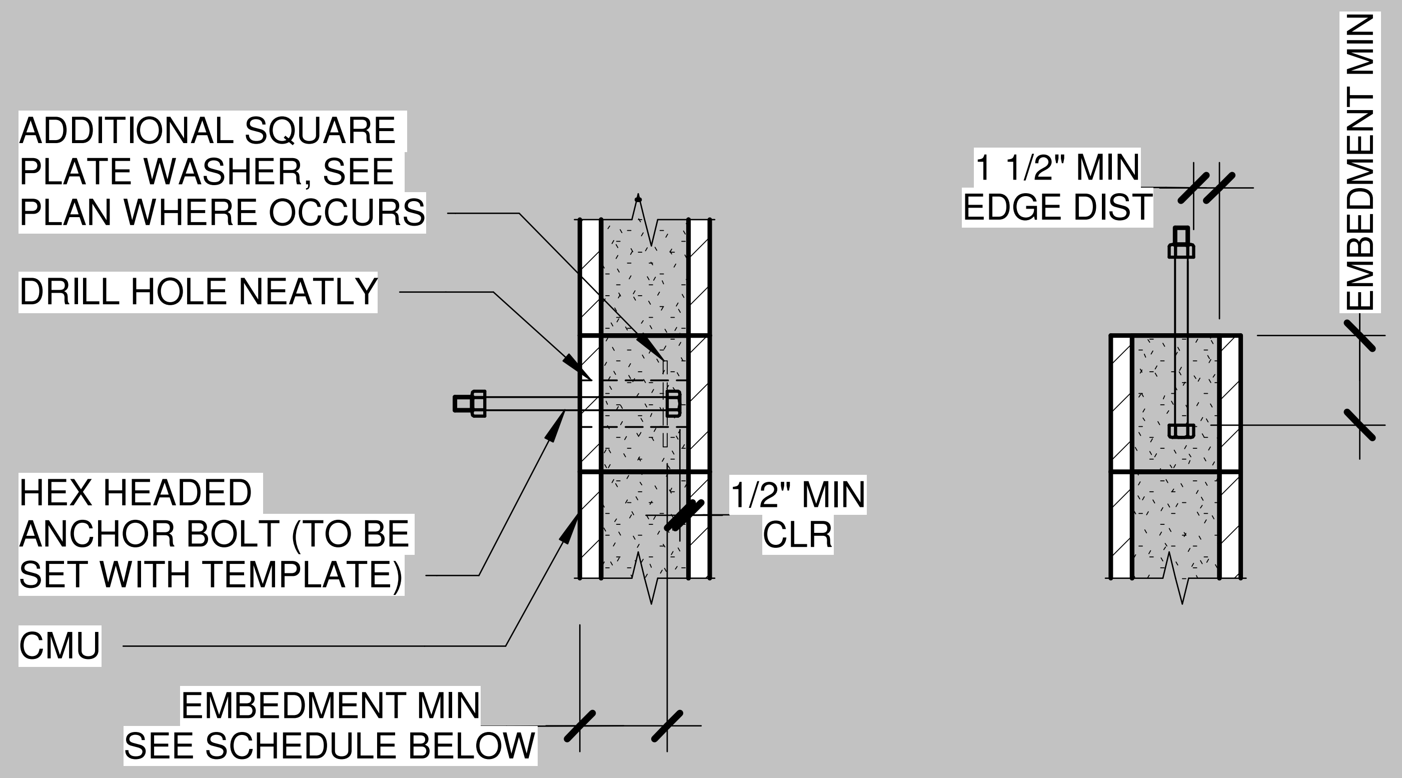
COLLECTOR BEAM BEARING ON CMU_HIGH DRAG LOAD

M-203

\\files\Corporate\Standards\CAD-BIM Standards\Content\2019 Revit\Structural_Details\R19_CMU_200_LATERAL CONNECTIONS TO CMU.rvt

Checklist should help reviews
- Slide not in Handout -

GOOD DETAIL



BOLT EMBEDMENT SCHEDULE

BOLT SIZE	BOLT EMBEDMENT		
	HORIZONTAL		VERT
	12" CMU	8" CMU	
1/2"	9"	5 1/4"	8"
5/8"	9"	5 1/4"	9"
3/4"	9"	-	10"
7/8"	9"	-	11"
1"	9"	-	12"

NOTE:

1. BOLT SPACING SHALL BE 8 BOLT DIAMETERS.

1 **ANCHOR BOLT CAST INTO CMU DETAIL**

3/4" = 1'-0"

COMPANY ABC

ANCHOR BOLT CAST INTO CMU DETAIL

M-114

\\files\Corporate\Standards\CAD-BIM Standards\Content\2019 Revit\Structural_Details\R19_CMU_100_FRAMING CONNECTIONS TO CMU.rvt

Masonry Checklist

- [x] f'm - masonry assembly strength
- [x] Verify all components of masonry are specified
- [ ] Consider masonry wall thickness and reinforcement
- [ ] Review masonry shear walls
- [ ] Review masonry partition walls
- [ ] Check that control joints are located on plans
- [ ] Review lintels, prefer masonry lintels where possible
- [ ] Review bearing plate details
- [ ] Consider conflicts between steel and masonry

March 1, 2020

MASONRY INSIGHTS

written in conjunction with International Masonry Institute

Masonry checklist: reviewing structural plans

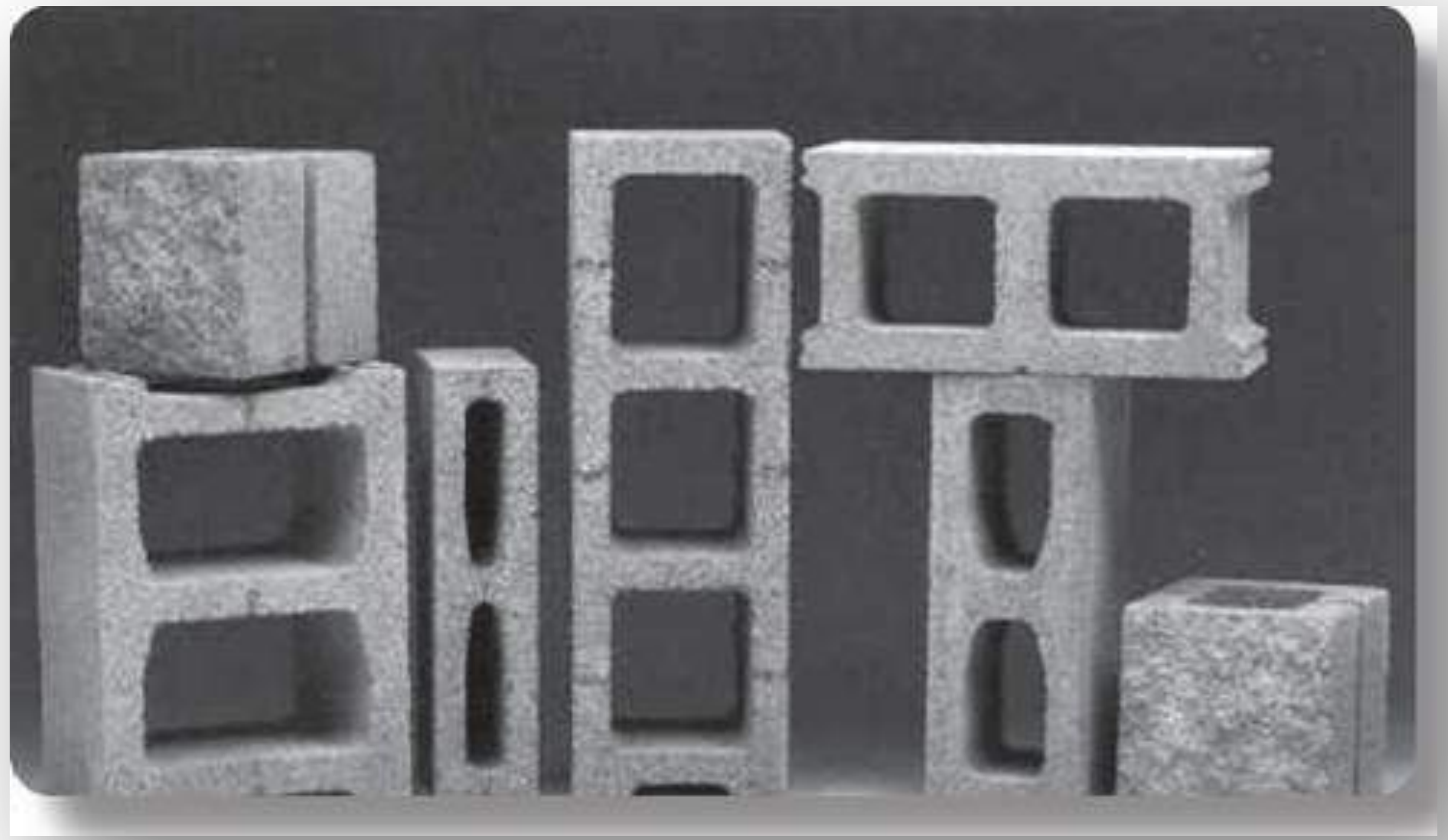
- ☐ f'_m (masonry assembly strength) for structural concrete or clay masonry is 2,000 psi or greater
  - ☐ concrete masonry f'_m = 2,500psi is the most common
  - ☐ clay masonry f'_m = commonly in the range of 3,000psi to 4,000psi
  - ☐ Masonry strengths up to 4,000 psi are permitted in current codes for strength design[1]
- ☐ Check that all components of masonry are specified:
  - ☐ Block strength: check masonry.forsei.com/masonry/cmudata/ to verify based on location
    - ☐ Commonly above 3250 psi for concrete masonry and 8250 psi for clay masonry
  - ☐ Mortar type (mortar strength need not be listed)
    - ☐ Recommend Type N for non-structural walls
      - ☐ Veneer and partition walls commonly use this mortar
      - ☐ Can be used in some structural applications, but reduces capacity
        - ☐ Not to be used below grade
        - ☐ Not to be used in seismic SDC D, E, or F
    - ☐ Recommend Type S for structural walls
      - ☐ Can be used below grade
      - ☐ Can be used in all seismic areas, SDC A, B, C, D, E, and F
    - ☐ Type M is high strength, but more costly and reduced workability
      - ☐ Can be used below grade
      - ☐ Used in high load applications and extreme environmental conditions
  - ☐ Grout strength
    - ☐ Should be at least 2,000 psi, and equal to or greater than f'_m

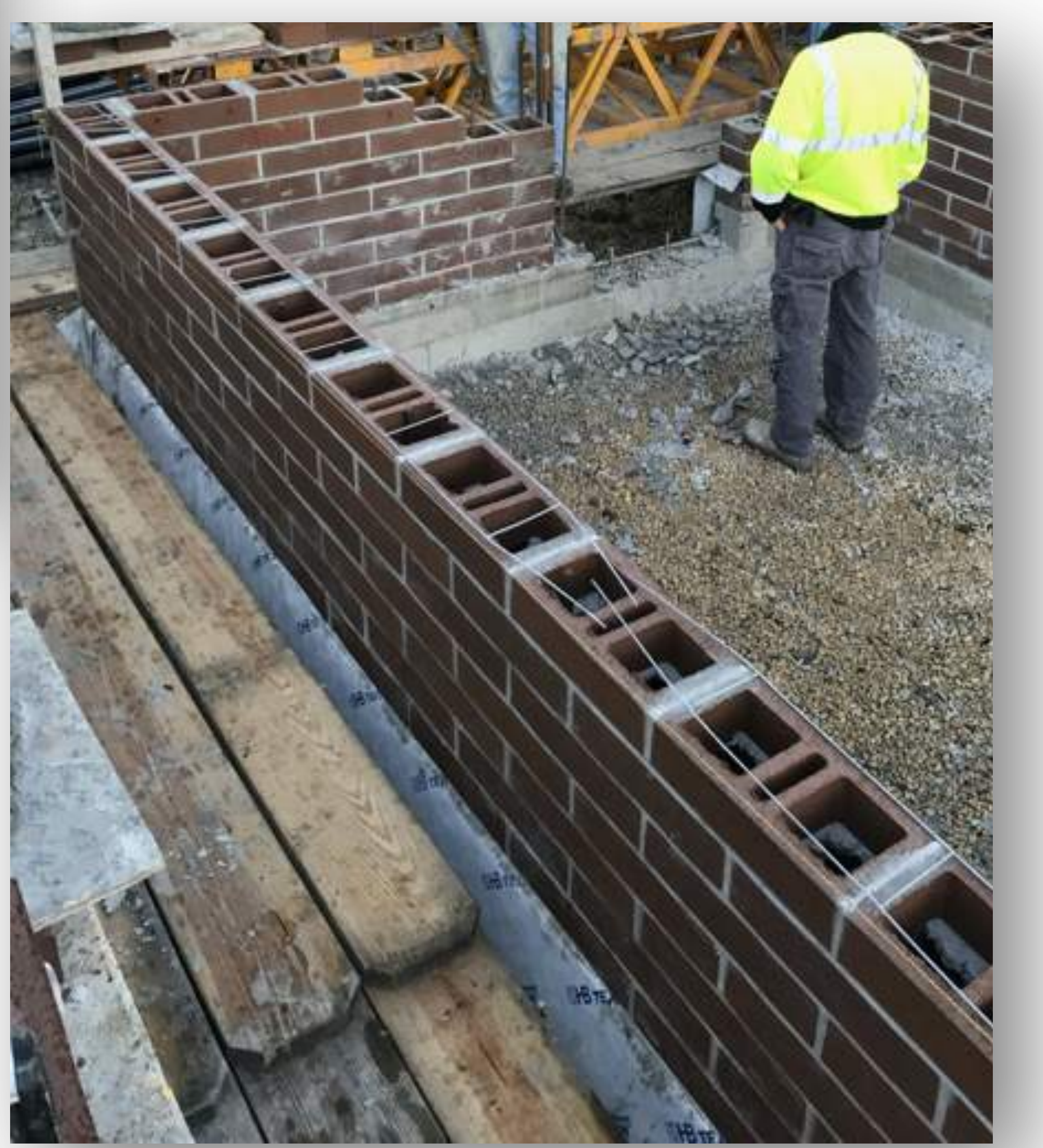
web: masonry.forsei.com 1

what's the purpose for each component?

Block

- Concrete Masonry Unit (CMU)
  - ASTM C-90
- Clay - Hollow Structural Brick
  - ASTM C-652 (structural)
  - veneer, non-structural is ASTM C-216





- fundamental component of a masonry wall
- the strength of the block is a key component in the strength of the wall

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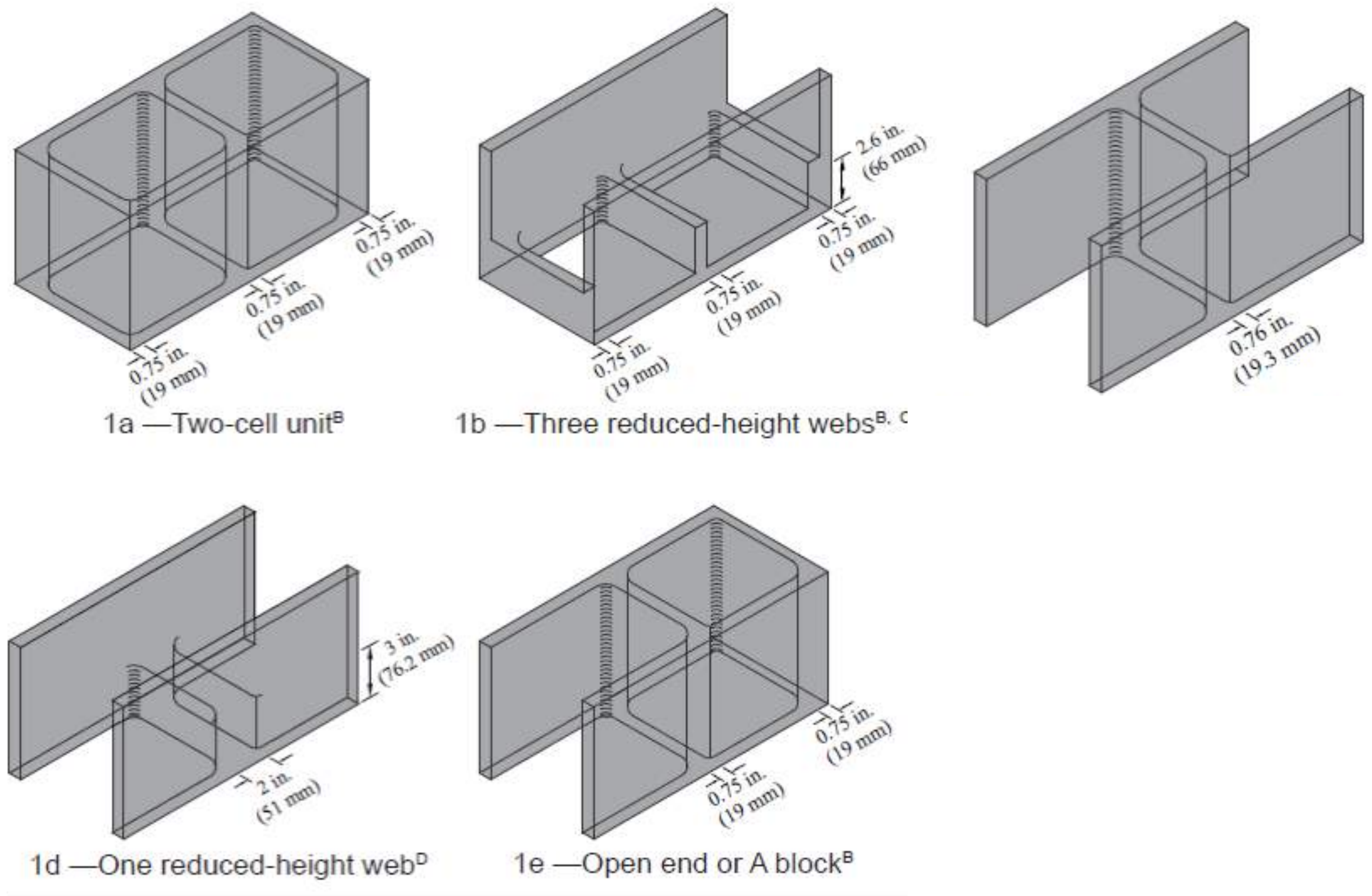
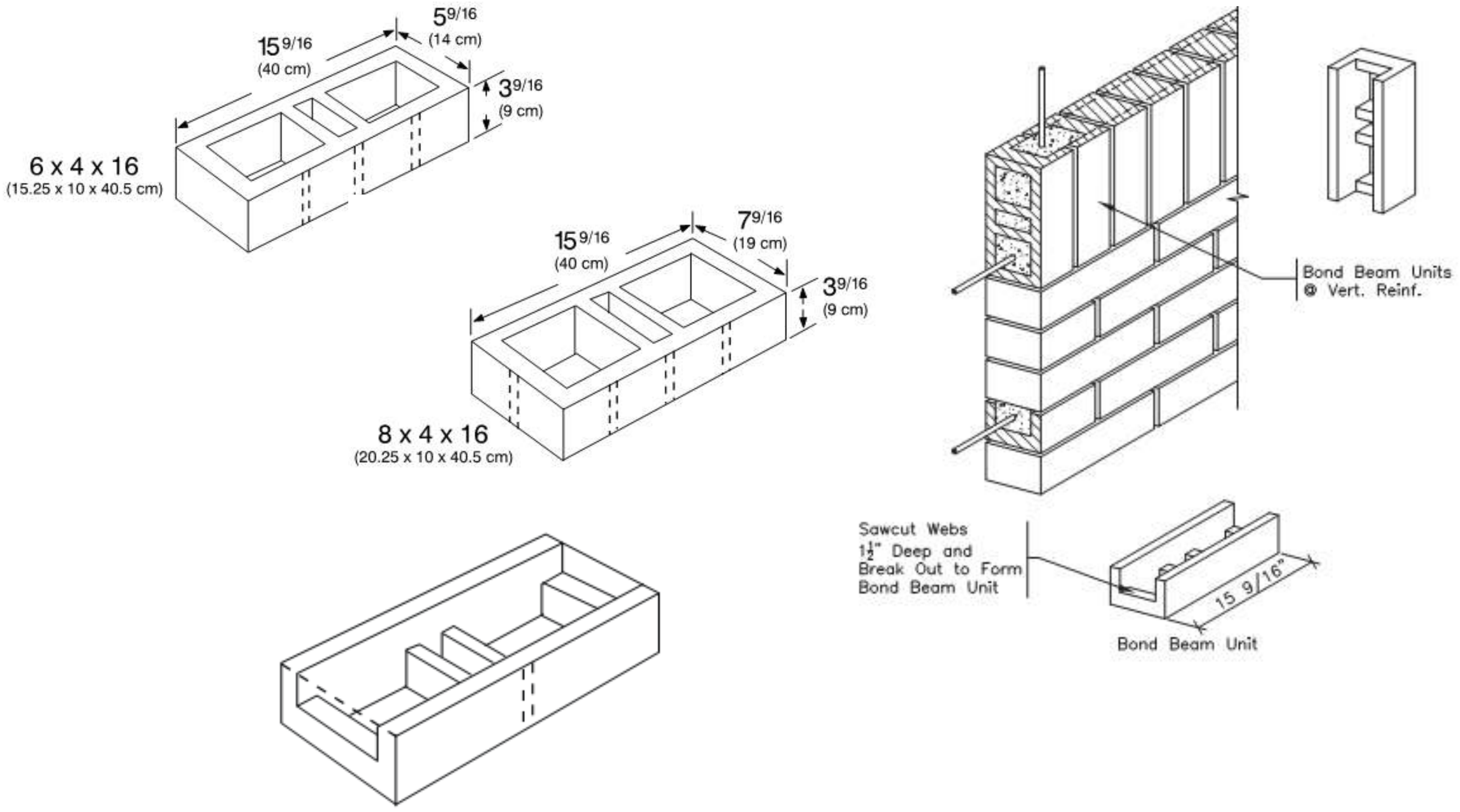
what’s the purpose for each component?

- block shapes

CONCRETE



CLAY



- and many, many more....

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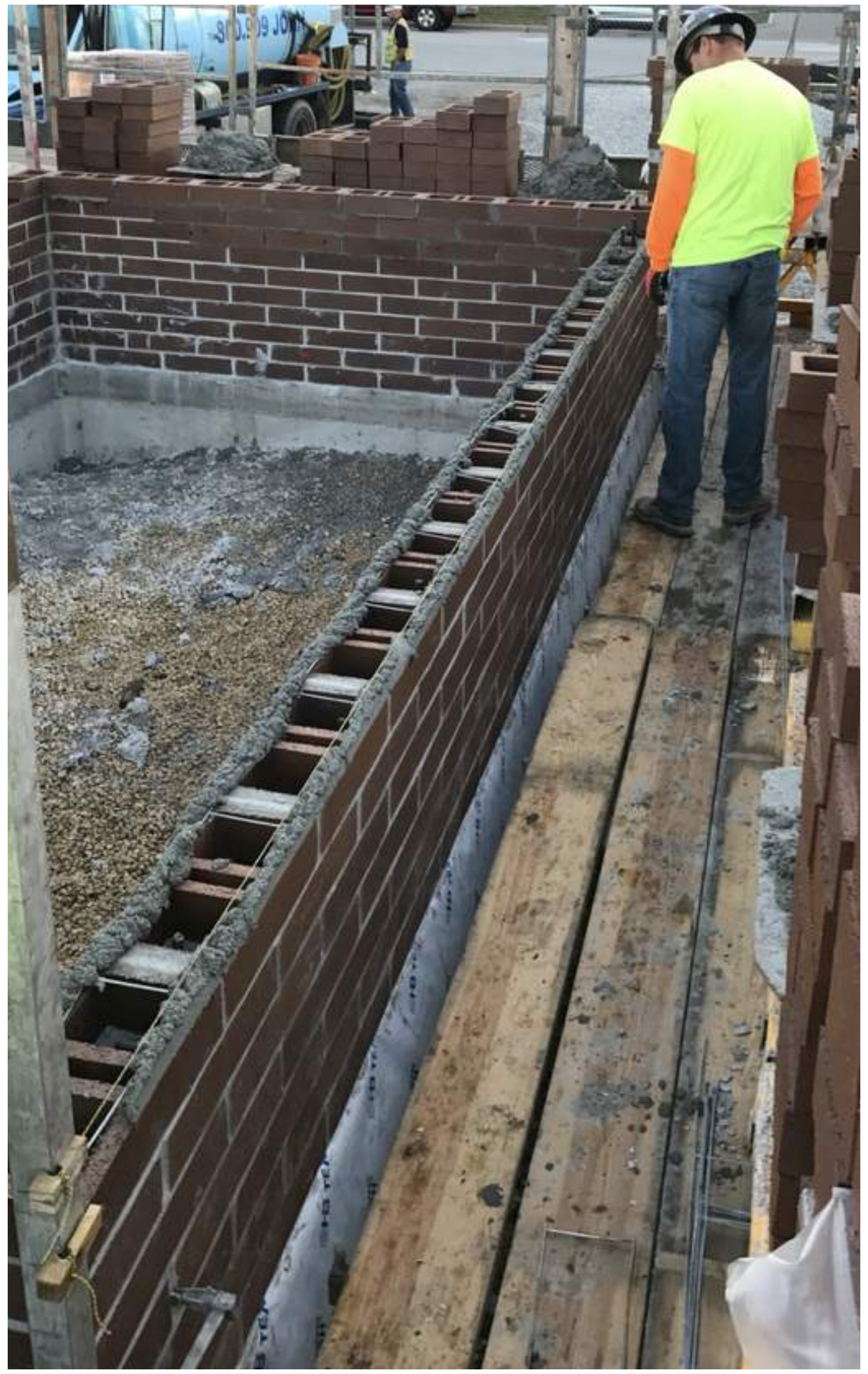
what’s the purpose for each component?



<u>Mortar</u>

- workable paste used to bind blocks together
- becomes hard when it sets
- made from a mixture of sand, a binder such as cement or lime, and water
- is not as strong as masonry units and doesn’t need to be
- its purpose is to be the “glue”

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what's the purpose for each component?

TYPES OF MORTAR

remember S for structural

these two mortars are equivalent for assembly strength, F'_m from code perspective

M **S** **N**

Mortar Compressive Strength

FULL STRENGTH

Assembly Compressive Strength by Code Unit Strength Method

Workability, Ease of Construction

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what's the purpose for each component?

Grout

- essentially fluid concrete
- fills cores of CMU
  - especially when there is reinforcement in the cores
- generally composed of a mixture of water, cement, sand, pea gravel
- fine or coarse grout
- applied as a thick liquid, and hardens over time
- NOT THE SAME AS MORTAR

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what's the purpose for each component?

<u>**Reinforcement**</u>

- strengthens wall
  - masonry (CMU, grout, mortar) are all good in compression, bad in tension, reinforcement is great in tension
- requires that you add grout in the cells that contain reinforcement
- vertical reinforcement generally needed at exterior walls

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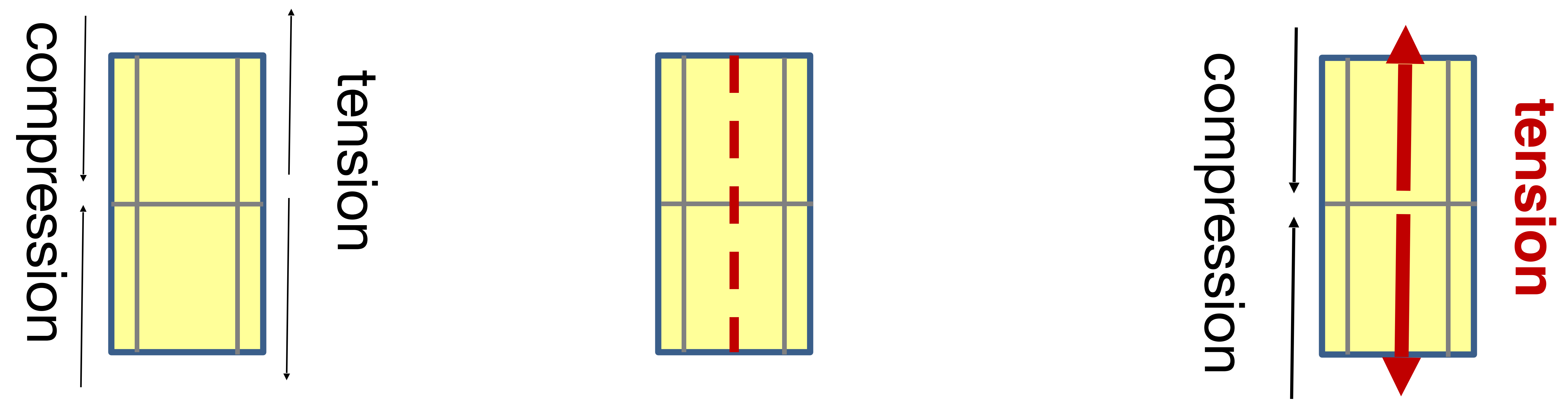
what’s the purpose for each component?



BENDING from LATERAL LOAD (i.e. wind) + ADD reinforcement = masonry in compression, steel in tension

- concrete is a material good in compression, not so good in tension
- adding steel keeps the wall from cracking

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wall reinforcement

TMS 402 - SD provisions

- increases wall bending strength
- prevents cracks
- should be less than #9 bar
- bar diameter to be less than 1/8 wall thickness
- bar area to be less than 4% of cell area

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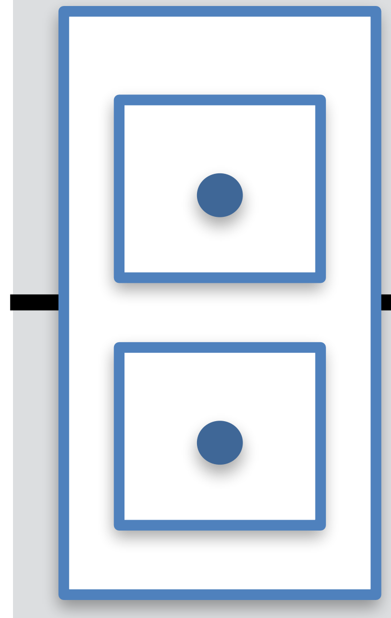
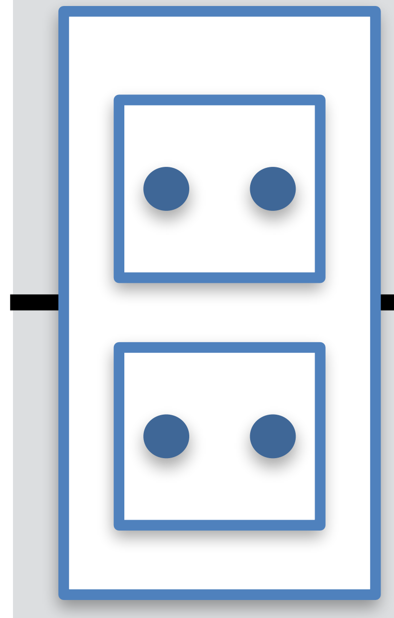
single reinf		#4	#5	#6	#7	#8	#9
	dia (in)	0.5	0.625	0.75	0.875	1	1.13
	A_s (in^2)	0.20	0.31	0.44	0.60	0.79	1.00
6 inch wall	area cell = 23.56	X	X	X			
8 inch wall	area cell = 33.31	X	X	X	X	X	
10 inch wall	area cell = 44.98	X	X	X	X	X	X
12 inch wall	area cell = 57.6	X	X	X	X	X	X
16 inch wall	area cell = 82.85	X	X	X	X	X	X

double reinf - each face		#4	#5	#6	#7	#8	#9
	dia (in)	0.5	0.625	0.75	0.875	1	1.13
	A_s (in^2)	0.20	0.31	0.44	0.60	0.79	1.00
6 inch wall	area cell = 23.56						
8 inch wall	area cell = 33.31	X					
10 inch wall	area cell = 44.98	X	X				
12 inch wall	area cell = 57.6	X	X	X			
16 inch wall	area cell = 82.85	X	X	X	X	X	

which options do masons prefer?

8" MASONRY, 22ft tall, 24ft long wall?

(1)#6@48in

(1)#5@32in

(2)#4@56in

(1)#5@40in - alternating staggered placement

12" MASONRY, 32ft tall, 24ft long?

A- (1)#7@56in

B- (1)#6bar@40in

C- (2)#5@64in

D- (1)#5@40in - alternating staggered placement

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preferred bar options

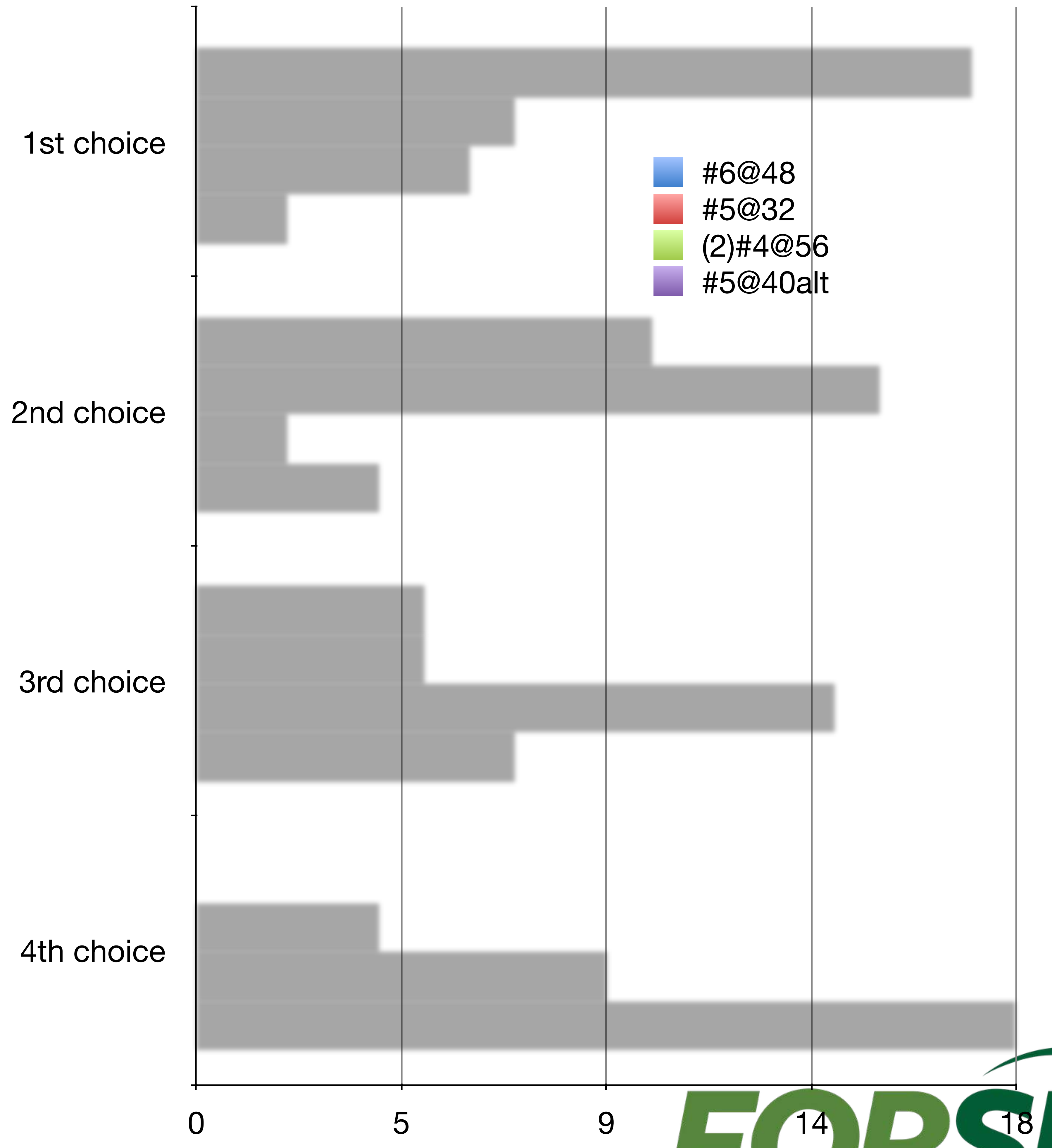
8" masonry, 22ft tall, 24ft long wall

(1)#6 bar @48in o.c.
(one bar per cell)

(1)#5 bar @32in o.c.
(one bar per cell)

(2)#4 bars @56in o.c.
(two bars per cell)

(1)#5 bar @40in o.c. (staggered-placed at inside face one cell, then outside face at 40in, then inside, outside, and alternating back and forth)



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preferred bar options

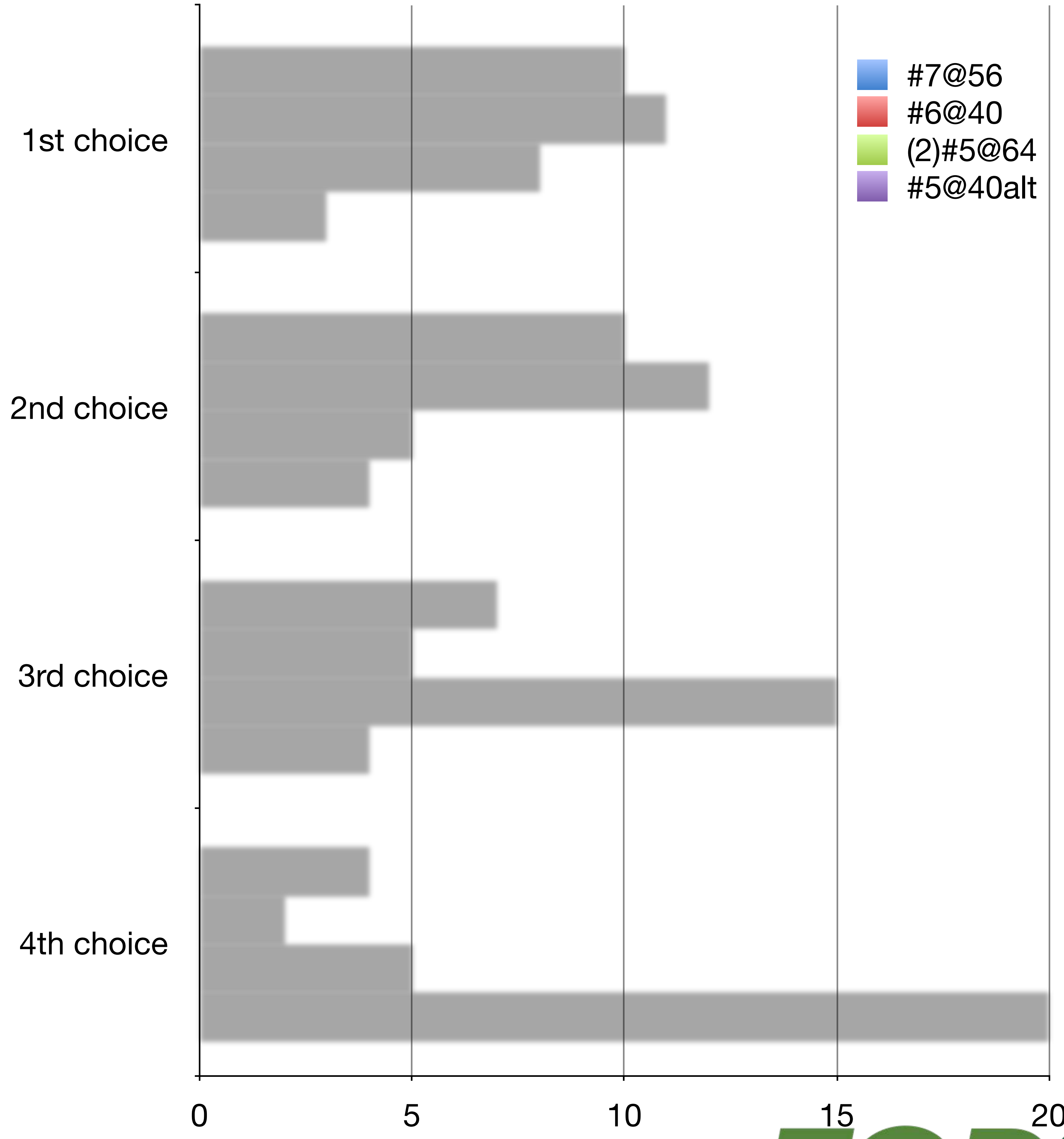
12" masonry, 32ft tall, 24ft long wall

(1)#7 bar @56in o.c.
(one bar per cell)

(1)#6 bar @40in o.c.
(one bar per cell)

(2)#5 bars @64in o.c.
(two bars per cell)

(1)#5 bar @40in o.c. (staggered-placed at inside face one cell, then outside face at 40in, then inside, outside, and alternating back and forth)



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masonry design notes
lap splices

- lap splices are different for a variety of reasons
- all of the following change lap lengths
  - bar sizes
  - reinforcement in center, or at each face
  - spacing
  - masonry wall strength
- include in masonry wall schedules

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masonry wall schedules with lap lengths

	MASONRY WALL SCHEDULE			
MARK	THICKNESS	VERTICAL REINFORCEMENT		NOTES
		BAR(S)@SPACING	LAP DISTANCE	
W1	8”	1-#4 @ 64” O.C.	12 inches	
W2	8”	1-#6 @ 32” O.C.	33 inches	
W3	8”	2-#5 @ 24” O.C.	24 inches	
W4	8”	1-#7 @ 8” O.C.	46 inches	
W5	12”	1-#6 @ 32” O.C.	21 inches	

f'_m = 2500 psi

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TEAM IMI

LAP LENGTHS?

more than
needed for
smaller bars

wall thickness, t_w:	8 inches	reinf. spacing:	8 inches
wall strength, f'_m:	2500 psi	reinf.position:	centered
reinf. Strength, f_y:	60000 psi		

Bar	db	γ	K	development length, l_d
#3	0.375	1	3.375	**12 inches**
#4	0.5	1	3.375	**12 inches**
#5	0.625	1	3.3125	**18 inches**
#6	0.75	1.3	3.25	**35 inches**
#7	0.875	1.3	3.1875	**49 inches**
#8	1	1.5	3.125	**75 inches**
#9	1.125	1.5	3.0625	**97 inches**

OLD LAP REQ of 48db

48 * db	comment
~~18 inches~~	too long
~~24 inches~~	too long
~~30 inches~~	too long
~~36 inches~~	too long
~~42 inches~~	too short
~~48 inches~~	too short
~~54 inches~~	too short

created in conjunction with TEAM IMI

Masonry Assembly Strength
Components of Masonry

- Don't *just* say "f'm = XXX psi"
- Call out each material: CMU, grout, and mortar
- Example:

  Masonry assembly strength shall be 2,500 psi

  - Block, f'_{CMU} shall be 3,250 psi or greater
  - Grout, f'_{G} shall be 2,500 psi or greater
  - Mortar shall be Type S
    - *don't need to call out strength*
- Also, it is possible to use two different masonry strengths on the same project!

created in conjunction with TEAM IMI

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What is f'm for Concrete Masonry

individual Concrete Masonry Unit, NET AREA psi		mortar type (Type S, N)		f'm, design strength of masonry
2000 psi	+	Type S	=	**2,000 psi**
3250 psi	+	Type S	=	**2,500 psi**
4500 psi	+	Type S	=	**3,000 psi**

TMS 602-2013 Table 2

TYPICAL

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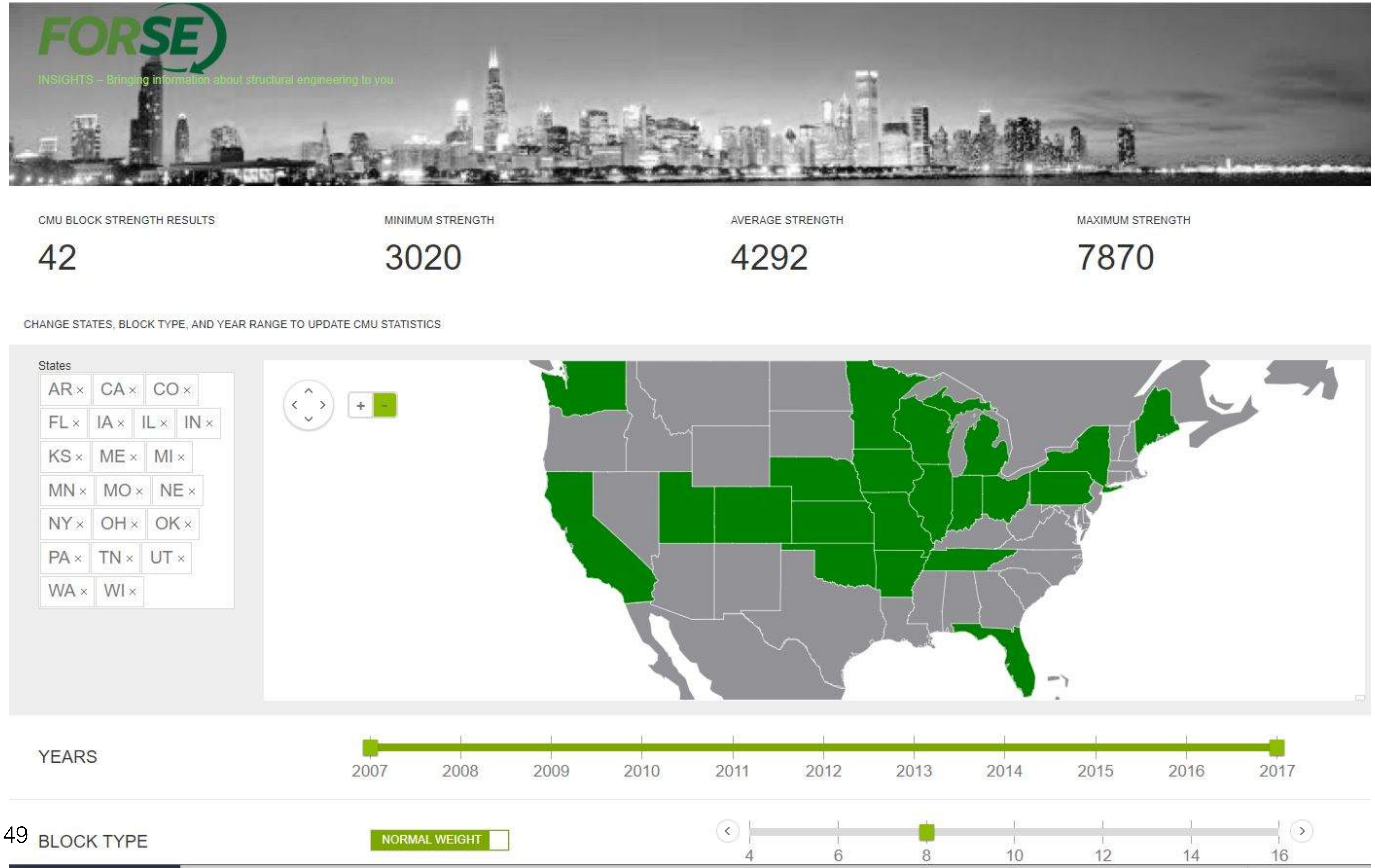
masonry.forsei.com/masonry/cmudata/



Includes block strength values for both concrete and clay units

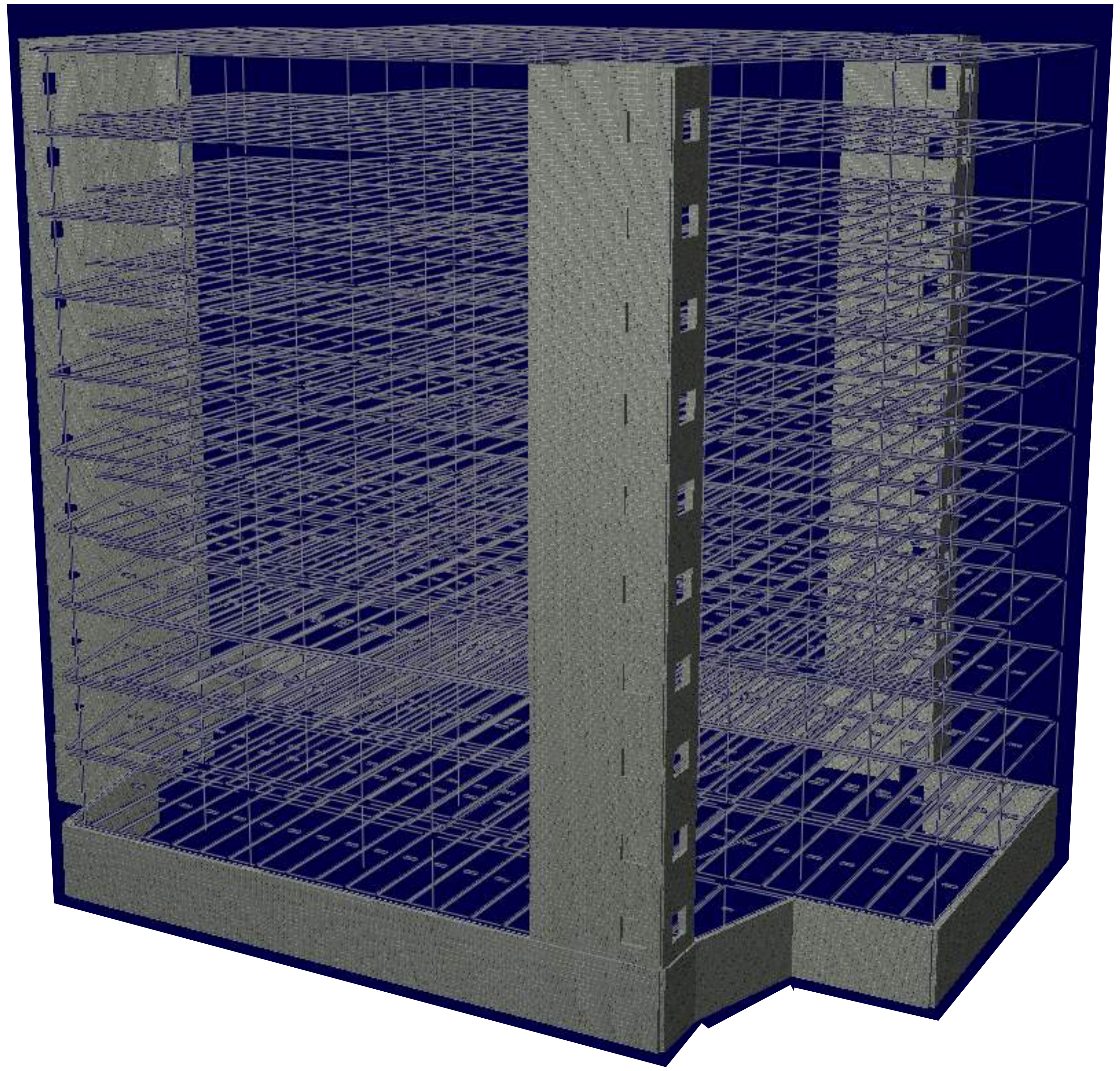
HIGHER STRENGTH MASONRY

Subject: Re: 4000psi Masonry

Hello […],
good question, the standard compressive “unit strength method" caps off at 3000 psi, but the strengths will continue to increase with an increase in unit strength. To achieve the f’m ≥ 4000 psi, you will need to get prism strength tests completed.
And in addition to specifying masonry assemble strength, f’m≥ 4000psi and requiring the prism tests be done, I think it would be wise to specify:

- block strength, f’cmu ≥ 5000psi
- grout strength, f’g ≥ 4000psi,
- mortar, Type M

Please let me know if you have further questions.
--
Samuel M Rubenzer, PE, SE I **FORSE Consulting** I
844.443.6773 ext 700 I www.FORSEconsulting.com



Why is f’m so important?

more efficient design w/ higher f’m

- **wall**
  - bearing wall
  - non-bearing wall
  - shear wall
- **lintel**
- **column/pilaster**
- **lap lengths**
  - much shorter
- **connections to masonry**
  - will be much more efficient
  - embed plates
  - post-installed anchors

FORSE

Notes on Drawings

MASONRY INSIGHTS

written in conjunction with International Masonry Institute

How to Specify Concrete Masonry f'_m = 2500 psi in the Midwest

According to the masonry code, **TMS 602 Specification for Masonry Structures** (formerly MSJC), designers can use the Unit Strength Method for determining masonry design strength, f'_m. The two components needed to use the Unit Strength Method are block strength and mortar type. A particular f'_m can be achieved by either: 1.) using stronger block and weaker mortar, or 2.) using weaker block and stronger mortar. Therefore simply stating a minimum f'_m on construction documents does not indicate to contractors what block or mortar should be used. Also by only specifying f'_m, the required strength of grout is left unknown.

f'_m Net area compressive strength of concrete masonry	Type S Mortar	Type N Mortar
	f'_{cmu} Net area compressive strength of ASTM C90 CMU	
1,750 psi	---	2,000 psi
2,000 psi	2,000 psi	2,650 psi
2,250 psi	2,600 psi	3,400 psi
2,500 psi	3,250 psi	4,350 psi
2,750 psi	3,900 psi	----
3,000 psi	4,500 psi	----

Table 2 from TMS 602: UNIT STRENGTH METHOD TABLE

Compressive strength of masonry based on the compressive strength of CMU and type of mortar used in construction (formatting revised for this paper)

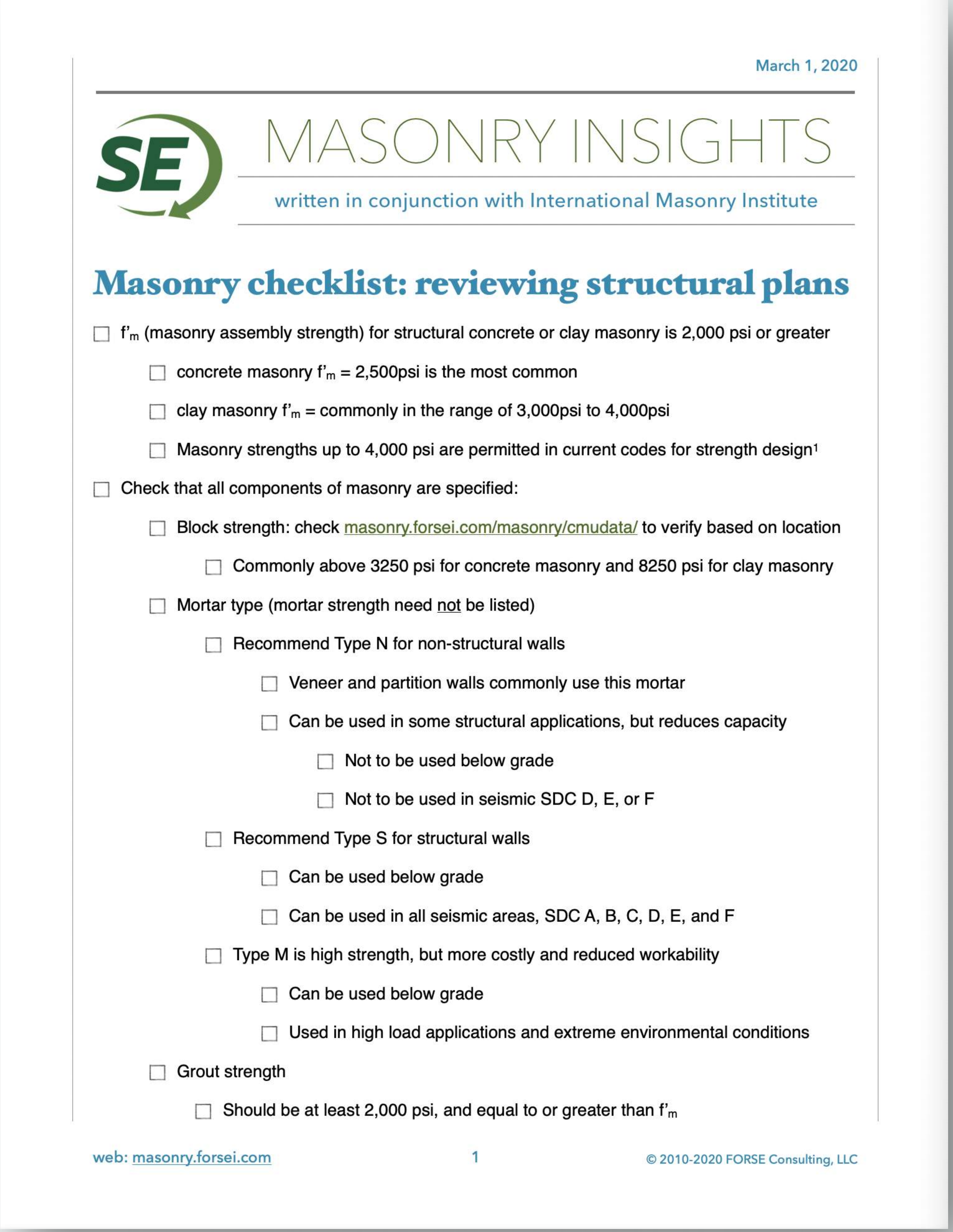
The key component for the strength of masonry walls is the blocks, commonly referred to as concrete masonry unit (CMU). CMU can be specified as normal weight, medium weight, or light weight. In the Midwest, the most common CMU is Normal weight. However, both Medium weight and Light weight can also be specified and used. **The common compressive strength for CMU, f'_{cmu} as determined by ASTM C90 tests, is 3,250 psi or higher.** Higher strengths can also be specified if desirable for a particular design, although cost and availability should be determined prior to specifying these higher values.

See http://masonry.forsei.com/masonry/cmudata/ for block strength data.

The next component that needs to be specified is the mortar. There is a lot of confusion over mortar strength and its effects on f'_m. The common mistake is to believe that masonry is only as good as its weakest element- the mortar. It's important to remember that mortar only makes up a small percentage of the overall wall as most of the material in a wall is higher strength CMU. There is also confusion over

Masonry Checklist

- ☐ f'm - masonry assembly strength
- ☐ Verify all components of masonry are specified
- ☑ Consider masonry wall thickness and reinforcement
- ☐ Review masonry shear walls
- ☐ Review masonry partition walls
- ☐ Check that control joints are located on plans
- ☐ Review lintels, prefer masonry lintels where possible
- ☐ Review bearing plate details
- ☐ Consider conflicts between steel and masonry



March 1, 2020

MASONRY INSIGHTS

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Masonry checklist: reviewing structural plans

- ☐ f'_m (masonry assembly strength) for structural concrete or clay masonry is 2,000 psi or greater
  - ☐ concrete masonry f'_m = 2,500psi is the most common
  - ☐ clay masonry f'_m = commonly in the range of 3,000psi to 4,000psi
  - ☐ Masonry strengths up to 4,000 psi are permitted in current codes for strength design[1]
- ☐ Check that all components of masonry are specified:
  - ☐ Block strength: check masonry.forsei.com/masonry/cmudata/ to verify based on location
    - ☐ Commonly above 3250 psi for concrete masonry and 8250 psi for clay masonry
  - ☐ Mortar type (mortar strength need not be listed)
    - ☐ Recommend Type N for non-structural walls
      - ☐ Veneer and partition walls commonly use this mortar
      - ☐ Can be used in some structural applications, but reduces capacity
        - ☐ Not to be used below grade
        - ☐ Not to be used in seismic SDC D, E, or F
    - ☐ Recommend Type S for structural walls
      - ☐ Can be used below grade
      - ☐ Can be used in all seismic areas, SDC A, B, C, D, E, and F
    - ☐ Type M is high strength, but more costly and reduced workability
      - ☐ Can be used below grade
      - ☐ Used in high load applications and extreme environmental conditions
  - ☐ Grout strength
    - ☐ Should be at least 2,000 psi, and equal to or greater than f'_m

web: masonry.forsei.com 1 © 2010-2020 FORSE Consulting, LLC

Masonry walls

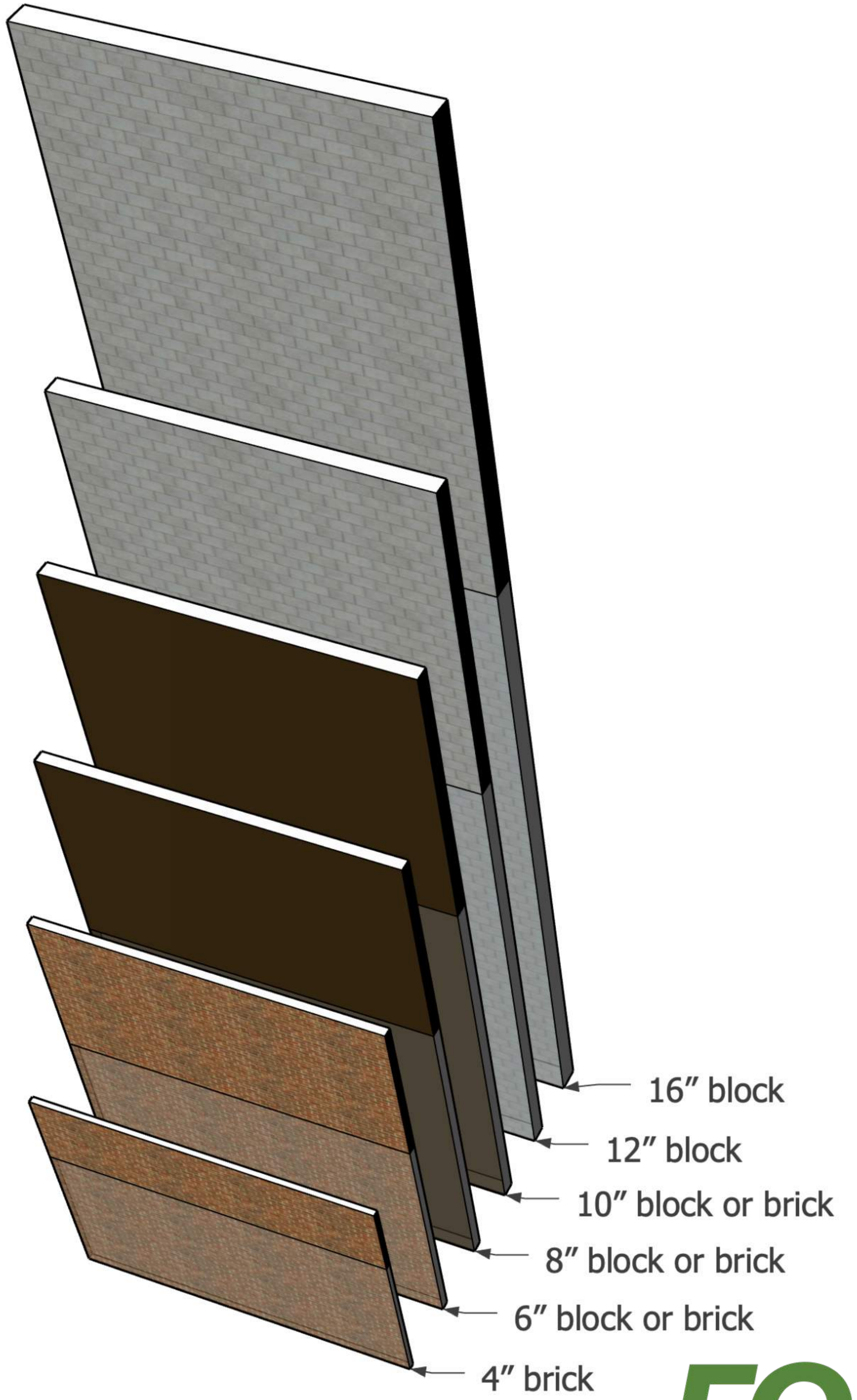
TMS 402 definition

- vertical element with horizontal length to thickness ratio greater than 3
  - 8” thick —> 24” long
  - 12” thick —> 36” long
- load bearing has loads greater than 200 lb/ft in addition to self-weight

Masonry walls

Reinforced walls can be designed to have a height:thickness (h/t) ratio up to 30:1 (common) or 50:1 (higher strength and heavily reinforced)

- 4” walls -10 ft to 15 ft tall
- 6” walls - 15 ft to 25 ft tall
- 8” walls - 20 ft to 33 ft tall
- 10” walls - 25 ft to 42 ft tall
- 12” walls - 30 ft to 50 ft tall
- 16” walls - 40 ft to 67 ft tall



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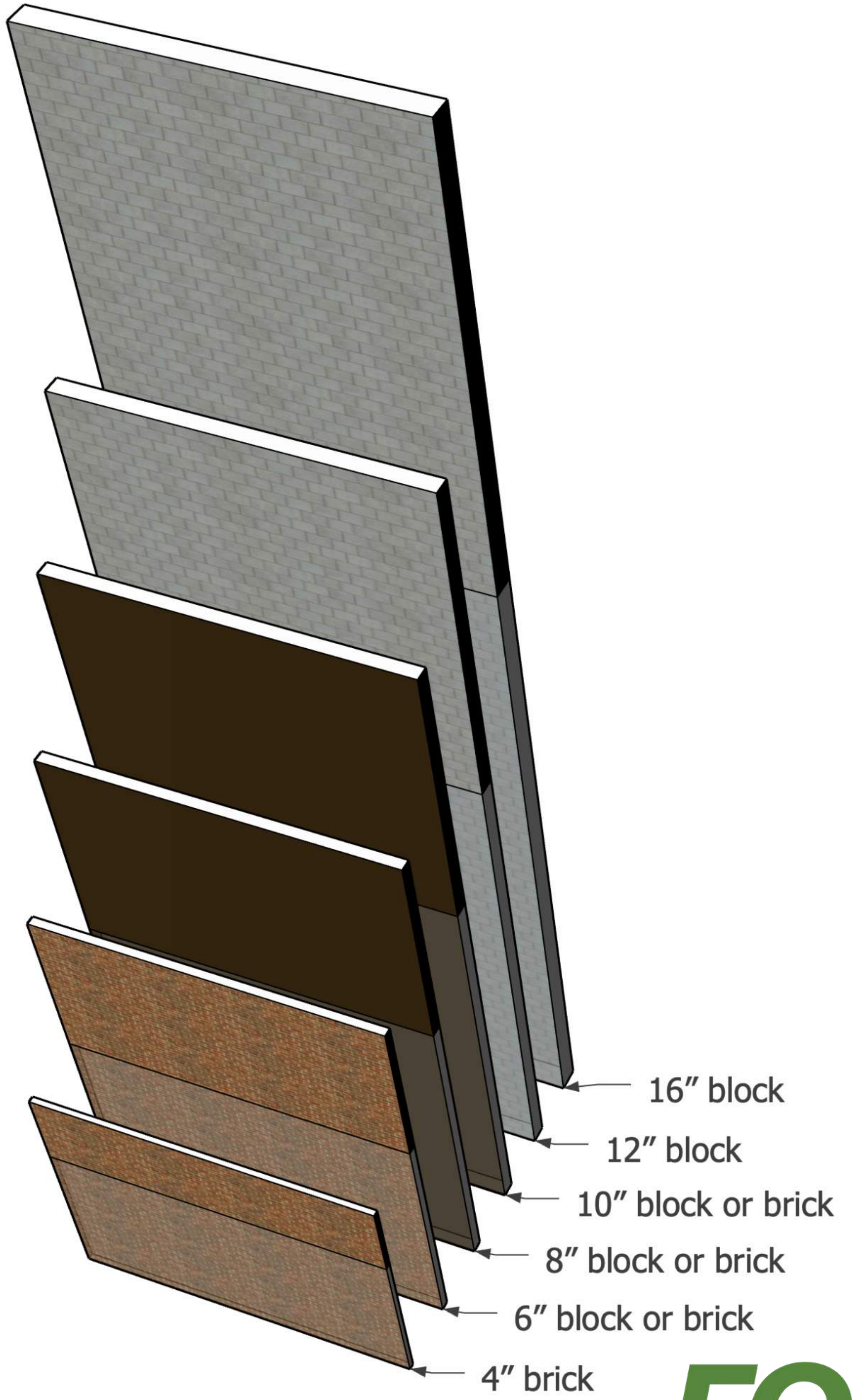
Masonry walls

Consider the following for reinforced walls as well:

- 4” is available for concrete and clay
  - only 4” clay masonry can be reinforced
- 6” - 8” - 10” are available for concrete and clay masonry and can be reinforced
- 12” - 16” are available for concrete only and can be reinforced



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Masonry Checklist

- ☐ f'm - masonry assembly strength
- ☐ Verify all components of masonry are specified
- ☐ Consider masonry wall thickness and reinforcement
- ☑ Review masonry shear walls
- ☑ Review masonry partition walls
- ☐ Check that control joints are located on plans
- ☐ Review lintels, prefer masonry lintels where possible
- ☐ Review bearing plate details
- ☐ Consider conflicts between steel and masonry

March 1, 2020

MASONRY INSIGHTS

written in conjunction with International Masonry Institute

Masonry checklist: reviewing structural plans

- ☐ f'_m (masonry assembly strength) for structural concrete or clay masonry is 2,000 psi or greater
  - ☐ concrete masonry f'_m = 2,500psi is the most common
  - ☐ clay masonry f'_m = commonly in the range of 3,000psi to 4,000psi
  - ☐ Masonry strengths up to 4,000 psi are permitted in current codes for strength design[1]
- ☐ Check that all components of masonry are specified:
  - ☐ Block strength: check masonry.forsei.com/masonry/cmudata/ to verify based on location
    - ☐ Commonly above 3250 psi for concrete masonry and 8250 psi for clay masonry
  - ☐ Mortar type (mortar strength need not be listed)
    - ☐ Recommend Type N for non-structural walls
      - ☐ Veneer and partition walls commonly use this mortar
      - ☐ Can be used in some structural applications, but reduces capacity
        - ☐ Not to be used below grade
        - ☐ Not to be used in seismic SDC D, E, or F
    - ☐ Recommend Type S for structural walls
      - ☐ Can be used below grade
      - ☐ Can be used in all seismic areas, SDC A, B, C, D, E, and F
    - ☐ Type M is high strength, but more costly and reduced workability
      - ☐ Can be used below grade
      - ☐ Used in high load applications and extreme environmental conditions
  - ☐ Grout strength
    - ☐ Should be at least 2,000 psi, and equal to or greater than f'_m

partition wall

TMS 402 definition

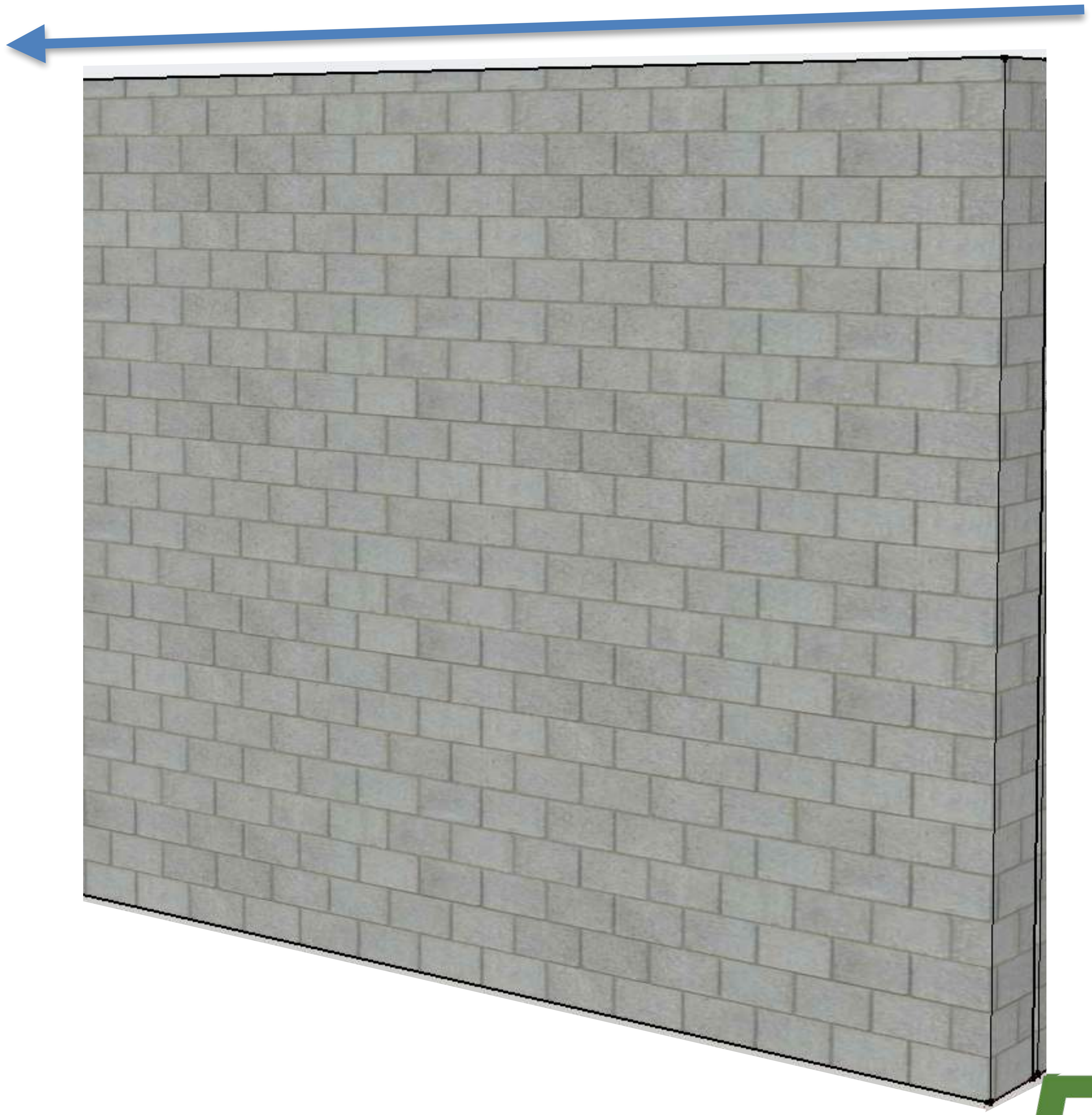
- an interior wall without structural function
- since MSJC 2013, new chapter 7, need to ensure no in-plane forces enter wall which are not accounted for

MORE LATER…

shear wall

TMS 402 definition

- resists in-plane lateral shear loads
- in seismic regions, we need to classify as:
  - ordinary plain (unreinforced)
  - detailed plain (unreinforced)
  - ordinary, intermediate, or special reinforced shear walls



Masonry shear walls for seismic loads IBC 2015 – seismic wall characteristics

Shear Wall Type	R	Ω_0	C_d	Allowable SDC
Ordinary Reinforced	2	2.5	1.75	A,B,C
Intermediate Reinforced	3.5	2.5	2.25	A,B,C
Special Reinforced	5	2.5	3.5	A,B,C,D,E,F

Factors based upon shear wall type used with building frame systems.
IBC Table 12.2-1, pg 73

Masonry shear walls for seismic loads
TMS 402-2016 – seismic wall characteristics

- Ordinary Reinforced Section - 7.3.2.4&7.3.2.3.1 (summary)
  - at least #4 vertical reinforcement within:
    - 16” of edge of opening and within last 8” of wall ends
  - 2-W1.7 horizontal joint reinforcement at 16” o.c.
    - or #4 @120” o.c. horizontal
  - reinforcement top and bottom of openings ≥ 16”
    - extend 24” past opening, nor less than $40d_b$
  - reinforcement within 16” of top of walls
  - based on ASD or SD
- Intermediate Reinforced - Section 7.3.2.5 (summary)
  - all requirements of Ordinary Reinforced
  - vertical reinforcement no further apart than 48” o.c.
- Special Reinforced - Section 7.3.2.6 (summary)
  - all requirements of Ordinary Reinforced
  - reinforcement no further than 48” o.c. vertically and horizontally ***and much more***

Partition Wall

<u>TMS 402-2016</u>

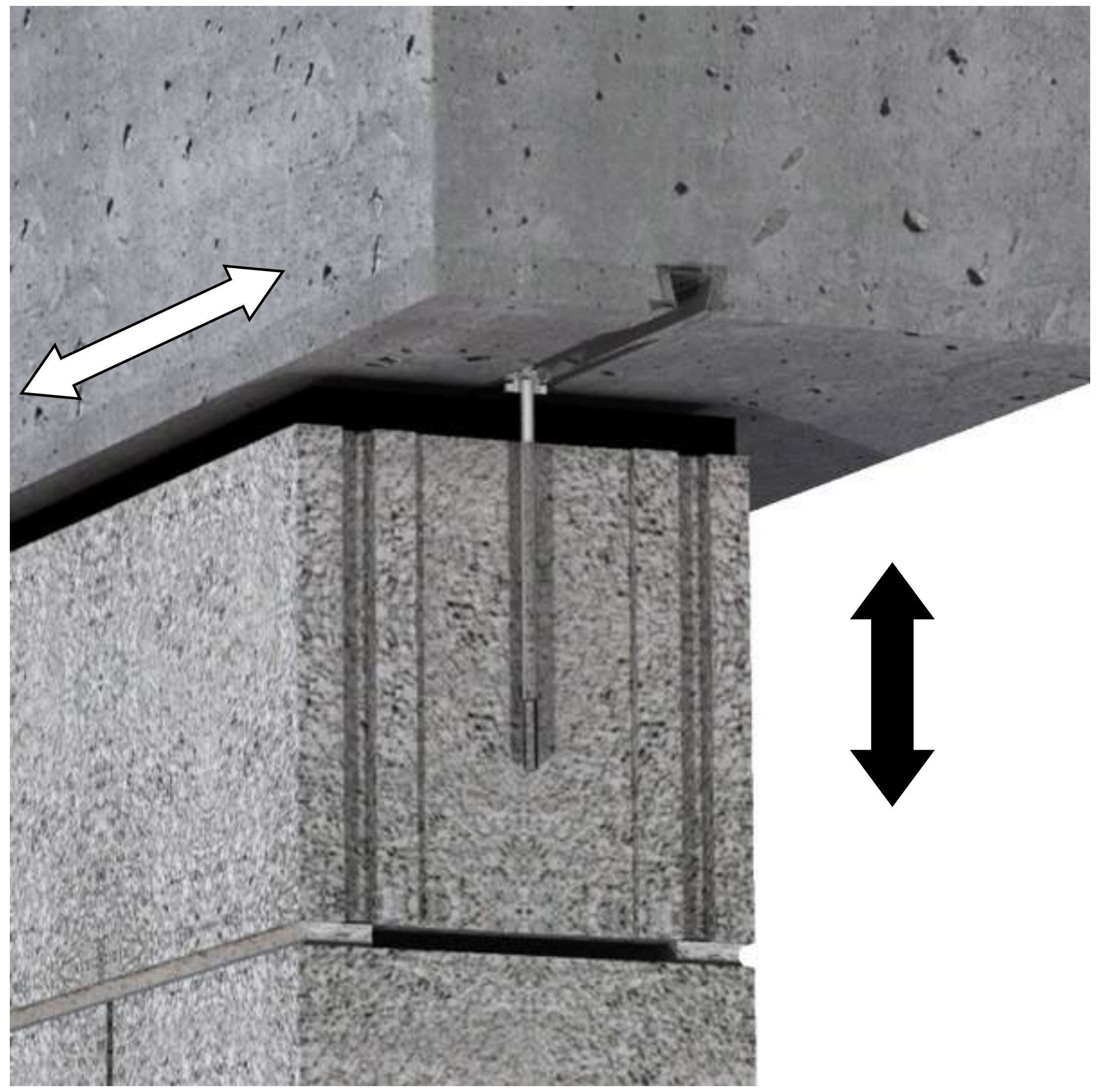
- an interior wall without structural function
- since MSJC 2013, new chapter 7, need to ensure no in-plane forces enter wall which are not accounted for

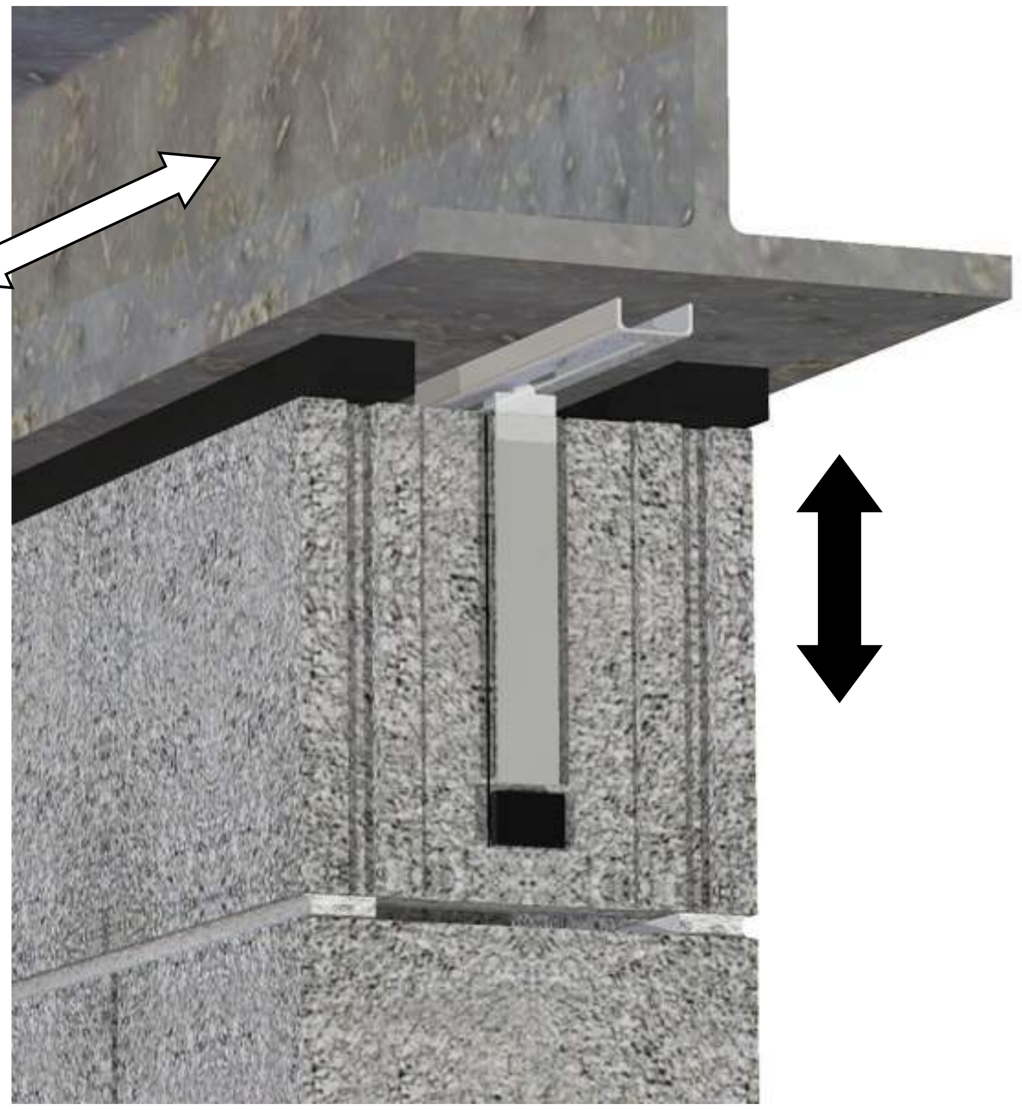
Masonry Partitions Getting Too Complicated

- Too much unnecessary reinforcement
- Studies have shown significant costs related to partition walls

- Savings occur when you realize:
  - Partition walls are not shear walls
  - No reinforcement is *required*
- Smarter connections are possible
  - don't want unintended loads

Simple Masonry Partition Connections

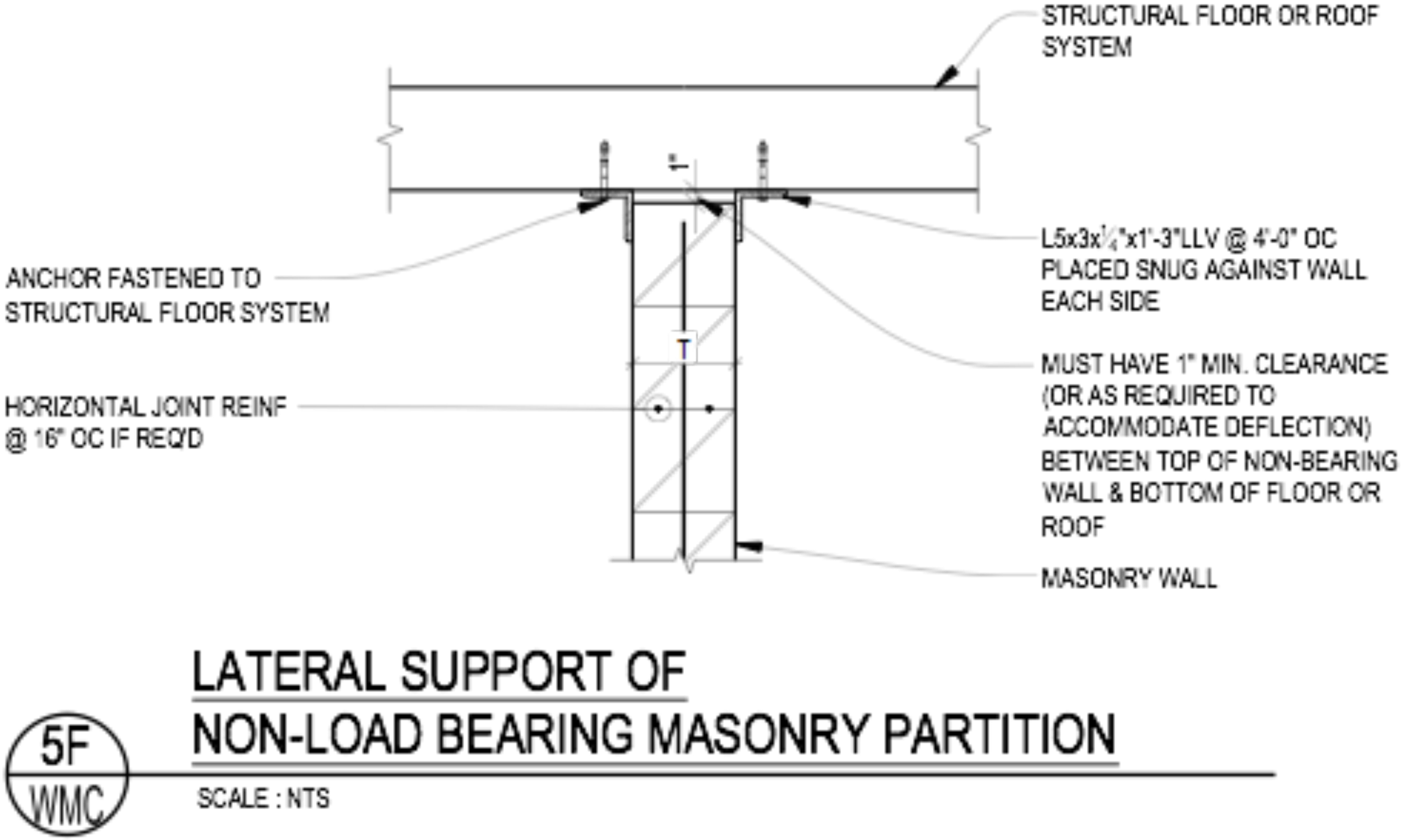




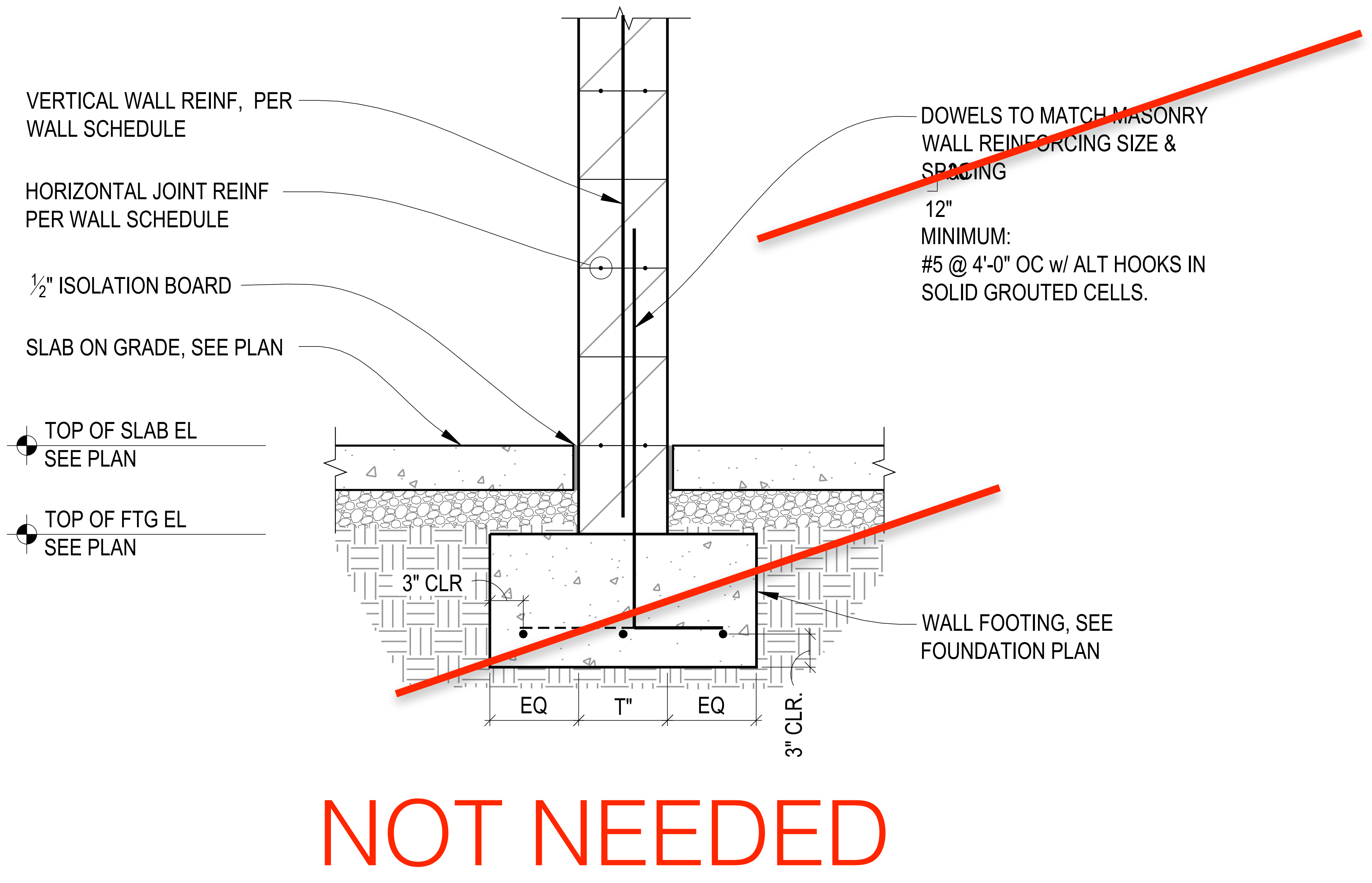
Partition Top Anchors (PTA)

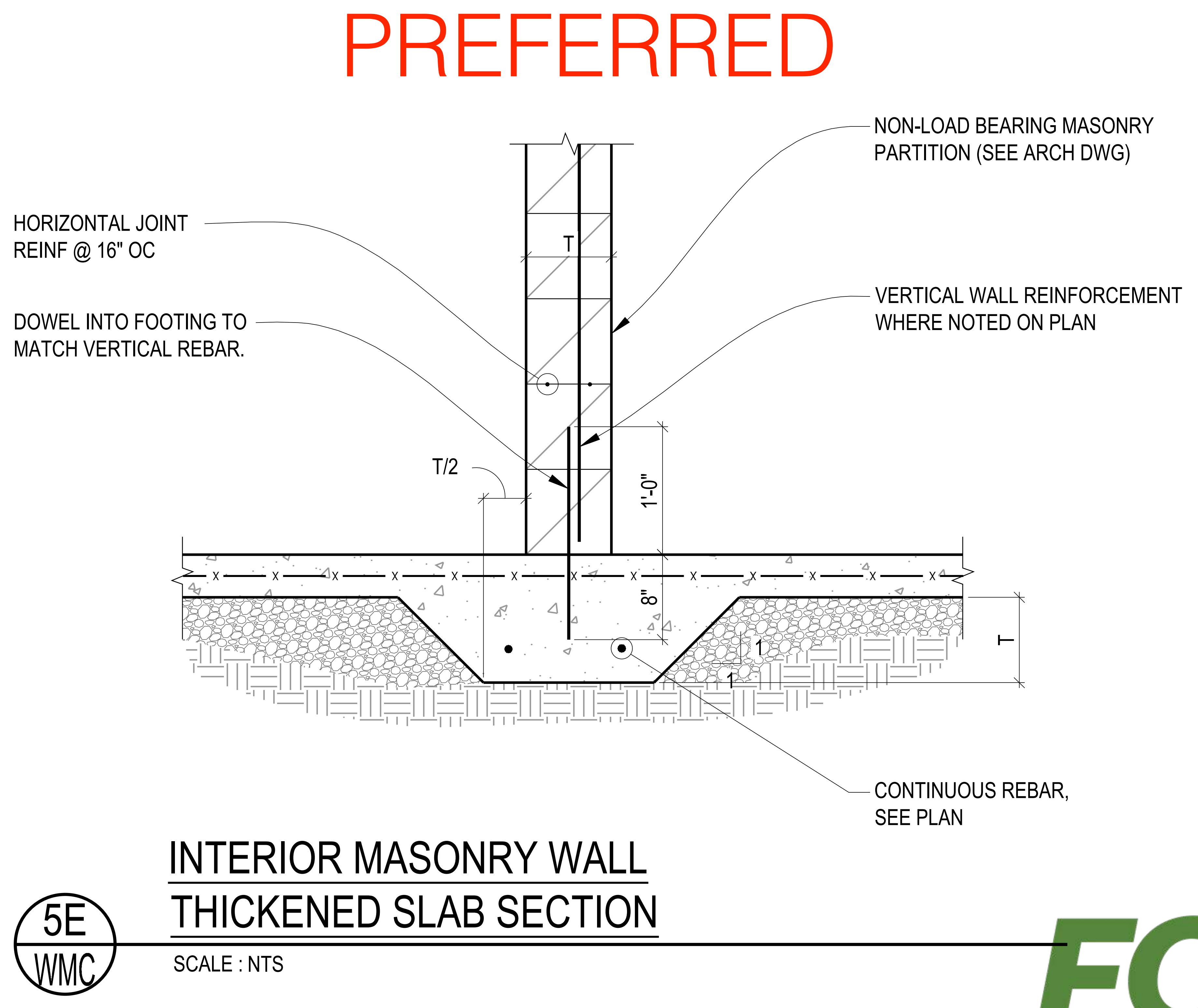
source: www.h-b.com

Simple Masonry Partition Connections



Simple Masonry Partition Connections





INTERIOR MASONRY WALL THICKENED SLAB SECTION

SCALE : NTS

Simplified

Interior Partition Wall, f'm=2500psi, mortar cement IBC min load — 5 psf service (8 psf factored) SDC A, B								
	10 ft	12 ft	14 ft	16 ft	18 ft	20 ft	24 ft	30 ft
6 inch	none	none	none	#4 @ 96	#4@96	#4 @ 72	#4 @ 40	#5 @ 24
8 inch	none	none	none	none	none	#4 @ 96	#5 @ 96	#5 @ 48
10 inch	none	none	none	none	none	none	none	#4 @ 96
12 inch	none	none	none	none	none	none	none	#4 @ 96
16 inch	none	none	none	none	none	none	none	none

Simplified

Interior Partition Wall, f'm=2500psi, mortar cement IBC min load — 5 psf service (8 psf factored) SDC C								
	10 ft	12 ft	14 ft	16 ft	18 ft	20 ft	24 ft	30 ft
6 inch	#4@120	#4@120	#4@120	#4 @ 96	#4 @ 96	#4 @ 72	#4 @ 40	#5 @ 24
8 inch	#4@120	#4@120	#4@120	#4@120	#4@120	#4 @ 96	#5 @ 96	#5 @ 48
10 inch	#4@120	#4@120	#4@120	#4@120	#4@120	#4@120	#4@120	#4 @ 96
12 inch	#4@120	#4@120	#4@120	#4@120	#4@120	#4@120	#4@120	#4 @ 96
16 inch	#4@120	#4@120	#4@120	#4@120	#4@120	#4@120	#4@120	#4@120

Simplified

Interior Partition Wall, f'm=2500psi, mortar cement IBC min load — 5 psf service (8 psf factored) SDC D								
	10 ft	12 ft	14 ft	16 ft	18 ft	20 ft	24 ft	30 ft
6 inch	#4@48	#4@48	#4@48	#4@48	#4@48	#4@48	#4 @ 40	#5 @ 24
8 inch	#4@48	#4@48	#4@48	#4@48	#4@48	#4@48	#4@48	#5 @ 48
10 inch	#4@48	#4@48	#4@48	#4@48	#4@48	#4@48	#4@48	#4@48
12 inch	#4@48	#4@48	#4@48	#4@48	#4@48	#4@48	#4@48	#4@48
16 inch	#4@48	#4@48	#4@48	#4@48	#4@48	#4@48	#4@48	#4@48

Simplified

Interior Partition Wall, f’m=2500psi, mortar cement IBC min load — 5 psf service (8 psf factored) SDC E or F								
	10 ft	12 ft	14 ft	16 ft	18 ft	20 ft	24 ft	30 ft
6 inch	#4@48	#4@48	#4@48	#4 @ 96	#4 @ 96	#4 @ 72	#4 @ 40	#5 @ 24
8 inch	#4@48	#4@48	#4@48	#4@48	#4@48	#4 @ 96	#5 @ 96	#5 @ 48
10 inch	#4@48	#4@48	#4@48	#4@48	#4@48	#4@48	#4@48	#4 @ 96
12 inch	#4@48	#4@48	#4@48	#4@48	#4@48	#4@48	#4@48	#4 @ 96
16 inch	#4@48	#4@48	#4@48	#4@48	#4@48	#4@48	#4@48	#4@48

more complicated
and solid grout
and min horiz reinf at 24" o.c.
etc...

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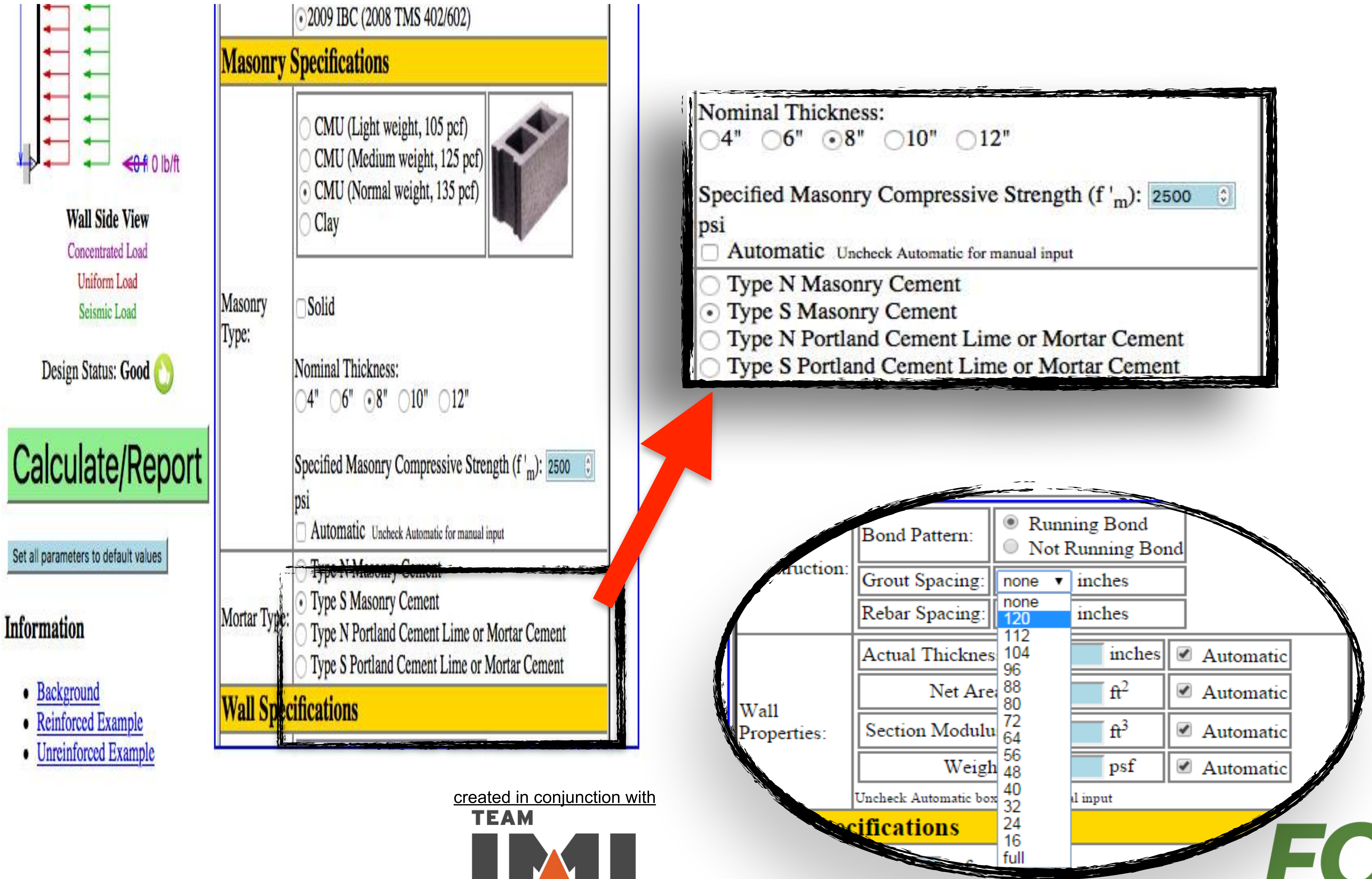
imiweb.org/structural-solutions/masonry-partition-wall-software/



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Load Combination	x (ft)	Axial Force (lb)	Moment (ft-lb)	A_s (sq in)	Steel	l_d inches	R_{top} lb/ft
A: $0.6D+w_L$	6.0	137	90	0.022	#3	12	30.0
G: 0.6D+0.7E	6.0	105	230	0.094	#3	12	76.6
H: $0.6D+0.75w_L+0.75(0.7E)$	6.0	113	240	0.098	#3	12	80.0

Reinforced Design Results

Steel size: #3 Grade 60 reinforcement at 56 inches

Development length: 12 inches

R_{top}: 80.0 lb/ft

Seismic load: 18.24 psf

Grout: ASTM C476, minimum compressive strength of 2800 psi

Seismic Design Category D:

Prescriptive seismic reinforcement needs to be provided in either the horizontal OR vertical direction. The calculated structural reinforcement may satisfy this requirement.

a. Horizontal reinforcement - Two longitudinal wires of W1.7 (9 gage) bed joint reinforcement spaced not more than 16 in. on center,or No. 4 bars spaced not more than 48 in. on center. Horizontal reinforcement needs to be provided within 16 in. of the top and bottom of the wall. If the wall is 4 inches thick, only one wire is required.
b. Vertical reinforcement - No. 4 bars spaced not more than 48 in. on center. Vertical reinforcement needs to be provided within 16 in. of the ends of the wall.

Grouting and Reinforcing: All masonry and grouting and reinforcing work shall be performed by masonry craftworkers who have successfully completed the International Masonry Institute (1-800-IMI-0988) training course for Grouting and Reinforced Masonry Construction, or equal.

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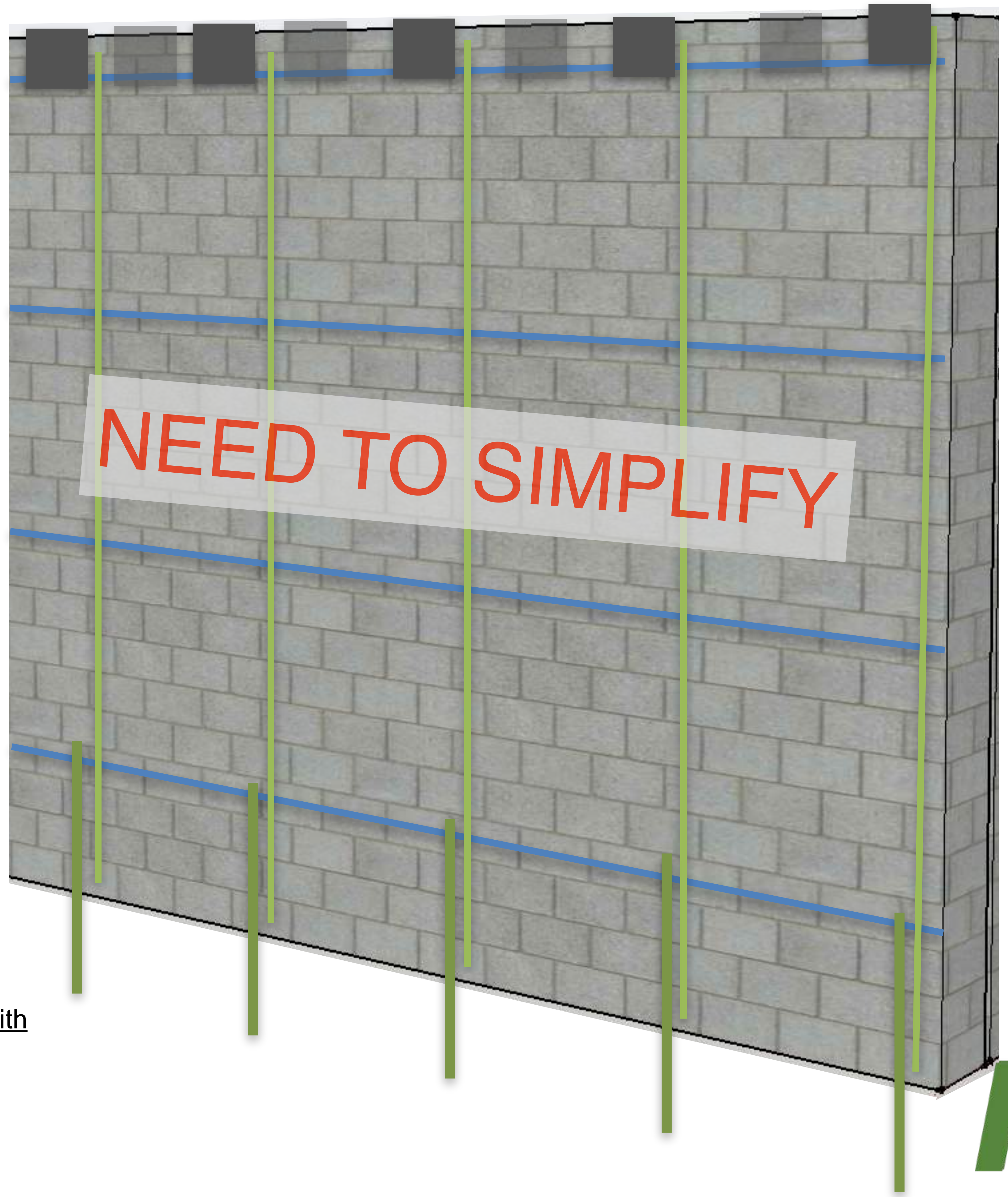
Masonry Partitions Getting Too Complicated

- So simplify when possible
  - No un-needed horizontal reinf.
    - SDC A, B, C, D
  - Quite possibly don't need top of wall bond beam
  - Minimize vertical reinf.
    - Don't need reinf. at 48" o.c. (max)
  - We can/should simplify top and bottom connections



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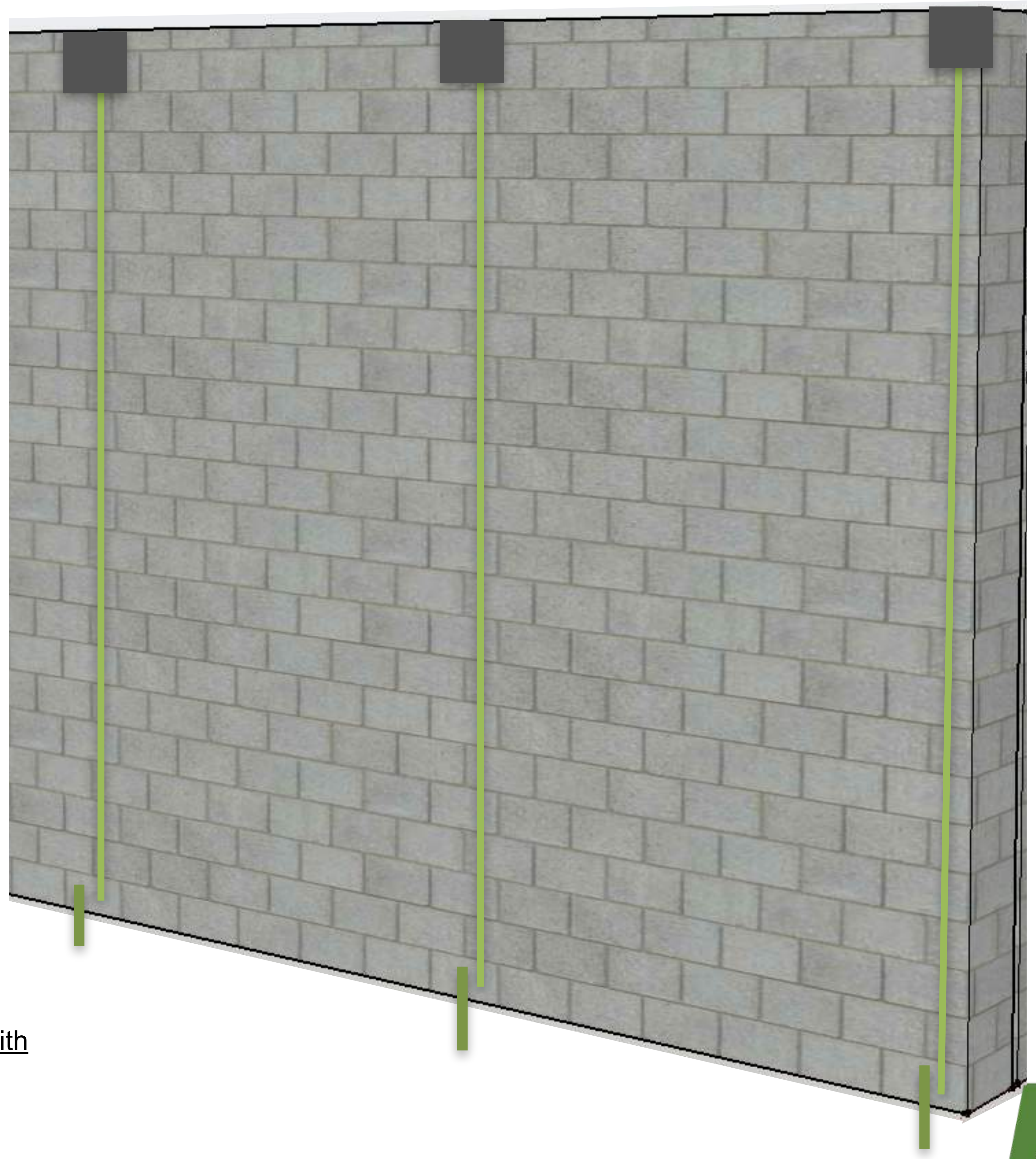
Masonry Partitions Getting Too Complicated

- So simplify when possible
  - No un-needed horizontal reinf.
    - SDC A, B, C, D
  - Minimize vertical reinf.
    - Don’t need reinf. at 48” o.c. (max)
  - We can / should simplify top and bottom connections



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Partition Walls

MASONRY INSIGHTS

Masonry Partition Walls

The Masonry Society's TMS 402 code defines a partition wall as an interior wall without any structural function. It is a non-load bearing wall that does not support a floor above, does not participate in the lateral system, and is not a wall that resists out-of-plane exterior wind or seismic loads. A structural engineer might think that if the wall serves no structural function, then it does not need to be included in their design considerations. This is not completely true, however.

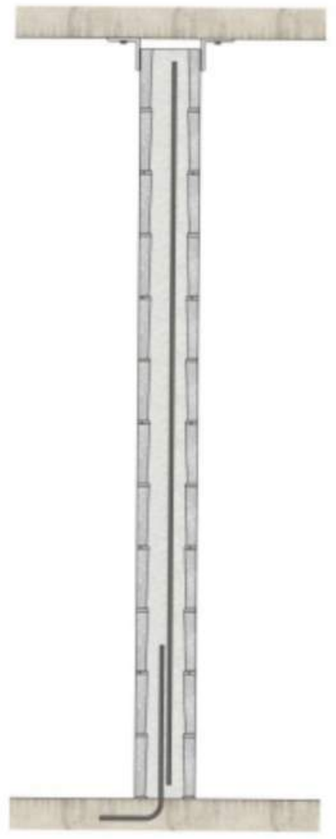


Figure 1: Partition Wall Section
IMI Detailing Series

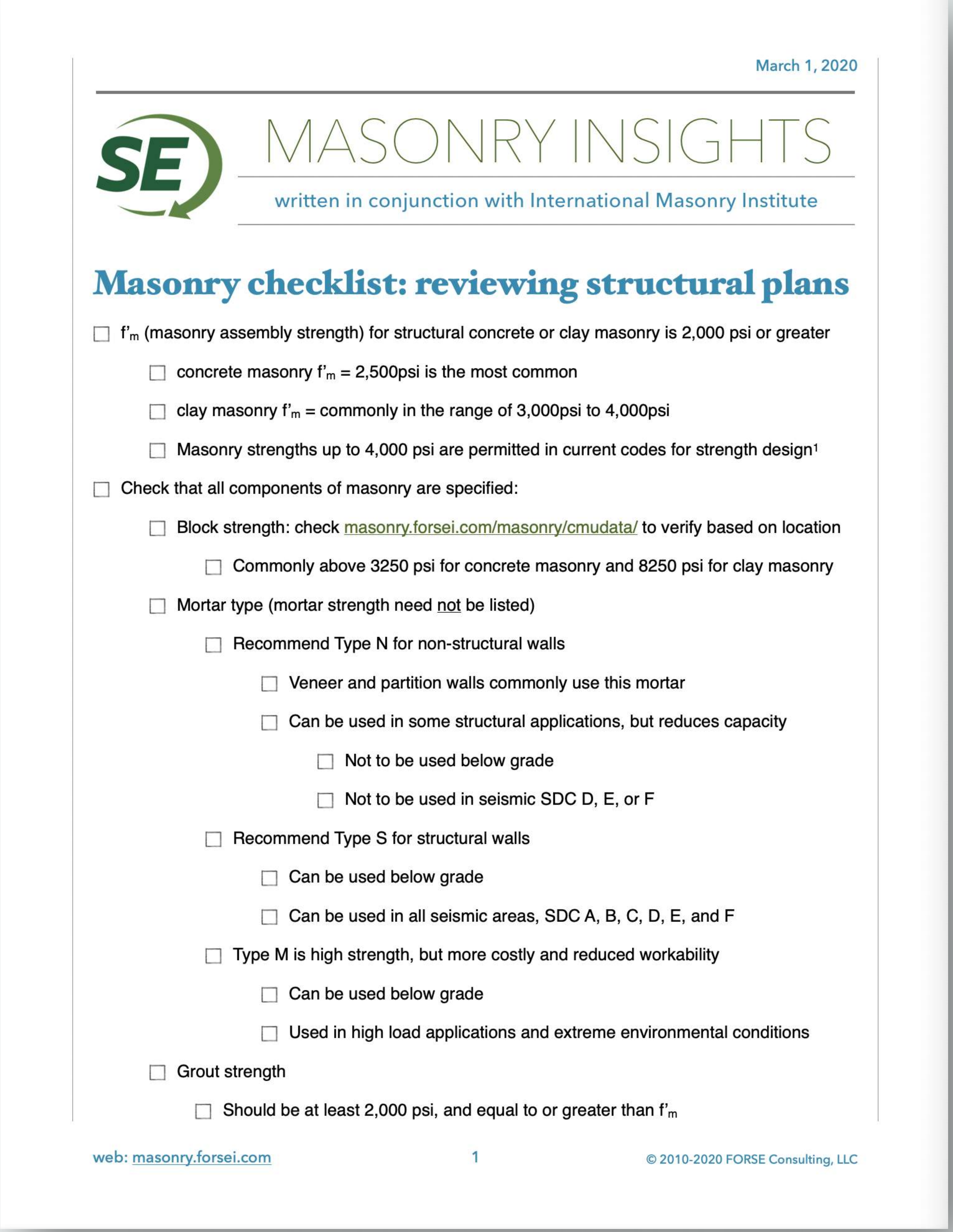
As a material, masonry has some advantages over other materials pertaining to partition walls. It offers durability, security, and a measure of fire and sound control. Masonry can provide energy savings due to its thermal mass, and it can require less maintenance than other building materials. There are also several finish options for masonry — it can be painted or burnished, rock-faced, or set in a stack bond pattern. With these advantages, it is apparent why masonry partition walls are prevalently used. Now that we have reviewed the benefits of masonry partition walls, let us look closer at design and detailing practices to take into consideration ways to result in more cost-effective partition wall designs.

What are reinforcement requirements for partition walls?

The first design item we will explore are reinforcement requirements for partition walls. If detailed correctly, the only load that partition walls are to be designed for is an interior horizontal design pressure. IBC Code 2015, Section 1607.14 requires a minimum interior pressure of 5 psf service (8 psf ultimate) to be considered. Partition walls should not resist any gravity loading. Therefore, partition wall height, thickness, and reinforcement (if any) do not need to be checked to resist loads other than minimal interior horizontal pressure. What does the TMS 402 Code mandate in terms of minimum reinforcement for partition walls? To understand TMS Code requirements, we first define partition walls as 'nonparticipating elements', which are masonry elements that are not part of the seismic (or lateral) force-resisting structural system. Per TMS 402-13 Section 7.4.1, partition walls in

Masonry Checklist

- ☐ f’m - masonry assembly strength
- ☐ Verify all components of masonry are specified
- ☐ Consider masonry wall thickness and reinforcement
- ☐ Review masonry shear walls
- ☐ Review masonry partition walls
- ☑ Check that control joints are located on plans
- ☐ Review lintels, prefer masonry lintels where possible
- ☐ Review bearing plate details
- ☐ Consider conflicts between steel and masonry


March 1, 2020

MASONRY INSIGHTS

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Masonry checklist: reviewing structural plans

- ☐ f'_m (masonry assembly strength) for structural concrete or clay masonry is 2,000 psi or greater
  - ☐ concrete masonry f'_m = 2,500psi is the most common
  - ☐ clay masonry f'_m = commonly in the range of 3,000psi to 4,000psi
  - ☐ Masonry strengths up to 4,000 psi are permitted in current codes for strength design[1]
- ☐ Check that all components of masonry are specified:
  - ☐ Block strength: check masonry.forsei.com/masonry/cmudata/ to verify based on location
    - ☐ Commonly above 3250 psi for concrete masonry and 8250 psi for clay masonry
  - ☐ Mortar type (mortar strength need not be listed)
    - ☐ Recommend Type N for non-structural walls
      - ☐ Veneer and partition walls commonly use this mortar
      - ☐ Can be used in some structural applications, but reduces capacity
        - ☐ Not to be used below grade
        - ☐ Not to be used in seismic SDC D, E, or F
    - ☐ Recommend Type S for structural walls
      - ☐ Can be used below grade
      - ☐ Can be used in all seismic areas, SDC A, B, C, D, E, and F
    - ☐ Type M is high strength, but more costly and reduced workability
      - ☐ Can be used below grade
      - ☐ Used in high load applications and extreme environmental conditions
  - ☐ Grout strength
    - ☐ Should be at least 2,000 psi, and equal to or greater than f'_m

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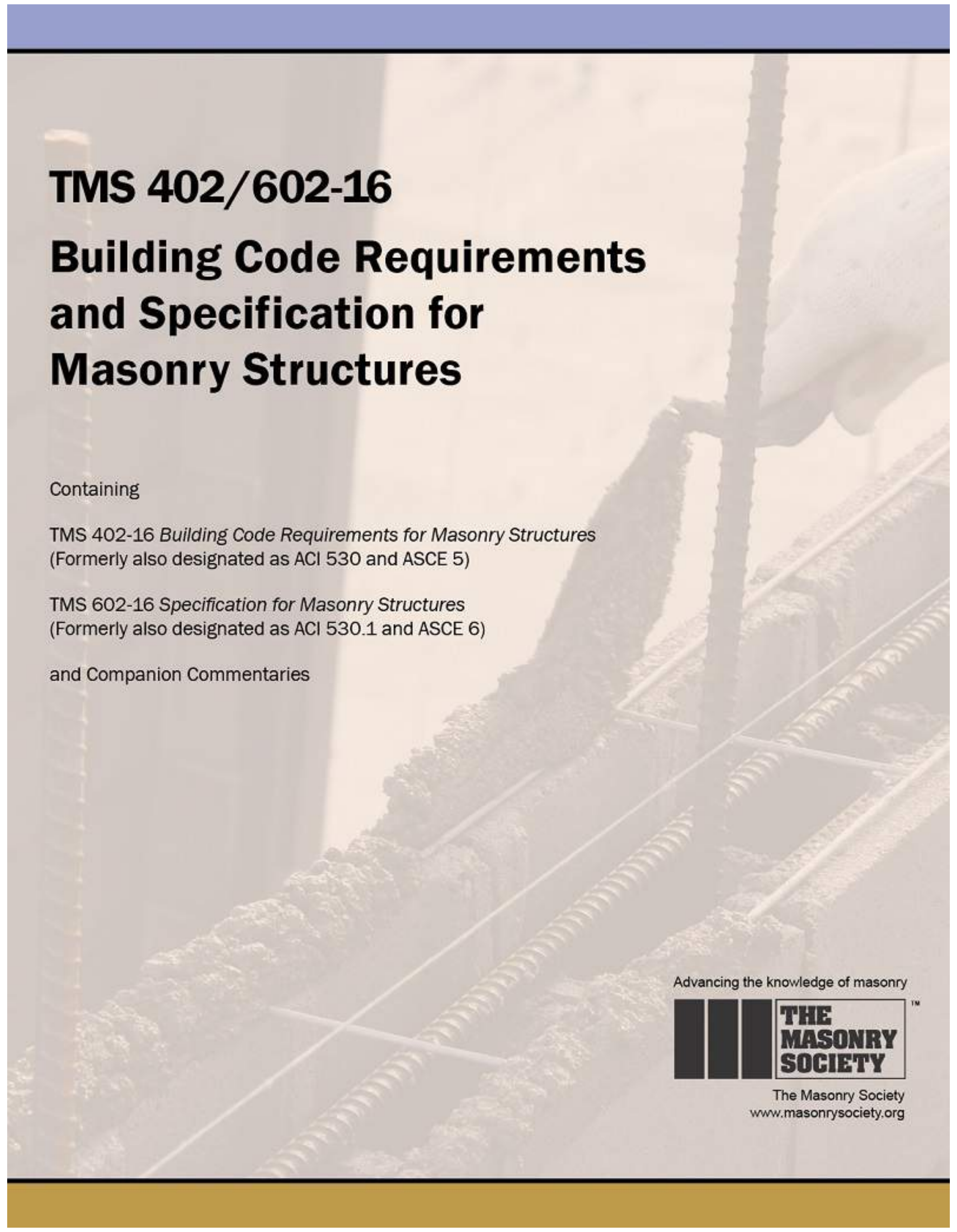
Check that control joints are located on plans



TMS 602 **Mandatory** Requirements Checklist
Notes to Architect / Engineer:

"Indicate type and location of movement joints on the project drawings."

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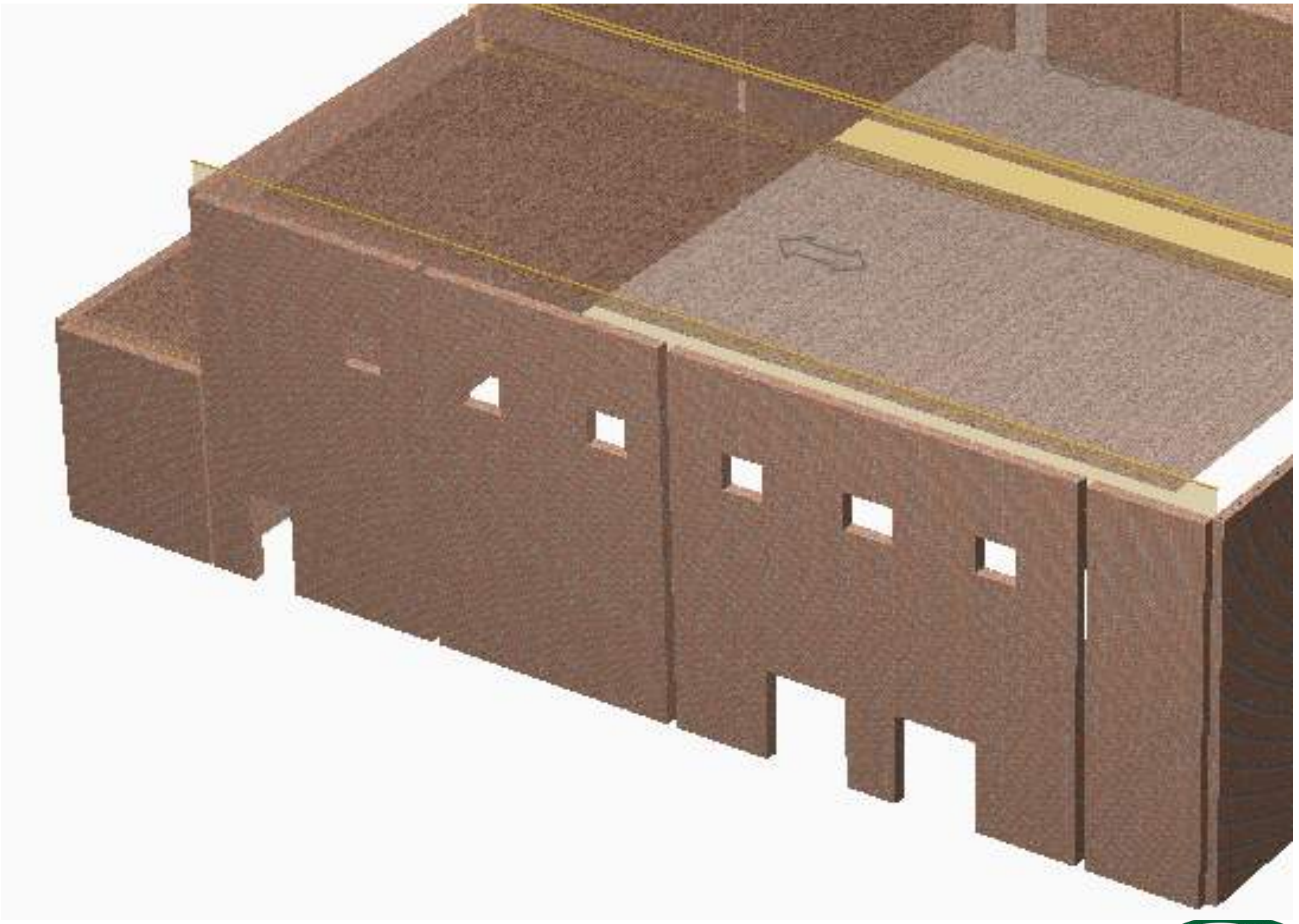
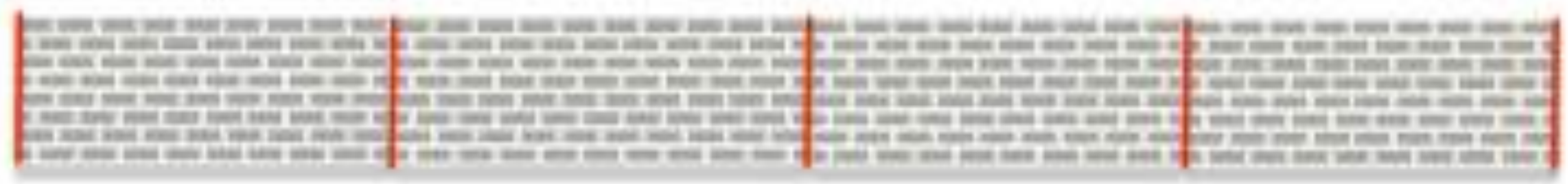
Control Joints – Impact on Wall Design

- Spacing between CJ is critical
  - TOO CLOSE
    - LESS effective lateral resistance
    - Shear wall may not work
  - TOO FAR APART
    - wall cracks from thermal loading on the wall without proper reinforcement

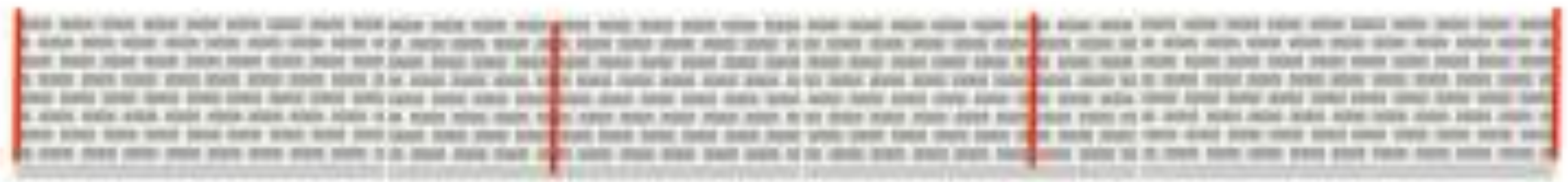


Control Joints – Impact on Wall Design

- Less wall length is better for thermal loading



HOWEVER — 3 long walls are 33% stronger then 4 short walls for in-plane lateral load resistance



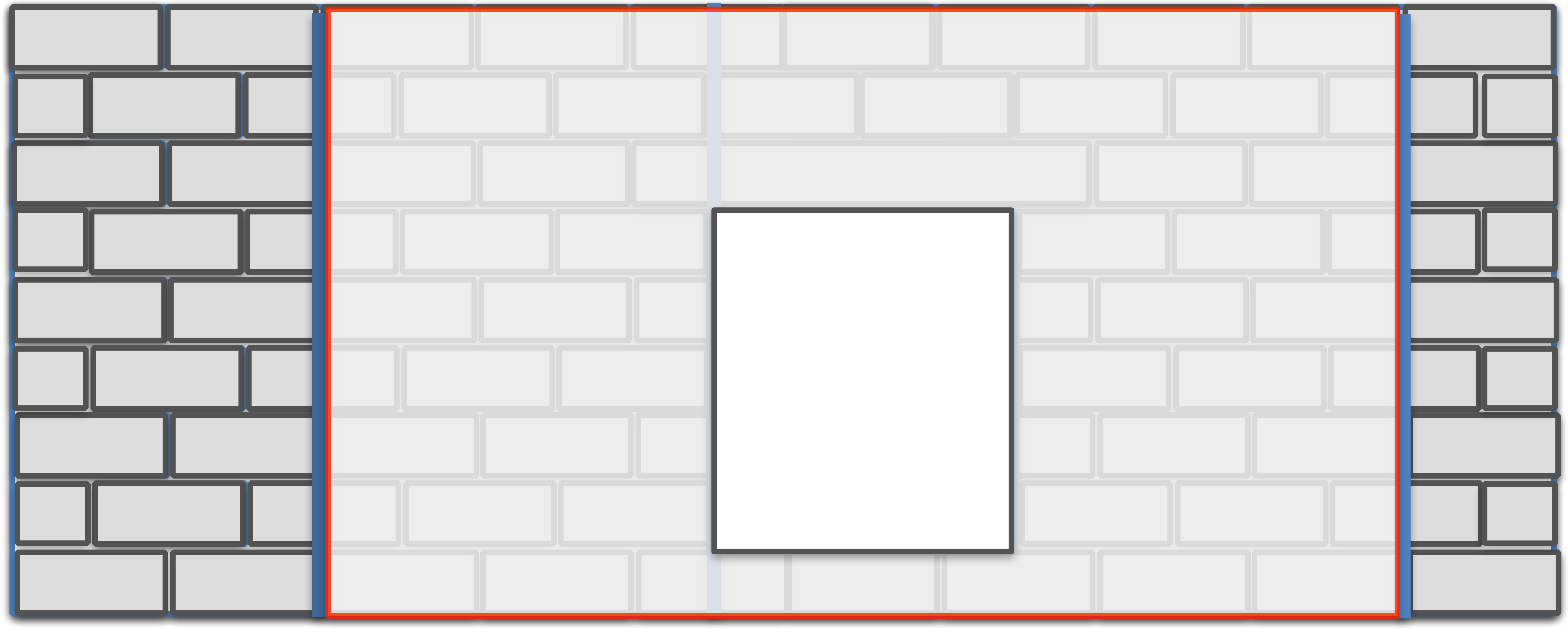
- So use as long of walls as possible without exceeding crack control length recommendations

Control Joints – Impact on Shear Wall Design

- Locate away from openings
  - Joints at openings result in the “loss” of shear wall length, decreased stiffness
  - Longer walls that have openings within them are much better for shear wall performance
    - Perforated shear walls are a more complicated design, but RAM Elements, RISA 3D, ETABS programs solve that issue

Control Joints – Impact on Shear Wall Design

Locate away from openings and you gain shear wall capacity/stiffness



a "perforated shear wall" can have 300% the capacity over two short walls

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Example of Perforated Shear Walls vs Multiple Short Walls

300% the capacity!

- Perforated wall
  - 8” block, f’m=2250psi
  - 20ft tall
  - 24’8” long
  - one 5ft x 8ft opening
  - capacity=96k at top
  - controlled by in-plane shear

- Multiple short walls
  - 8” block, f’m=2250psi
  - 20ft tall
  - Two 8’-0” walls
- capacity = 32.6k at top
- controlled by in-plane moment

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Masonry Design Notes
General Notes

<u>don't define control joint spacing via notes</u>

- brick veneer (MJ) and concrete masonry (CJ) have different movement requirements
  - one expands, one contracts
  - one does not have reinf, one does have reinforcement
- designers are required by code to locate movement joints
  - make specific locations on plans and elevations
  - don't try to define with words

Locating Movement Joints

- locate CJ's on plan or elevations (1)
- veneer MJ's on elevations (2)

Locating MJs and CJs via a sentence in the general notes only is <u>not</u> enough information for the contractor

(1) typically located by structural engineer

(2) typically located by architect

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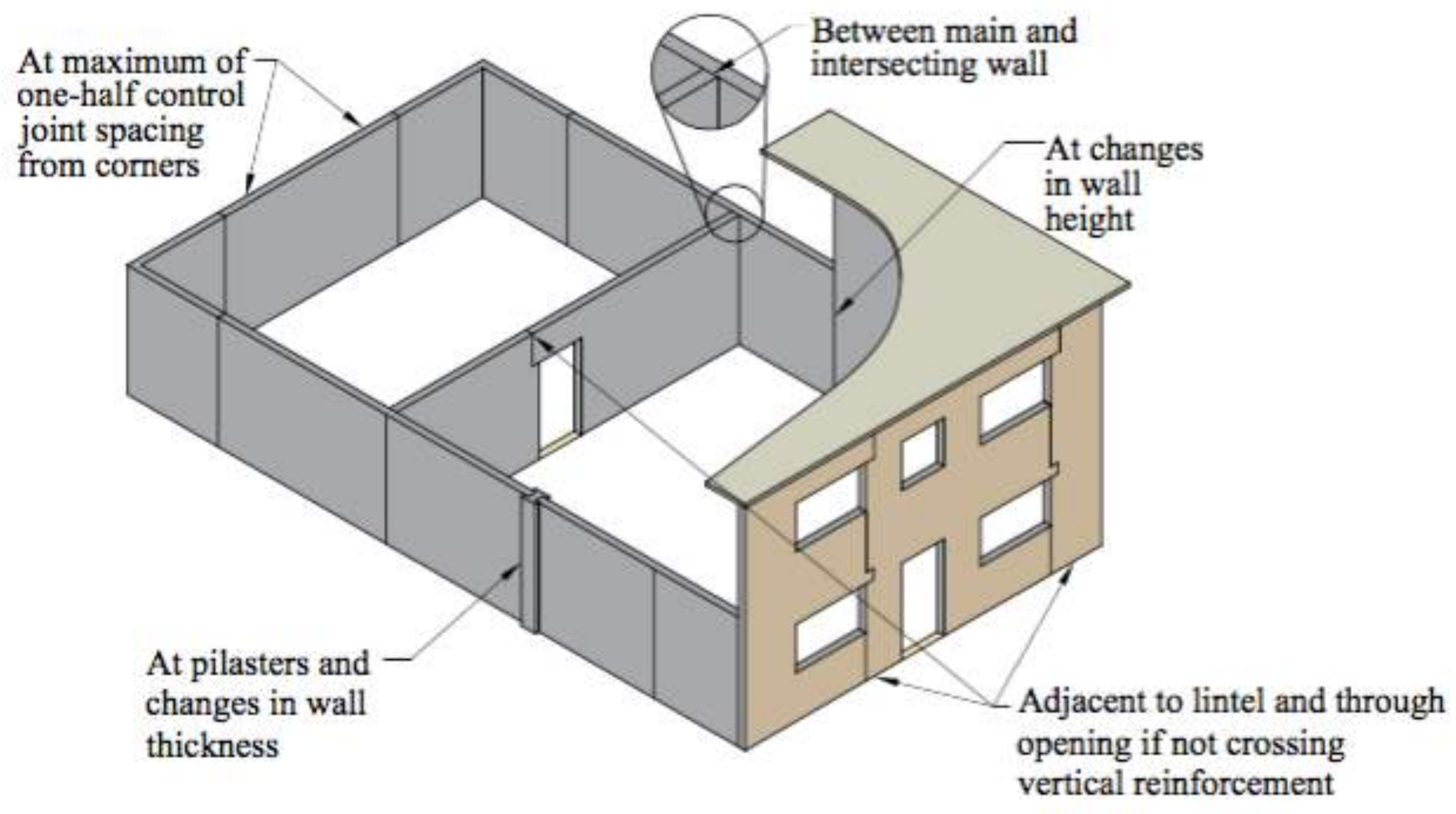
CJs and horizontal reinforcement

Options for controlling cracking

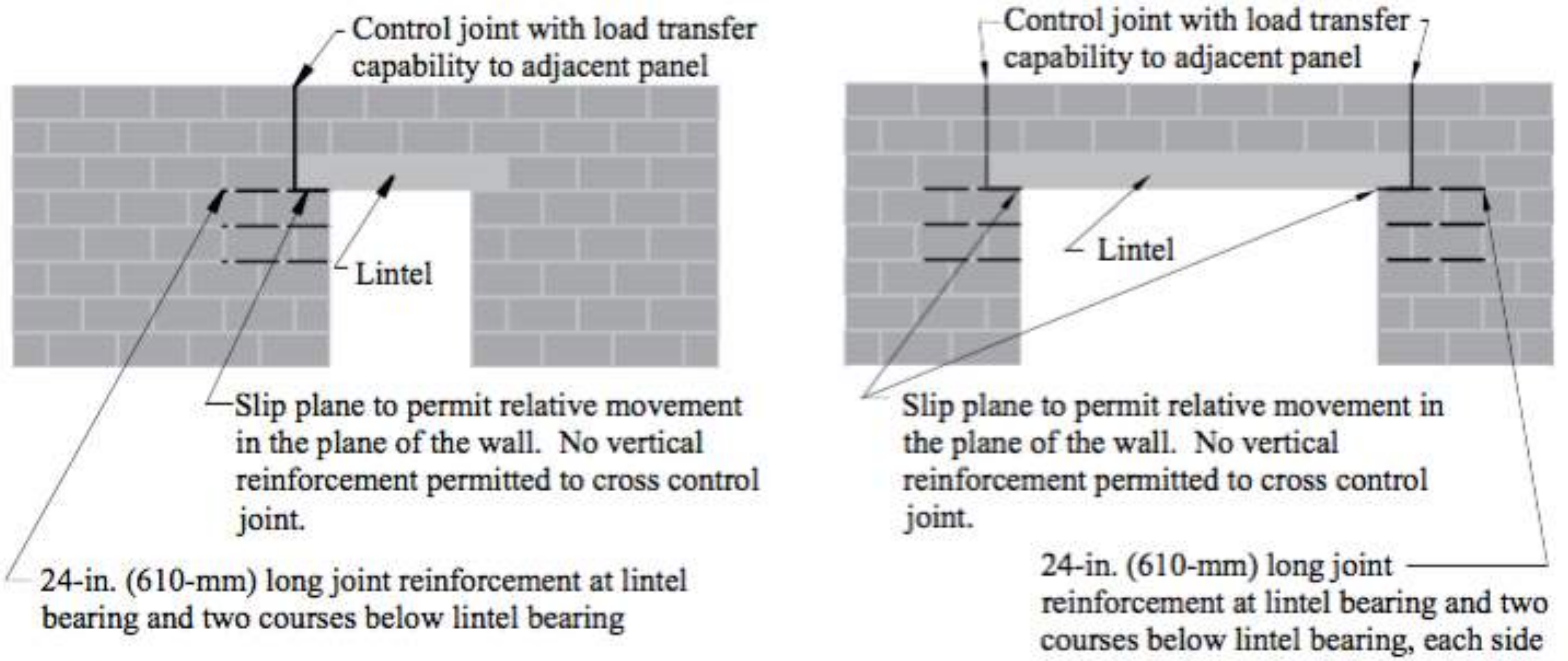
1. min. horiz. reinf. and control joints for masonry
   - does NOT need bar reinforcement like concrete
   - needs gauge reinforcement
   - CJ based on max 25 ft or 1.5 x wall height
2. additional horizontal reinforcement and NO (less) control joints



CJs and horizontal reinforcement

Options for controlling cracking

1. min. horiz. reinf. and control joints for masonry
   - CJ in unreinforced wall:



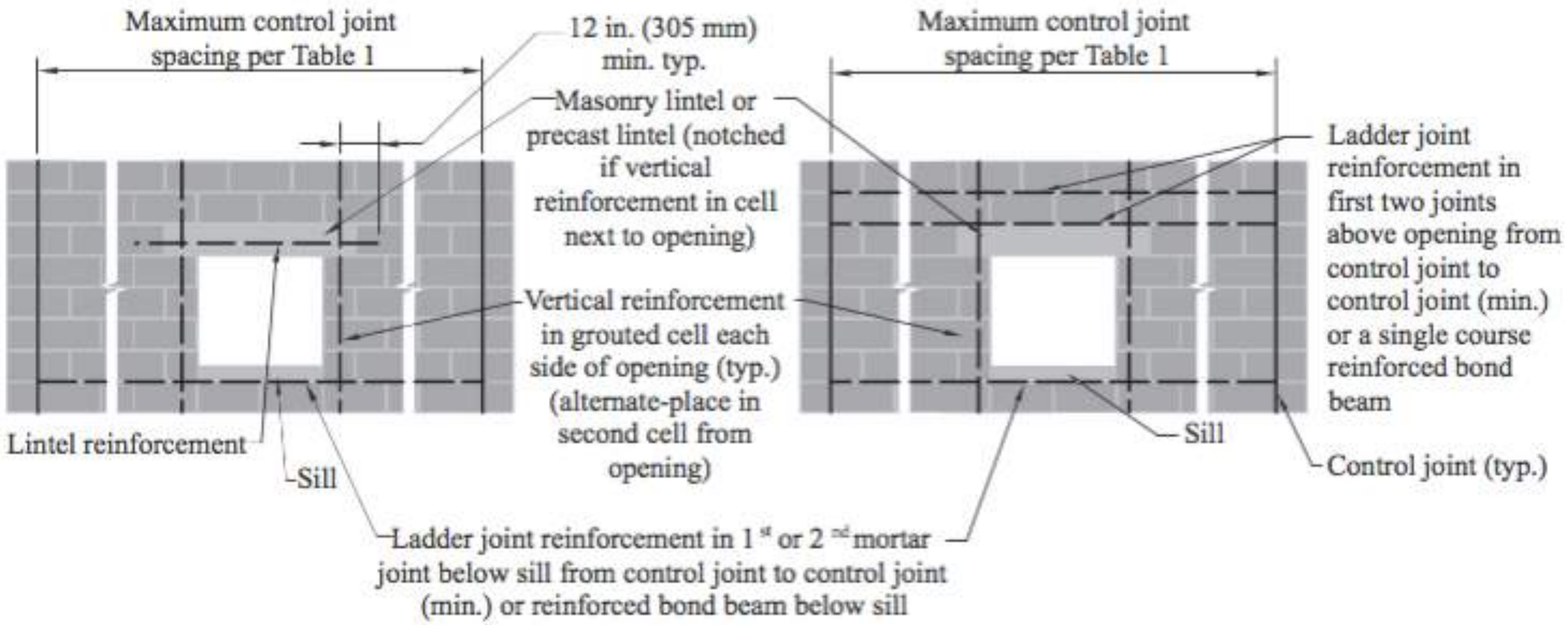
2a—Openings less than 6 ft (1,829 mm) **2b—Openings wider than 6 ft (1,829 mm)**

Control Joints at Openings in Walls With No Reinforcement in Adjacent Cells

CJs and horizontal reinforcement

Options for controlling cracking

1. min. horiz. reinf. and control joints for masonry
   – CJ in reinforced wall: (AWAY FROM OPENINGS!!)



2c—Preferred strengthening of opening with reinforcement—extending lintel reinforcement and joint reinforcement under the sill

2d—Opening strengthened with joint reinforcement (first two courses over opening and under sill)

Control Joints at Openings Wrapped with Reinforcement

CJs and horizontal reinforcement

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CJs and horizontal reinforcement

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CJs and horizontal reinforcement

Options for controlling cracking

2. additional horizontal reinforcement and NO (less) control joints

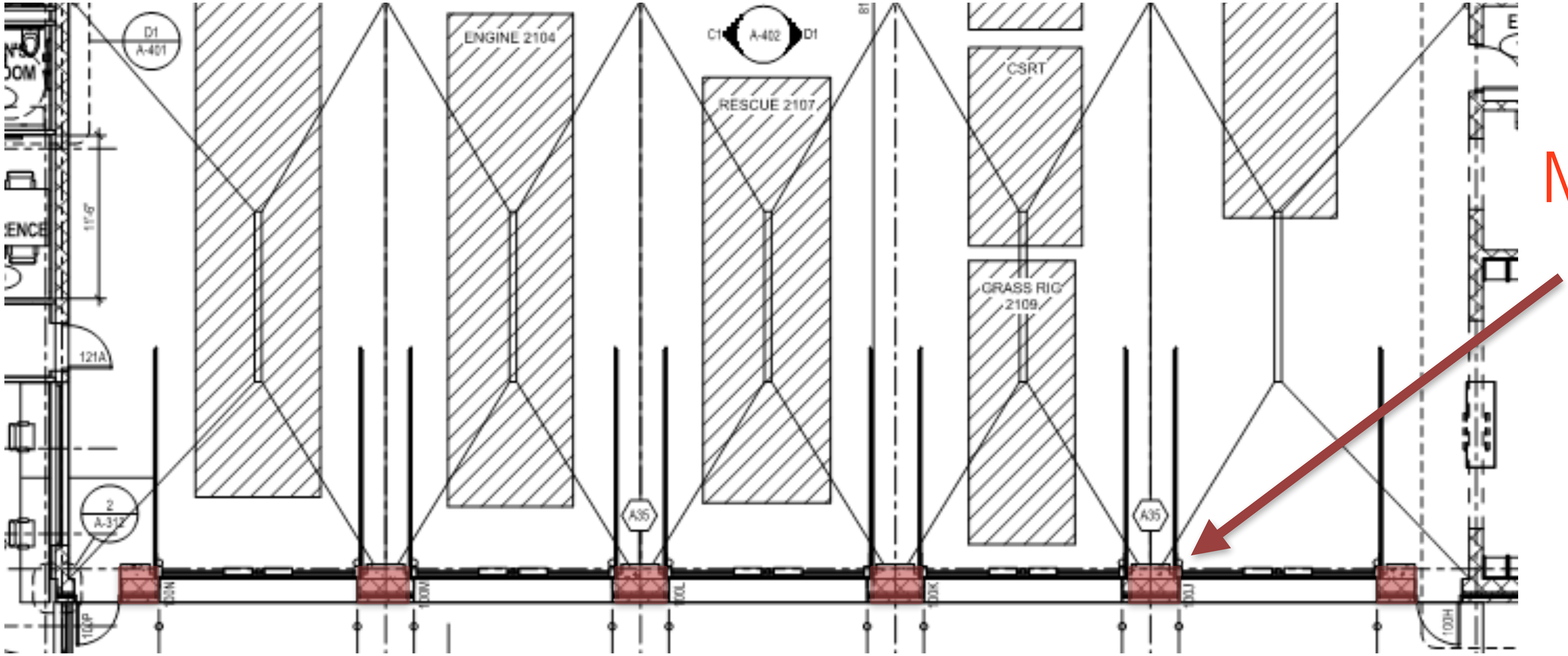
– use horiz. reinf. of 0.002 A (similar to concrete, but less area)

Table 3—Maximum Spacing of Horizontal Reinforcement to Meet the Criteria As > 0.002An[1]

Wall thickness, in. (mm)	Maximum spacing of horizontal reinforcement, in. (mm) Reinforcement size		
	No. 6 (M19)	No. 5 (M16)	No.4 (M13)
Ungrouted or partially grouted walls			
6 (152)	48 (1219)	48 (1219)	32 (813)
8 (203)	48 (1219)	40 (1016)	24 (610)
10 (254)	48 (1219)	32 (813)	16 (406)
12 (305)	48 (1219)	24 (610)	8 (203)
Fully grouted walls			
6 (152)	32 (813)	24 (610)	16 (406)
8 (203)	24 (610)	16 (406)	8 (203)
10 (254)	16 (406)	16 (406)	8 (203)
12 (305)	16 (406)	8 (203)	8 (203)

1. A_n includes cross-sectional area of grout in bond beams

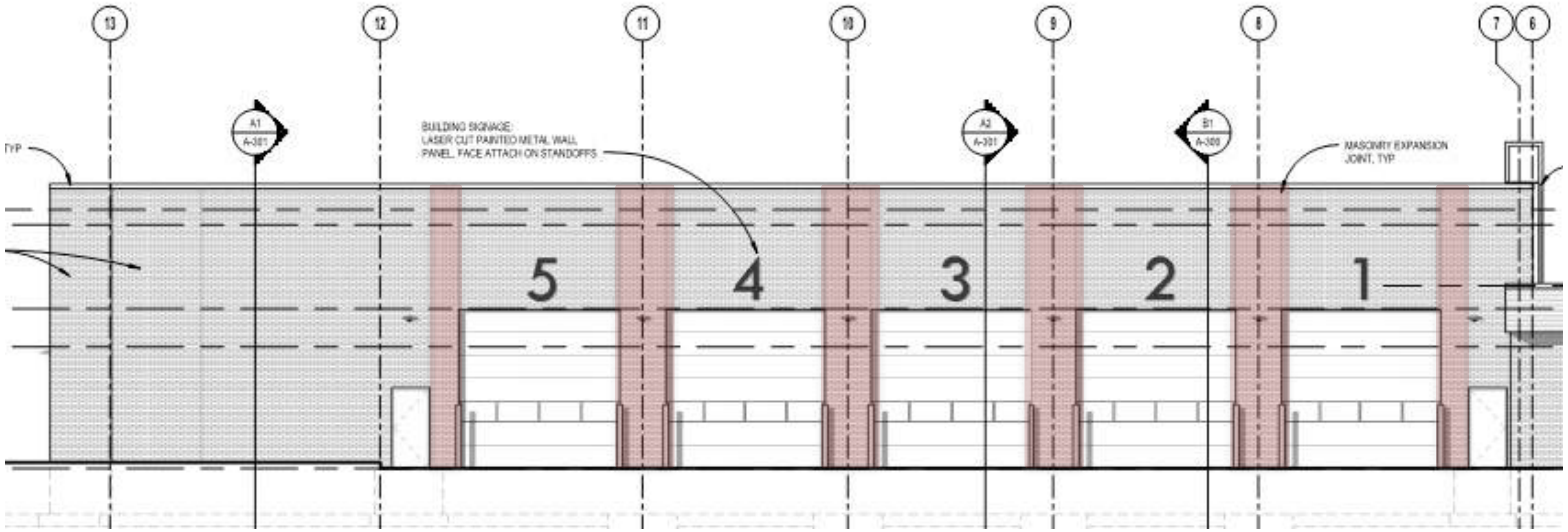
CJs and horizontal reinforcement - example



MINIMAL AREAS TO PLACE CONTROL JOINTS

PLAN VIEW

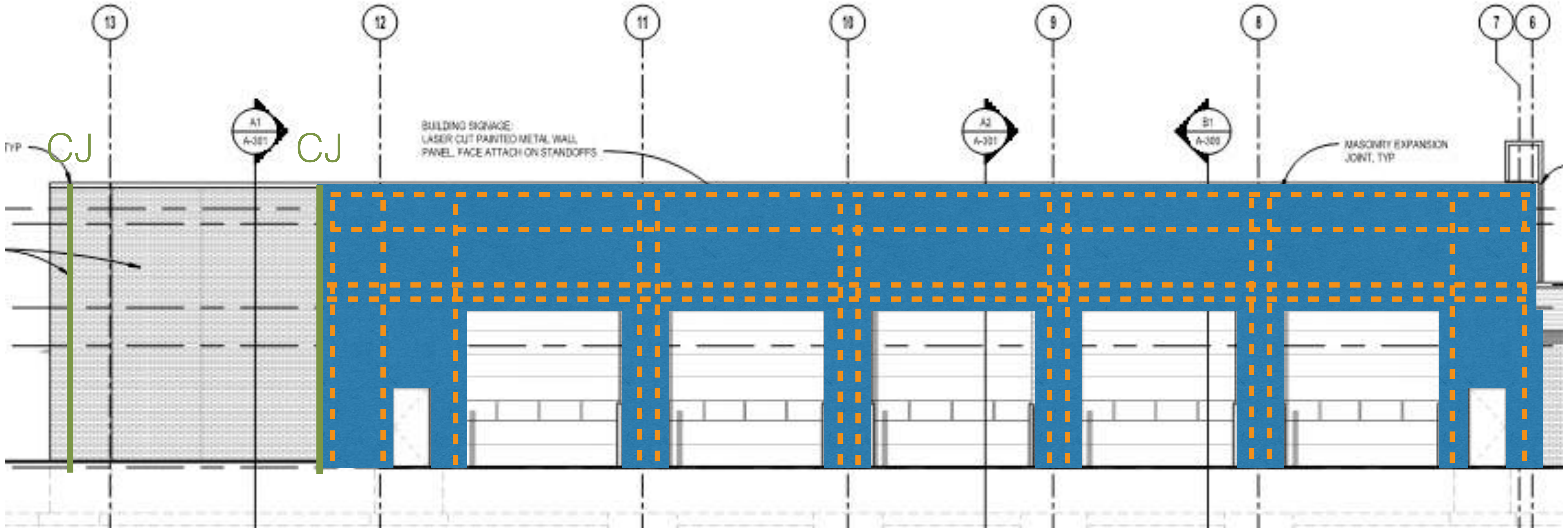
CJs and horizontal reinforcement - example



ELEVATION VIEW

MINIMAL AREAS TO PLACE CONTROL JOINTS

No Control Joints at Large Doors

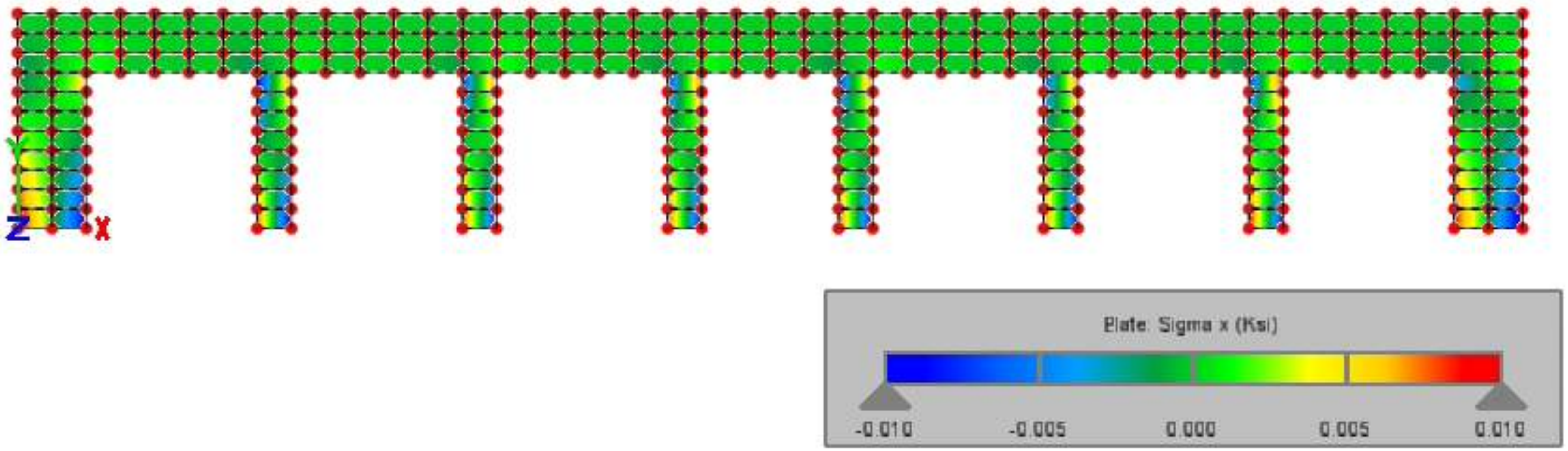


DESIGN AREA AROUND DOORS WITHOUT CONTROL JOINTS

THEN RESUME STANDARD PRACTICE FOR THE REST OF THE BUILDING

FORSE

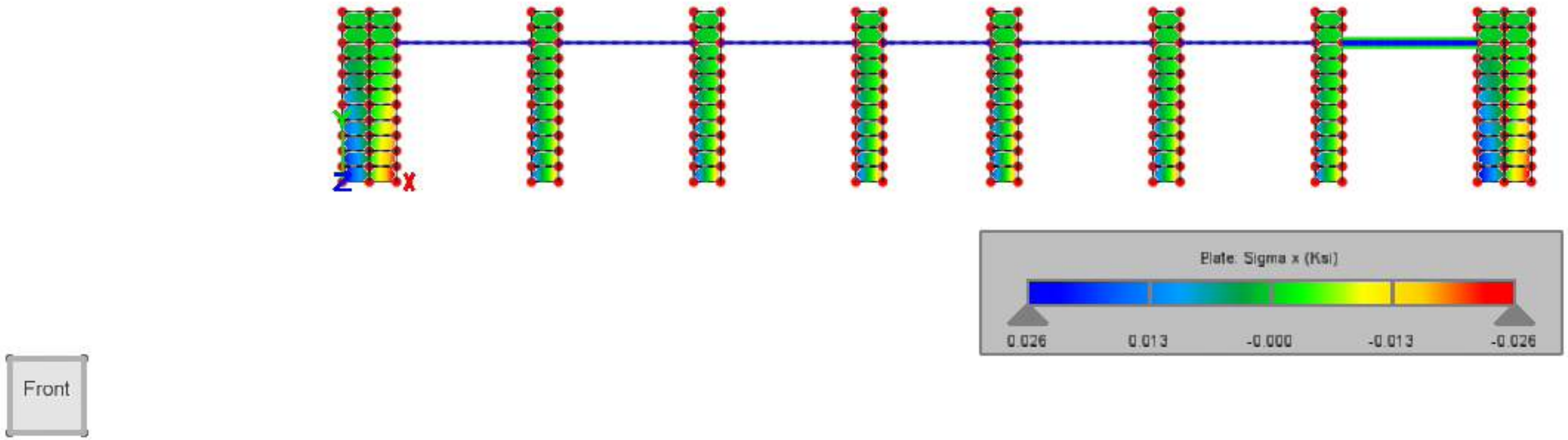
Example - Single Story Wall with Openings
Eliminate CJ and Use Masonry Lintels



reasonable deflection and stress


FIRE
EXTINGUISHER

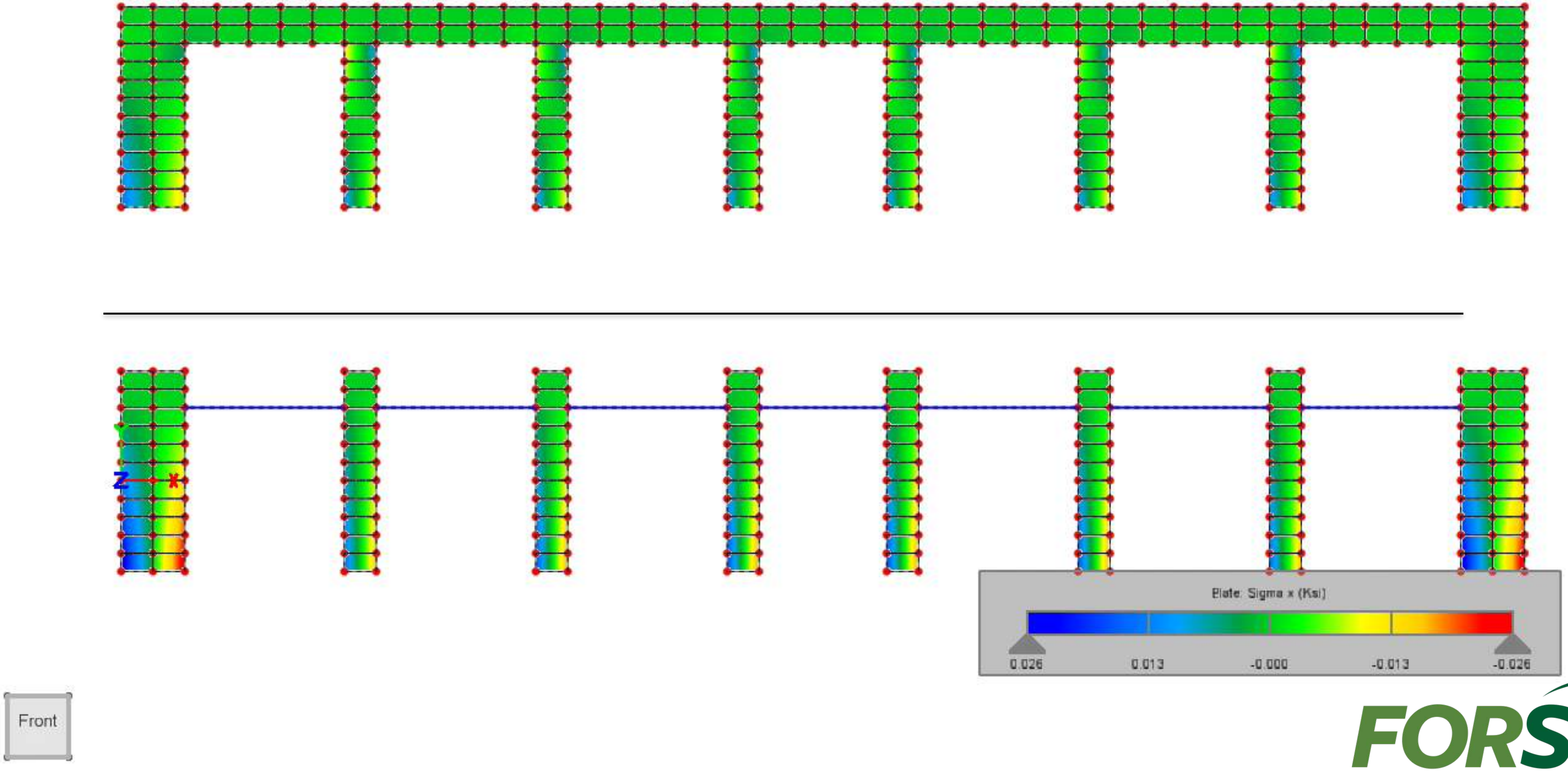
Example - Single Story Wall with Openings if Using CJ and Steel Lintels



very little capacity with the isolated masonry piers to support steel beam lintels (NOT IDEAL)


CAT
CULLEN
HYDRO-MOBILE.COM

Example - Single Story Wall with Openings
Compare Masonry Lintels vs. CJ and Steel Lintels



Masonry Checklist

- ☐ f'm - masonry assembly strength
- ☐ Verify all components of masonry are specified
- ☐ Consider masonry wall thickness and reinforcement
- ☐ Review masonry shear walls
- ☐ Review masonry partition walls
- ☐ Check that control joints are located on plans
- ☑ Review lintels, prefer masonry lintels where possible
- ☐ Review bearing plate details
- ☐ Consider conflicts between steel and masonry

March 1, 2020

MASONRY INSIGHTS

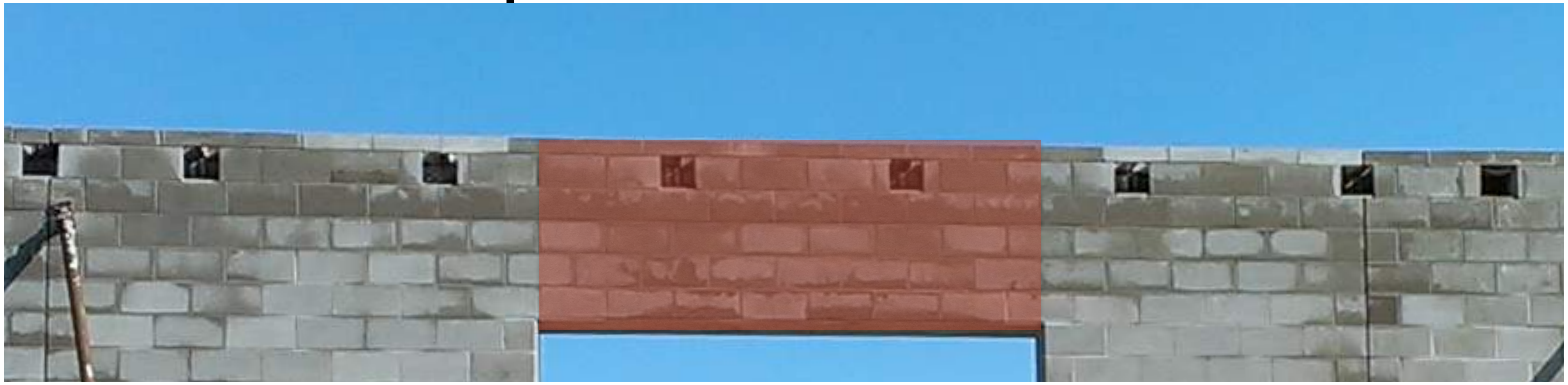
written in conjunction with International Masonry Institute

Masonry checklist: reviewing structural plans

- ☐ f'_m (masonry assembly strength) for structural concrete or clay masonry is 2,000 psi or greater
  - ☐ concrete masonry f'_m = 2,500psi is the most common
  - ☐ clay masonry f'_m = commonly in the range of 3,000psi to 4,000psi
  - ☐ Masonry strengths up to 4,000 psi are permitted in current codes for strength design[1]
- ☐ Check that all components of masonry are specified:
  - ☐ Block strength: check masonry.forsei.com/masonry/cmudata/ to verify based on location
    - ☐ Commonly above 3250 psi for concrete masonry and 8250 psi for clay masonry
  - ☐ Mortar type (mortar strength need not be listed)
    - ☐ Recommend Type N for non-structural walls
      - ☐ Veneer and partition walls commonly use this mortar
      - ☐ Can be used in some structural applications, but reduces capacity
        - ☐ Not to be used below grade
        - ☐ Not to be used in seismic SDC D, E, or F
    - ☐ Recommend Type S for structural walls
      - ☐ Can be used below grade
      - ☐ Can be used in all seismic areas, SDC A, B, C, D, E, and F
    - ☐ Type M is high strength, but more costly and reduced workability
      - ☐ Can be used below grade
      - ☐ Used in high load applications and extreme environmental conditions
  - ☐ Grout strength
    - ☐ Should be at least 2,000 psi, and equal to or greater than f'_m

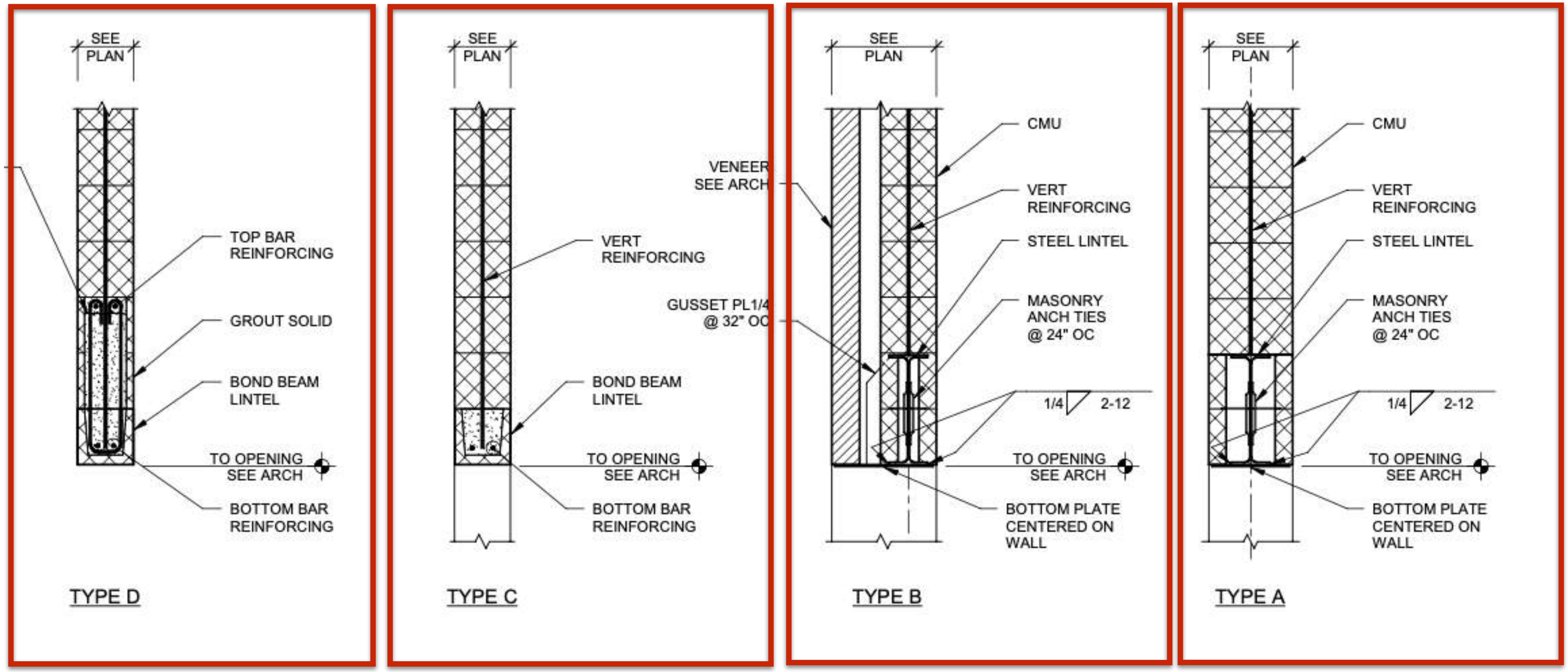
web: masonry.forsei.com 1

Lintel options - materials



1. Masonry
    1. best option for both structure and architecture
2. Steel
    1. common, but generally not needed
    2. creates complexity - worth the trouble?
3. Precast

BEST



Also good!
- except don't use stirrups unless needed
- use stirrups before structural steel

Better:
-Structurally
  - Stronger
  - More robust
-Architecturally
-Constructible

All these issues
+Poor torsion
+Poor cxn to wall
+Poor integrity

-Expensive
-Weaker overall
-Thermal issues
-Leads to cracks

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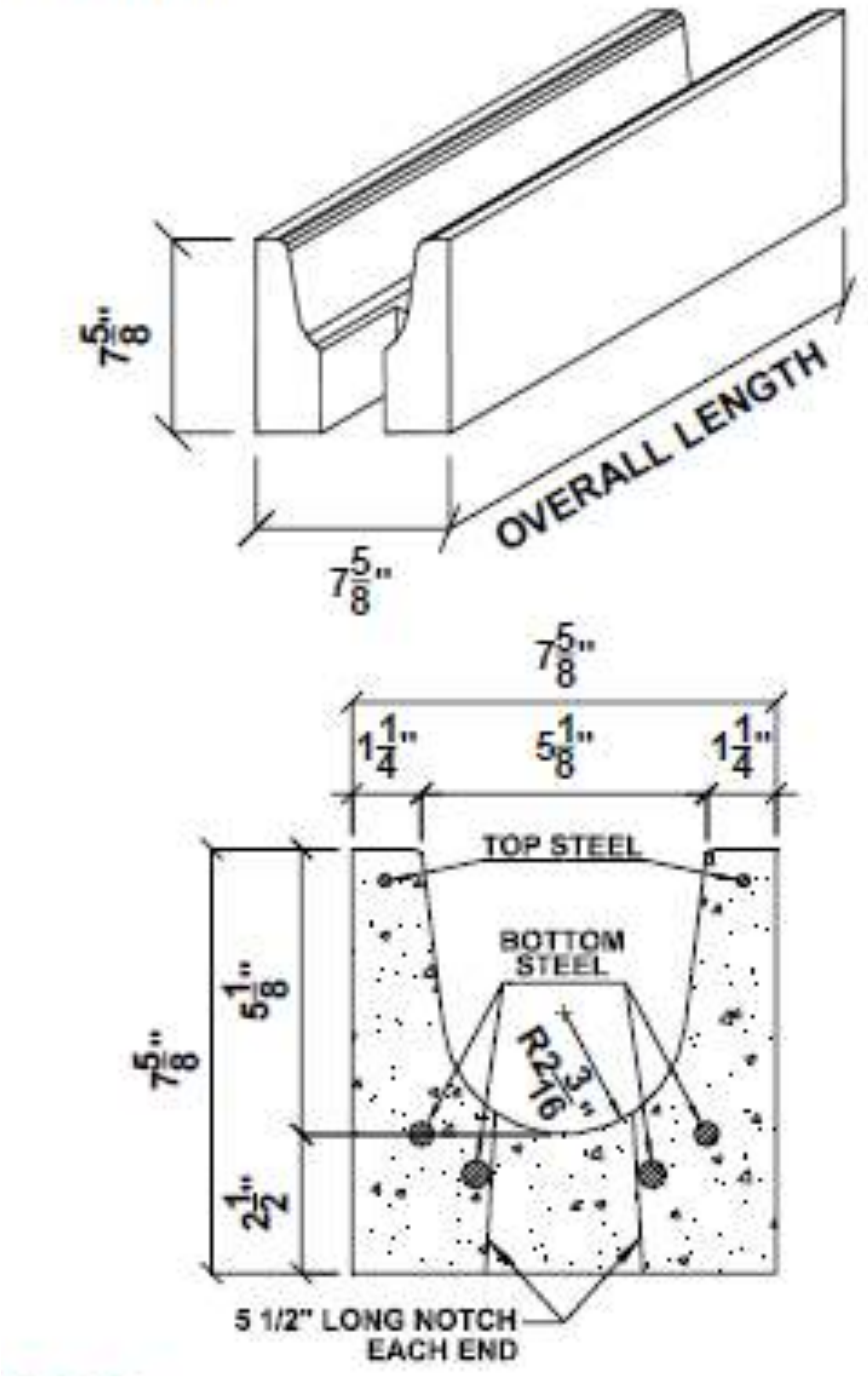
Precast Lintels



- need crane or lift access
- compatible aesthetic with masonry
- <u>needs to be modular with masonry</u>
- special anchoring required to prevent roll off
- additional coordination issue for mason
- Potential scheduling issue

created in conjunction with TEAM IMI

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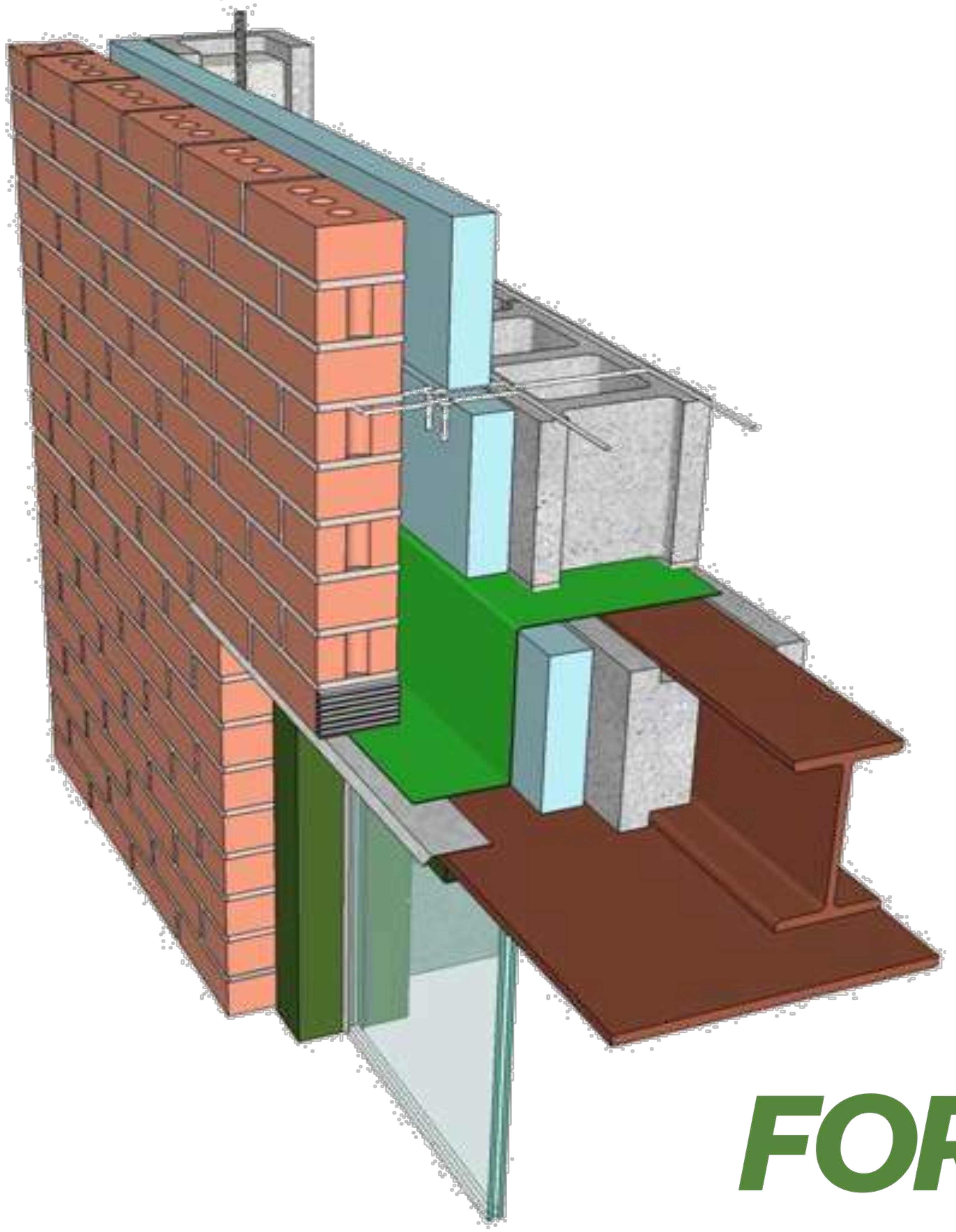
steel lintels

- Very common
  - should they be common?
- scheduling critical
  - much longer lead time than block
- needs corrosion protection
  - flashing
  - treatment
- bearing plates often required
- thermal bridging issue
- Differential movement
  - Steel moves different than masonry
- used to solve shoring
  - but more complicated!



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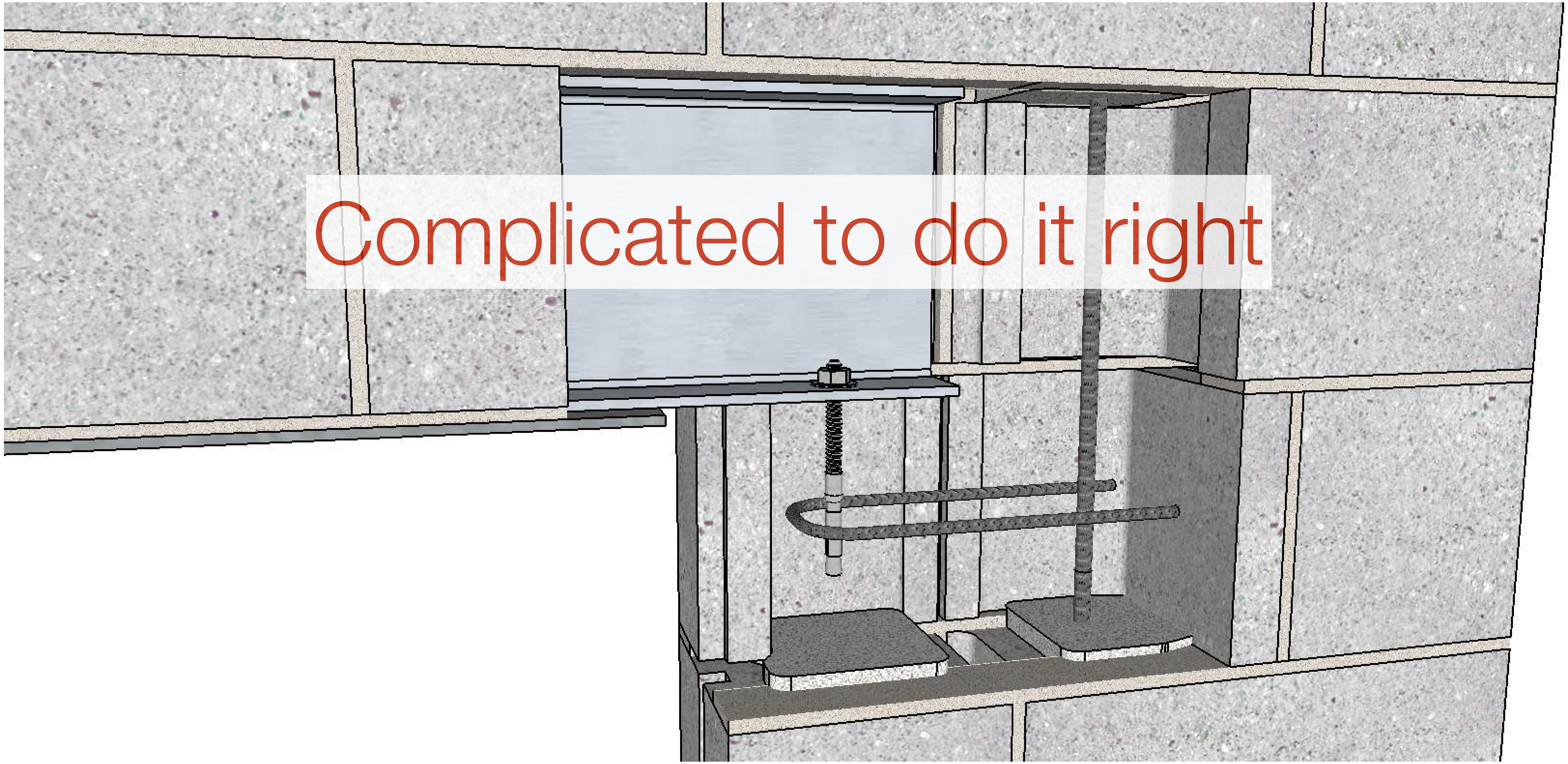
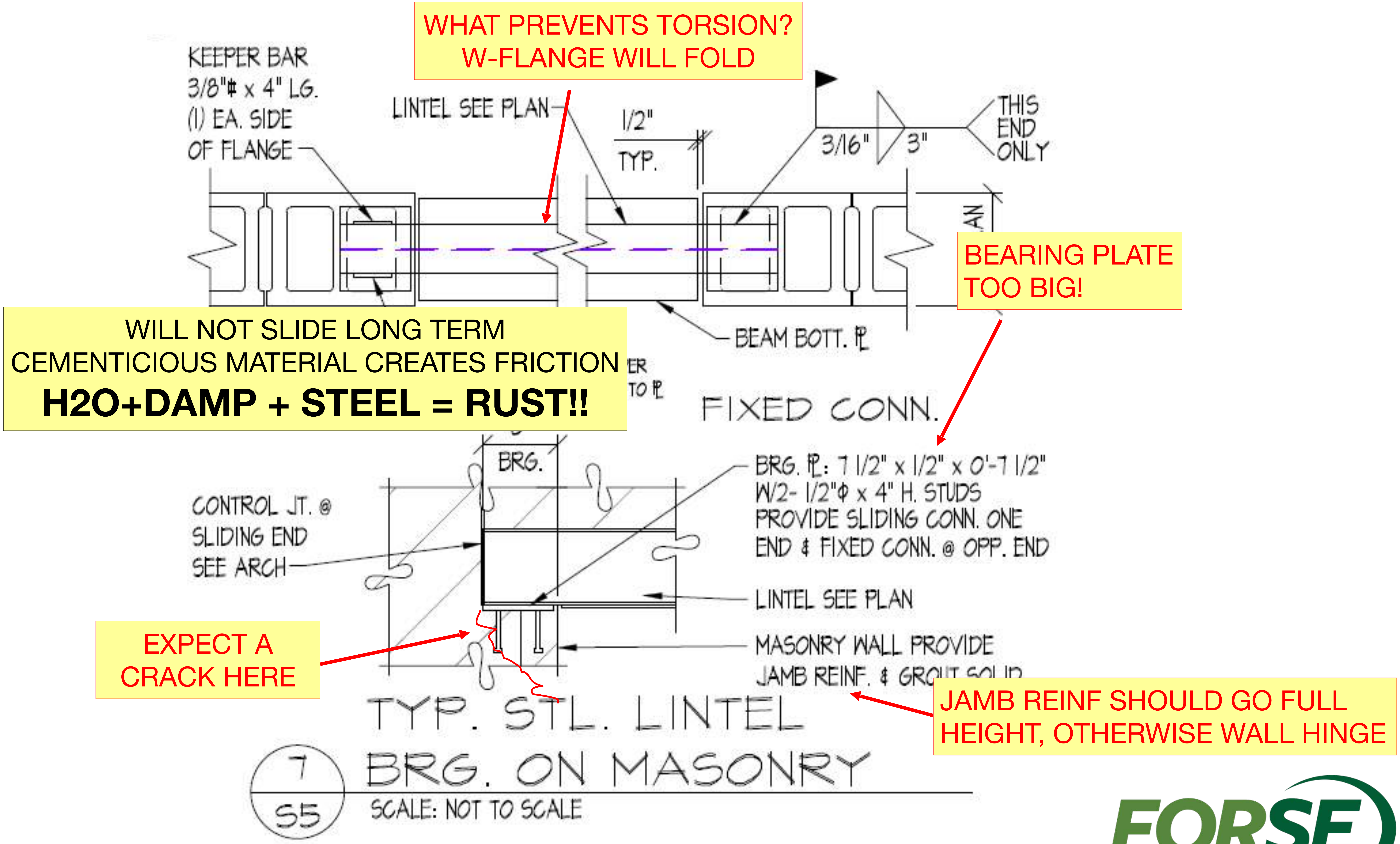
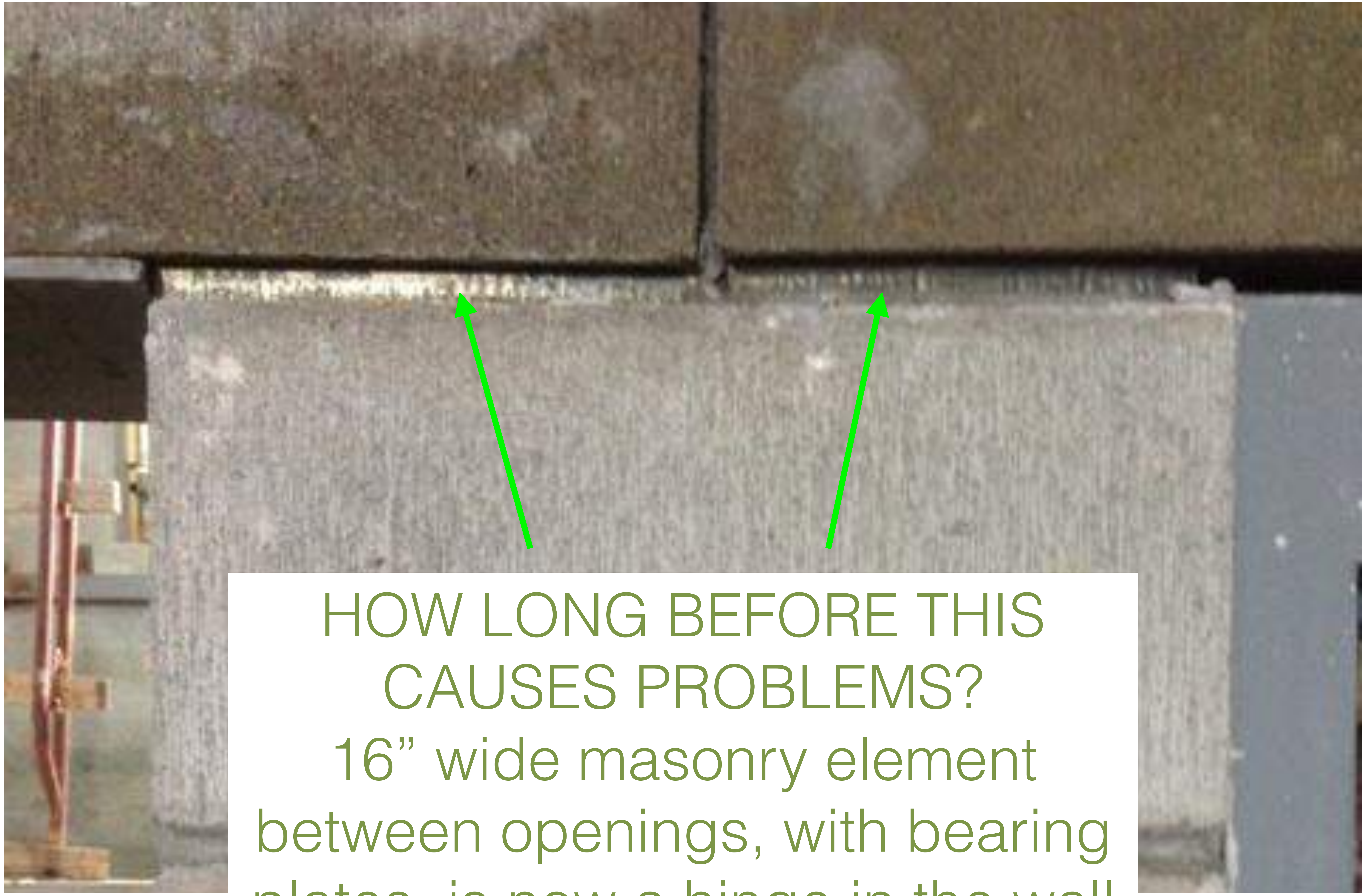

Complicated to do it right

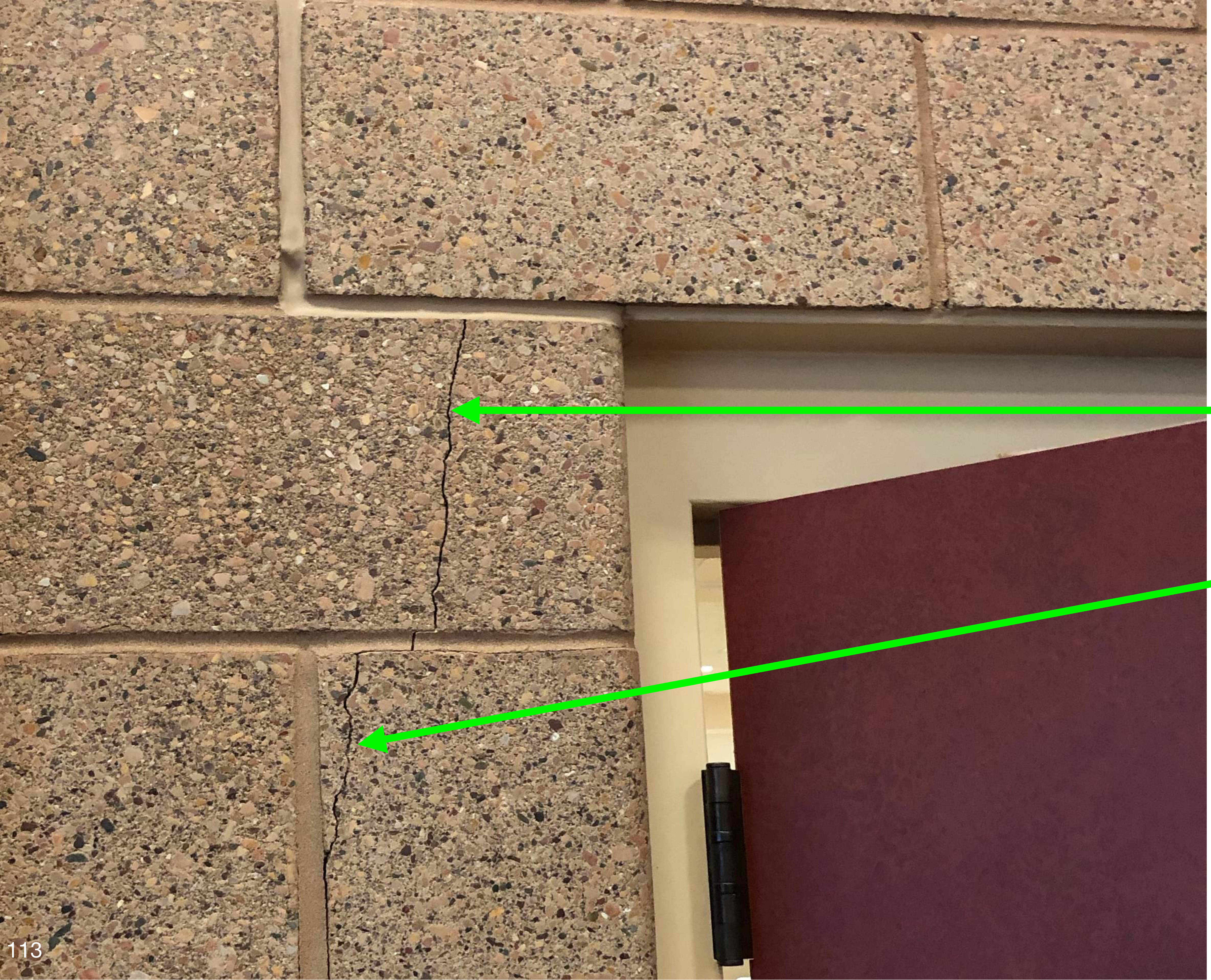

WHAT PREVENTS TORSION?
W-FLANGE WILL FOLD
KEEPER BAR
3/8"# x 4" LG.
(1) EA. SIDE
OF FLANGE
LINTEL SEE PLAN
1/2"
TYP.
3/16"
3"
THIS
END
ONLY
BEARING PLATE
TOO BIG!
BEAM BOTT. PL
WILL NOT SLIDE LONG TERM
CEMENTICIOUS MATERIAL CREATES FRICTION
H2O+DAMP + STEEL = RUST!!
FIXED CONN.
BRG.
BRG. PL: 7 1/2" x 1/2" x 0'-7 1/2"
W/2- 1/2"Φ x 4" H. STUDS
PROVIDE SLIDING CONN. ONE
END & FIXED CONN. @ OPP. END
CONTROL JT. @
SLIDING END
SEE ARCH
LINTEL SEE PLAN
MASONRY WALL PROVIDE
EXPECT A
CRACK HERE
JAMB REINF SHOULD GO FULL
HEIGHT, OTHERWISE WALL HINGE
TYP. STL. LINTEL
7
S5
BRG. ON MASONRY
SCALE: NOT TO SCALE

COULD HAVE BEEN AVOIDED WITH MASONRY LINTEL



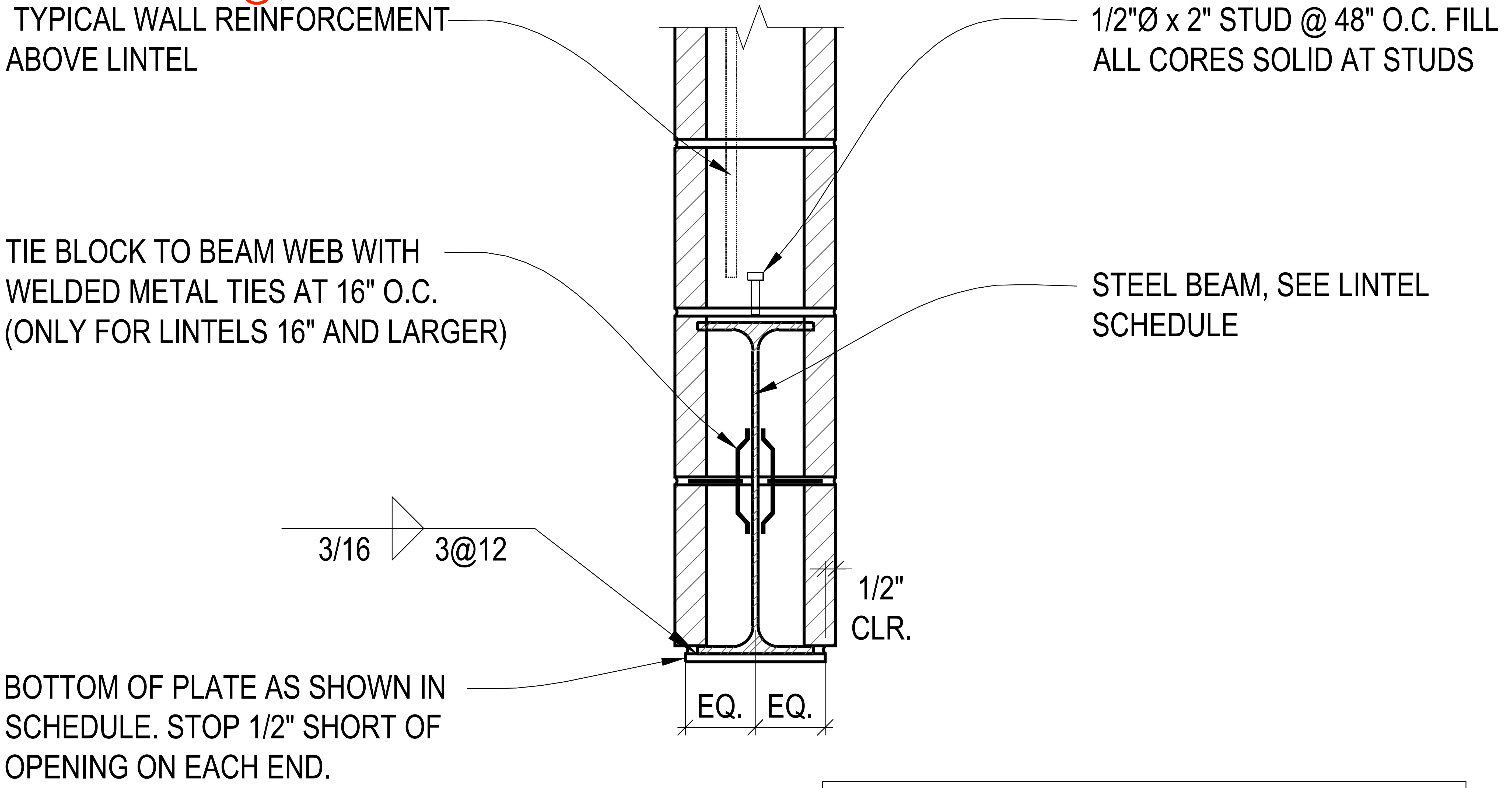
HOW LONG BEFORE THIS CAUSES PROBLEMS?

16” wide masonry element between openings, with bearing plates, is now a hinge in the wall



INTERIOR WALL AND STEEL LINTEL STILL CAUSES PROBLEMS!

critical that the size of the steel lintel be consider, depth needs to match coursing, width needs to consider needed blocks to conceal



CENTER MASONRY LEDGE ON BEAM @ ALL LINTELS. USE LEDGE SIZE AS SHOWN IN SCHEDULE

2D
WMC

STEEL LINTEL DETAIL

SCALE : 1" = 1'-0"

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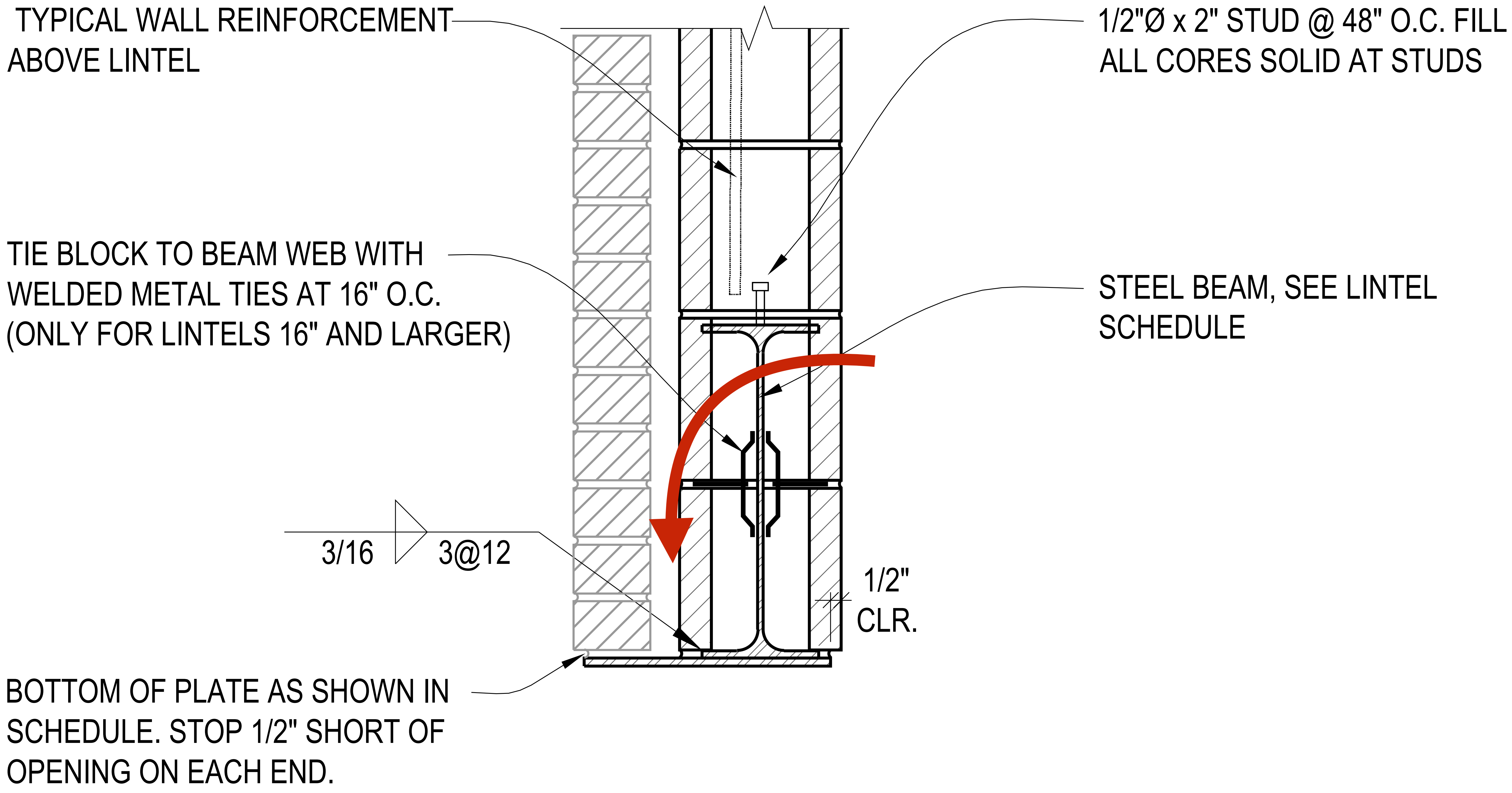


torsion needs to be considered for
steel loaded eccentrically

2F
WMC

STEEL LINTEL DETAIL

SCALE : 1" = 1'-0"

Masonry lintels

- fast
- economical
- matches wall
- moves at same rate of wall
- built-in-place or prefabricated
- any length possible
  - no length restrictions
  - can span, 20, 30, 40 —> 50ft
  - the longer the lintel, the MORE masonry makes sense!

FORSE

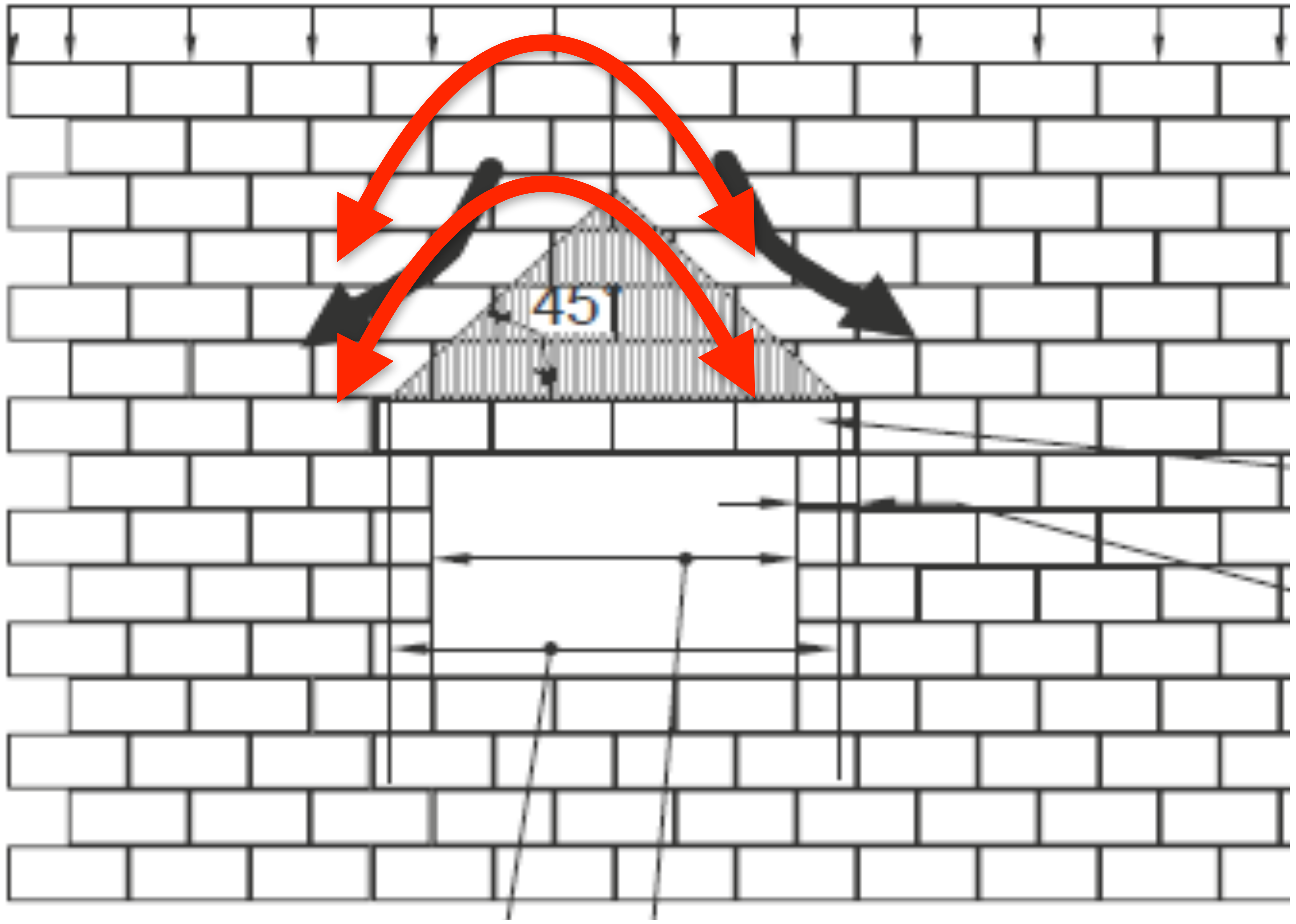
lintels (beams)

TMS 402 - Lintels

- bottom bars
  - common to have 1 or 2
- top bars
  - more common with FEA designs
  - less common in traditional (old) methods
- stirrups
  - use only when necessary
  - consider additional depth
- span
  - length=clear span plus depth of member
  - minimum of 4 inch bearing
  - deflection < L/600
- consider horizontal bending

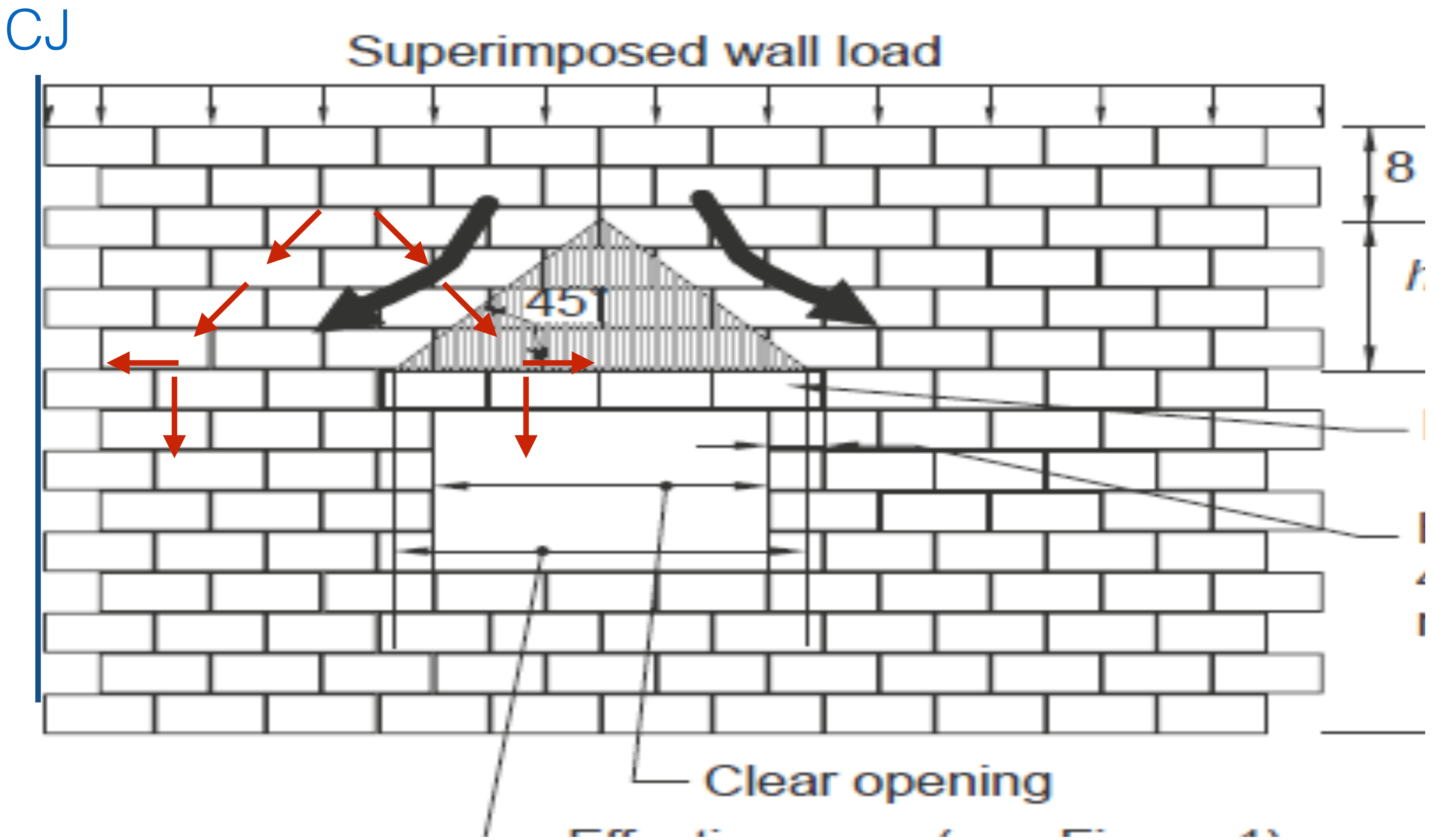
lintels (beams)

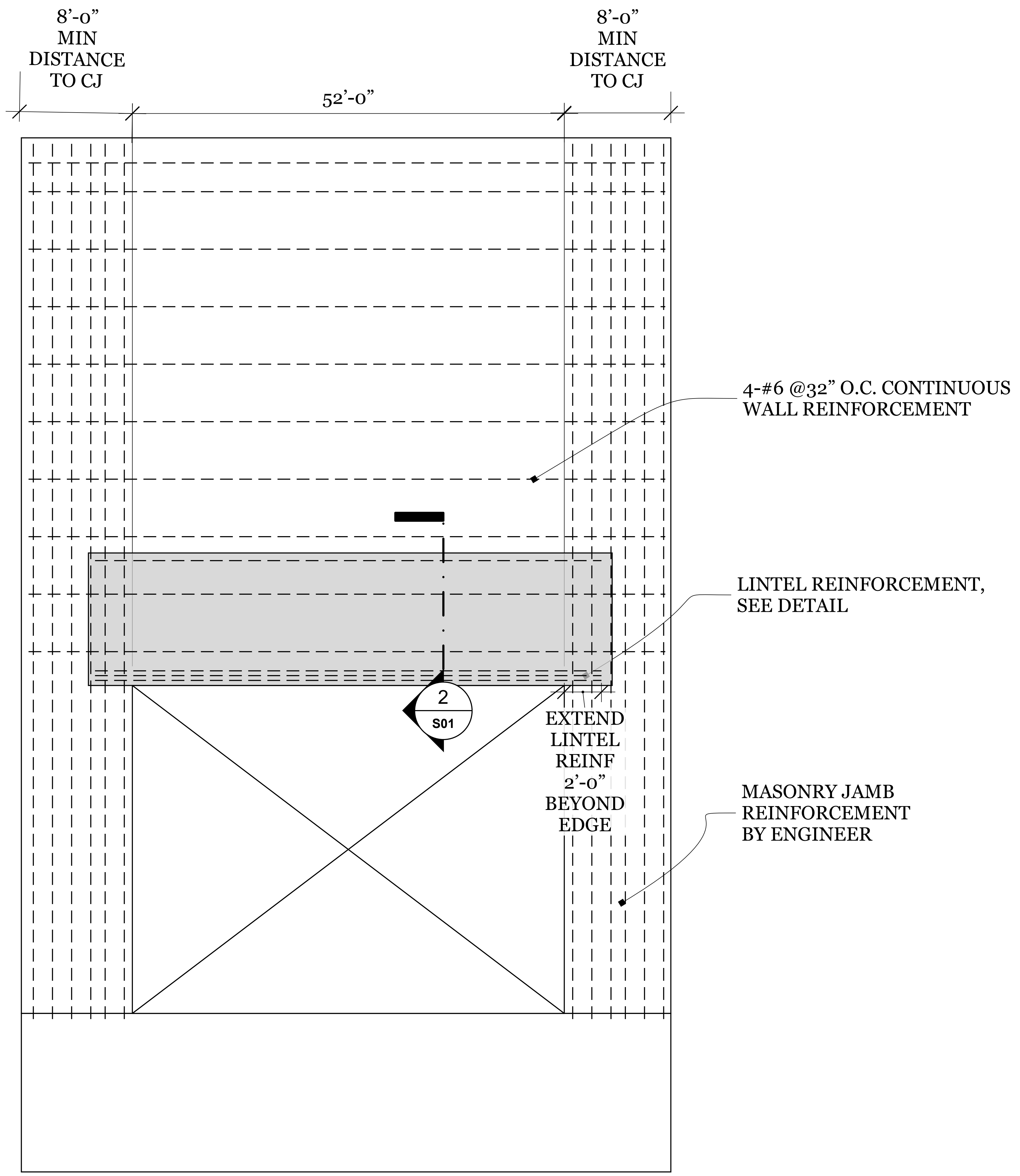
- masonry lintels
  - made with special blocks
    - alternate precast U-shape lintels achieve same goal
  - lintel (within wall) performs better with CJ's away from opening edge
- consider arching action (figure - NCMA TEK 17-1C)



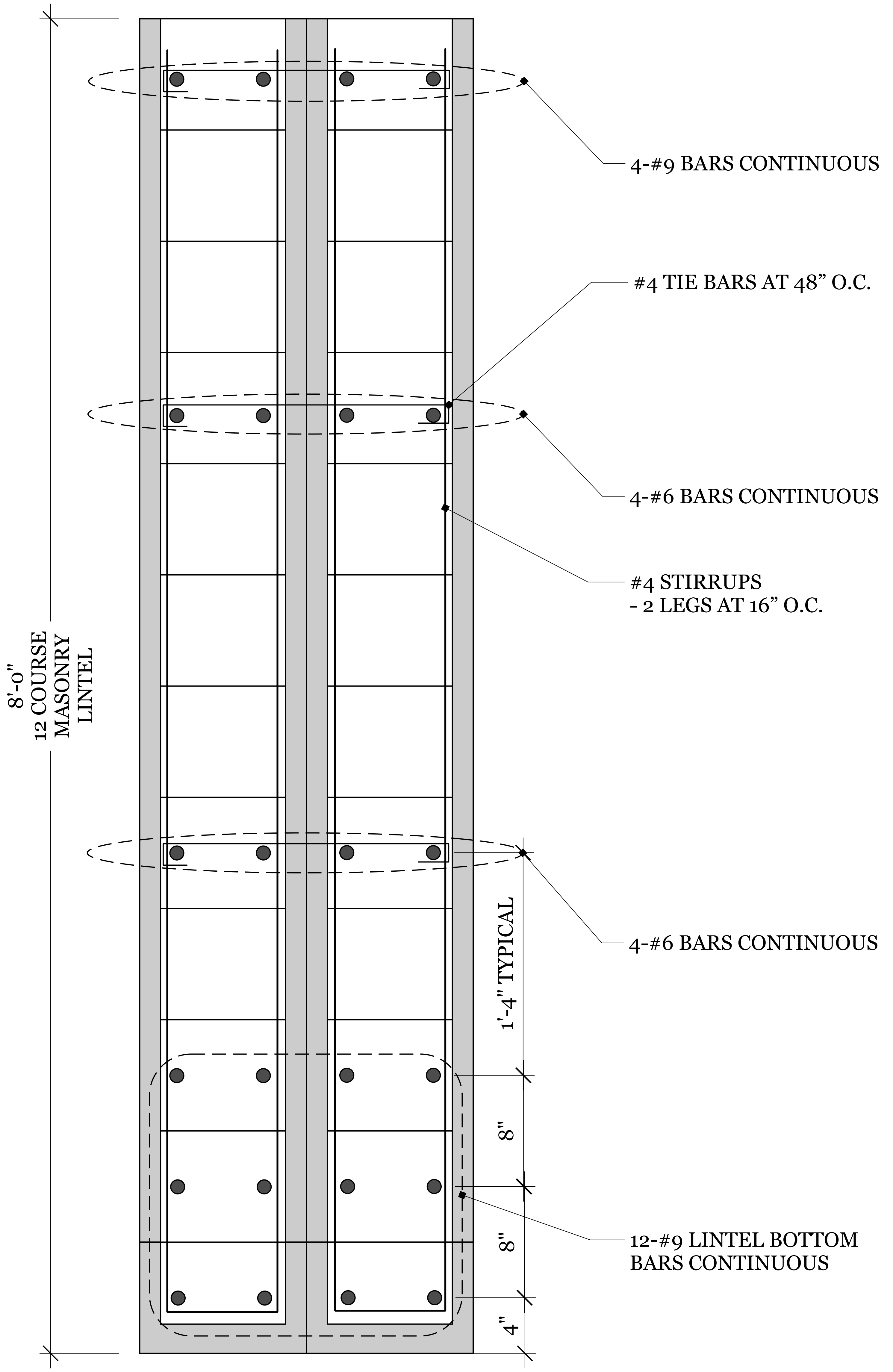
Masonry Lintel Analysis By Hand - Consider Reduced Load

- Load on lintel from triangular area, as long as:
  - No control joint at opening
  - Masonry jambs must resist thrust
- considered arching action





1 WALL ELEVATION
Scale: NTS



2 LINTEL SECTION
Scale: 1":1'-0"

52 ft lintel for ECCC

FORSE

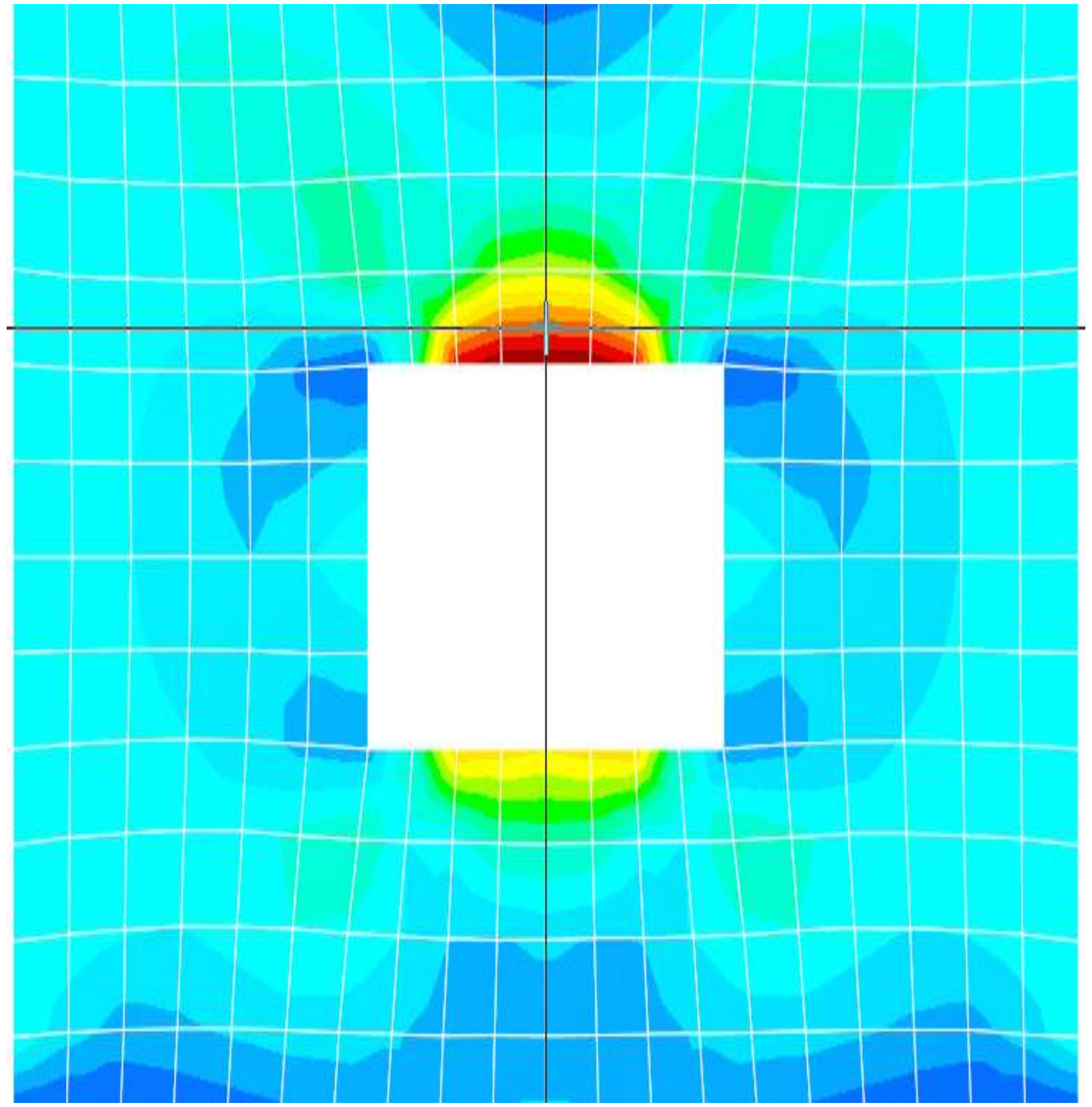
structural masonry

REVISIONS		
	MM/DD/YY	REMARKS
1	__/__/__	...
2	__/__/__	...
3	__/__/__	...
4	__/__/__	...
5	__/__/__	...

S 01

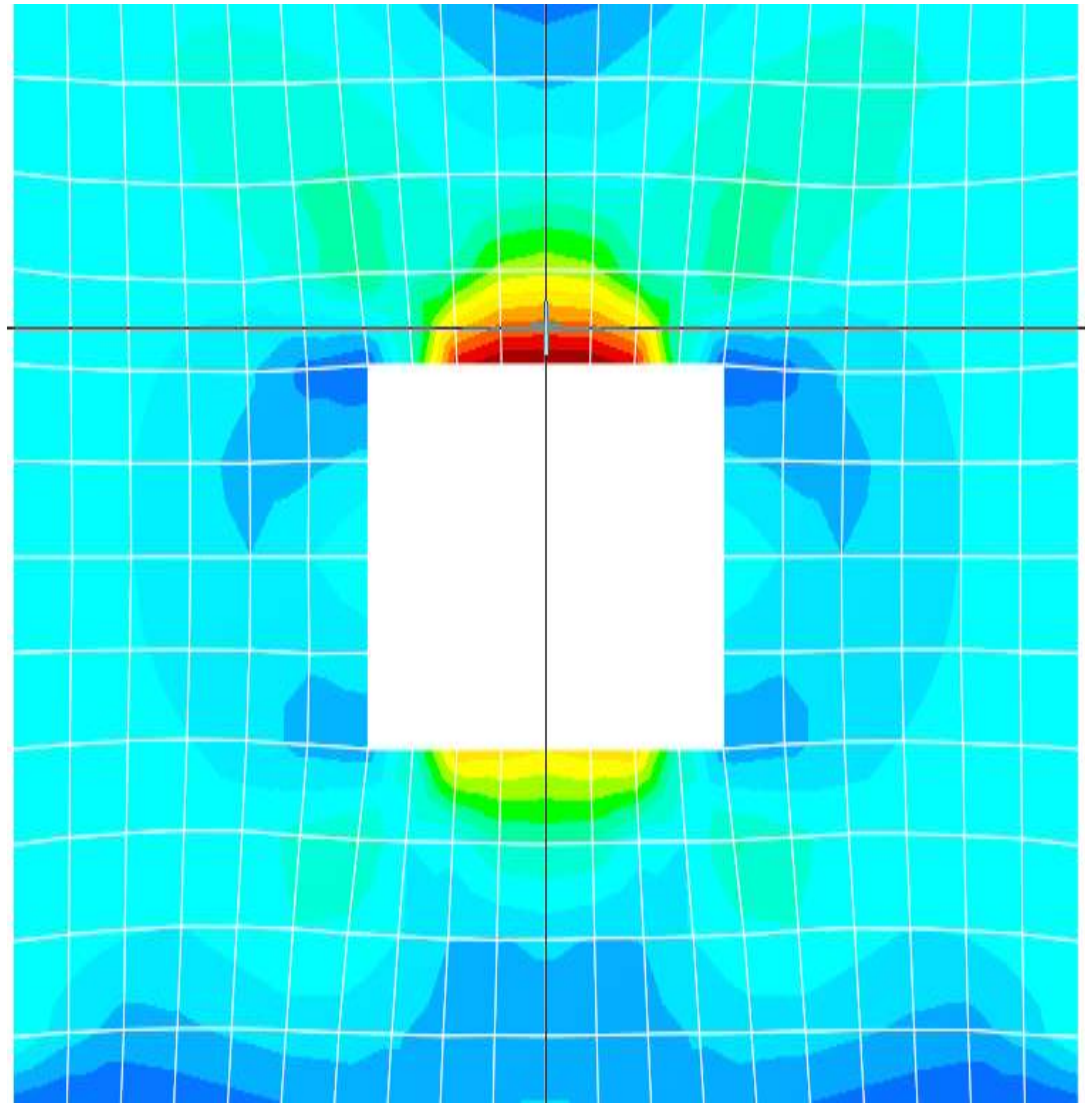
Masonry Lintel Analysis in Finite Element Model (FEM)

- The lintel is part of the wall mesh
  - Not a separate entity for a masonry lintel
- We evaluate the stresses and forces in the wall meshed area above the opening for determining lintel loads for design

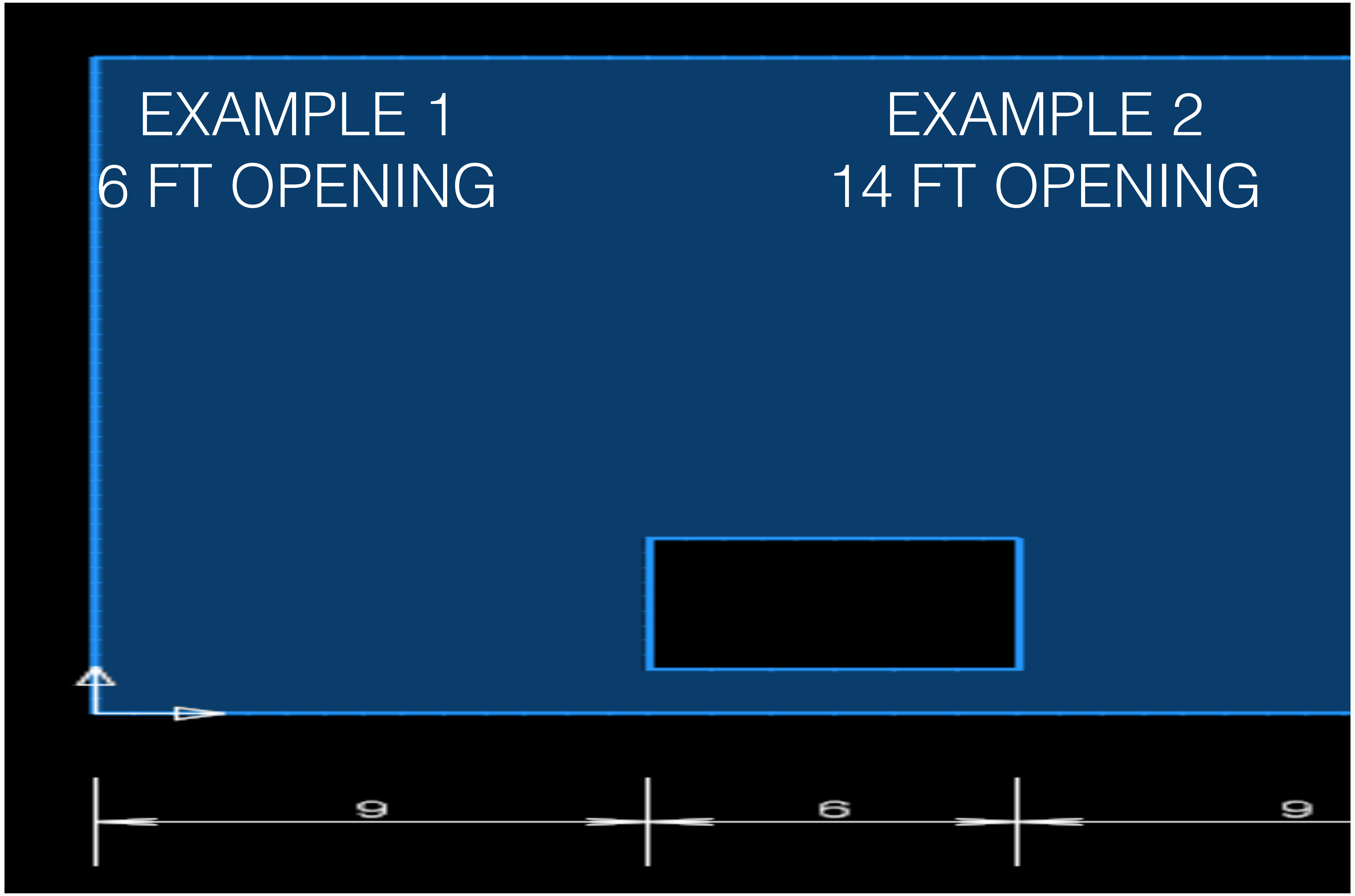


Masonry Lintel in FEM

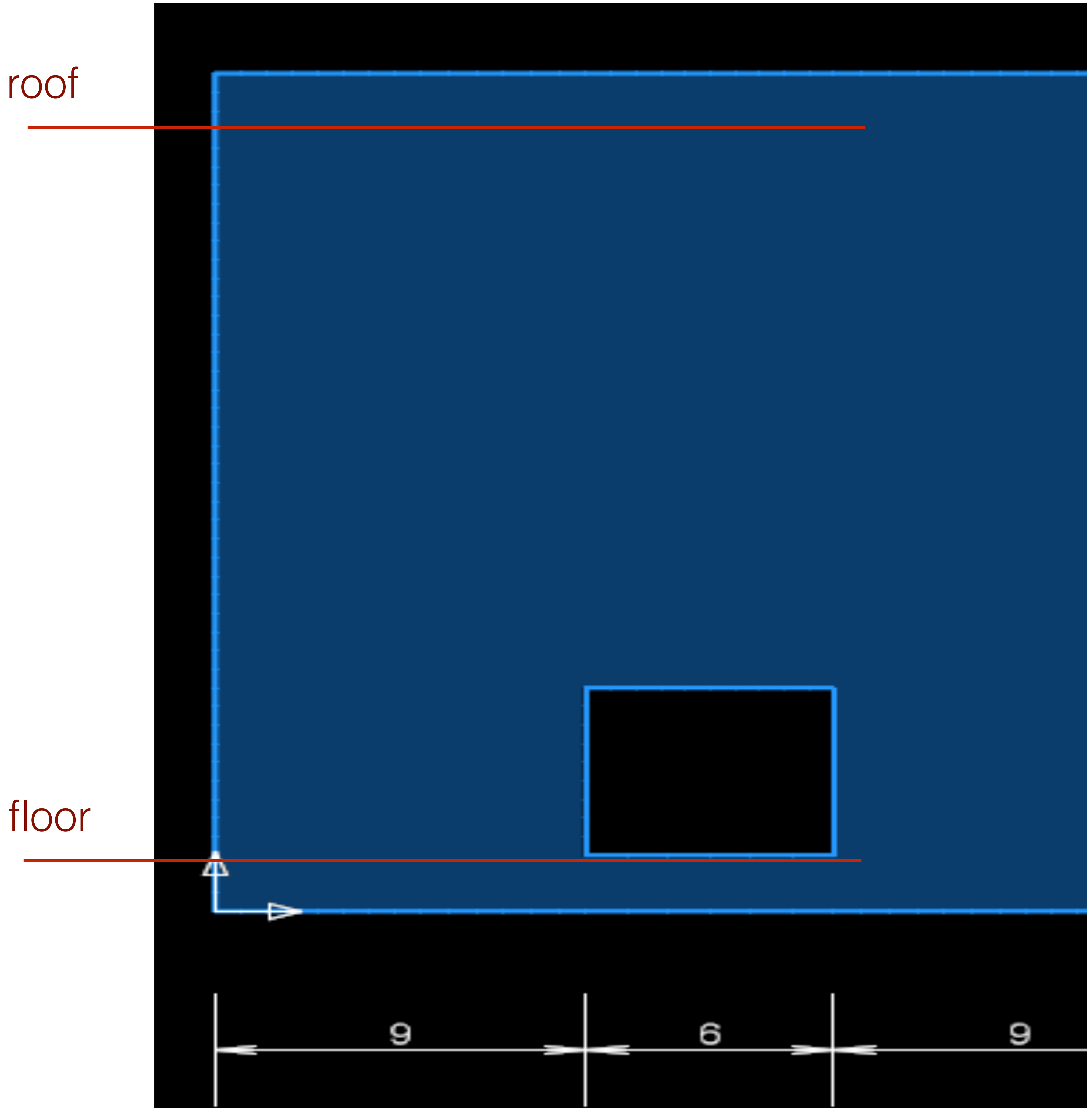
- Similar to a **fixed end beam** between columns
- For shear walls, you may consider the wall above the opening to be a **coupling beam**
- The loads used in the design of lintels are actual wall forces generated by the finite element analysis of the wall.



FEA Analysis Results for Different Openings in Masonry Walls



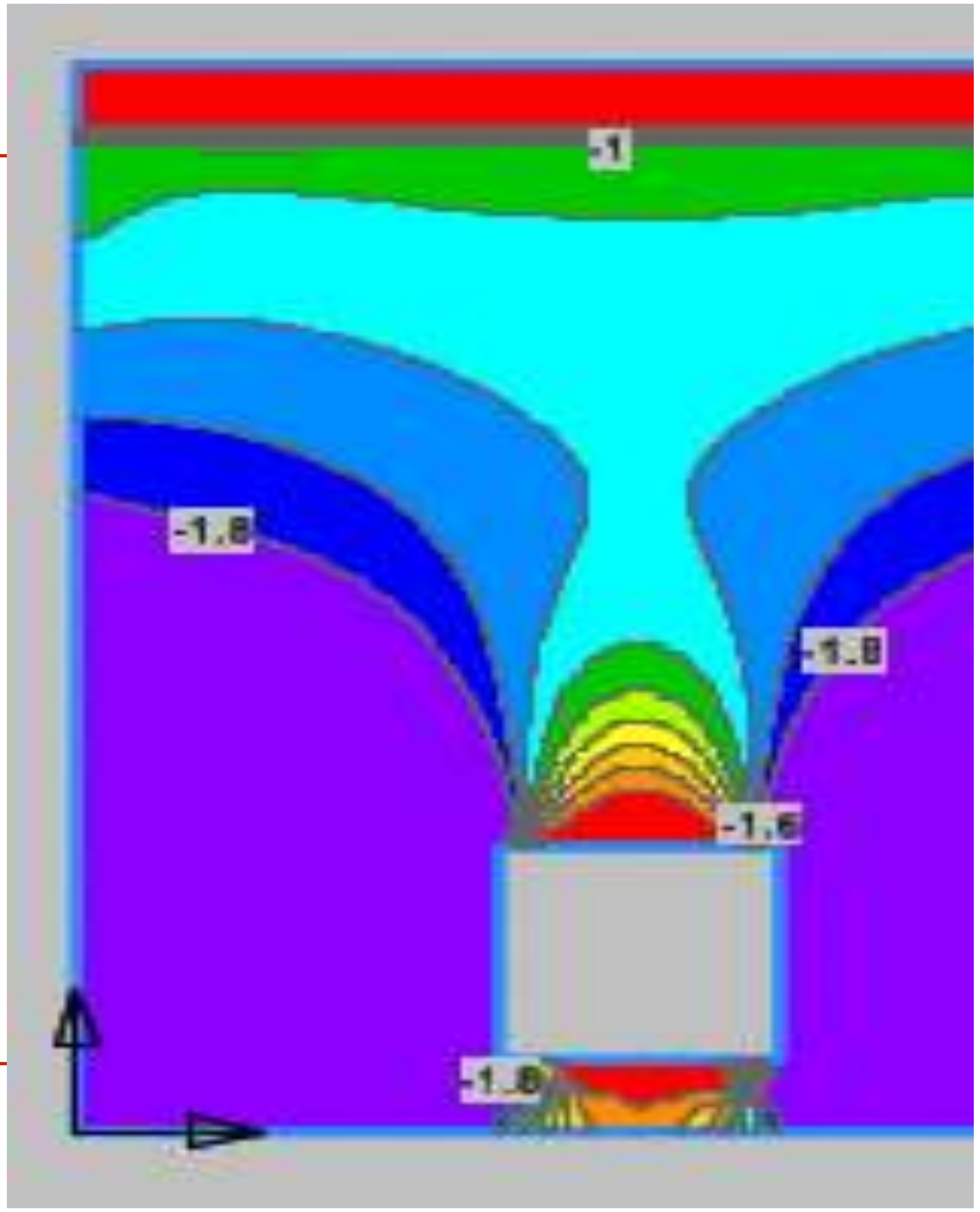
FEA Analysis Results for 2 Different Masonry Walls



<u>Scenario 1</u>

- 6ft opening
- 28ft high wall
- loads 20ft above opening

Axial Forces in Masonry from FEM

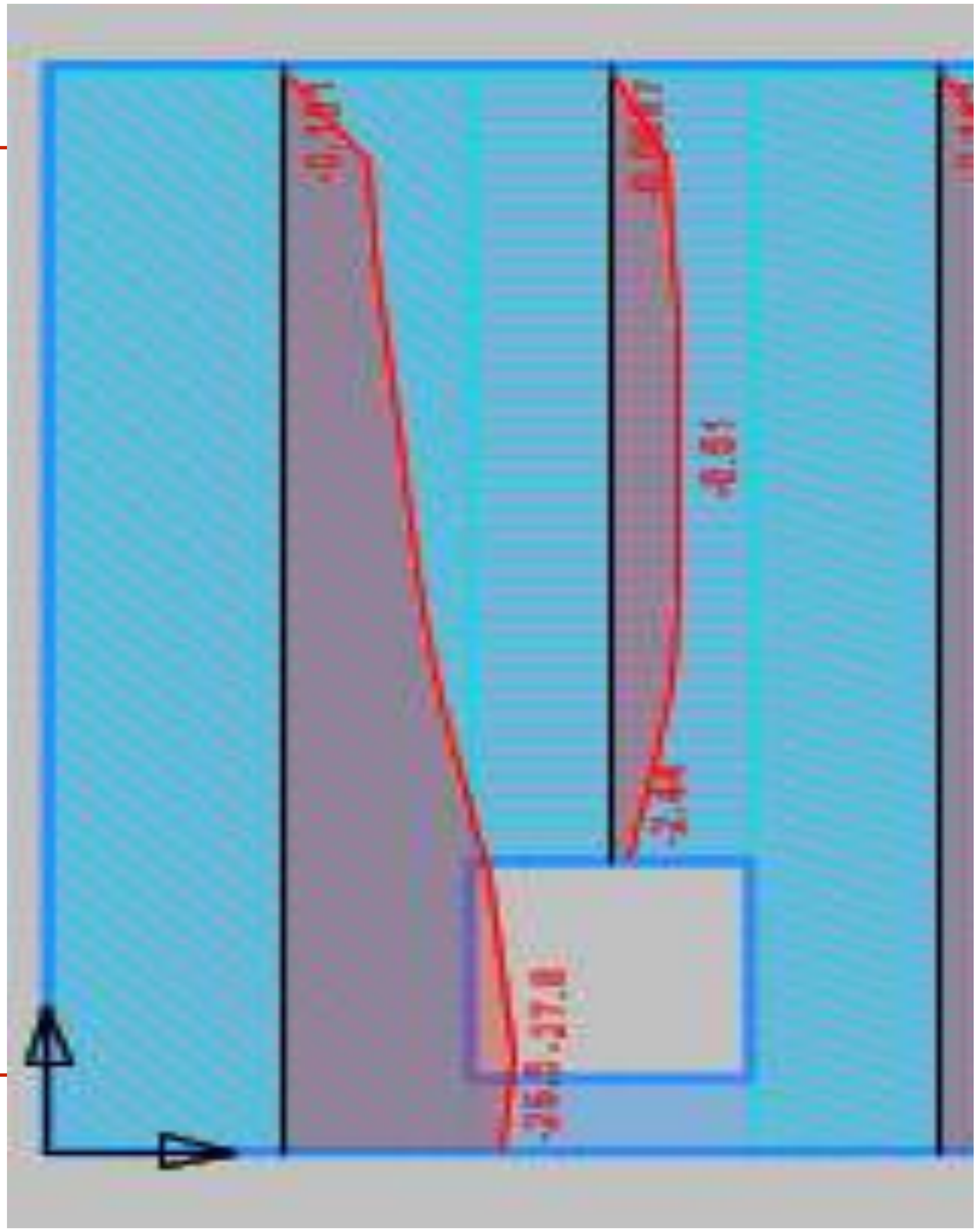


Scenario 1

- Red area indicates low axial forces
- Green, to blue, to purple indicate increasing axial
- Arching action seen in finite elements

Axial Forces in Masonry from FEM

roof

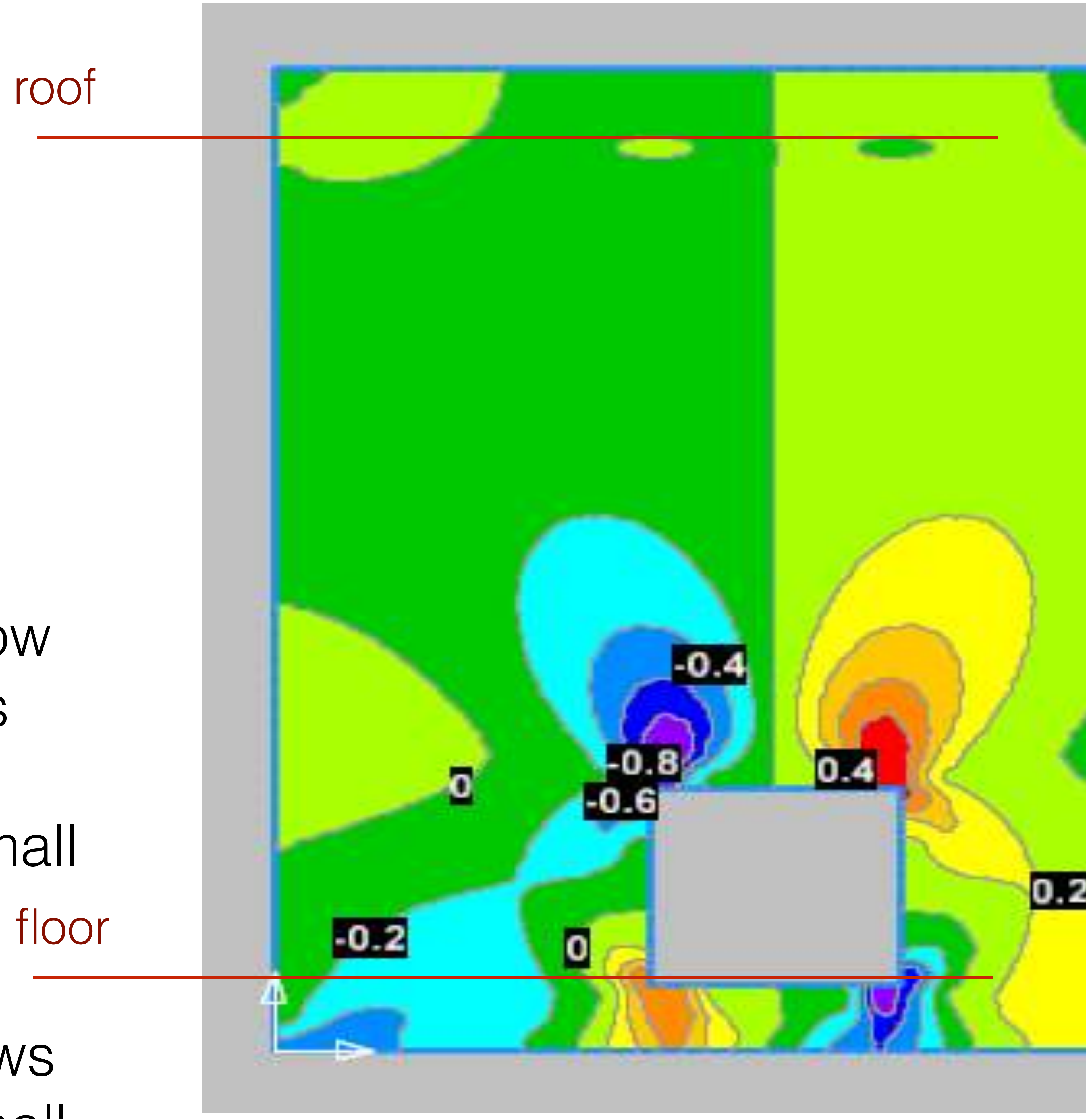


floor

Scenario 1

- vertical strip loads
- tapers to zero above opening
- arching action seen in finite elements

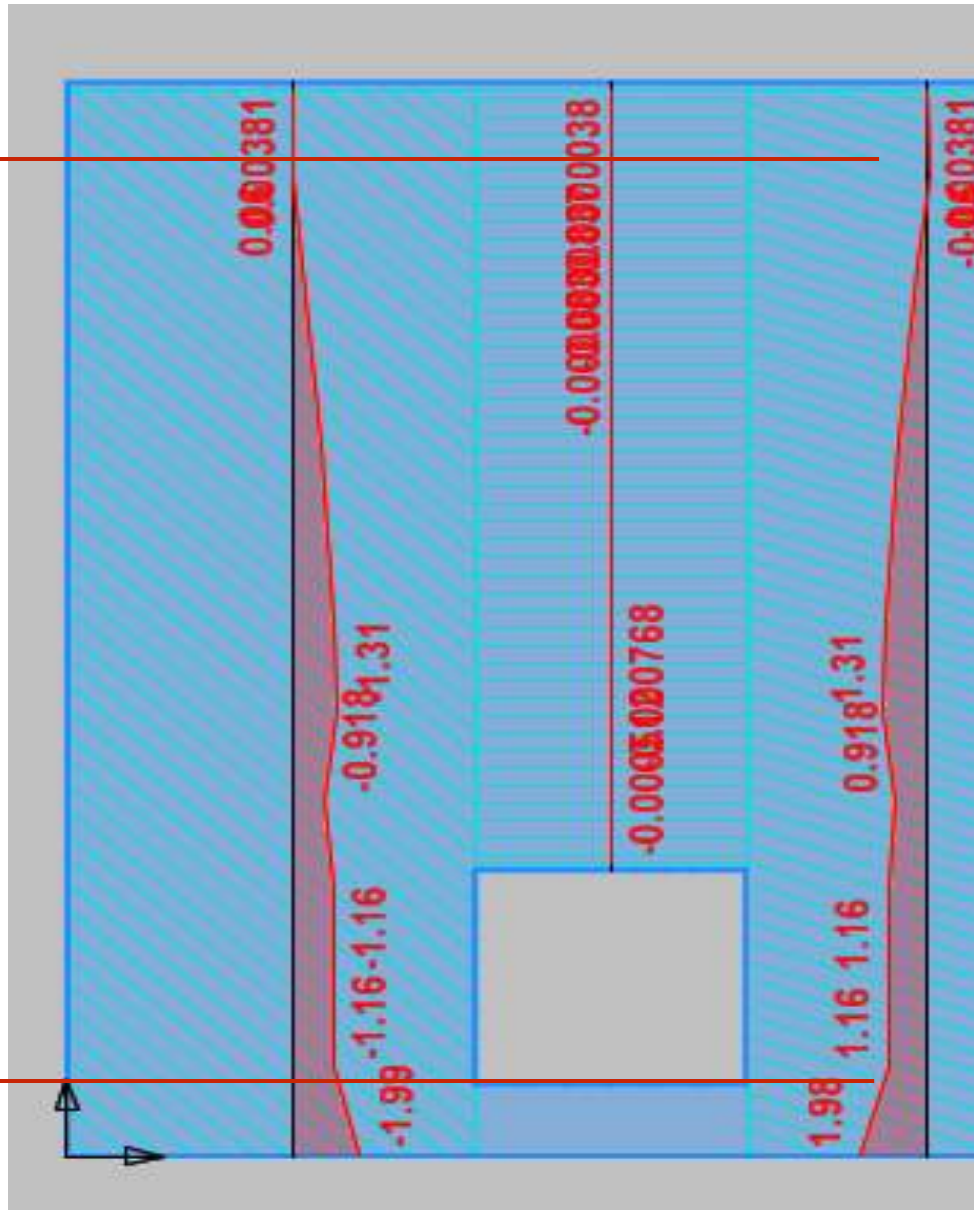
Trust Forces in Masonry from FEM



Scenario 1

- Green and yellow indicate low (and opposing) thrust forces
- Thrust gets higher only in small areas near opening
- Tall wall above opening allows actual thrust forces to be small

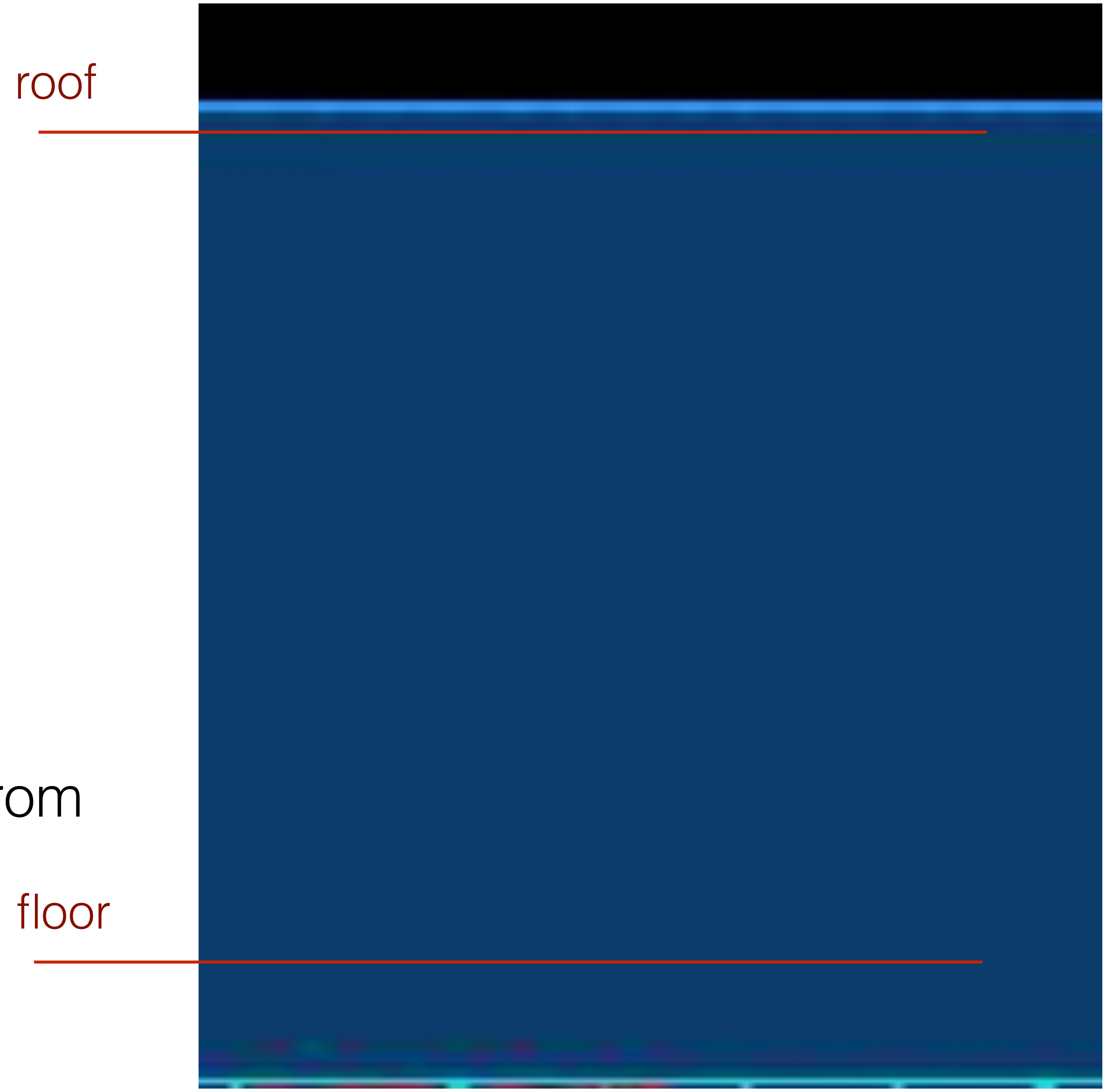
Thrust Forces in Masonry from FEM



Scenario 1

- vertical strip loads
- Thrust is zero above opening
- Tall wall above opening allows actual thrust forces to be small

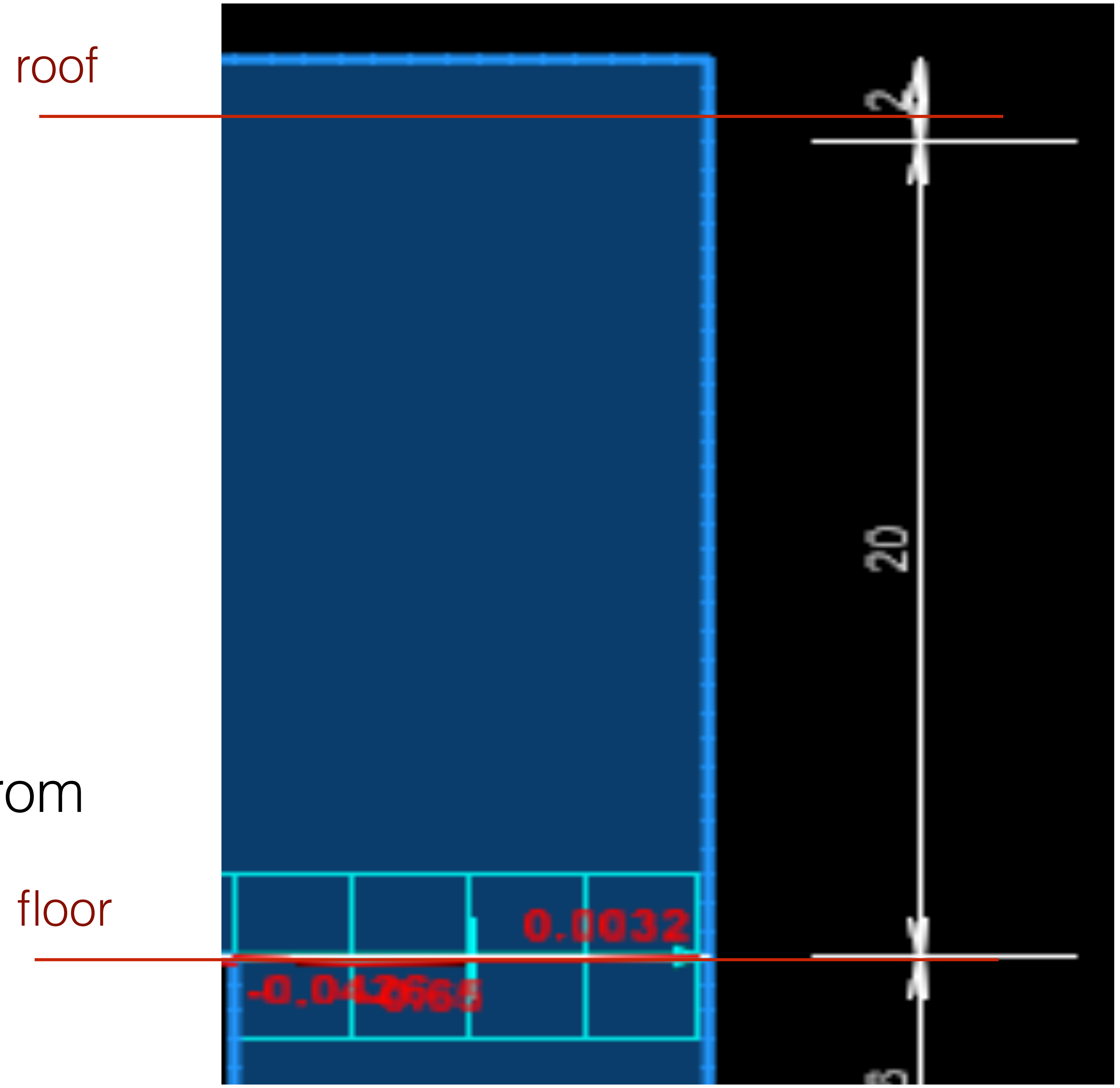
Vertical Shear Forces in Lintel



<u>Example 1</u>

- minimal shear force
- arching keeps “lintel” load from being significant
- entire wall above opening contributes

Vertical Moment Forces in Lintel



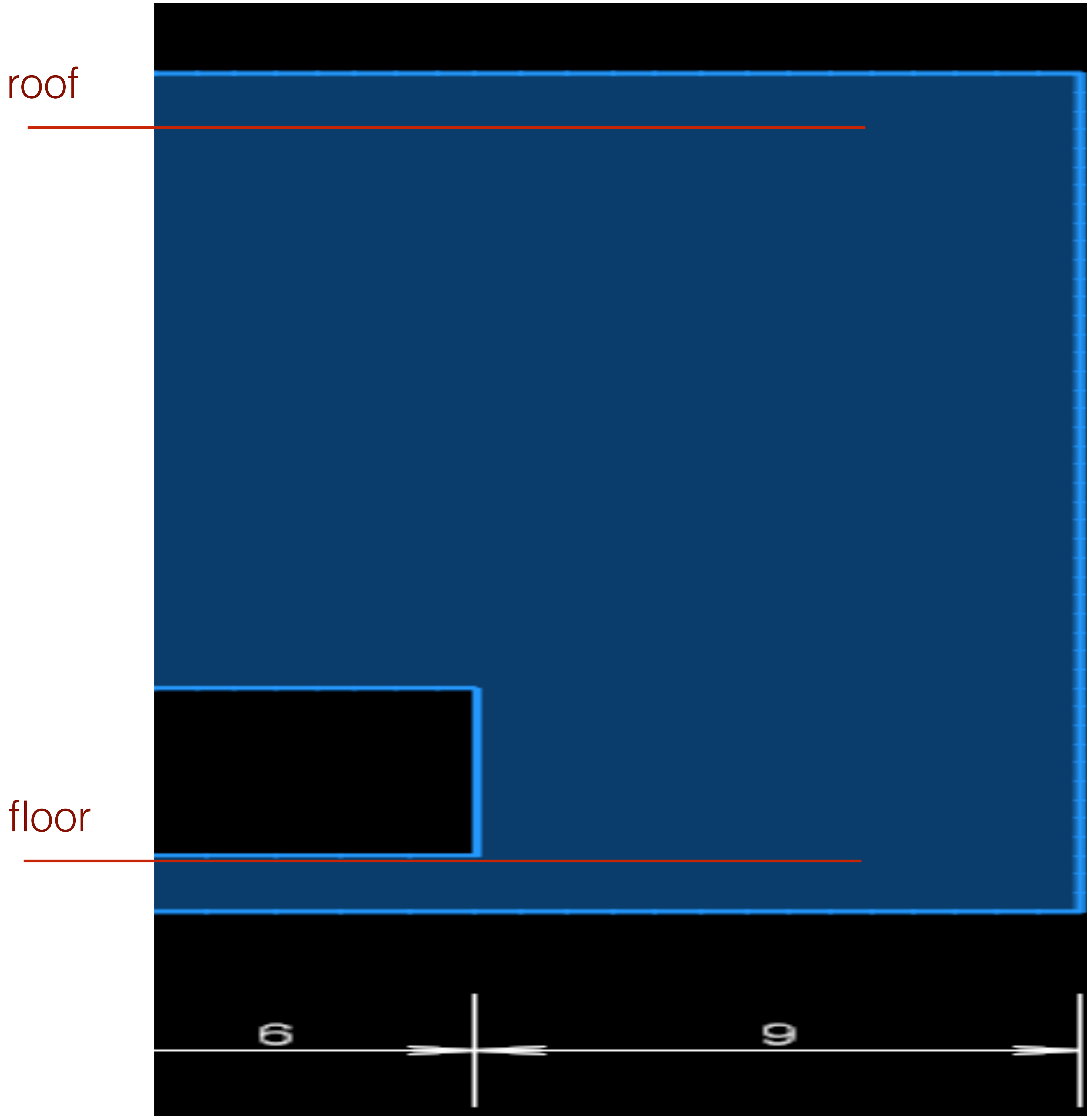
<u>Example 1</u>

- minimal moment forces
- arching keeps “lintel” load from being significant
- entire wall above opening contributes

FEA Analysis Results for 2 Different Masonry Walls

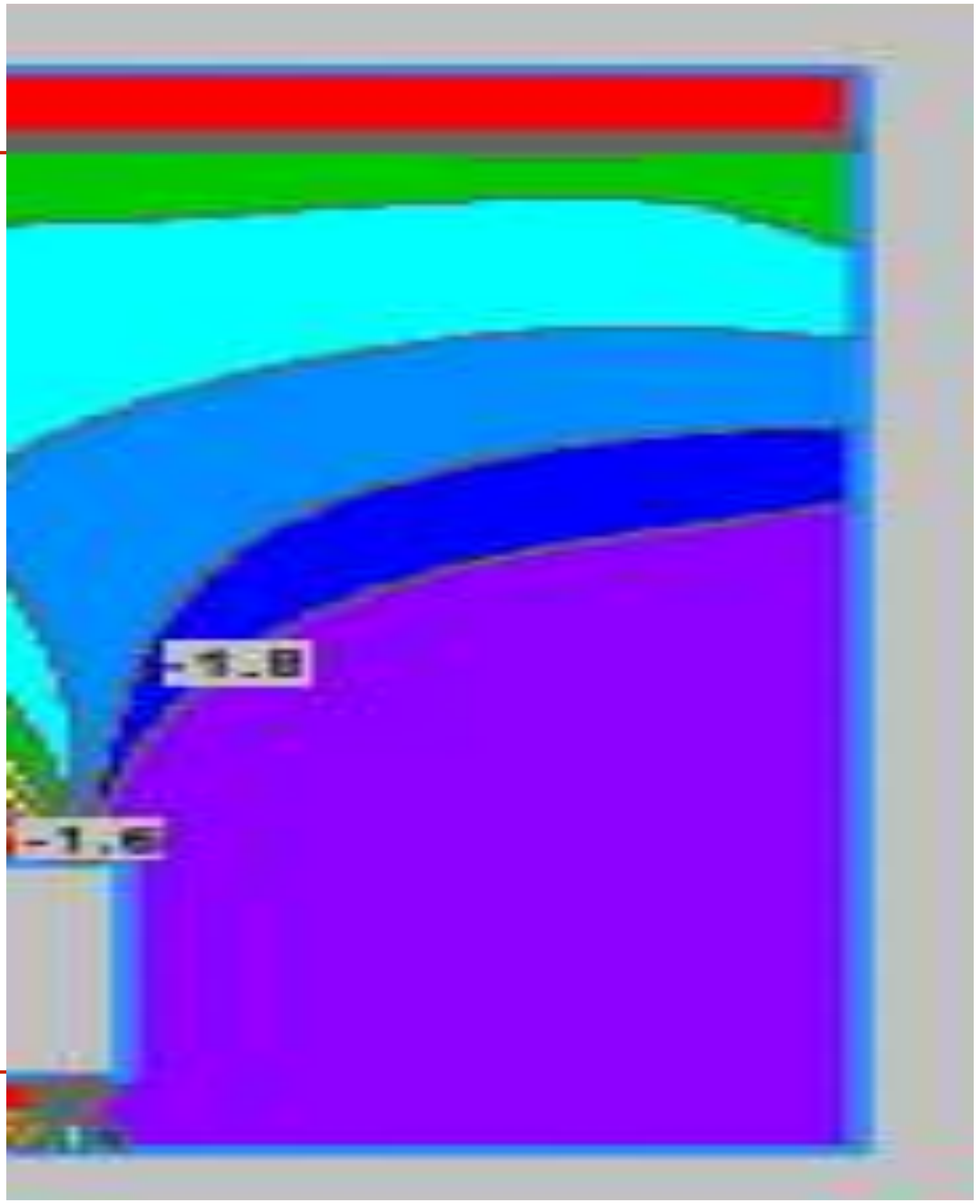
Scenario 2

- 14 ft opening
- 28 ft high wall
- loads 20 ft above opening



Axial Forces in Masonry from FEM

roof

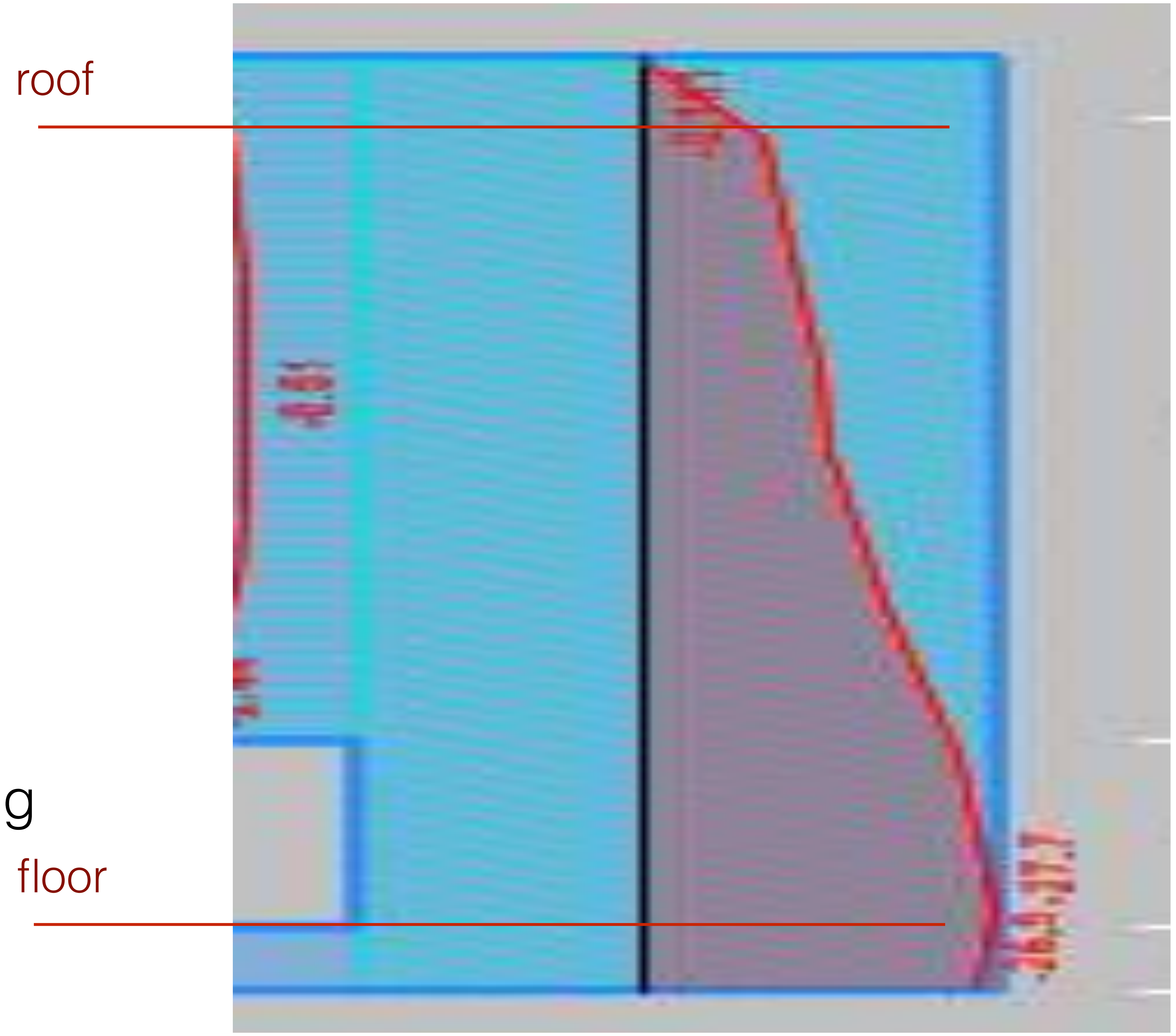


floor

<u>Scenario 2</u>

- Red area indicates low axial forces
- blue and purple indicate higher axial force
- Arching action seen in finite elements

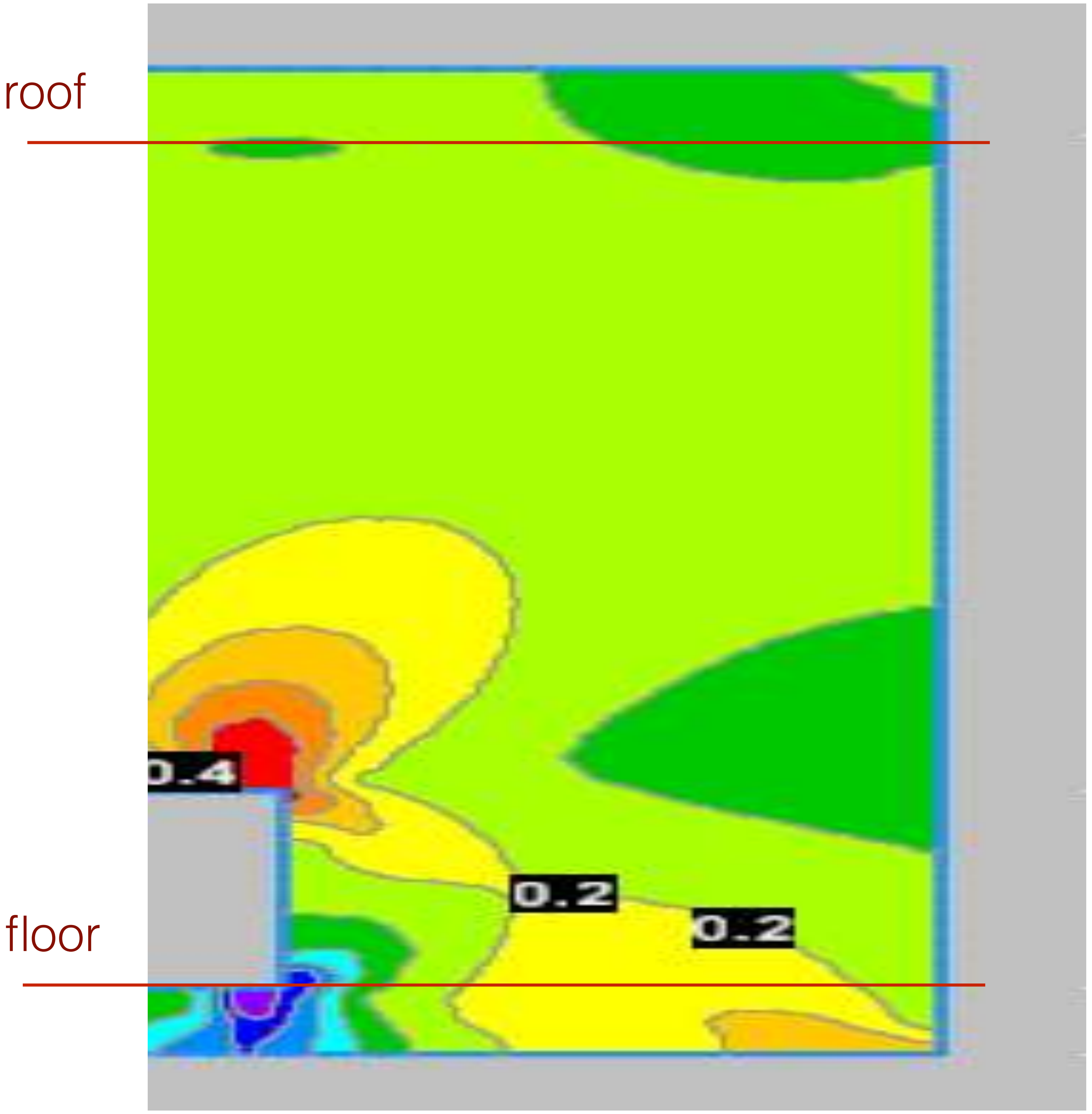
Axial Forces in Masonry from FEM



Scenario 2

- vertical strip loads
- tapers to zero above opening
- arching action seen in finite elements

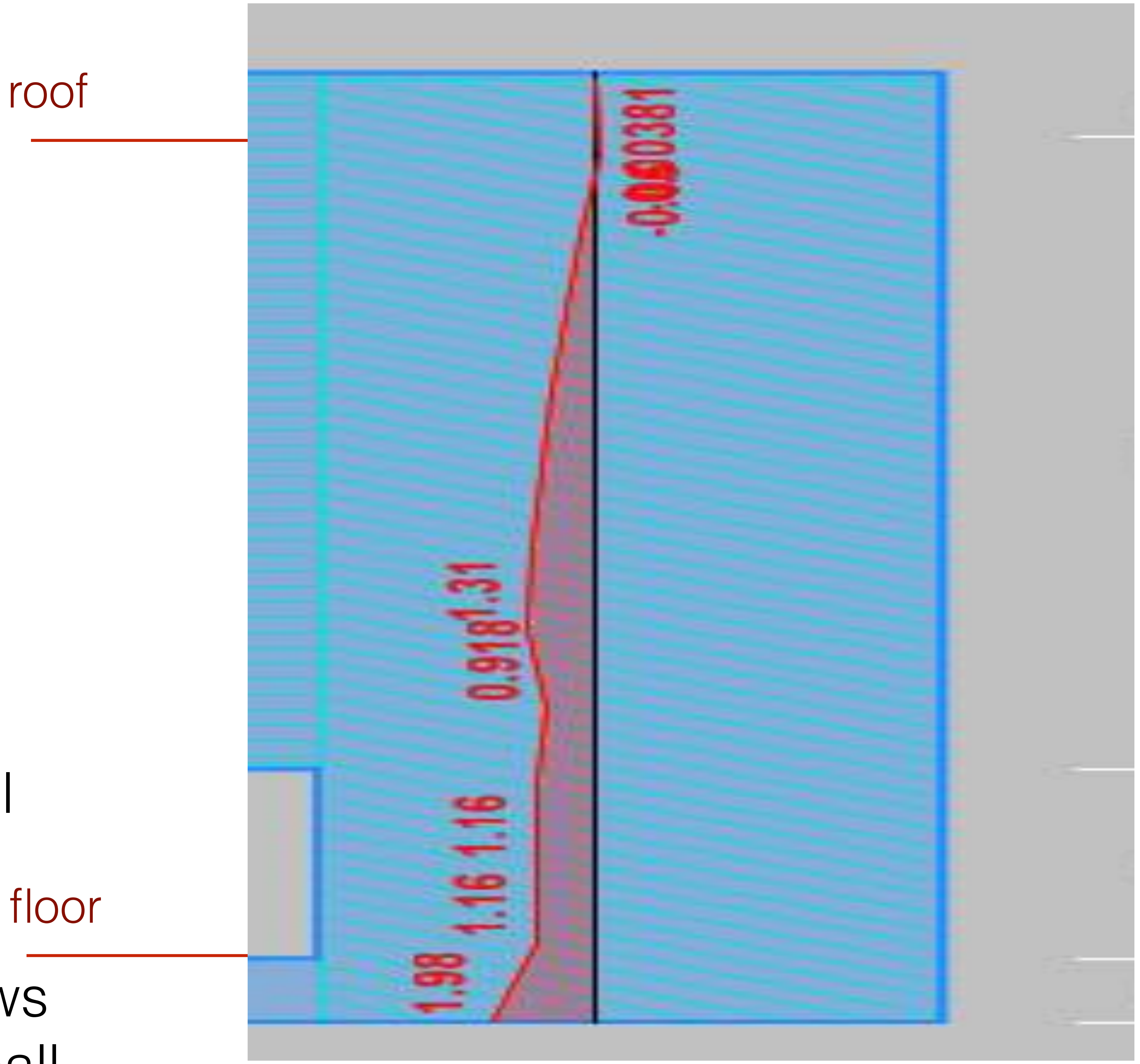
Thrust Forces in Masonry from FEM



Scenario 2

- Green and yellow indicate low (and opposing) thrust forces
- Thrust gets higher only in small areas near opening
- Tall wall above opening allows actual thrust forces to be small

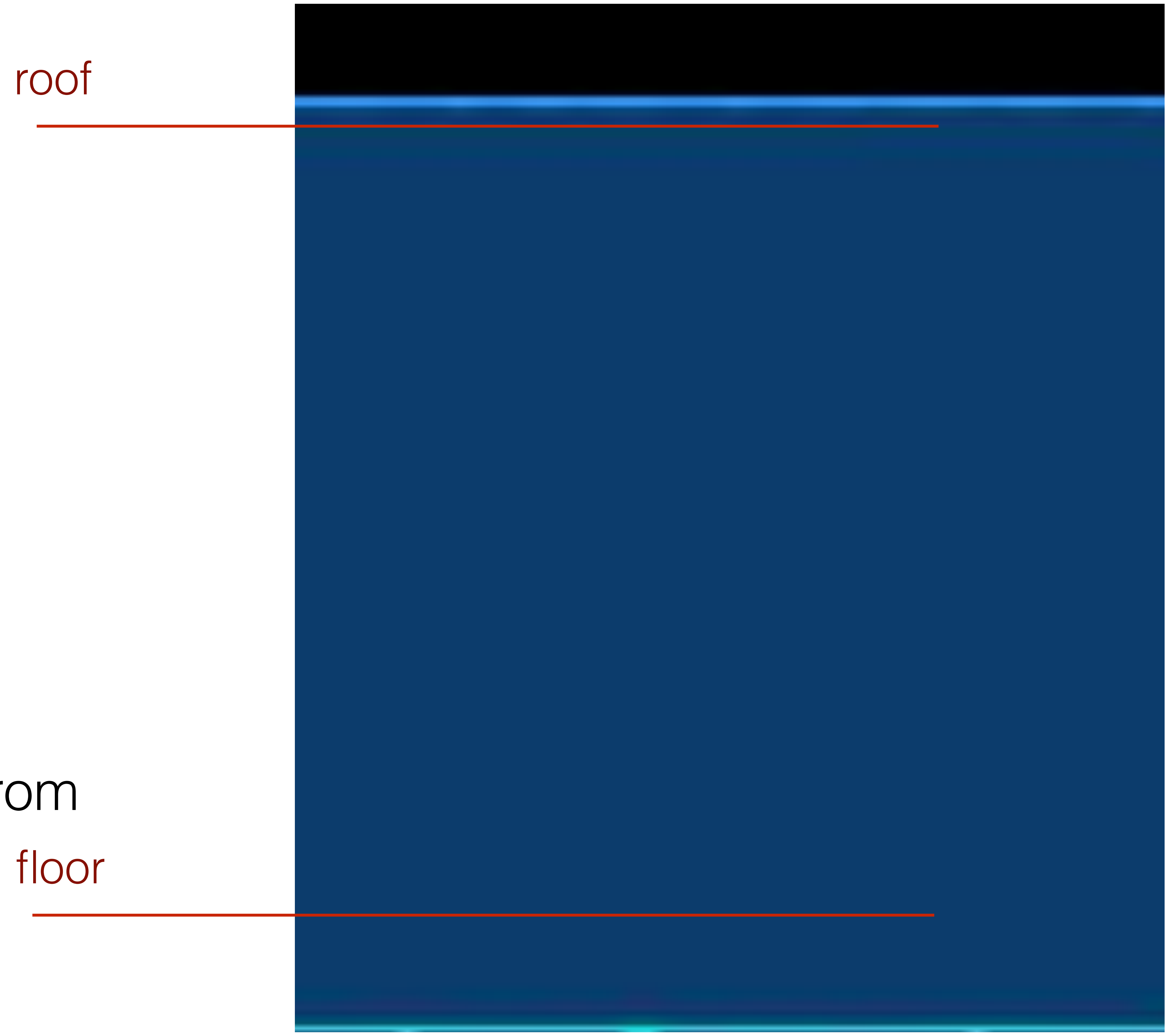
Thrust Forces in Masonry from FEM



<u>Scenario 2</u>

- vertical strip loads
- Thrust is not too high after all above opening
- Tall wall above opening allows actual thrust forces to be small

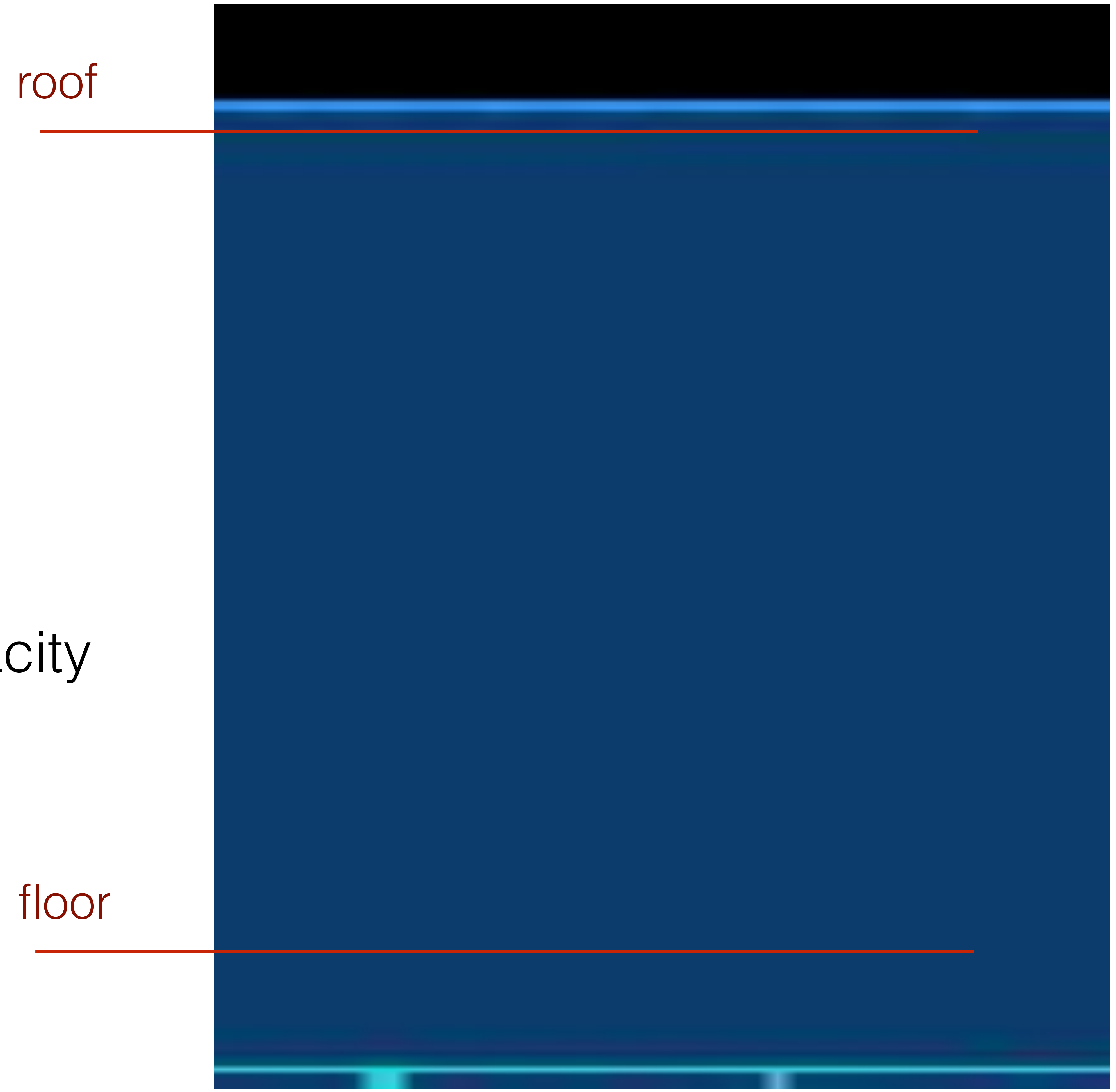
Vertical Shear Forces in Lintel



Scenario 2

- still relatively minimal shear force
- arching keeps “lintel” load from being significant
- entire wall above opening contributes

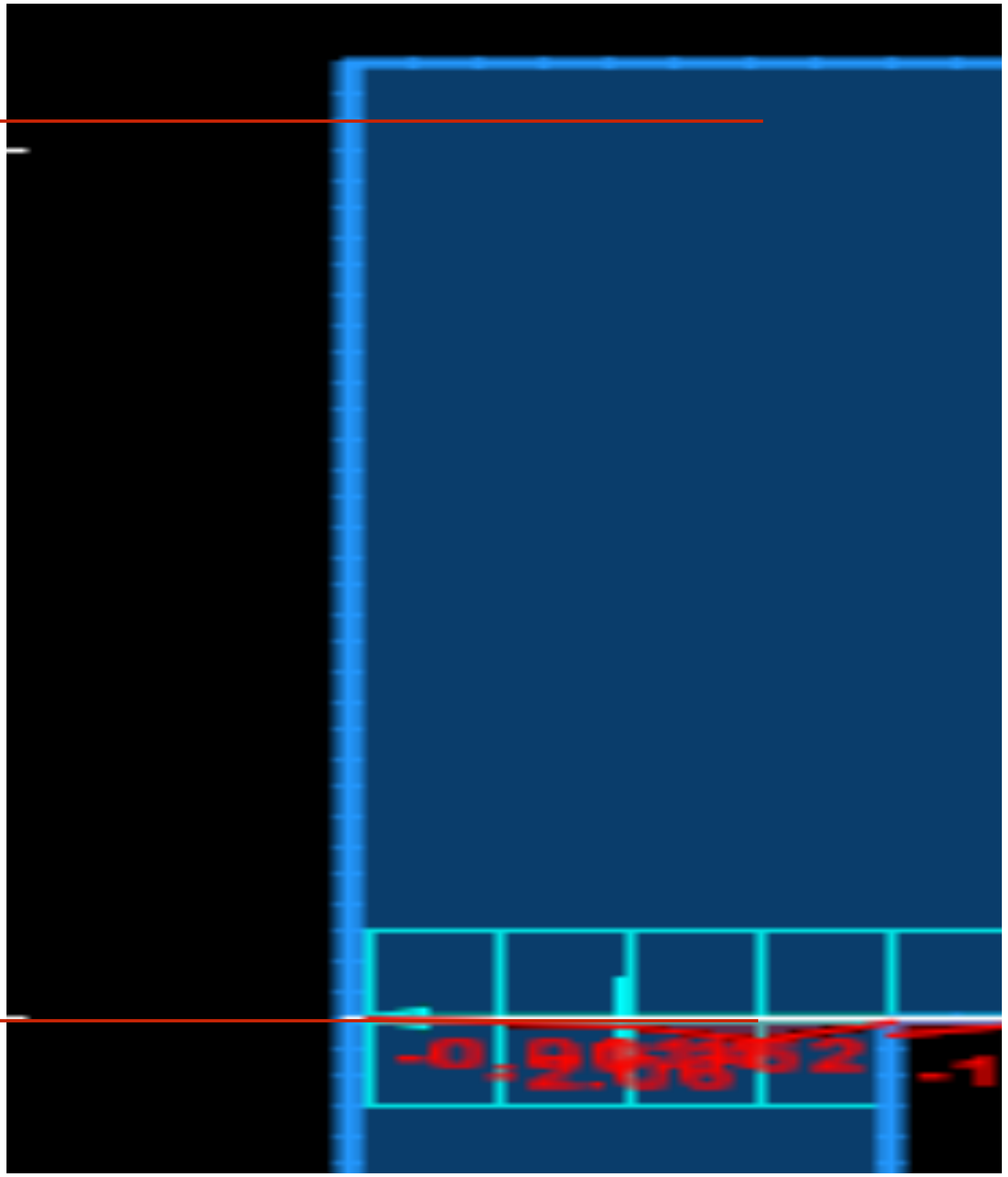
Vertical Shear Forces in Lintel



Example 2

- deeper lintel has more capacity and more load
- still relying on arching
- 2x the design force than the shallower section

Vertical Moment Forces in Lintel

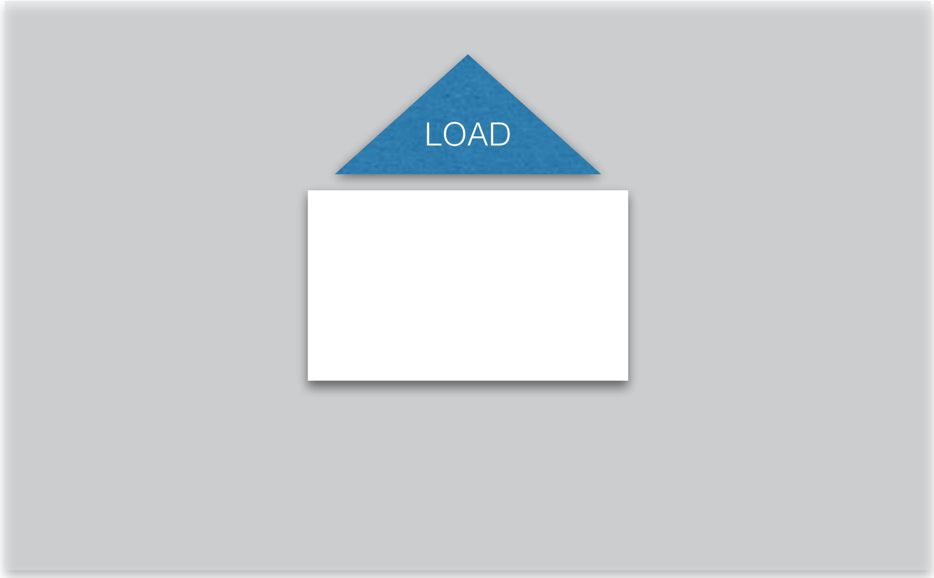


Example 2

- deeper lintel has more capacity and more load
- still relying on arching
- 4x the design force than shallower section

Lintel Forces - Full Wall - V Force comparison

EXAMPLE	EXAMPLE 1	EXAMPLE 2
Length	6 ft	14 ft
Wall height above	22 ft	22 ft
Wall weight	45 psf	45 psf
DL (wall SW)	1.0 kip / ft	1.0 kip / ft
Top of wall loads		
DL	0.3 kip / ft	0.3 kip / ft
LL	0.3 kip / ft	0.3 kip / ft
Total uniform load		
1.2 DL + 1.6 LL	2.0 kip / ft	2.0 kip / ft
Analysis options	Shear, V	
- pinned ends no arching action	6.1	14.2
- fixed ends no arching action	6.1	14.2
- pinned ends with arching action	1.8	4.2
- fixed ends with arching action	1.8	4.2
- FEA model	2.3	3.9



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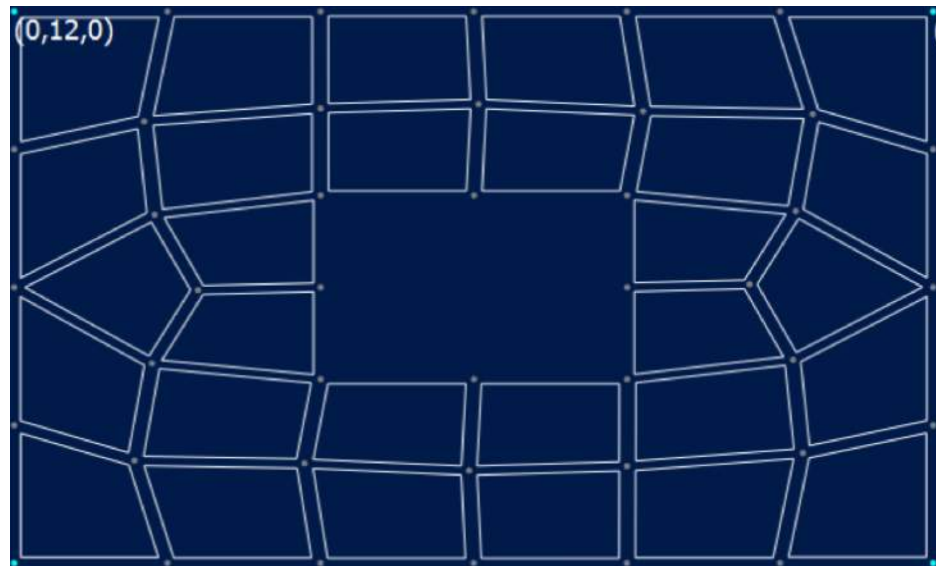
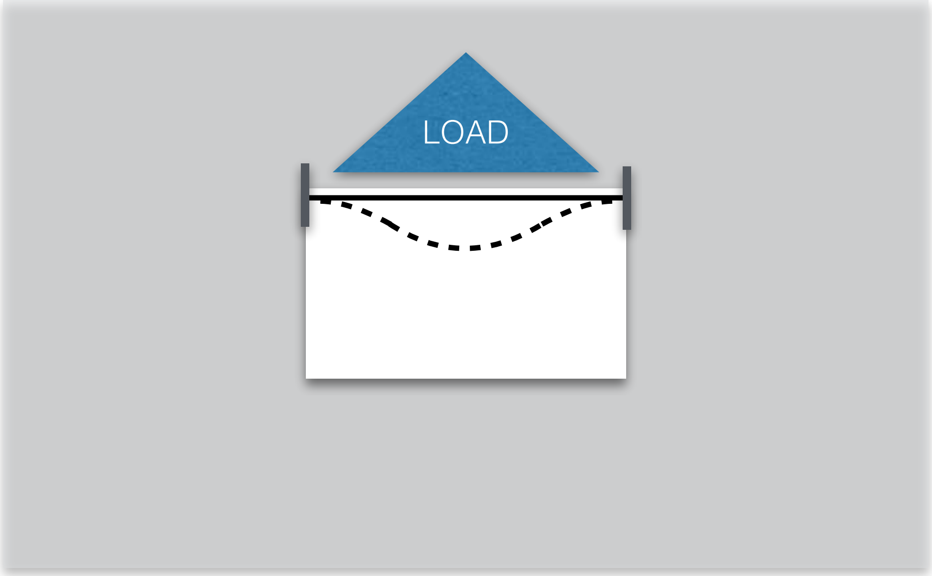


This confirms **FEA** is similar to hand calcs for both the examples when **arching action** is considered

Lintel Forces - Full Wall - M Force comparison

EXAMPLE	EXAMPLE 1	EXAMPLE 2
Length	6 ft	14 ft
Wall height above	22 ft	22 ft
Wall weight	45 psf	45 psf
DL (wall SW)	1.0 kip / ft	1.0 kip / ft
Top of wall loads		
DL	0.3 kip / ft	0.3 kip / ft
LL	0.3 kip / ft	0.3 kip / ft
Total uniform load		
1.2 DL + 1.6 LL	2.0 kip / ft	2.0 kip / ft
Analysis options	Moment, M	
- pinned ends no arching action	9.1	49.7
- fixed ends no arching action	6.1	33.1
- pinned ends with arching action	3.6	19.4
- fixed ends with arching action	2.2	12.1
- FEA model	0.9	8.2



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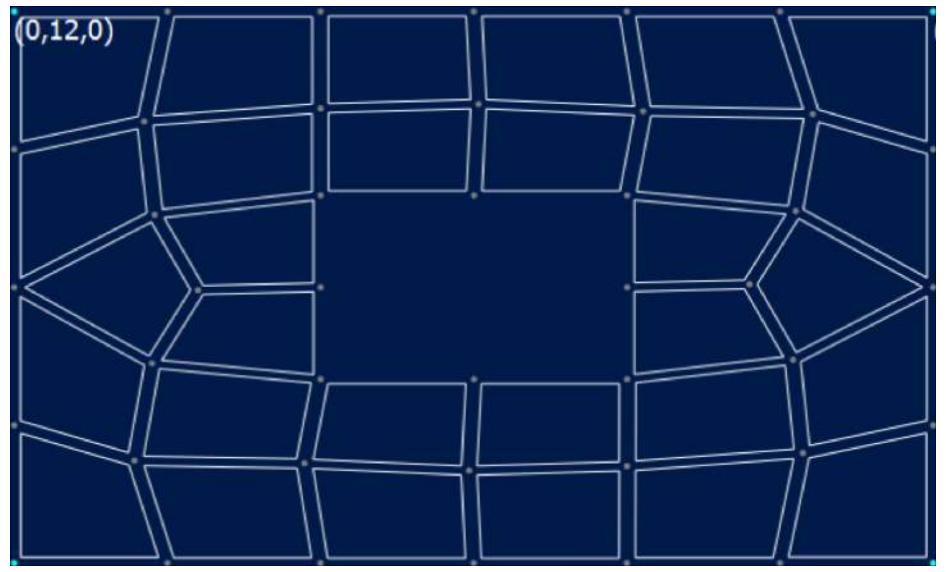


This indicates **FEA** is most similar to hand calcs for both the examples when **arching action** and **fixed end supports** are considered

SHEAR LOAD - 14FT OPENING

- pinned ends
no arching action

14.2 k

STEEL lintels usually have CJs at each end, therefore the force is similar to *pinned ends, no arching action*

- FEA model

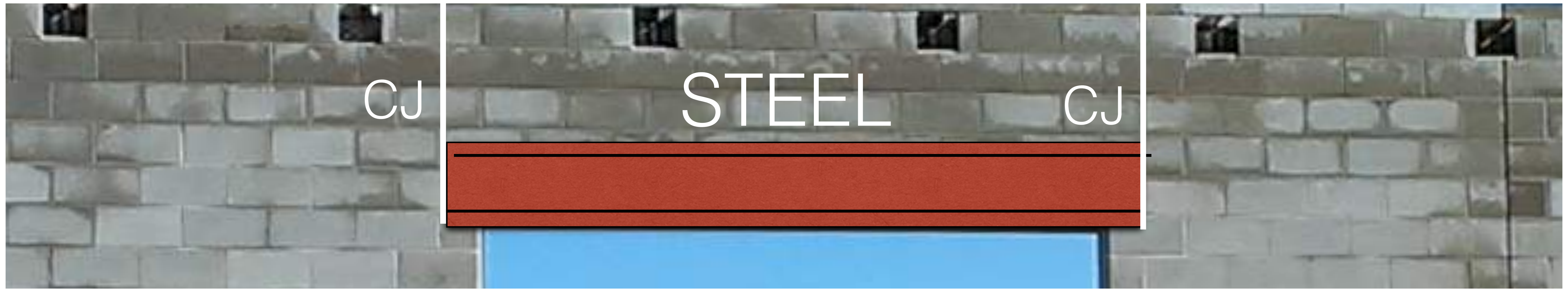
3.9 k

MASONRY lintels are integral with the wall, therefore the force for design would be based on *fixed ends, and arching action* or **FEA model**

MASONRY LINTELS GENERALLY CAN BE DESIGNED FOR LESS LOADS!!

FORSE

DESIGN MOMENT - 14FT OPENING



- pinned ends
no arching action — **49.7 ft-k**

STEEL lintels usually have CJs at each end, therefore the force is similar to *pinned ends, no arching action*

- FEA model — **8.2 ft-k**

MASONRY lintels are integral with the wall, therefore the force for design would be based on *fixed ends, and arching action* or **FEA model**

MASONRY LINTELS GENERALLY CAN BE DESIGNED FOR LESS LOADS!!

Masonry vs "Other" Lintels

- "Other" lintel advantages
  - No shoring
  - ~~More capacity~~ (perceived)
- Other lintel challenges
  - Isolated, simple member
  - Bearing issues
  - Thermal issues
  - Cracking issues
  - Performance issues
  - Construction issues-scheduling differing materials

Simple shoring solutions

created in conjunction with
TEAM IMI

Simple shoring solutions

created in conjunction with
TEAM IMI

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Prefabricated masonry lintels

Prefabricated masonry lintel

created in conjunction with
TEAM
IMI

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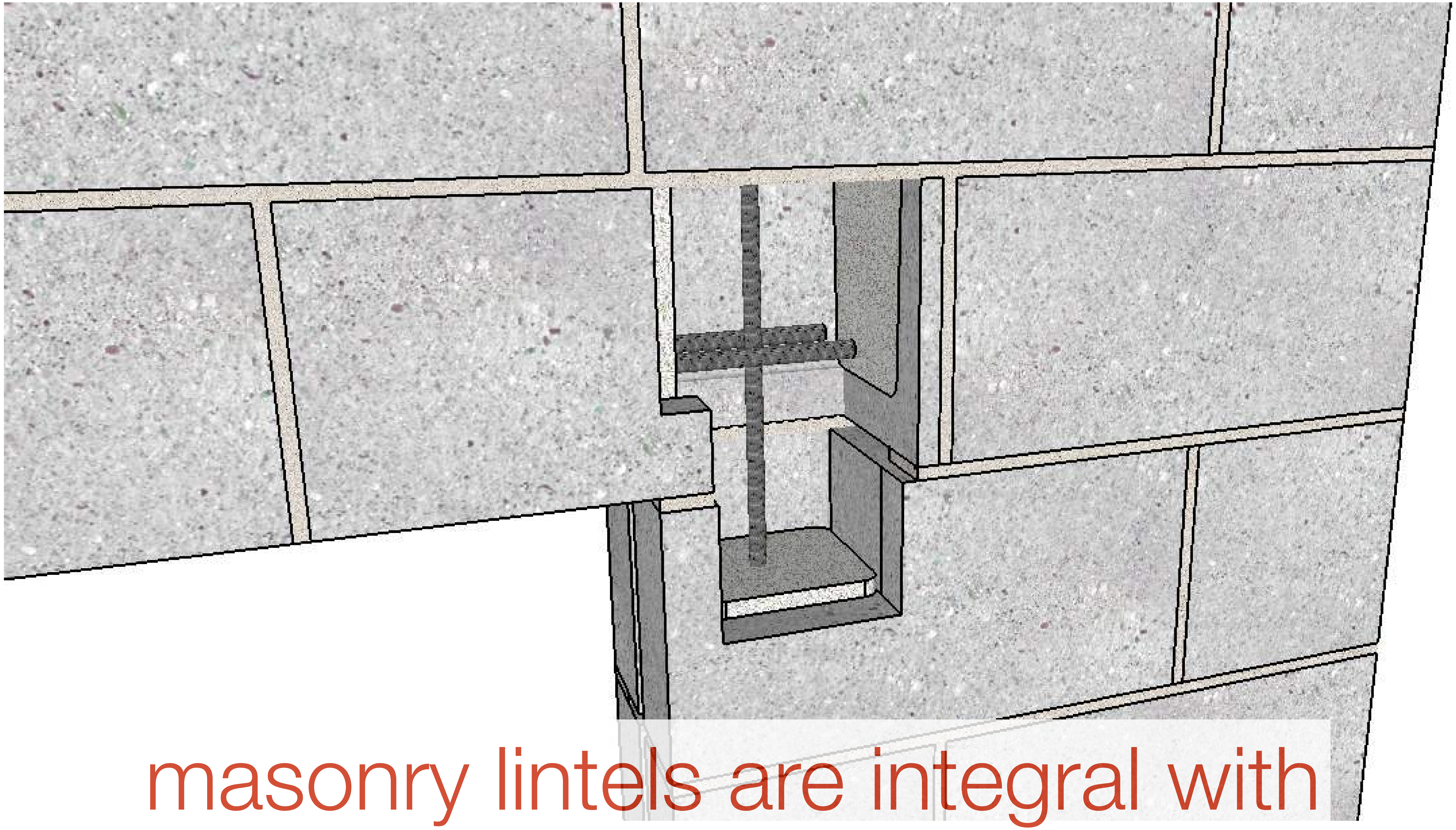
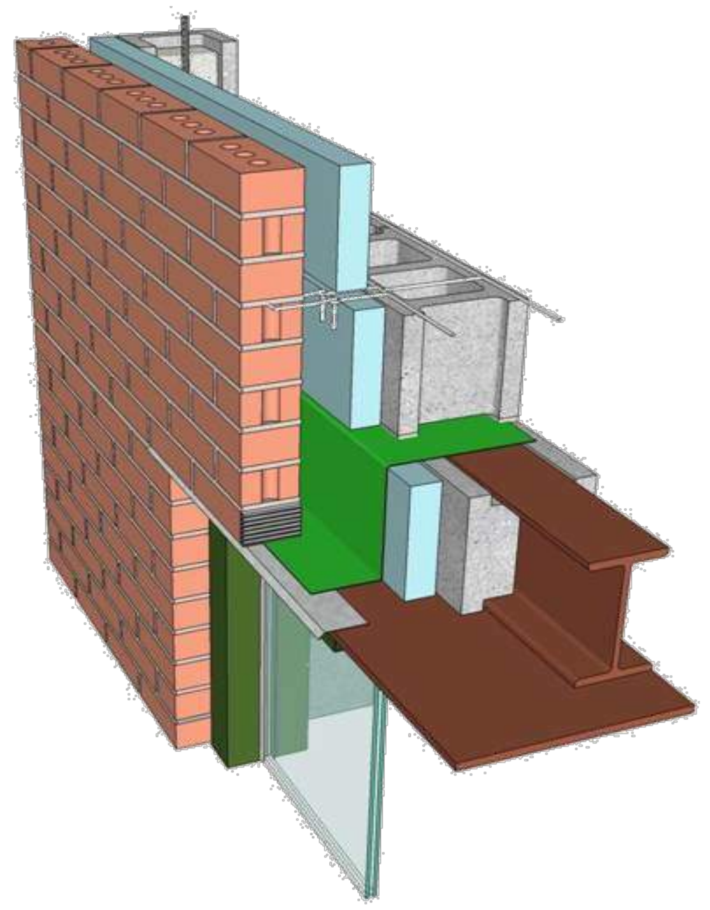


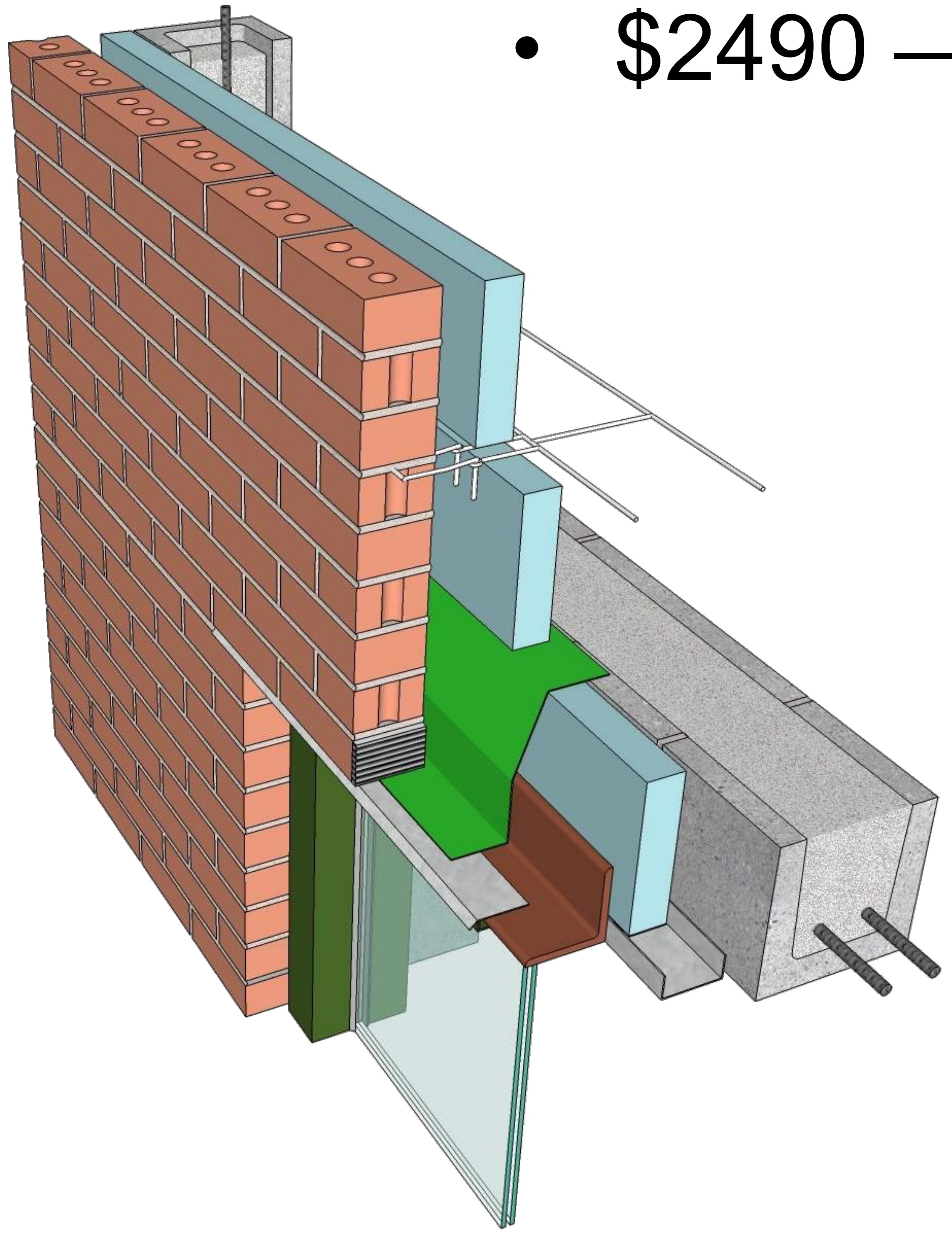
masonry lintels are integral with masonry wall, creates a robust efficient design

Costs Examples – Lintels



Steel lintel costs examples:

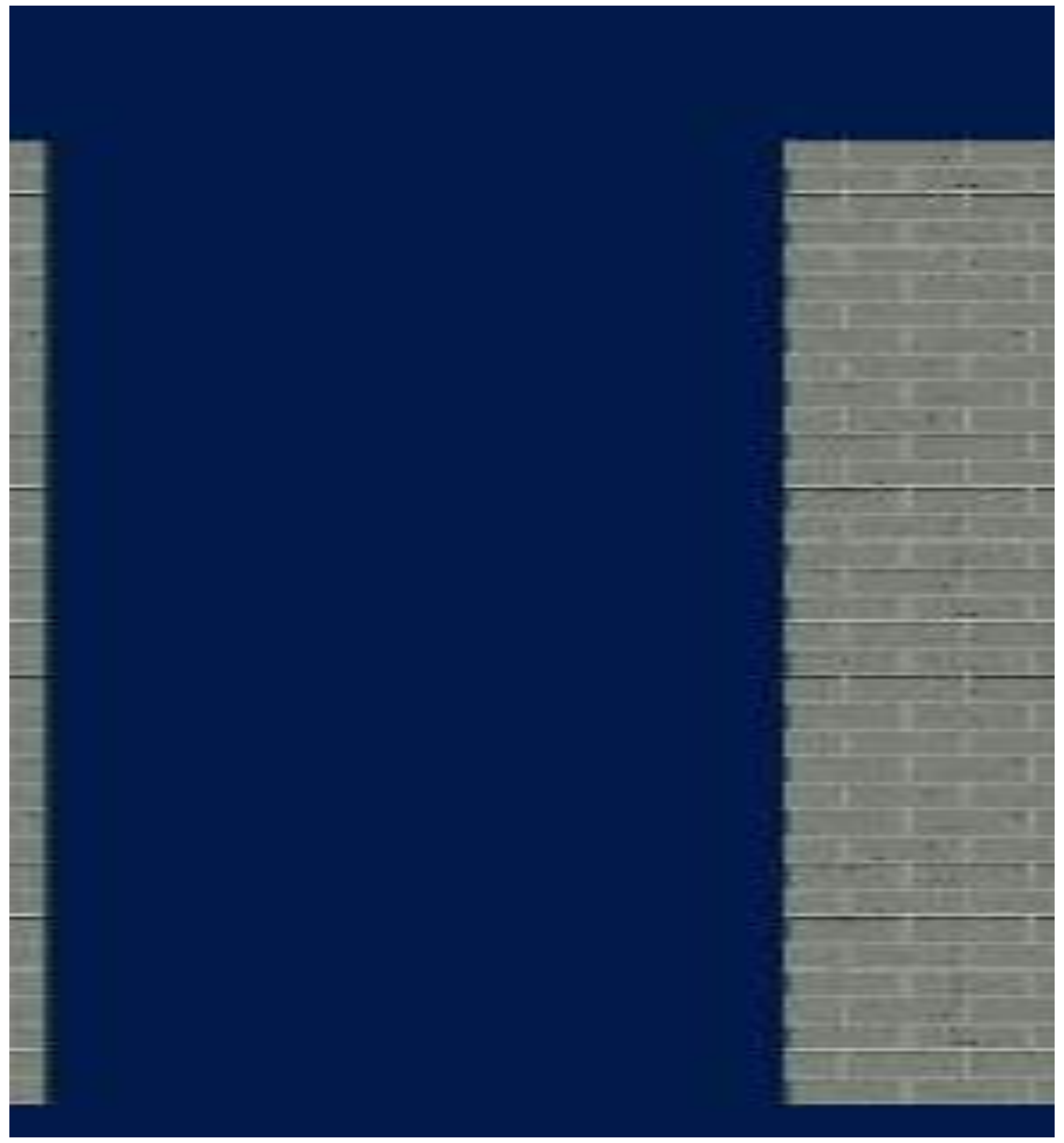
- $1906 —> W8x15 —>$159/ft
- $2237 —> W16x26 —>$186/ft
- $2490 —> W24x55 —>$207/ft



Masonry lintel cost examples:

- $1341 —> 8 inch —>$112/ft
- $1440 —> 16 inch —>$120/ft
- $1538 —> 24 inch —>$128/ft
- all less expensive than W8 steel

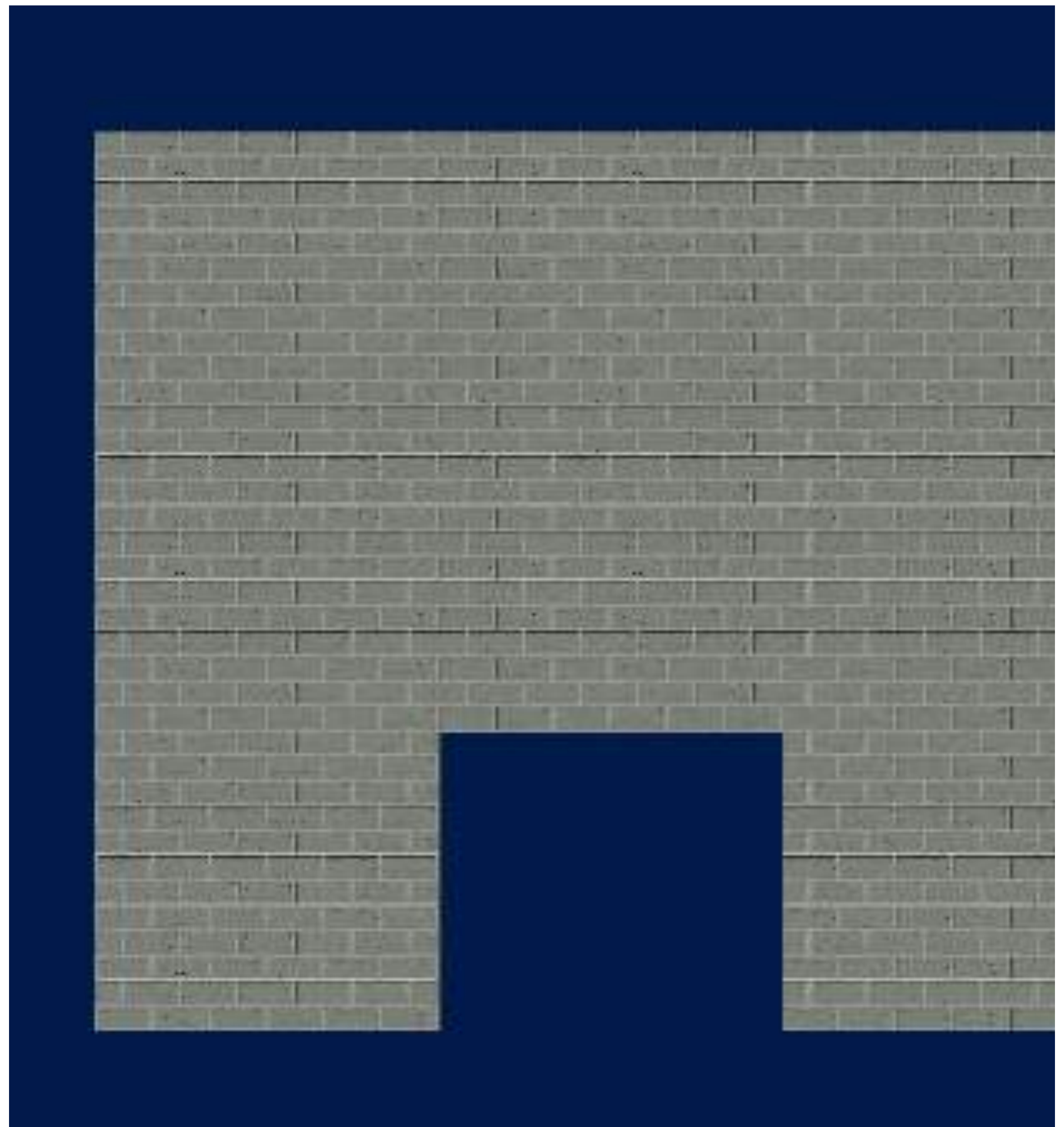
Lintel Cost - Example 1



- non-load bearing
- 24ft high wall
- 8ft wide by 7’-4” door

- Steel lintel required - W8x15

—>$1,272
  - used CJ on one or both sides of the opening
  - no arching action



- Masonry lintel required - 8 inch

—>$896
  - CJ 8ft way from opening edge
  - arching action utilized

- 40% less for masonry!

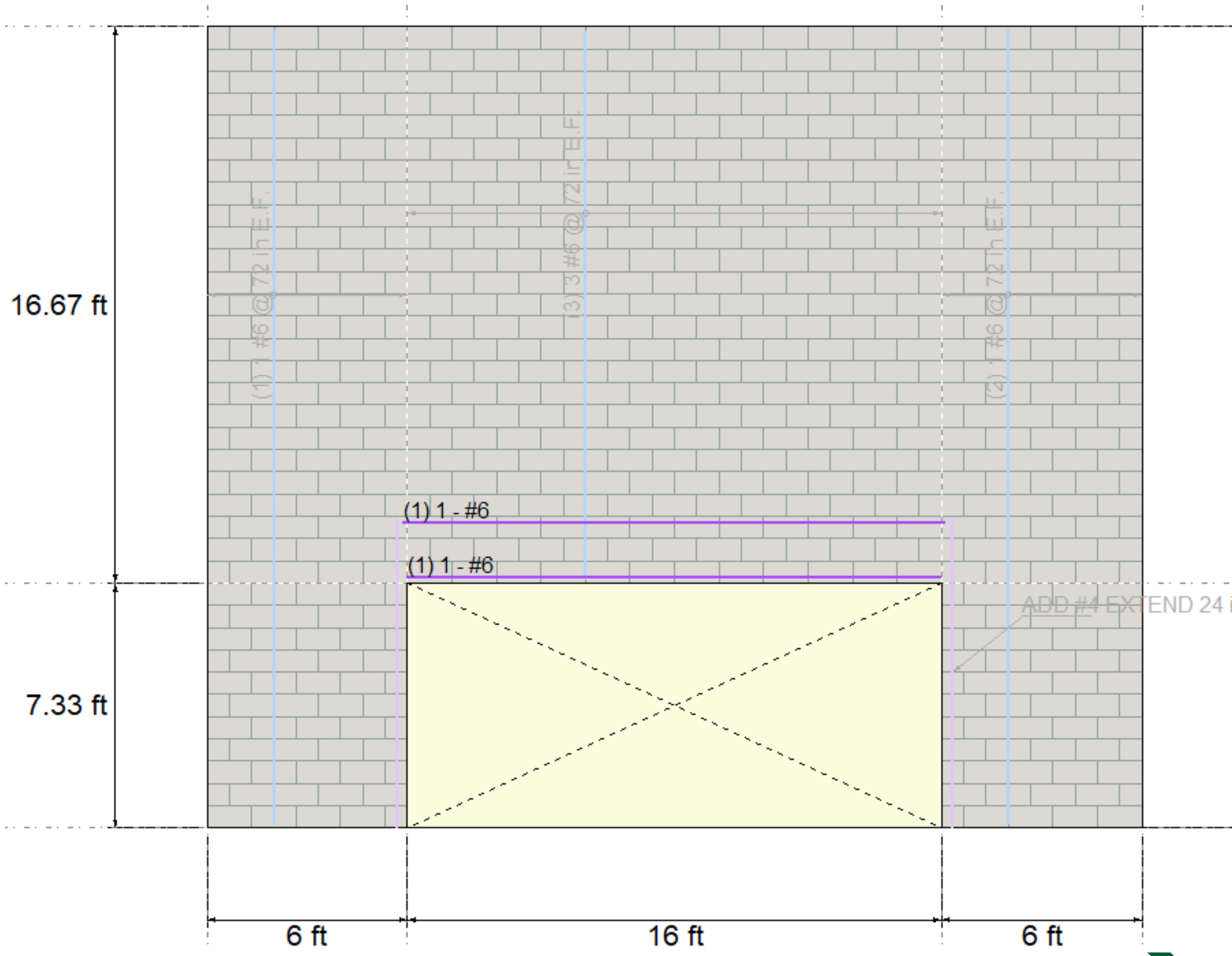
Lintel Cost - Example 2

- load bearing
- 24ft high wall
- 16ft wide by 7'-4" door

- Steel lintel required - W24x55
  —>$3,312
  - used CJ each side of the opening
  - no arching action

- Masonry lintel required - 24 inch
  —>$2,048
  - CJ 8ft way from opening edge
  - arching action utilized

- 62% less for masonry!



LINTELS

- how to detail?
  - masonry lintels (or precast)
    - integral with wall
    - more robust and stronger
    - MORE AFFORDABLE!!
  - steel lintels
    - “foreign” “isolated” element - new material, different properties
    - architectural considerations for adding steel

MASONRY INSIGHTS
written in conjunction with International Masonry Institute

Lintels for Masonry Walls

In recent years, there has been a renewed interest in using reinforced masonry lintels instead of steel lintels. There are several reasons to consider masonry lintels:

A) Previously it was thought the only way to reduce shoring was to specify a steel lintel. This is no longer true due to:

1) New and innovative methods for shoring to build in-place masonry lintels.

2) Availability of pre-fabricated masonry lintels.

3) Precast concrete lintels that allows better integration with masonry.

B) Steel lintels are not performing as well over time due to:

1) Differential movement from dissimilar materials creating serviceability issues.

2) Steel lintels are often detailed to slide at one end, however in some cases the bearing is rusting and binding, preventing the steel from sliding which results in issues at the bearing.

3) Large bearing plates are being specified which result in aesthetic and constructibility issues.

4) Challenging interface details of vertical masonry reinforcement, steel bearing, and control joint.

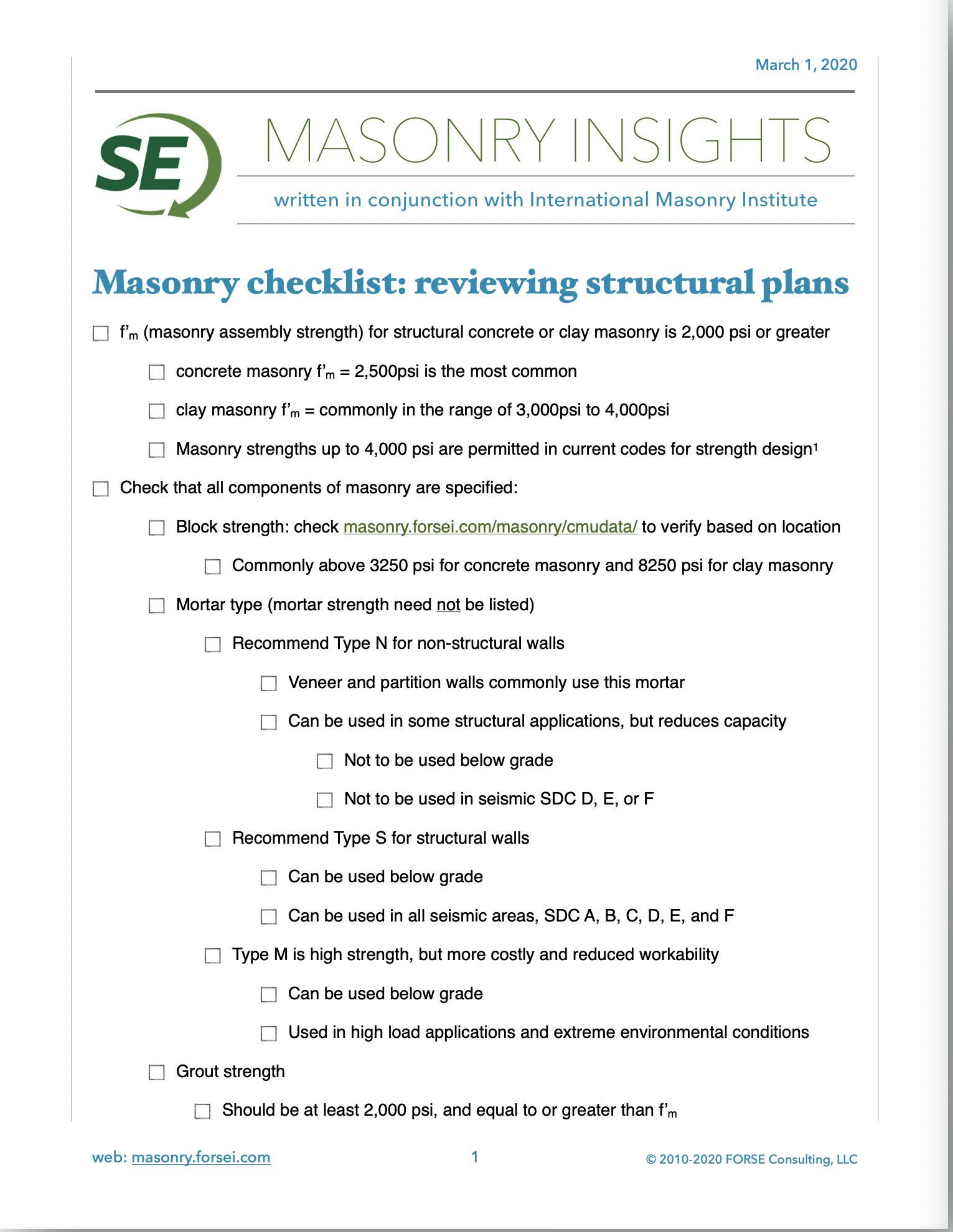
C) Steel lintels require additional and costly reinforcement. The required U-bar in Figure 1 on the following page is difficult and expensive to place, but is essential to prevent cracking. The vertical jamb reinforcement must be shifted away from the opening, which requires the jamb to be designed for more tributary width, resulting in a larger jamb. This condition also requires additional grout under the steel bearing. See Figure 1 on the following page.

D) Masonry lintels create an integral joint with vertical jamb reinforcement. This leads to a more robust design that has many design benefits and is less expensive . See Figure 2 on the following page.

E) Perhaps the most compelling reason to use masonry or precast lintels is due to the ability to use arching action, which allows the design load to be much smaller. Arching action, which will be discussed later in the article, requires the lintel to be built integrally with the jamb and no control joints (CJ) at the openings. Steel lintels often require CJ’s at the end of the lintel due to differential movement, which prevent arching action and therefore requires much more load for the design.

Masonry Checklist

- ☐ f'm - masonry assembly strength
- ☐ Verify all components of masonry are specified
- ☐ Consider masonry wall thickness and reinforcement
- ☐ Review masonry shear walls
- ☐ Review masonry partition walls
- ☐ Check that control joints are located on plans
- ☐ Review lintels, prefer masonry lintels where possible
- ☑ Review bearing plate details
- ☐ Consider conflicts between steel and masonry


March 1, 2020

MASONRY INSIGHTS

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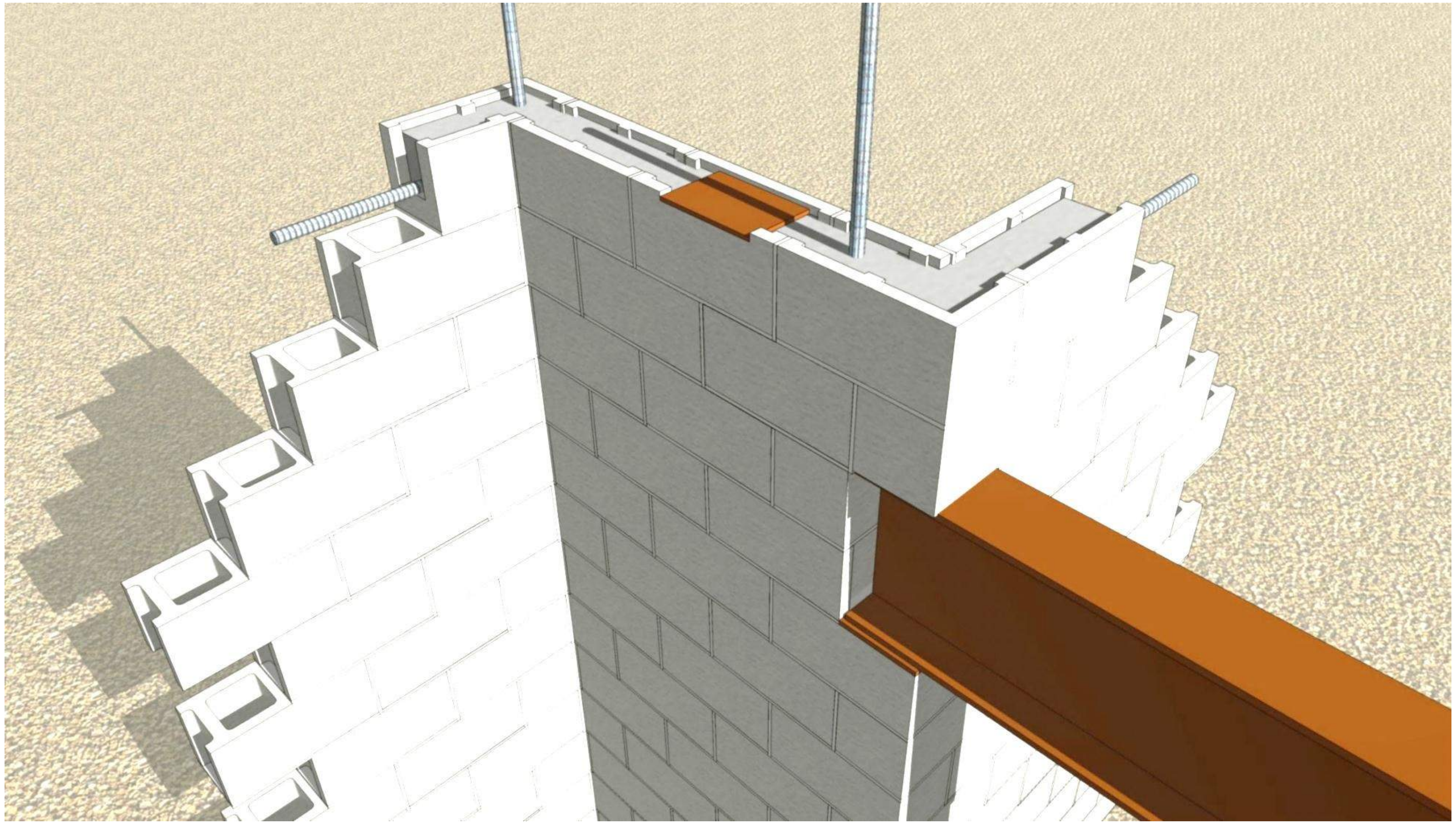
Masonry checklist: reviewing structural plans

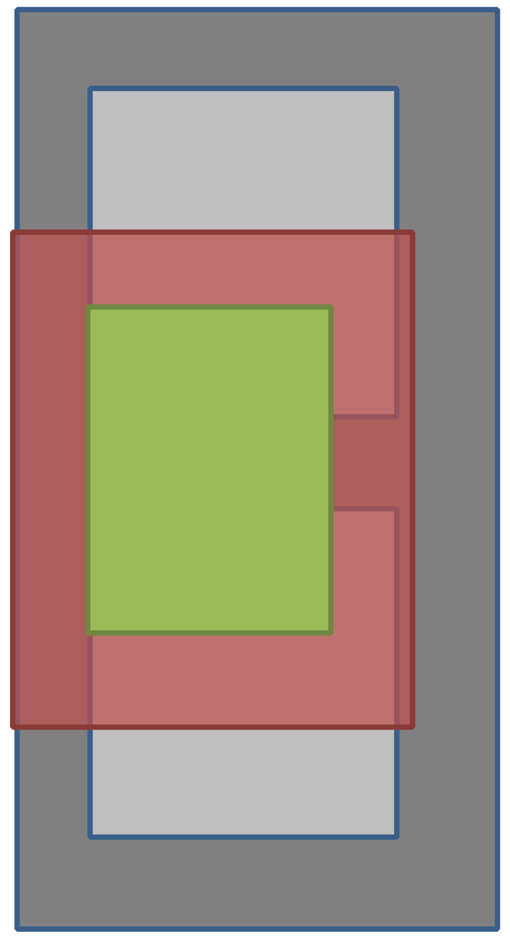
- ☐ f'_m (masonry assembly strength) for structural concrete or clay masonry is 2,000 psi or greater
  - ☐ concrete masonry f'_m = 2,500psi is the most common
  - ☐ clay masonry f'_m = commonly in the range of 3,000psi to 4,000psi
  - ☐ Masonry strengths up to 4,000 psi are permitted in current codes for strength design[1]
- ☐ Check that all components of masonry are specified:
  - ☐ Block strength: check masonry.forsei.com/masonry/cmudata/ to verify based on location
    - ☐ Commonly above 3250 psi for concrete masonry and 8250 psi for clay masonry
  - ☐ Mortar type (mortar strength need not be listed)
    - ☐ Recommend Type N for non-structural walls
      - ☐ Veneer and partition walls commonly use this mortar
      - ☐ Can be used in some structural applications, but reduces capacity
        - ☐ Not to be used below grade
        - ☐ Not to be used in seismic SDC D, E, or F
    - ☐ Recommend Type S for structural walls
      - ☐ Can be used below grade
      - ☐ Can be used in all seismic areas, SDC A, B, C, D, E, and F
    - ☐ Type M is high strength, but more costly and reduced workability
      - ☐ Can be used below grade
      - ☐ Used in high load applications and extreme environmental conditions
  - ☐ Grout strength
    - ☐ Should be at least 2,000 psi, and equal to or greater than f'_m

web: masonry.forsei.com 1

Bearing Plates – Capacity and What's Required

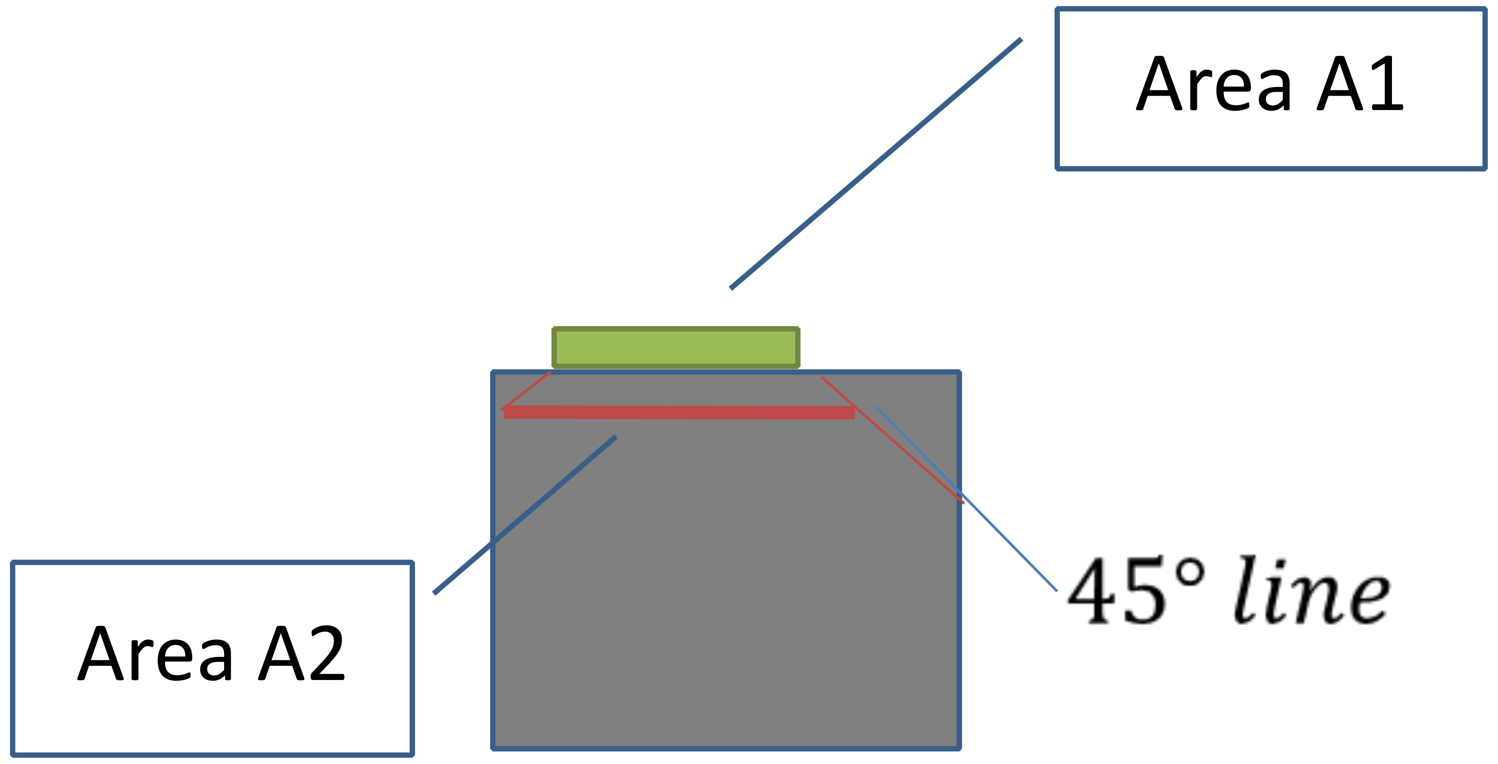


Bearing Plates
– Capacity and What's Required



top view

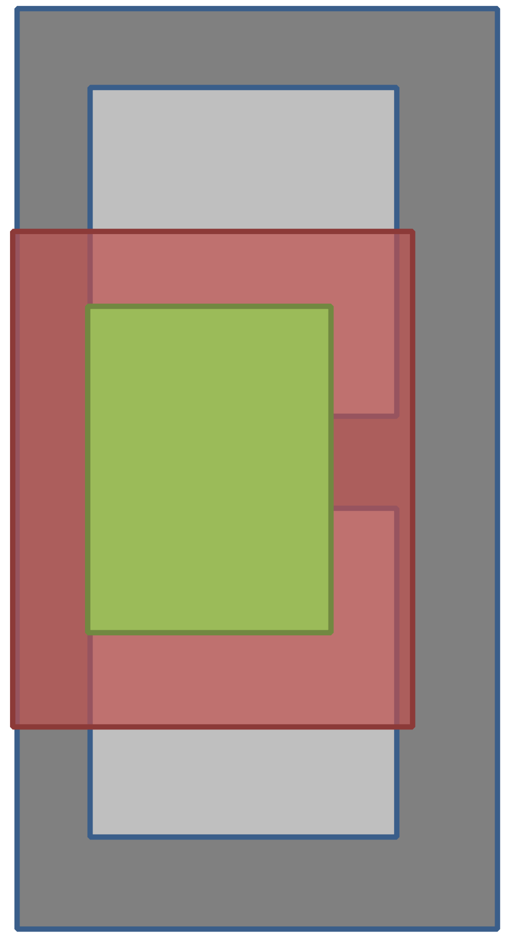
- bearing capacity
  - un-restrained
  - restrained
    - calculation for determining bearing capacity
  - helps to move bearing plates away from face of masonry



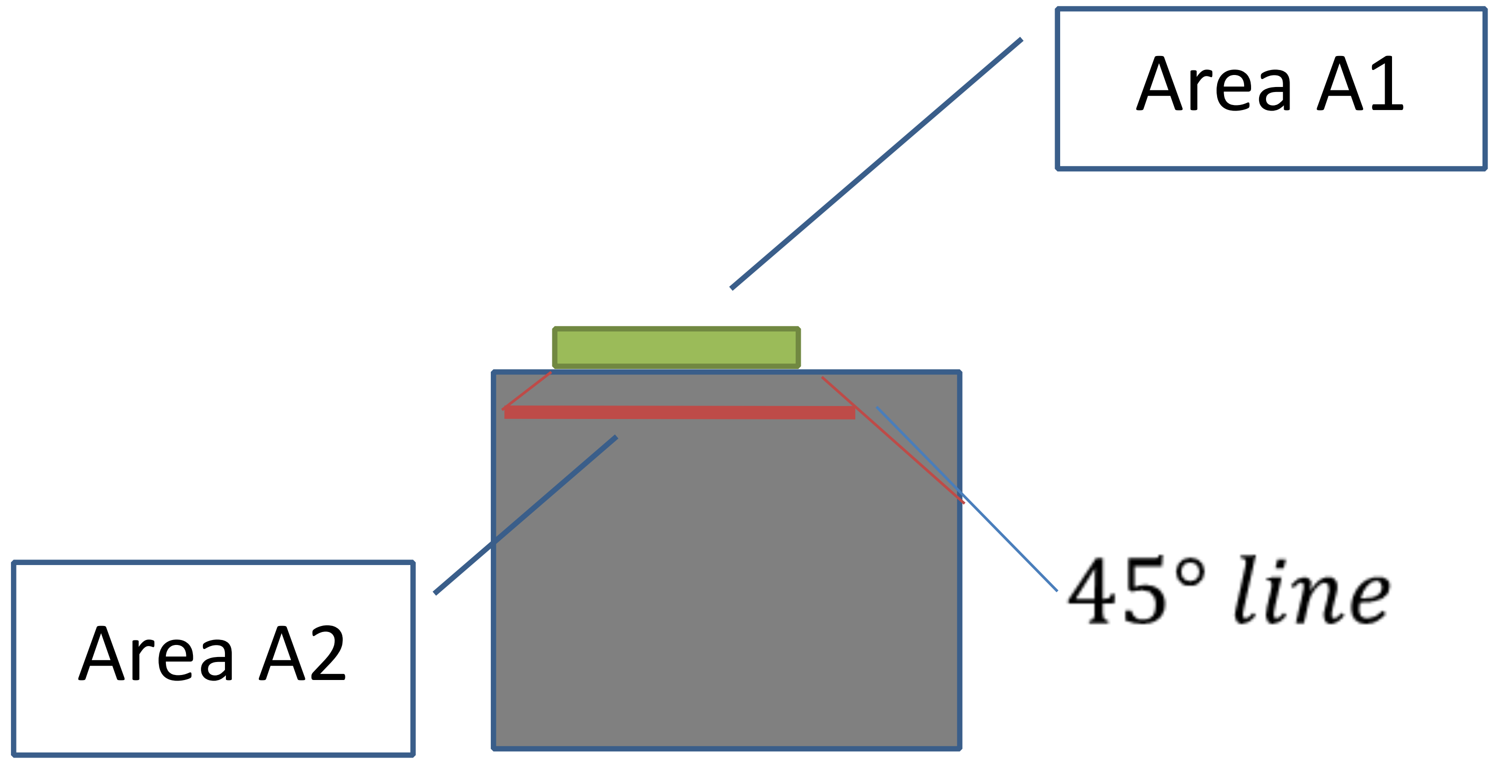
side view

- bearing plates vs beam flanges
  - are bearing plates required?
    - not in every situation

Bearing Plates – Capacity and What's Required



- nominal capacity is product of effective bearing area and 0.80 f'_m
- notice that design bearing capacity has two factors:
  - ϕ=0.60 for the nominal capacity
  - the other for the capacity reduction factor.
- Bearing area is the lower of $\begin{cases} A_1\sqrt{A_2/A_1} \\ 2A_1 \end{cases}$



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Oversized bearing plates are expensive and unnecessary

block
(7 5/8" thick)

bearing plate, both
ends of all lintels
(actual 7" x 7" sq.)

Project had 600 lintels and 1200 bearing plates

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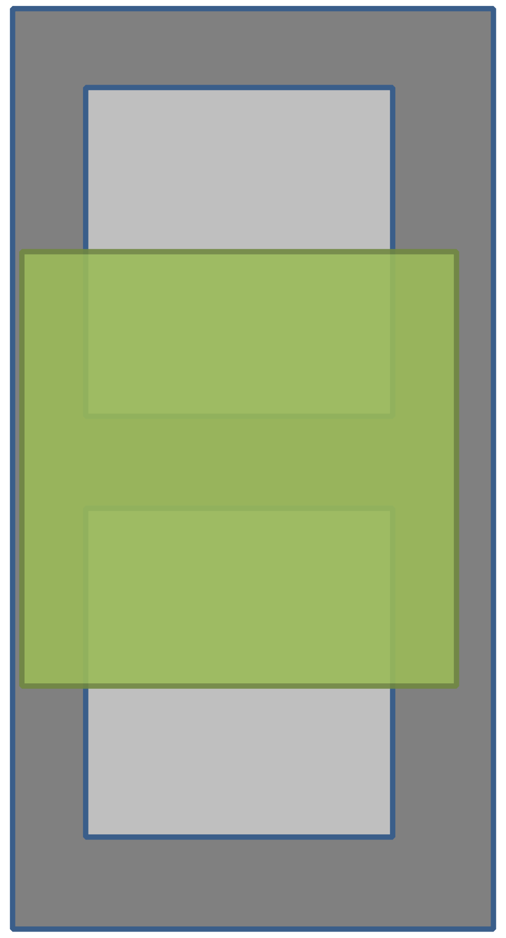
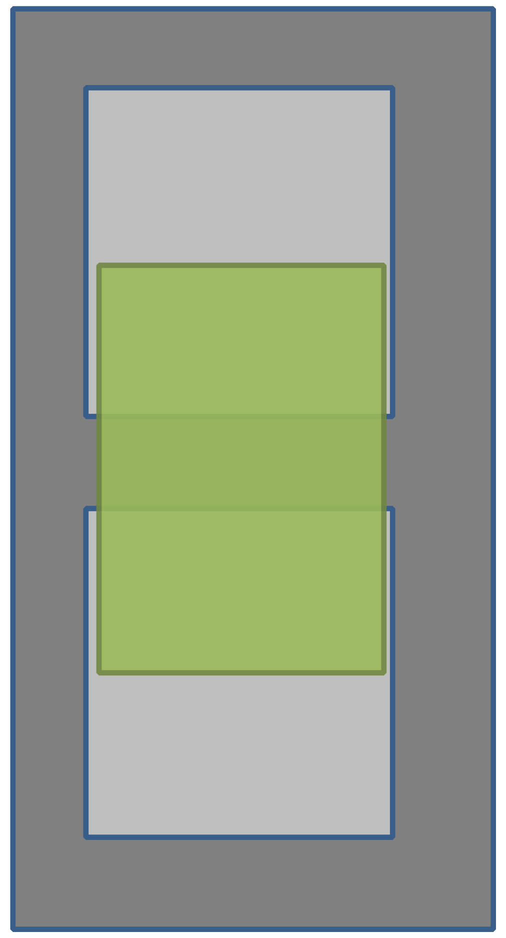
Oversized bearing plates are expensive and unnecessary



7x7 bearing plate at edge

=



5x7 bearing plate, inset 1¼"

- A_1= 49 in^2
- A_2= 49 in^2
- A_{br}= 49 in^2

- A_1= 35.0 in^2
- A_2= 71.3 in^2
- A_{br}= 49.9 in^2

Smaller bearing plate that fits between the face shells has as much bearing capacity because the bearing area is confined

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March 1, 2020

SE MASONRY INSIGHTS

written in conjunction with International Masonry Institute

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  - ☐ Grout strength
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web: masonry.forsei.com 1

Inefficient design = high cost & slow installation

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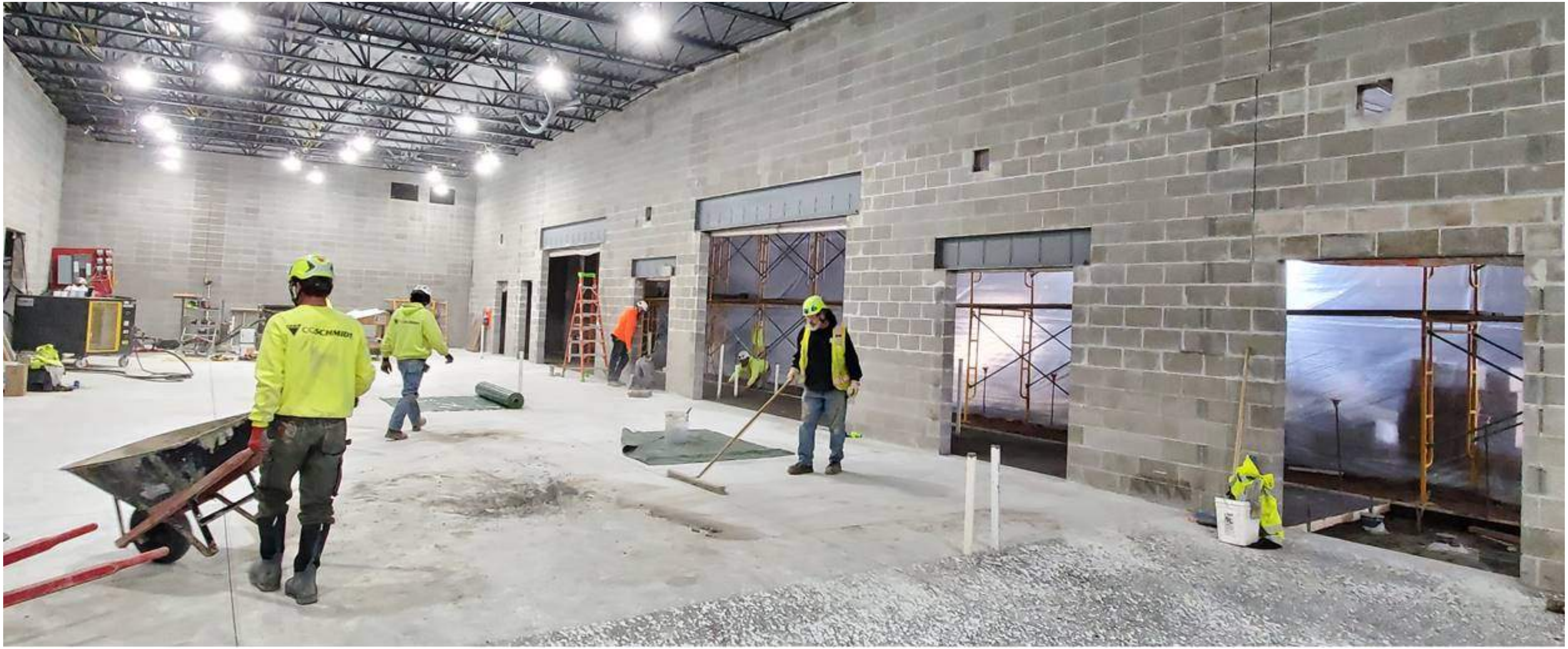
Redundant members - Masonry sufficient without steel



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Redundant members - Masonry sufficient without steel

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Redundant members - Masonry sufficient without steel

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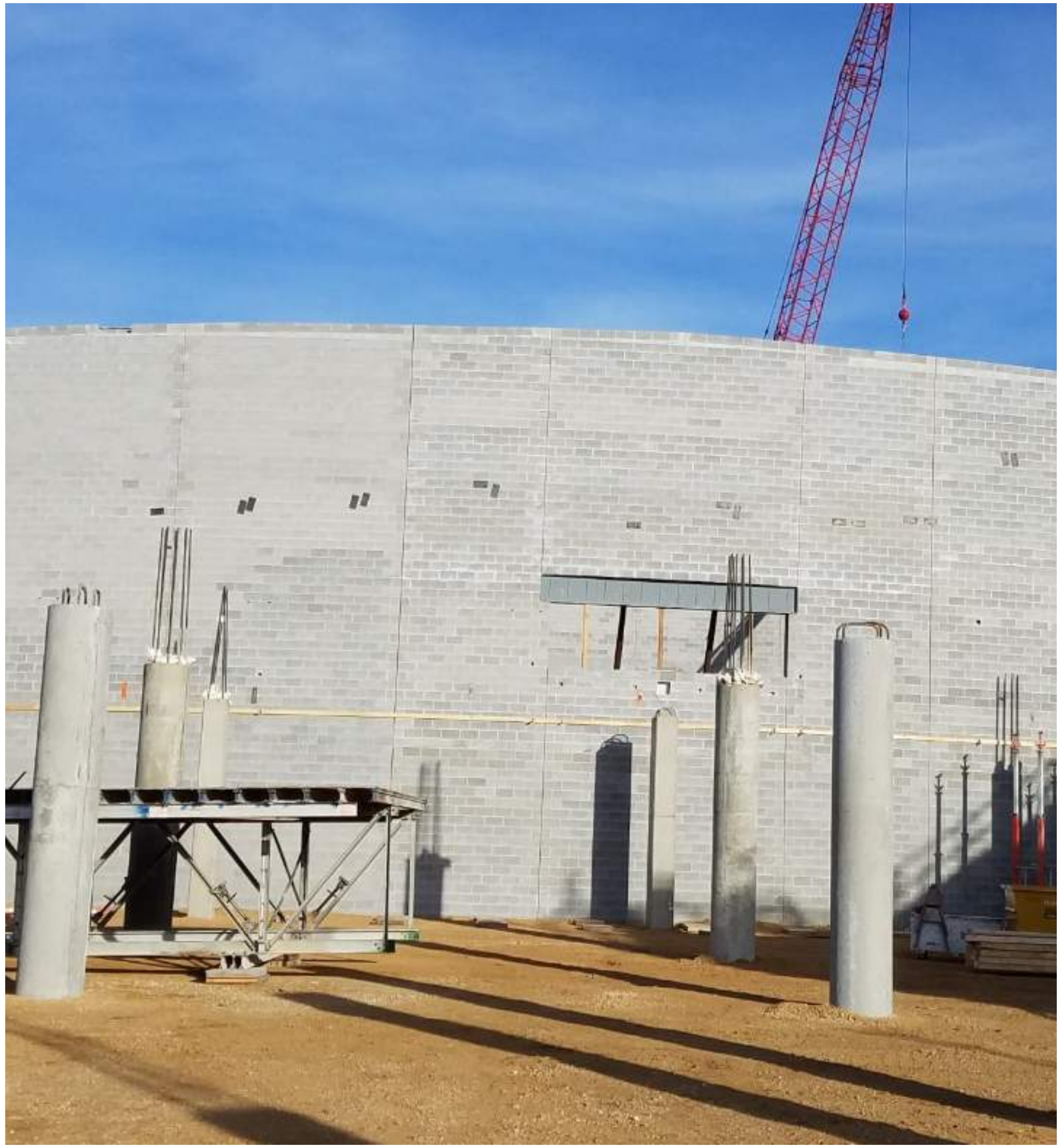
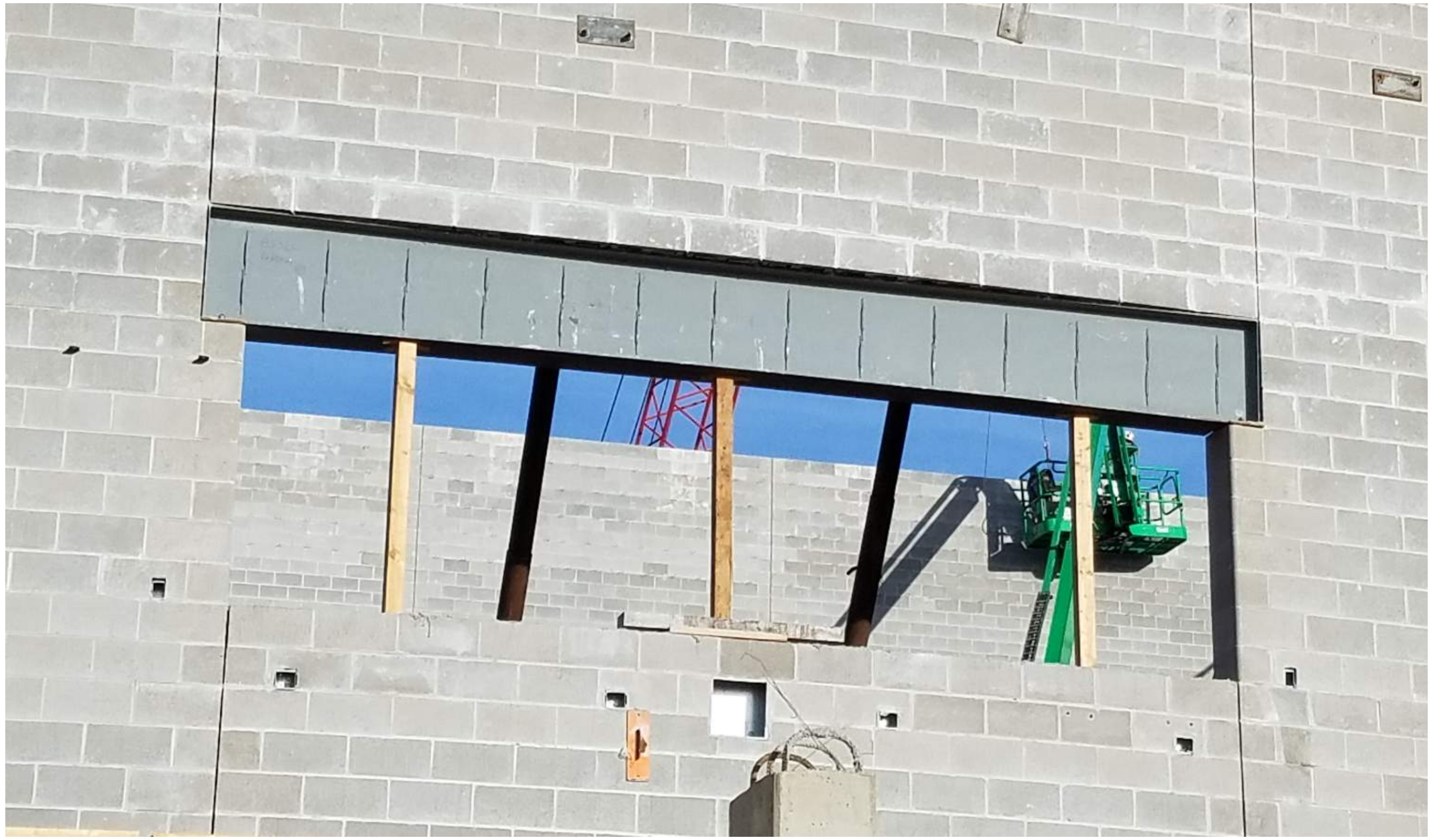
Redundant members - Masonry sufficient without steel



Steel Lintels —> CJs at Ends
—> Inefficient



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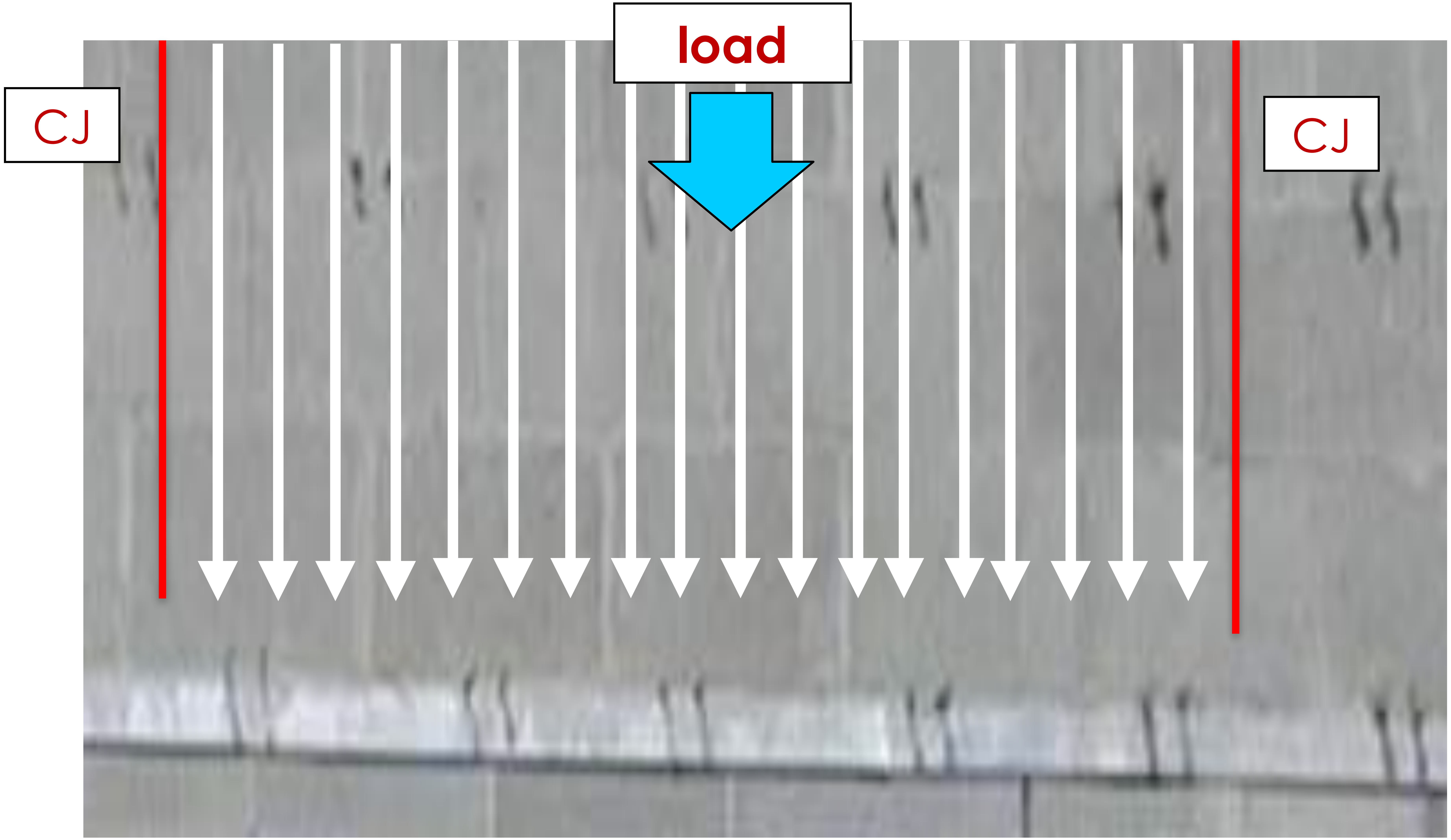
Steel Lintels —> CJs at Ends —> NO ARCHING—> Inefficient



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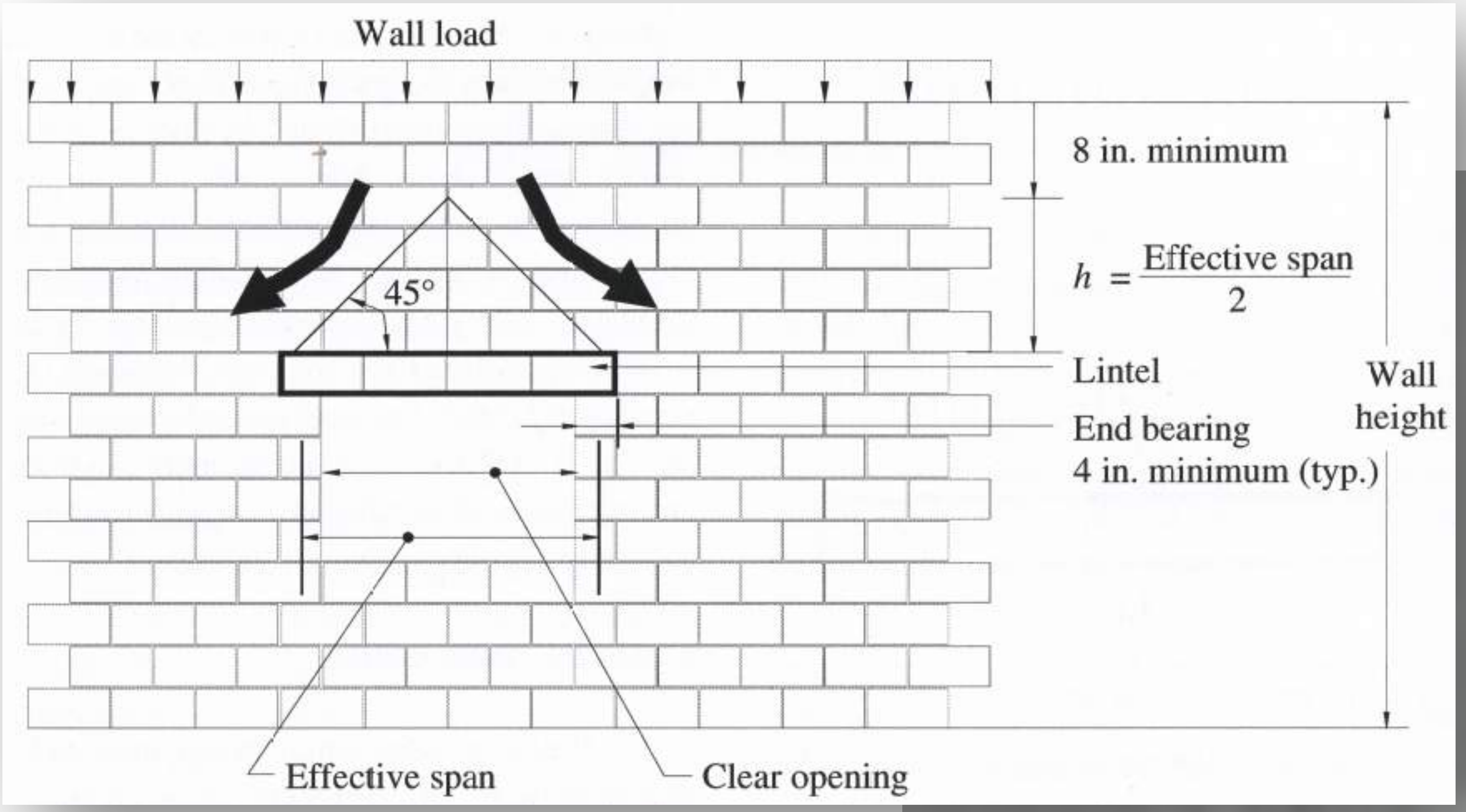
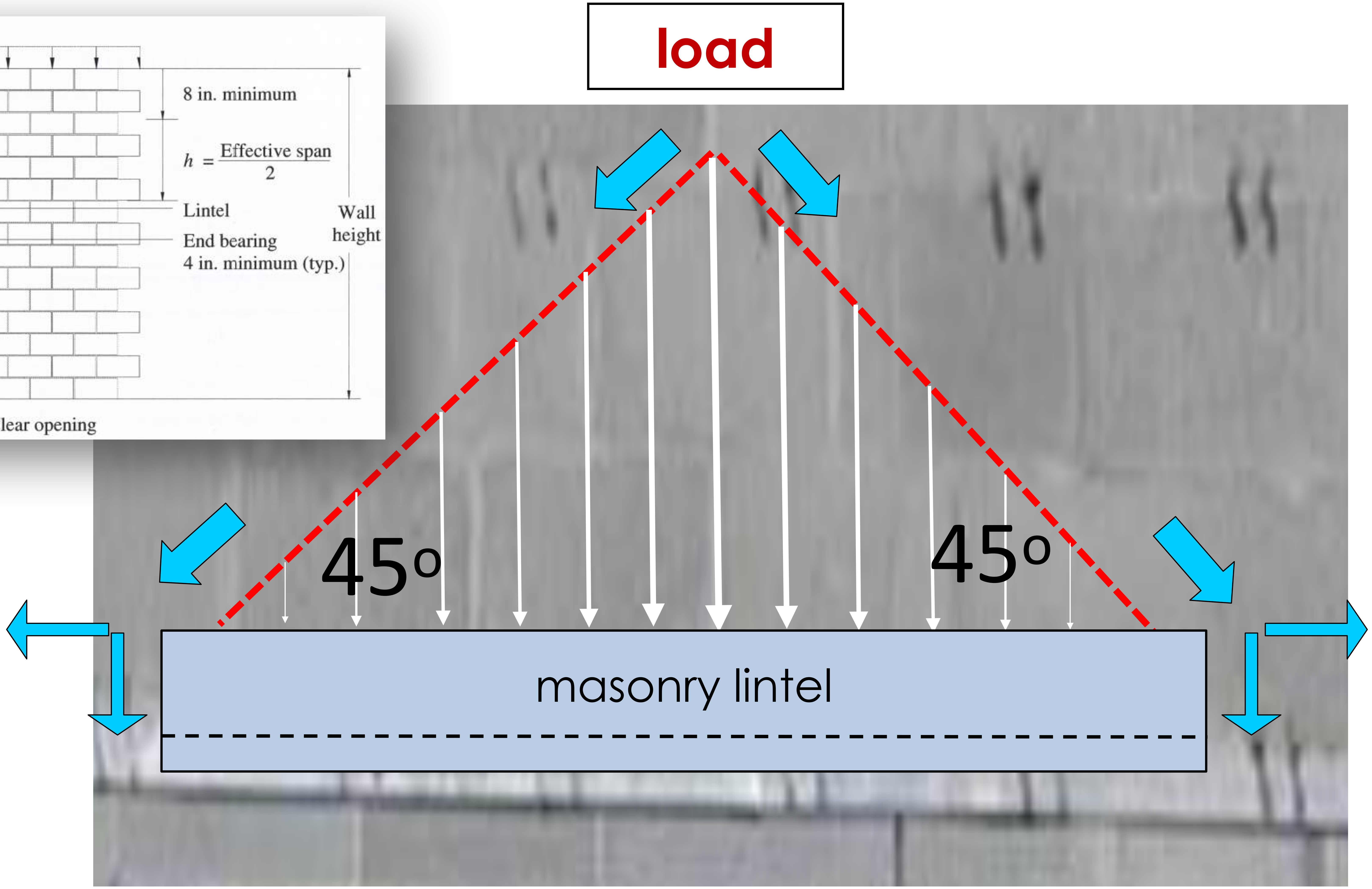
Integrated Lintels —> No CJs at Ends —> ARCHING—> EFFICIENT





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Complicated, Slow, Expensive & Less Robust Steel Lintels

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Complicated, Slow, Expensive & Less Robust Steel Lintels

Complicated, Slow, Expensive & Less Robust Steel Lintels

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Complicated, Slow, Expensive & Less Robust Steel Lintels

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Complicated, Slow, Expensive & Less Robust Steel Lintels

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Complicated, Expensive Bearing Plate at Masonry

$f'_c = 3000$psi

?? Why so different ??

$f'_m = 2800$psi

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Complicated, Expensive - Necessary??

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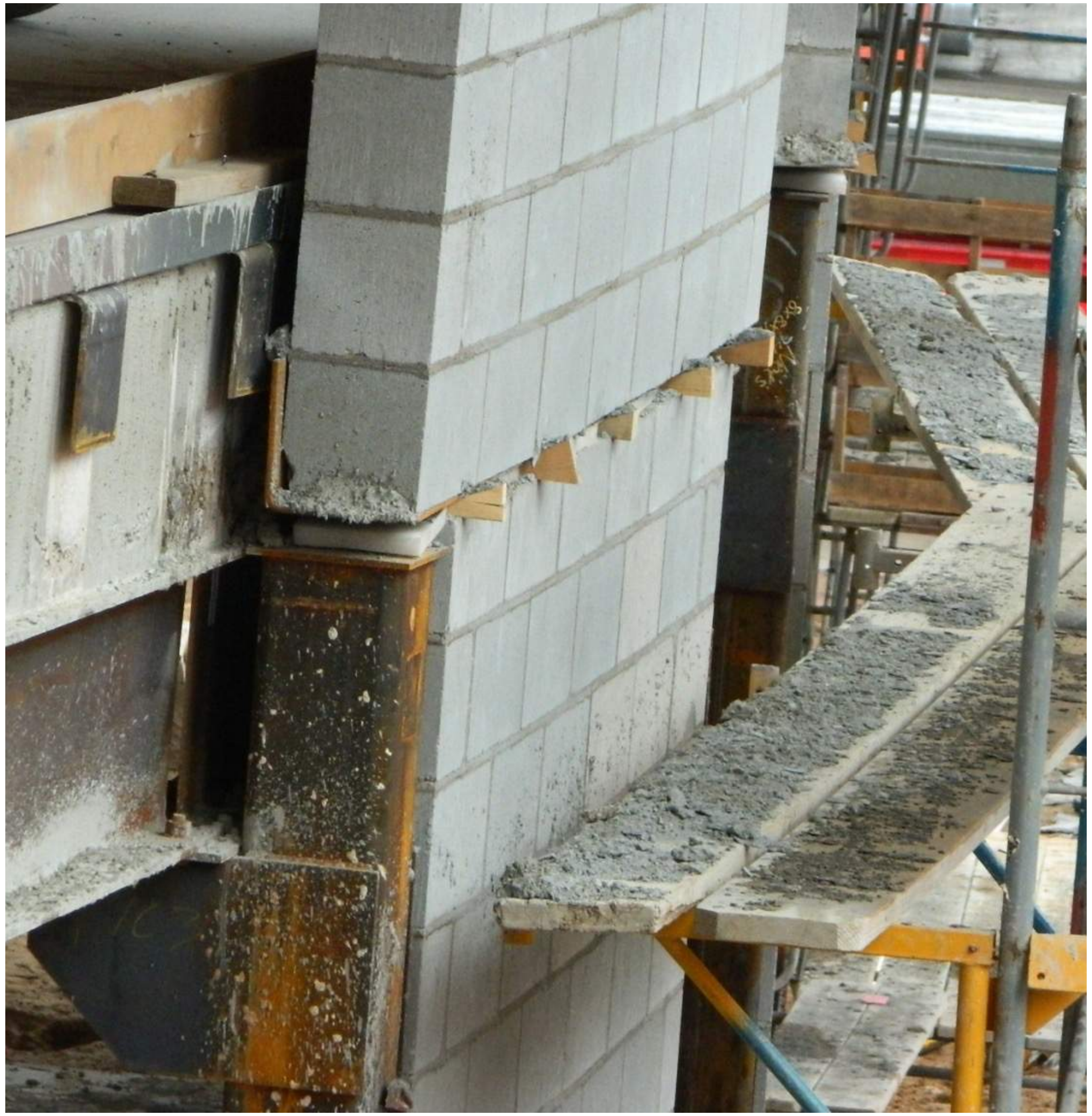
Complicated, Expensive - Necessary??

Different Material, Differential Movement —> Failures

Complicated, Expensive - Necessary??



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Redundant members - Masonry sufficient without steel

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Redundant members - Masonry sufficient without steel

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Redundant members - Masonry sufficient without steel

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Redundant members - Masonry sufficient without steel

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Redundant members - Masonry sufficient without steel

…and now these architectural masonry blocks are going to look a little weird

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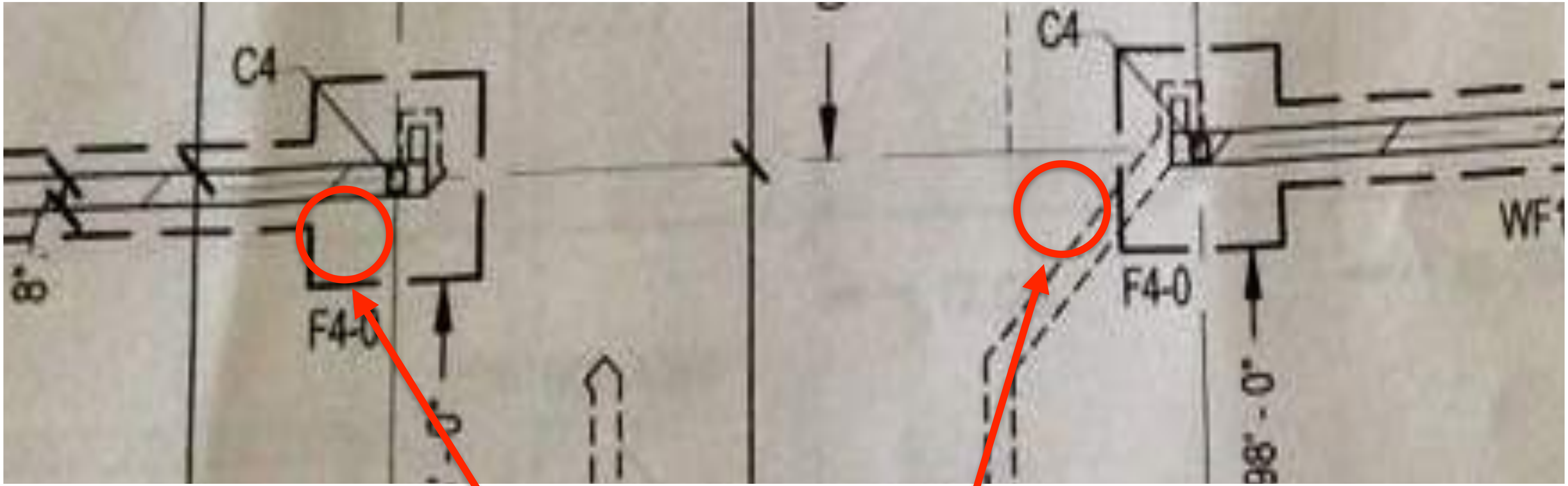
CASE STUDY - MASONRY/STEEL INTERFACES



WHY USE A DIFFERENT MATERIAL WITHIN A MASONRY WALL MORE THAN CAPABLE OF CARRYING THE ROOF LOAD?

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CASE STUDY - MASONRY/STEEL INTERFACES

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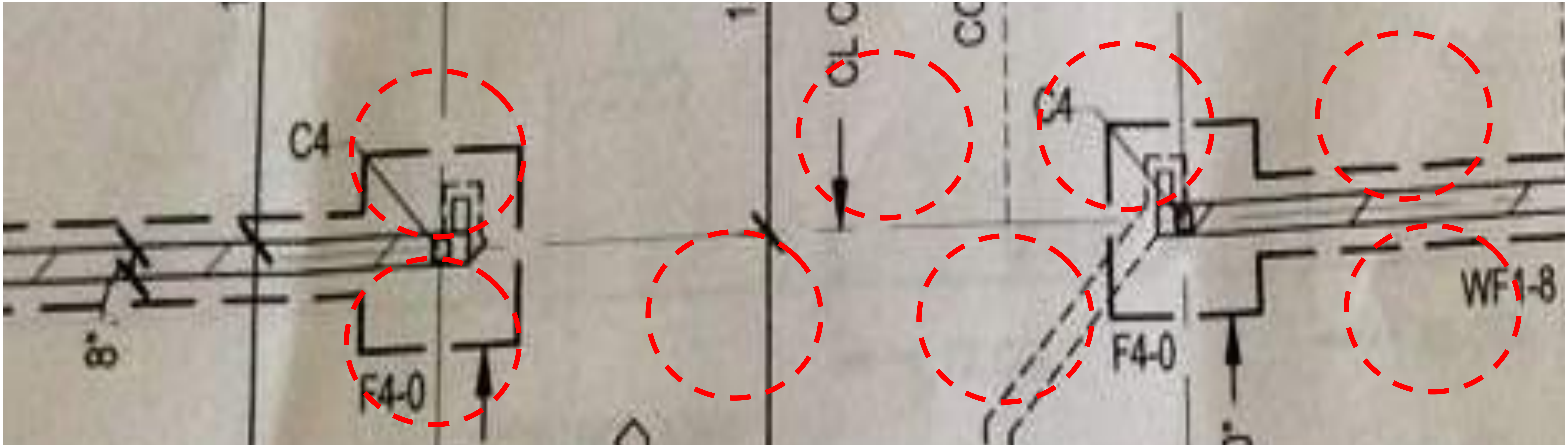
CASE STUDY - MASONRY/STEEL INTERFACES



MORE COST

- 46 total columns - extra steel
- 46 footing pads - extra concrete
- Extra cutting for masons

MASONRY PIER OPTION

- Add grout and reinforcing to end of wall
- Add bearing plate
- Masonry pier had capacity for 80k load
  - Each beam reaction was maybe 20k

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CASE STUDY: Utilizing Masonry Walls

Not necessarily a typical masonry building

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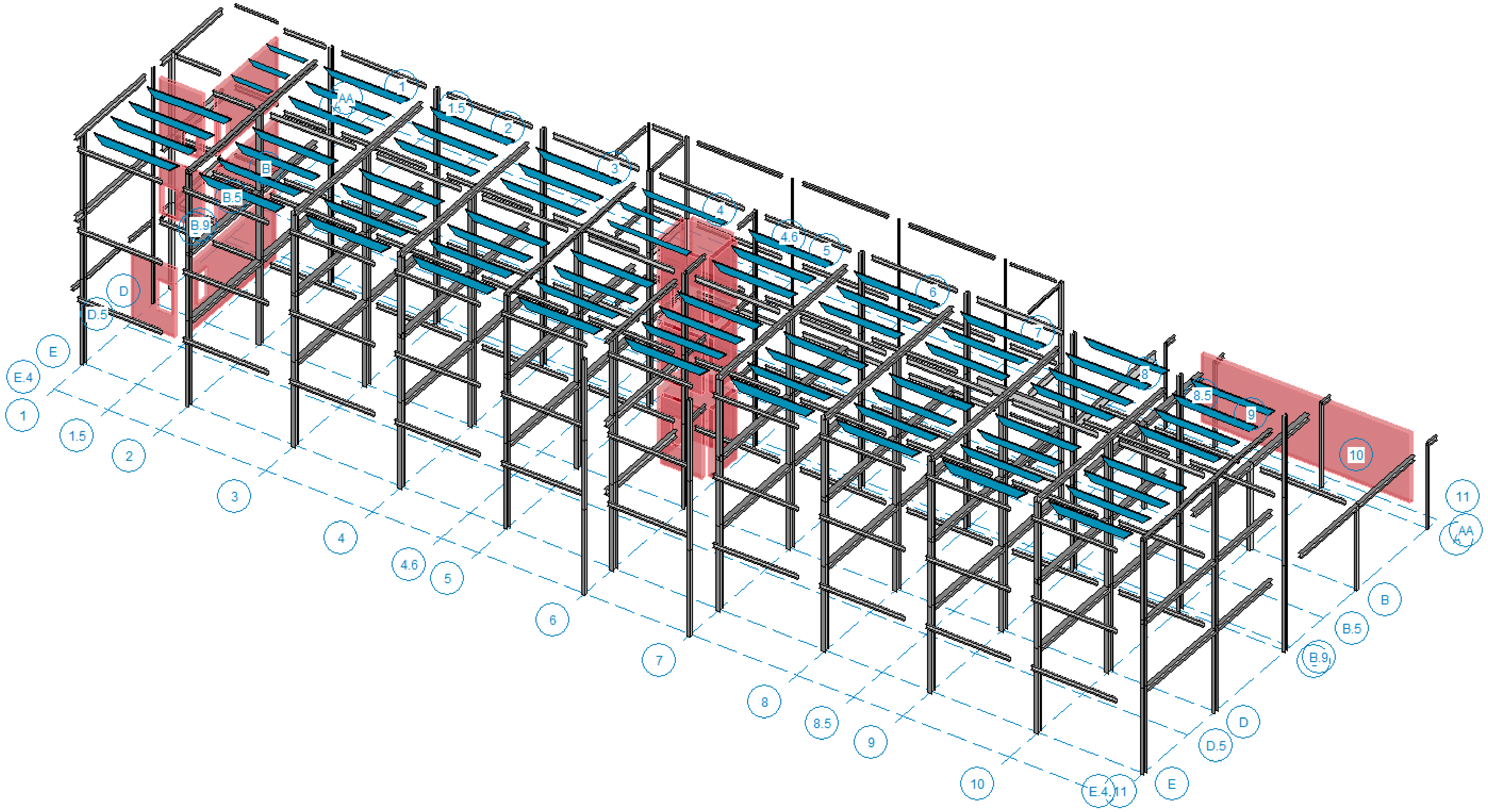
Key to masonry was rethinking lintel construction

Prefab lintels made construction faster/more efficient

Lintels/piers had rigid connections making lateral frames

Final design worked well with masonry wall or interconnected lintel/pier frames for structural gravity and lateral system

CASE STUDY: Utilizing Masonry Walls

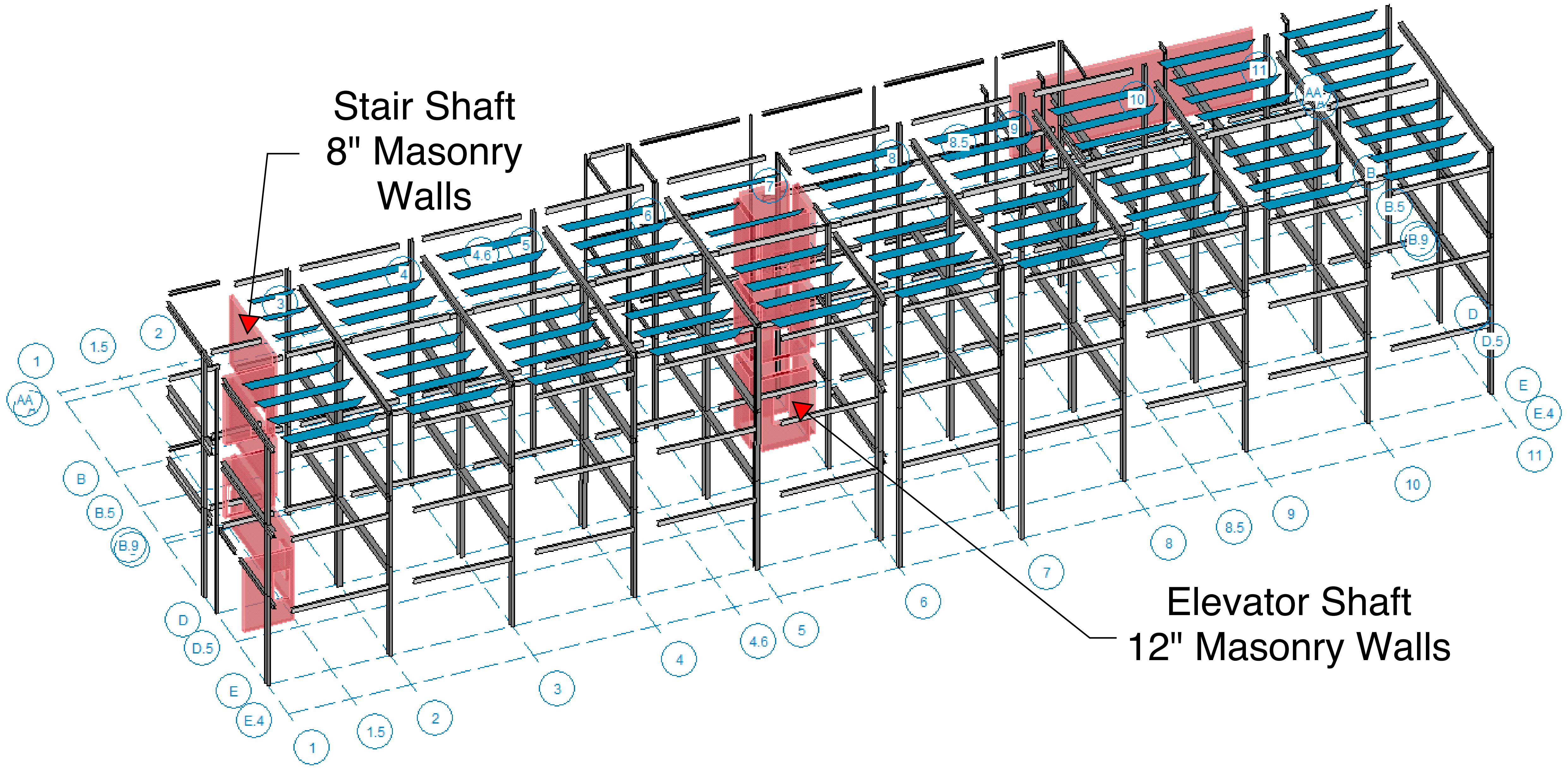


CASE STUDY: Utilizing Masonry Walls

Sample Project Structural System

<u>3 story structure</u>

- **<u>Masonry</u>** stair and elevator shaft walls
- **<u>Steel</u>** floor framing and columns

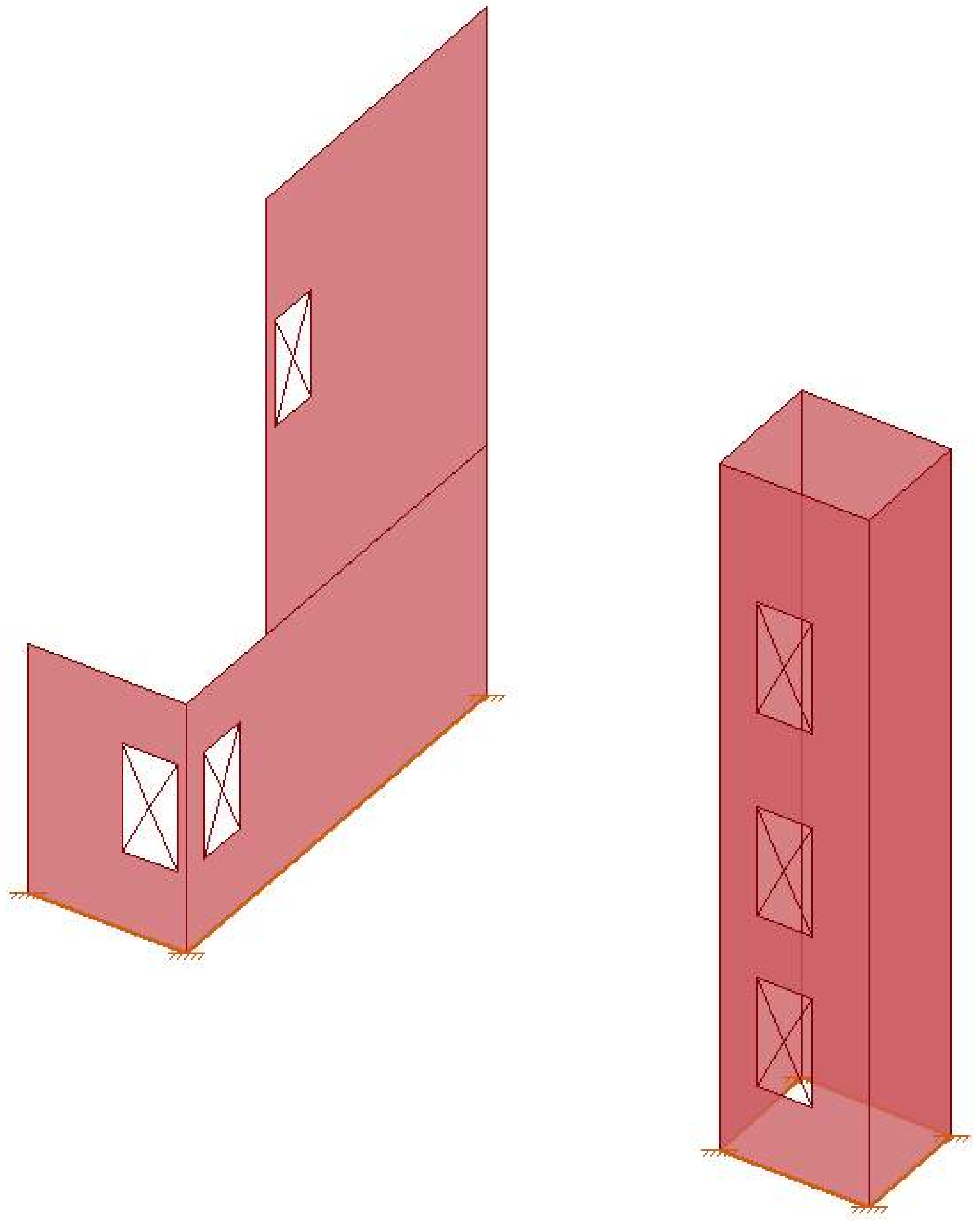


CASE STUDY: Utilizing Masonry Walls

Masonry System

Original **Masonry** System

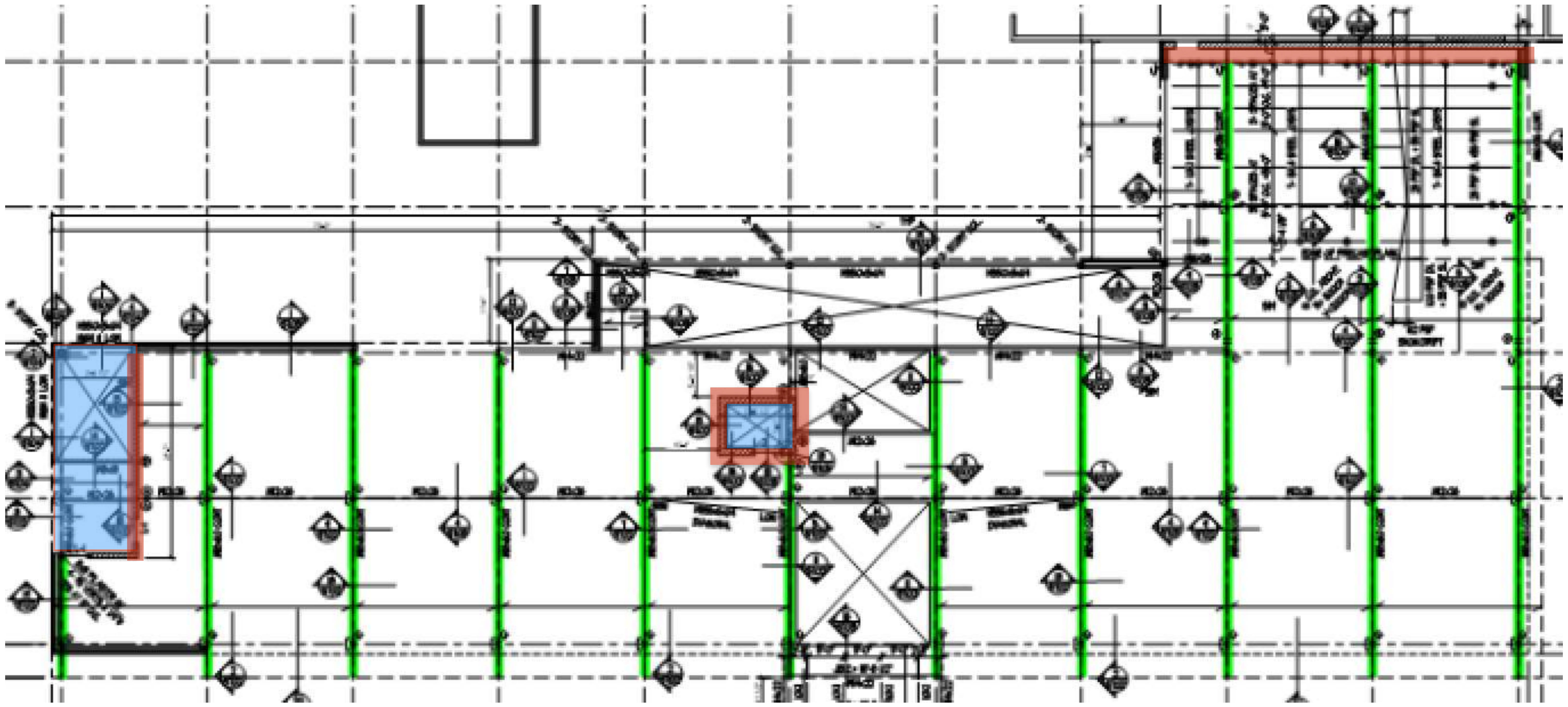
- Stairs: 8” masonry walls with #5@24” o.c. vertical reinforcement
- Elevators: 12” walls with #5@24” o.c. vertical reinforcement
- *f’m = 1750 psi*



CASE STUDY: Utilizing Masonry Walls

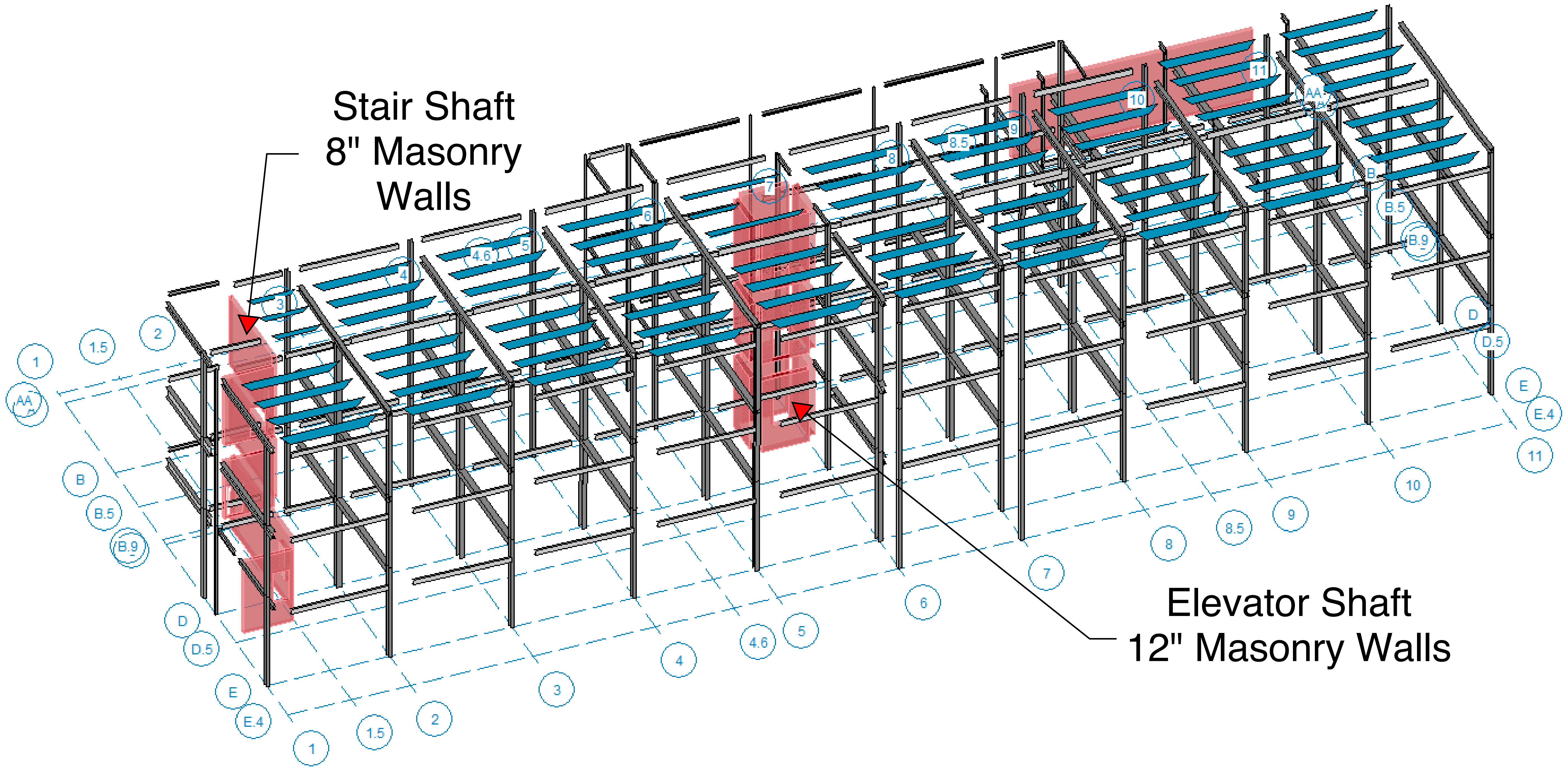
Steel System

- Steel beams, roof joists, and columns
- **11 Moment Frames** in the N-S direction



CASE STUDY: Utilizing Masonry Walls

Masonry Walls were ADEQUATE to resist full lateral loads

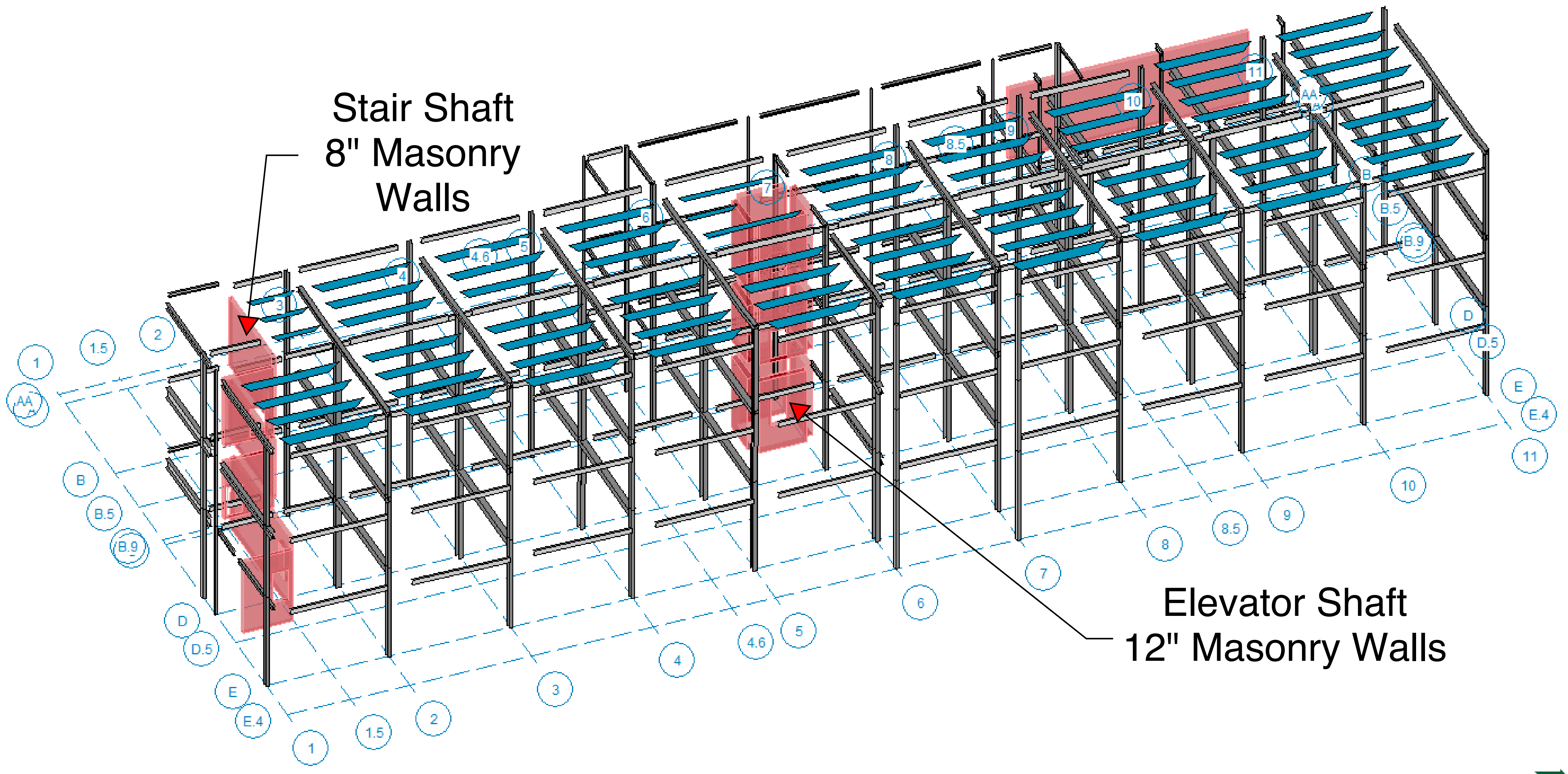


CASE STUDY: Utilizing Masonry Walls

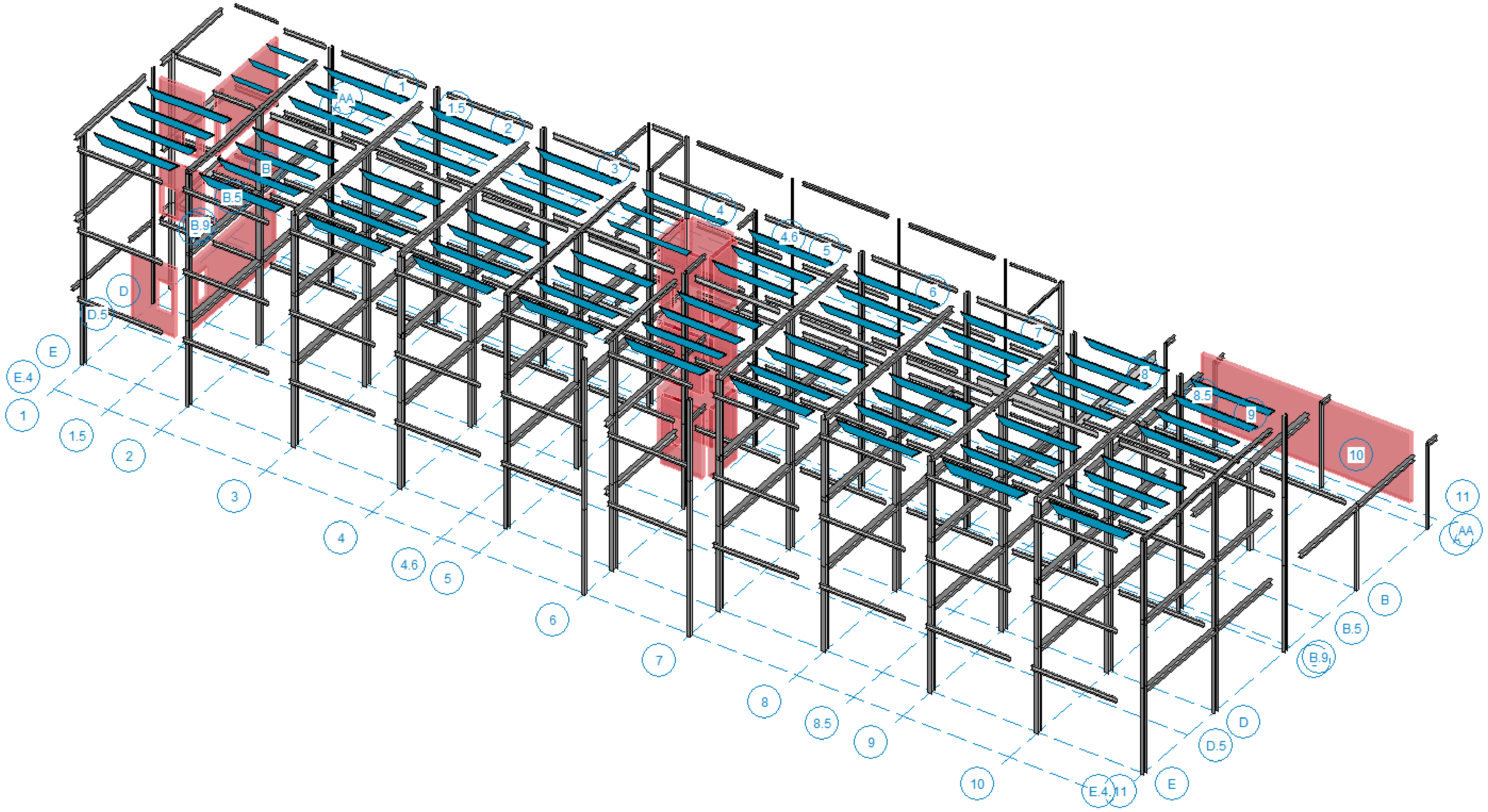
Masonry System

Revised **Masonry** System to resist all lateral

- Stairs: **SAME** 8” masonry walls with #5@24” o.c. vertical reinforcement
- Elevators: **SAME** 12” walls with #5@24” o.c. vertical reinforcement
- Added horizontal #5 @40 in o.c.
- ***f’m = 2500 psi***



Utilize Masonry Walls!!!!



structural engineering workflow…

Steel design

- start with typical sizes and strength
- need more strength?
    - use larger sizes
    - use higher strength

Concrete design

- start commonly available strength and typical size
- need more strength?
    - specify larger sizes
    - use higher strength

Masonry design

- ~~start with MINIMUM strength?~~
- ~~need more strength?~~
    - ~~use larger blocks?~~
    - ~~that's it????~~

wrong way to do it!!

structural engineering workflow…

the right way…

Steel design

- start with typical sizes and strength
- need more strength?
  - use larger sizes
  - use higher strength
- Available as "product"
- Strength is uniform throughout industry
- Easy to modify sizes, extreme to vary strength

Concrete design

- start commonly available strength and typical size
- need more strength?
  - specify larger sizes
  - use higher strength
- Not a "product"
- Strength varies with normal range
- Easy to modify sizes and strength

Masonry design

- start with commonly available strength and typical sizes
- need more strength?
  - use larger blocks
  - use higher strength
- Available as "product"
- Strength varies with normal range
- Easy to modify sizes and to vary strength

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Masonry Checklist

MASONRY INSIGHTS

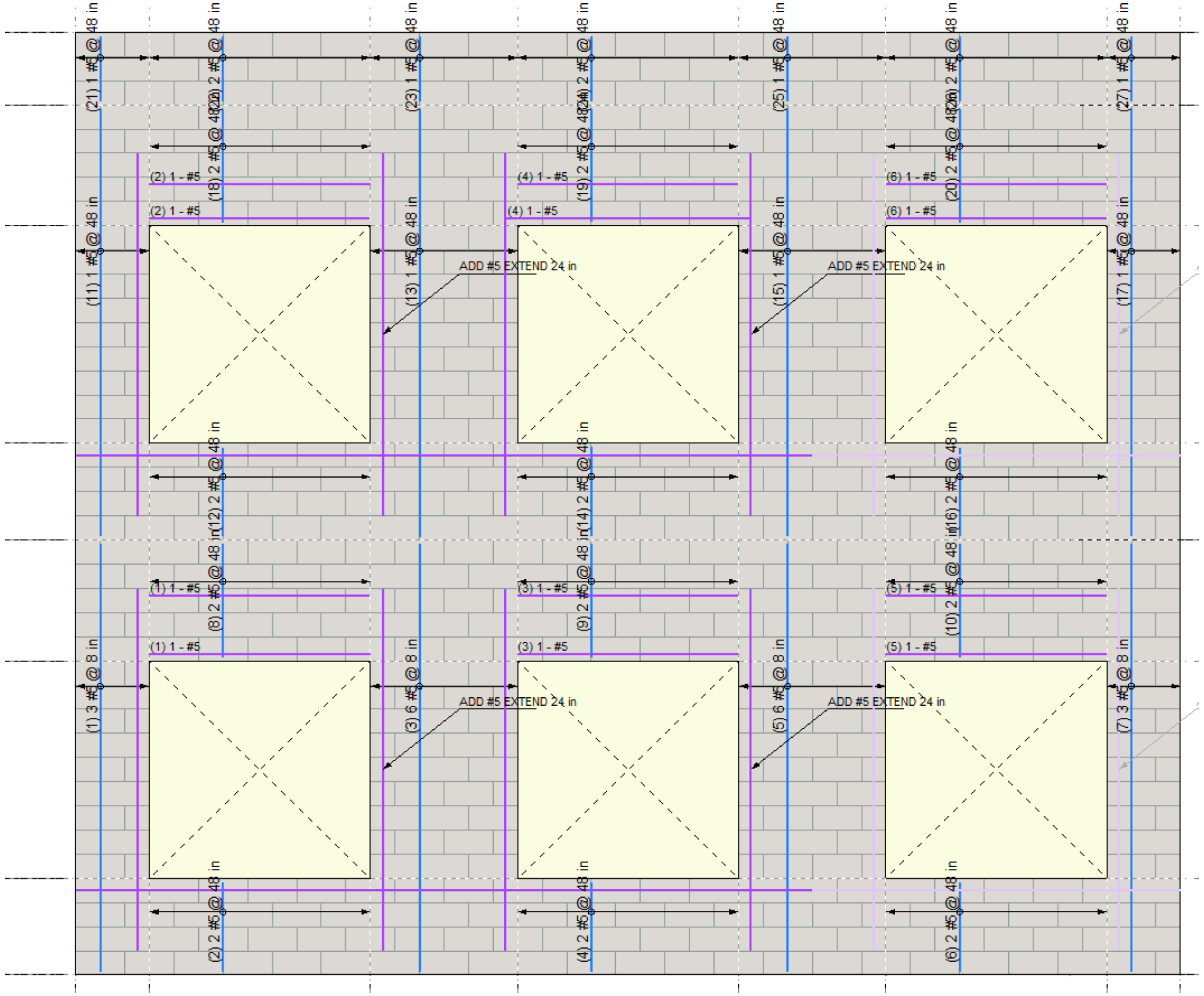
written in conjunction with International Masonry Institute

Masonry checklist: reviewing structural plans

- ☐ f'm (masonry assembly strength) is 2,000 psi or greater
    - ☐ ideally in Midwest it should be 2,500 psi
    - ☐ strengths between 2,000 to 4,000 psi are permitted in current codes[1]
- ☐ check that all components of masonry are specified
    - ☐ block strength (check www.forsei.com/cmudata to verify based on project location)
    - ☐ mortar type (mortar strength need not be listed)
        - ☐ recommend Type S for structural walls
        - ☐ recommend Type N for non-structural walls (partition walls)
    - ☐ grout strength
        - ☐ should be at least 2,000 psi, and equal to or greater than f'm
- ☐ check that control joints (CJ)'s are located on plans
    - ☐ CJ's in reinforced structural walls
        - ☐ at common wall locations [2]: generally at 25 ft spacing or less, change of wall height, building corners
        - ☐ at a distance (recommend 2 ft) away from opening edges[3], not at opening edges
    - ☐ CJ's in unreinforced non-structural masonry walls
        - ☐ at common wall locations [2]
        - ☐ at openings edges [4]
    - ☐ CJ not needed when sufficient horizontal reinforcement [5] is provided

Conclusion - Key Points

- F'm = 2,500 – 3,000 psi
- Software helps, FEA needed as well
- Use masonry lintels vs steel lintels
- CJ's away from openings
  - increased capacity
- Use capacity of masonry
  - bearing and shear
- Many partition walls can be un-reinforced
- **Up to 30% savings over in-efficient designs**



Key points

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Key points regarding masonry as an excellent choice for structural systems

Masonry has the opportunity to be used more, and in better ways in structural engineering:

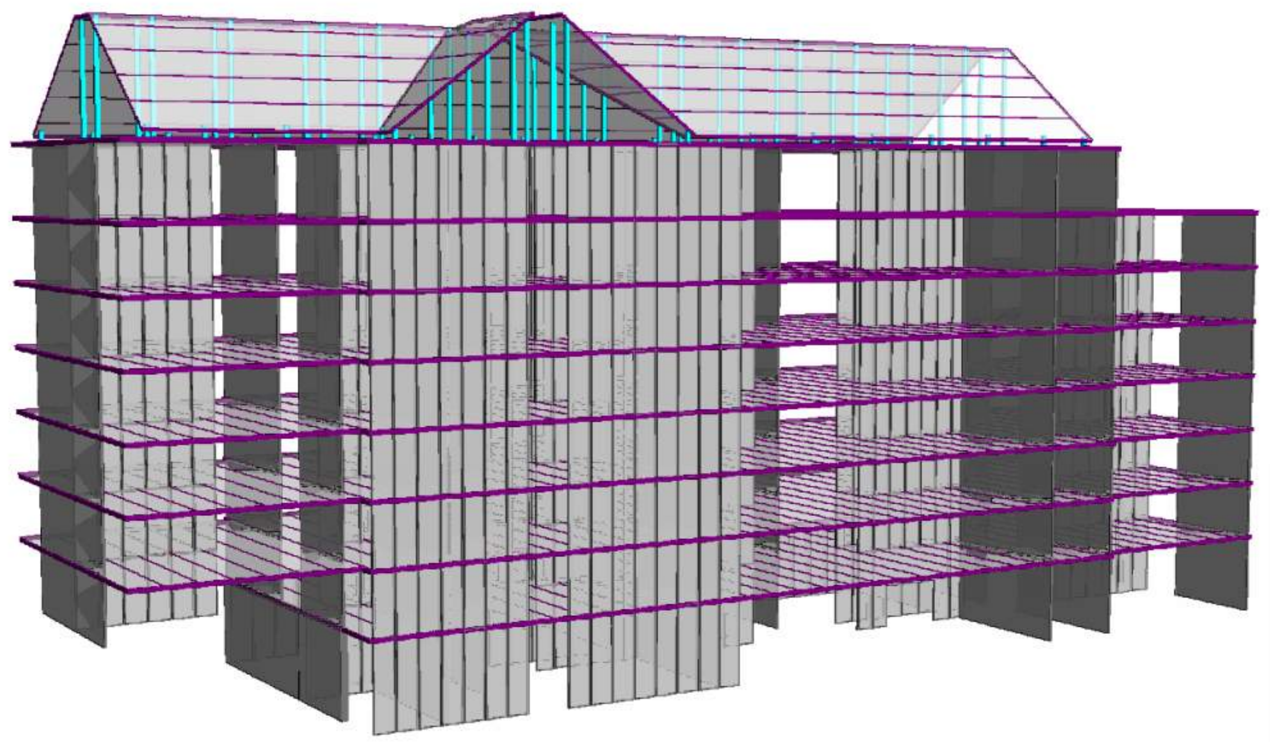
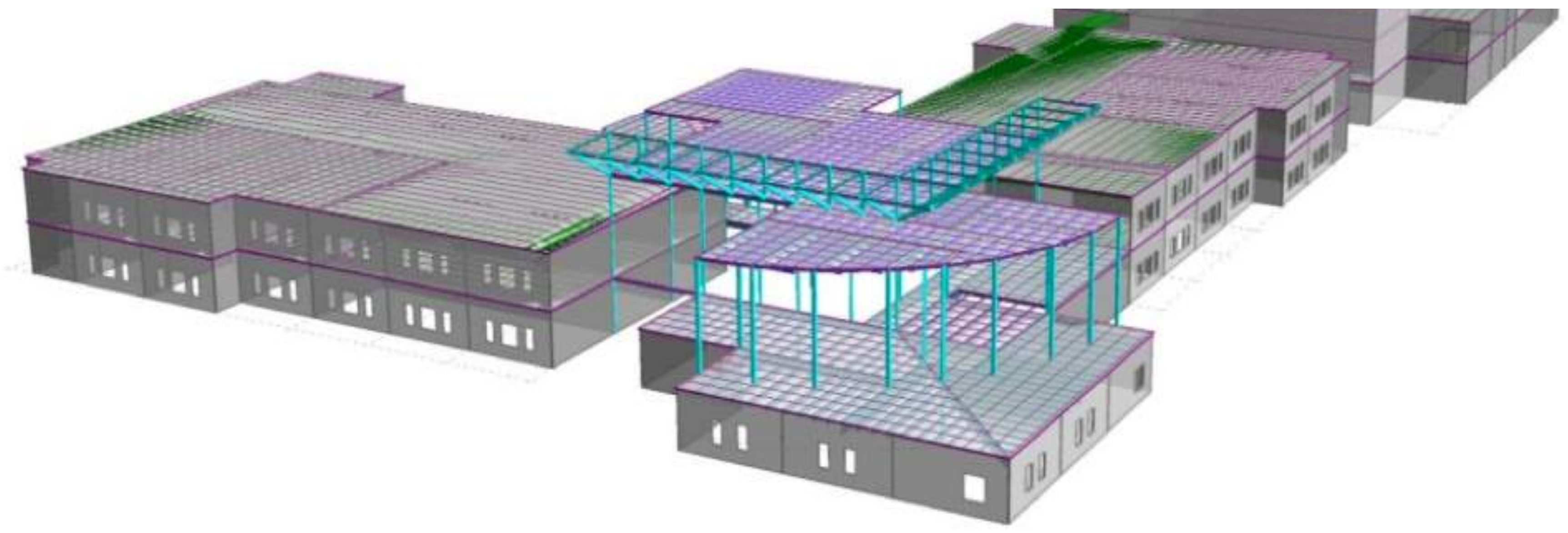
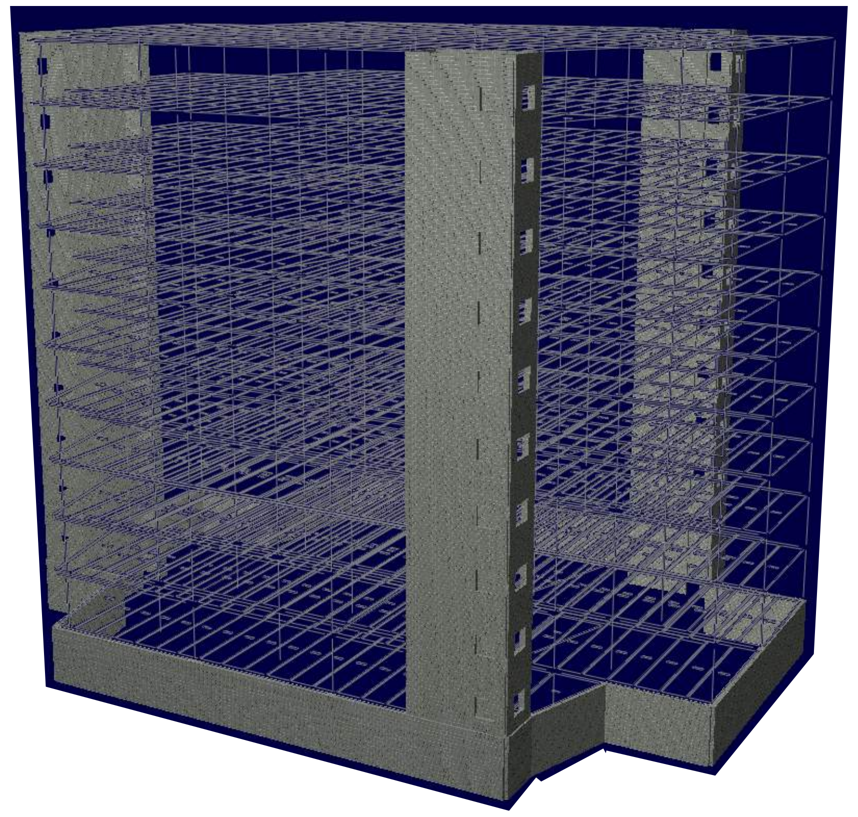
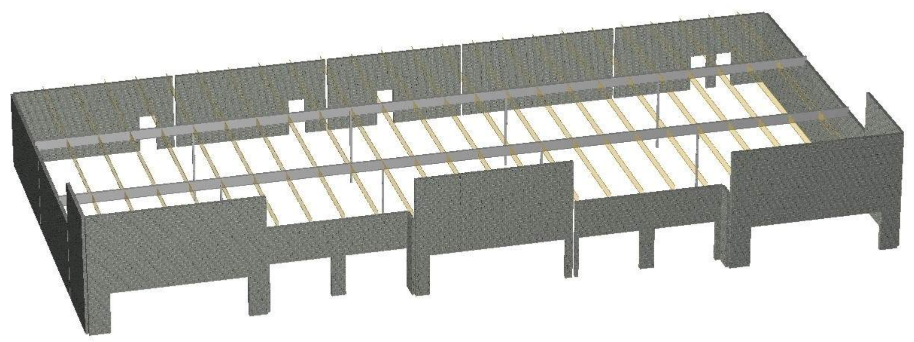
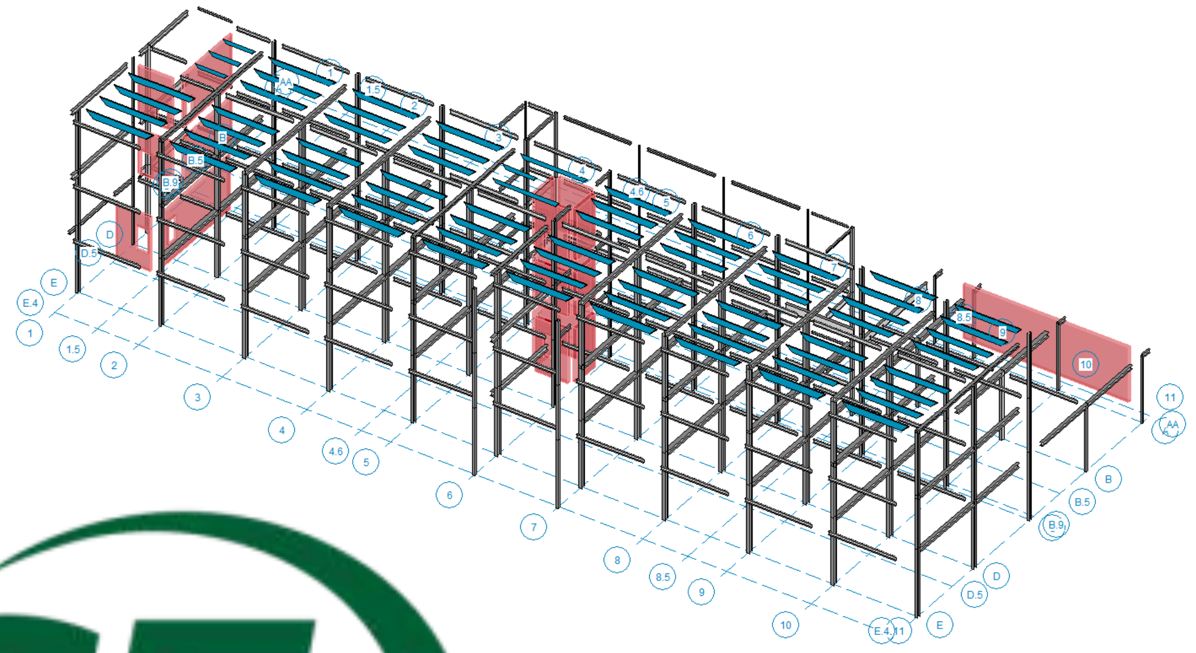
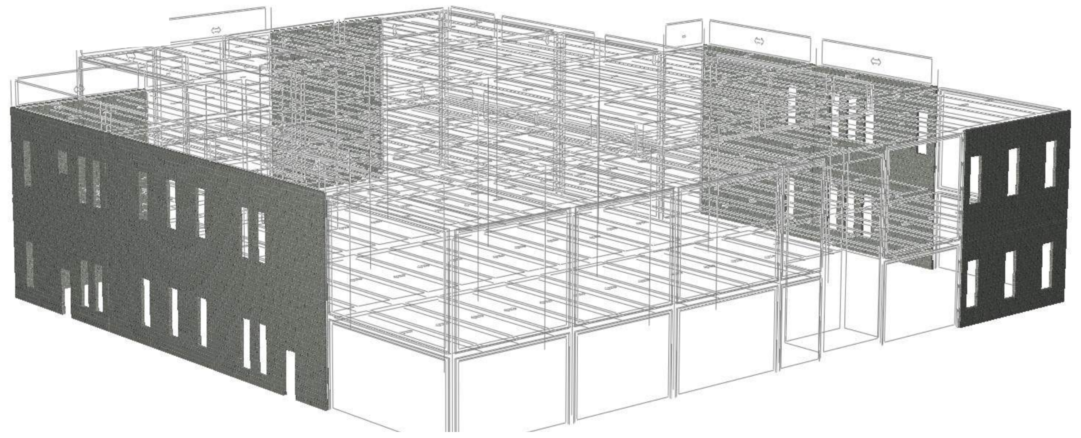
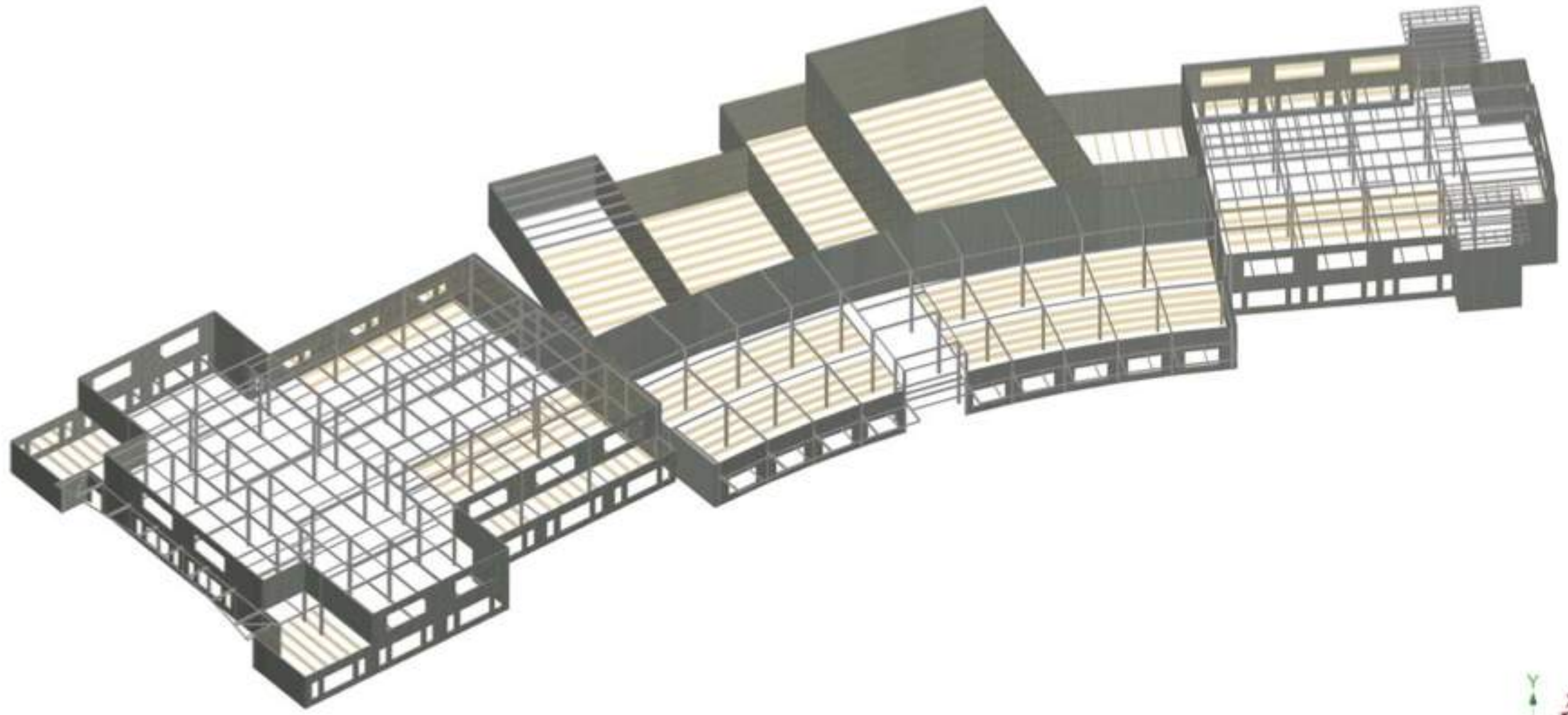
1. Increase the understanding of **actual masonry design strength (f'm)**, designers should be using a default of 2500 psi (NOT 1500 psi) - see the following website: www.FORSEI.com/cmudata

   A. Designs strengths should start at **f'm= 2,500 psi**, verify with test results from manufacturer

   - Design strengths can be specified higher, up to 4,000 psi
   - more efficient design w/ higher f'm in each of the following areas:
     - walls (bearing walls, non-bearing walls, shear walls)
     - lintels (when designed as masonry)
     - column/pilasters
     - lap lengths, much shorter
     - connections to masonry (bearing plates, embed plates and post-installed anchors)

2. Create an awareness of the **availability of masonry design software**
   - many engineers are still using spreadsheets for masonry design
   - much more sophisticated tools such as finite element analysis software, gives engineers the ability to solve complex analysis problems and helps create an efficient solution

3. Be aware **engineers must locate CJ for structural masonry walls**. Check that control joints (CJ)'s are located on plans:
   - CJ's in unreinforced masonry walls, regularly in walls, corners, edge of openings, etc.
     - at common wall locations, per Figure 1 per NCMA TEK 10-2C (2010)
     - at openings per NCMA TEK 10-2C (2010), Figure 2a or Figure 2b (page 3)
   - **CJ's in reinforced structural walls, NOT at openings**
     - at common wall locations, per NCMA TEK 10-2C (2010) or TEK 10-3
     - not at opening edges per NCMA TEK 10-2C (2010), Figure 2c or Figure 2d (page 3)

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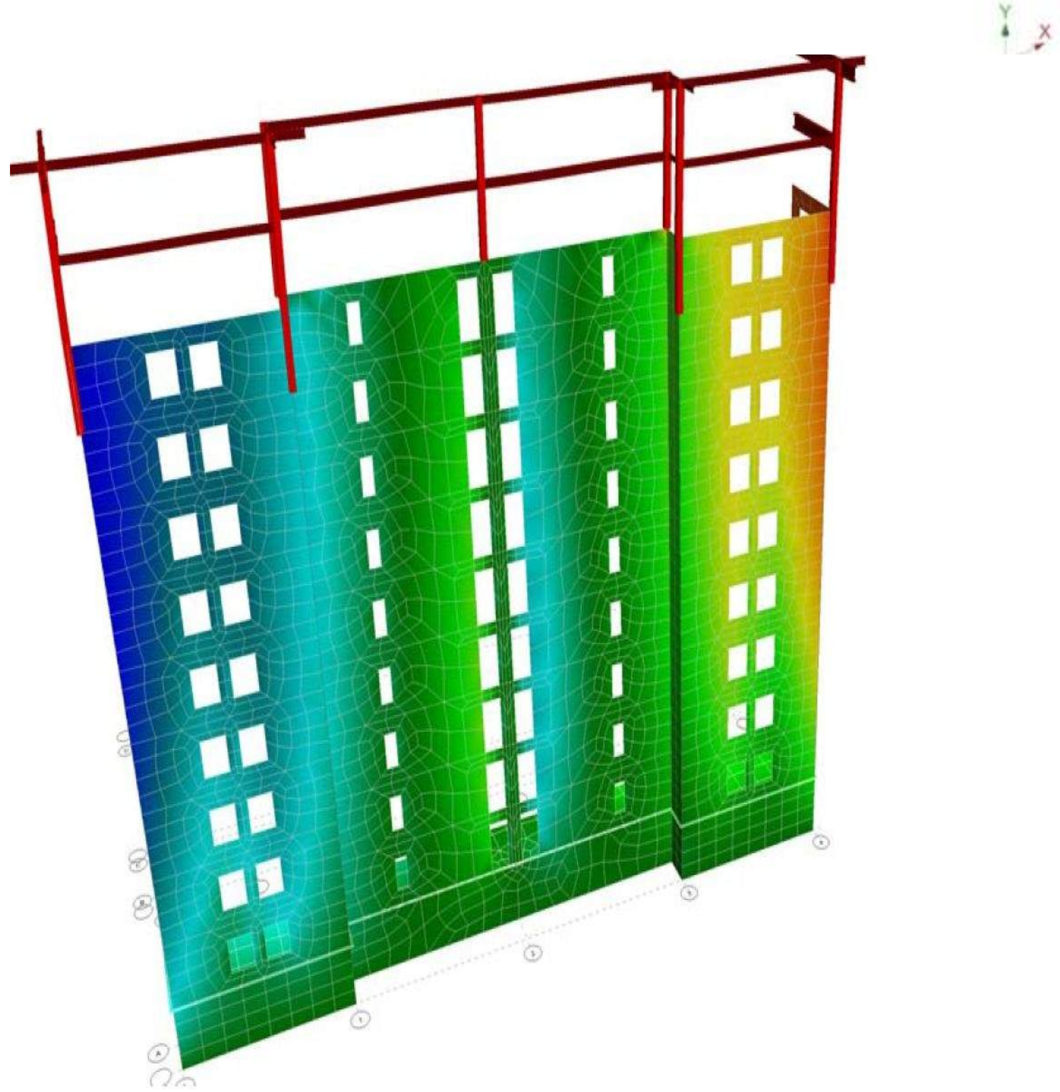
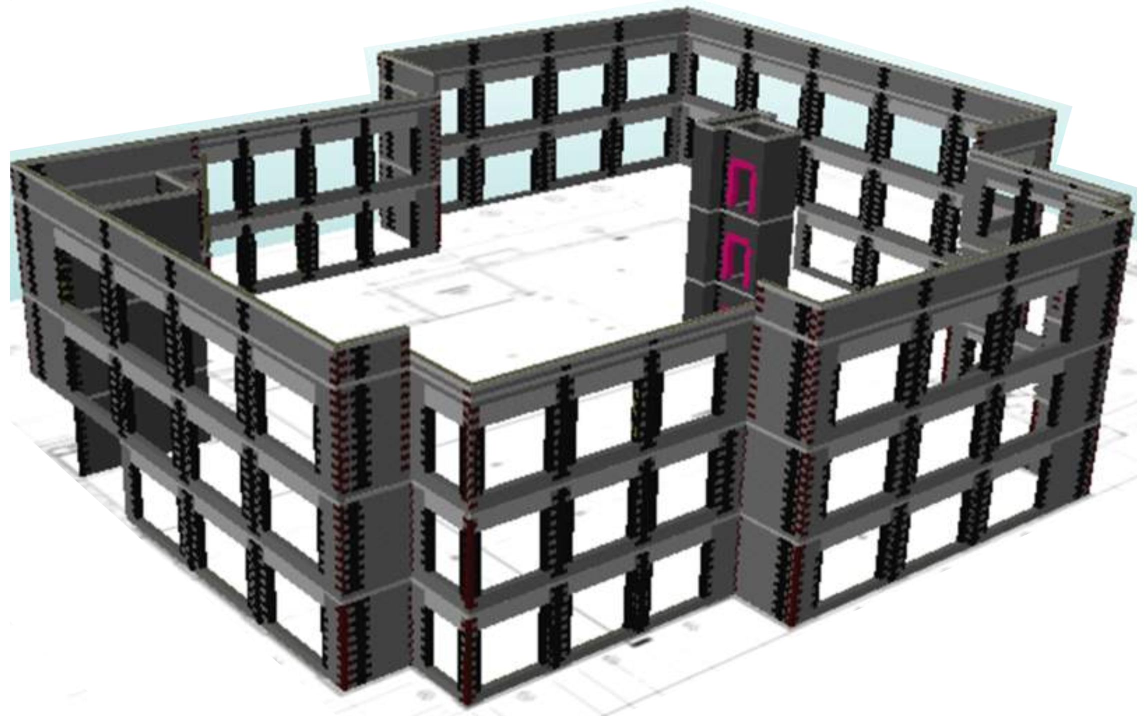
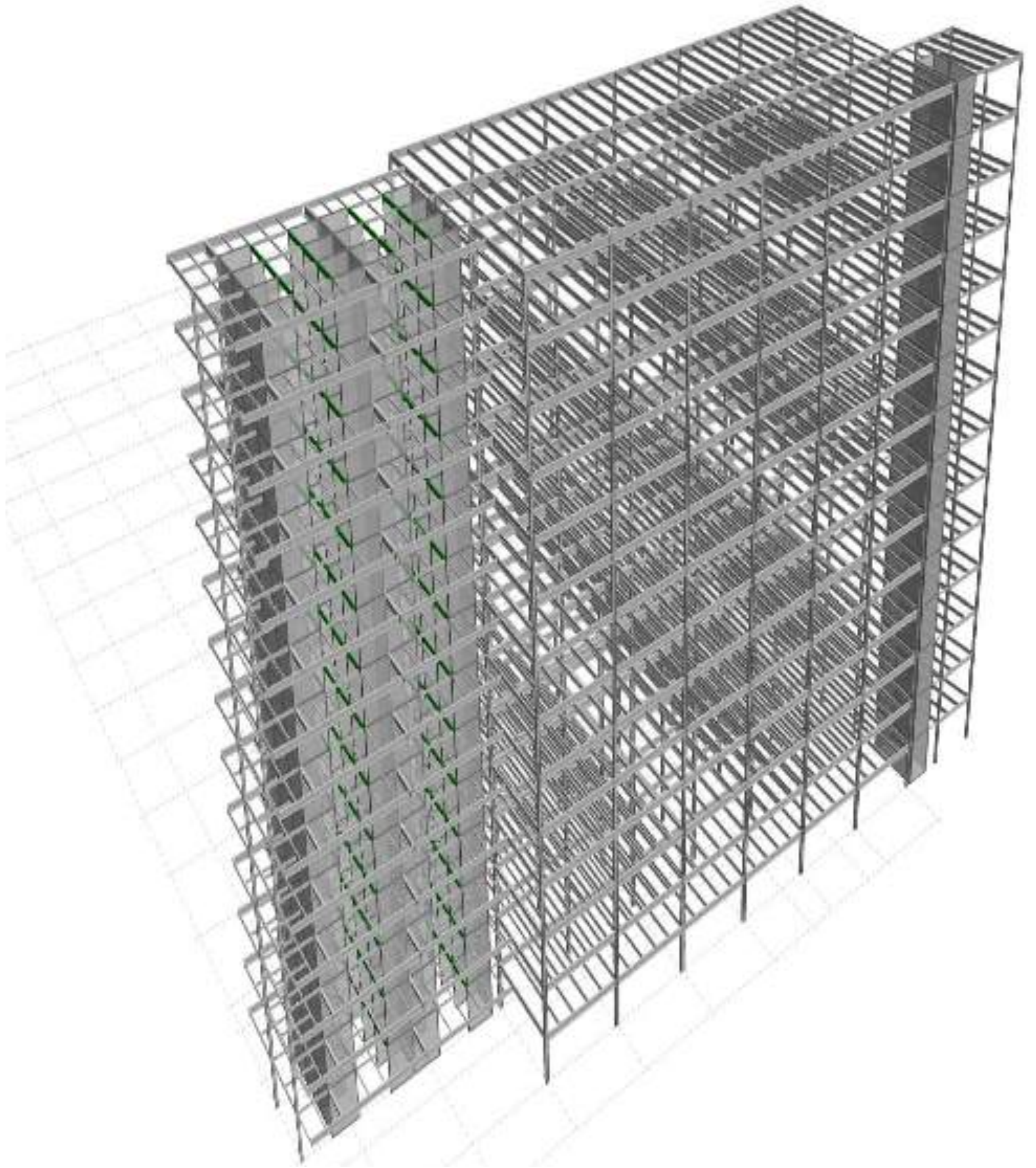

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Questions

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Additional slides…

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Where to Use Structural Masonry?

Where to use Structural Masonry?	BUILDING SYSTEMS				
	WOOD	COLD-FORMED STEEL	STEEL	CONCRETE /PT CONC	PRECAST
FoundationWalls	✓✓	✓✓✓	✓✓✓	✓	✓
Basement Walls	✓✓	✓✓	✓✓	✓	✓
Shear/Shaft Walls	✓✓✓	✓✓✓	✓✓✓ HYBRID	✓✓ HYBRID	✓
Exterior Bearing Walls	✓	✓	✓✓ HYBRID		✓✓✓
Interior Bearing Walls	✓	✓	✓✓		✓✓✓
Interior Partition Walls			✓	✓✓✓	✓✓✓

structural masonry design
software

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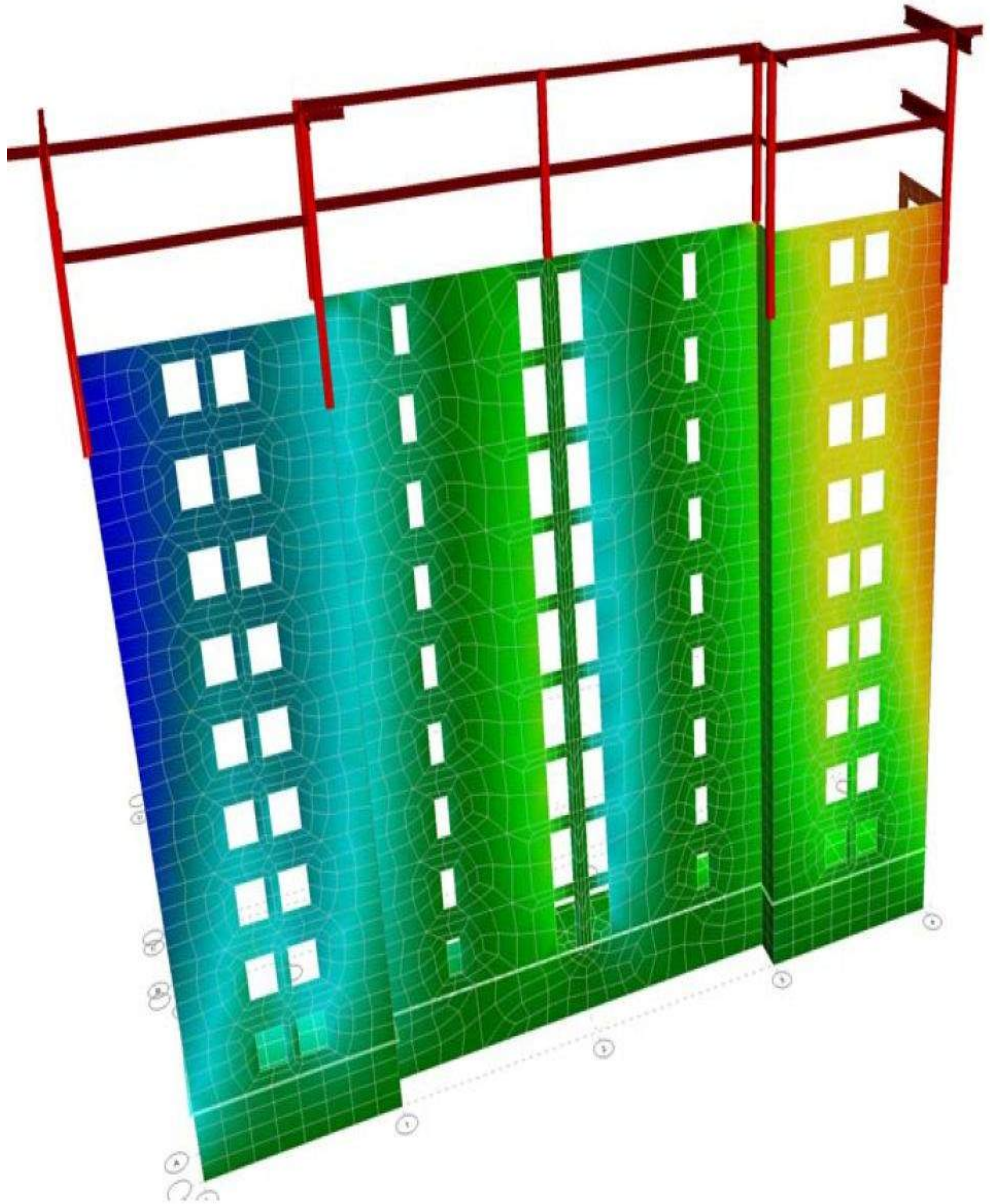
Masonry Software Comments

- **Finite Element Analysis (FEA) identifies true wall behavior**
  - more *accurate* analysis
  - more *accurate* design
    - reinforcement where you need it
  - save design time
  - better use of materials
  - saves owners material cost
    - more **economical** design



summary - component design options

PROGRAM	Material options	ASD or SD	walls bending	walls shear	lintels	parapets	multi-story
IMI Partition Wall v2	yes	ASD	yes				
NCMA SMDS	yes	both	yes	yes	yes		
IES QuickWall	yes	both	yes	yes	yes	yes	
TEDDS	yes	both	yes	yes	yes	yes	
ENERCALC	yes	both	yes	yes	yes	yes	2-story

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summary - FEA design options

PROGRAM	Material options	ASD or SD	walls bending	walls shear	lintels	parapets	multi-story	hybrid
RAM Masonry / RAM Elements	yes	both	yes, with openings		yes	yes	yes	direct
RISA Floor / RISA 3D	yes	both	yes, with openings		yes	yes	yes	manual
ETABS	yes	SD	yes, with openings		yes	yes	yes	

Conclusions – Masonry Design with FEA

- Types of Masonry handled by FEA tools
  - Unreinforced
  - Reinforced
  - Hybrid
  - Perforated
  - Wall groups

- FEA Design tools
  - RAM Elements
  - RISA 3D
  - ETABS
- Component design tools, with links to FEA
  - QuickMasonry, with link to VisualShearwall
  - TEDDS, with link to TEKLA Structural Designer

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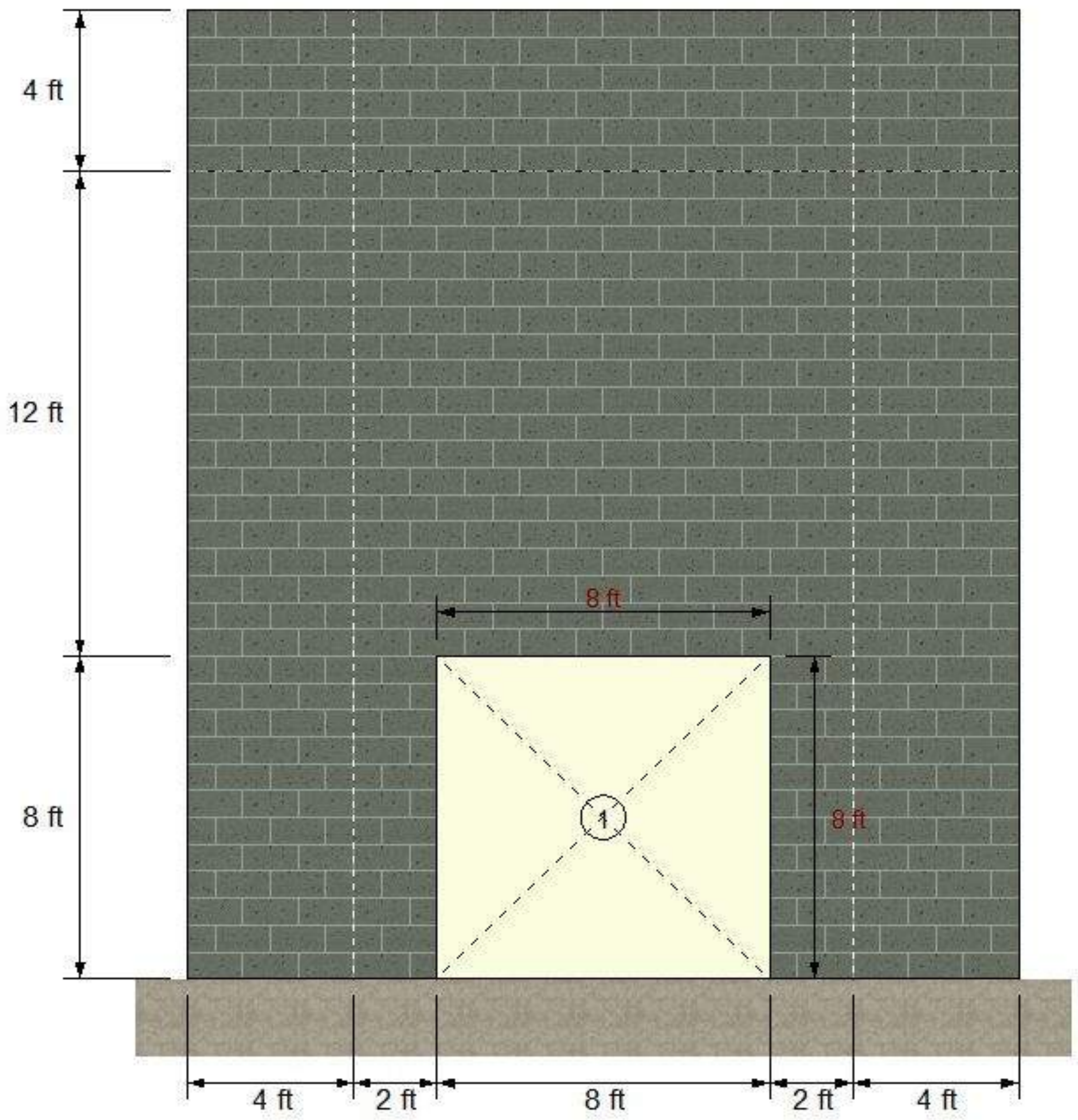
Quick Example

masonry design with component design software and FEA

Quick Example



20ft clear height
4ft parapet
8ft x 8ft opening

1.0 klf DL at 2in eccen
1.4 klf LL at 2in eccen

20 psf wind pressure

Quick Example

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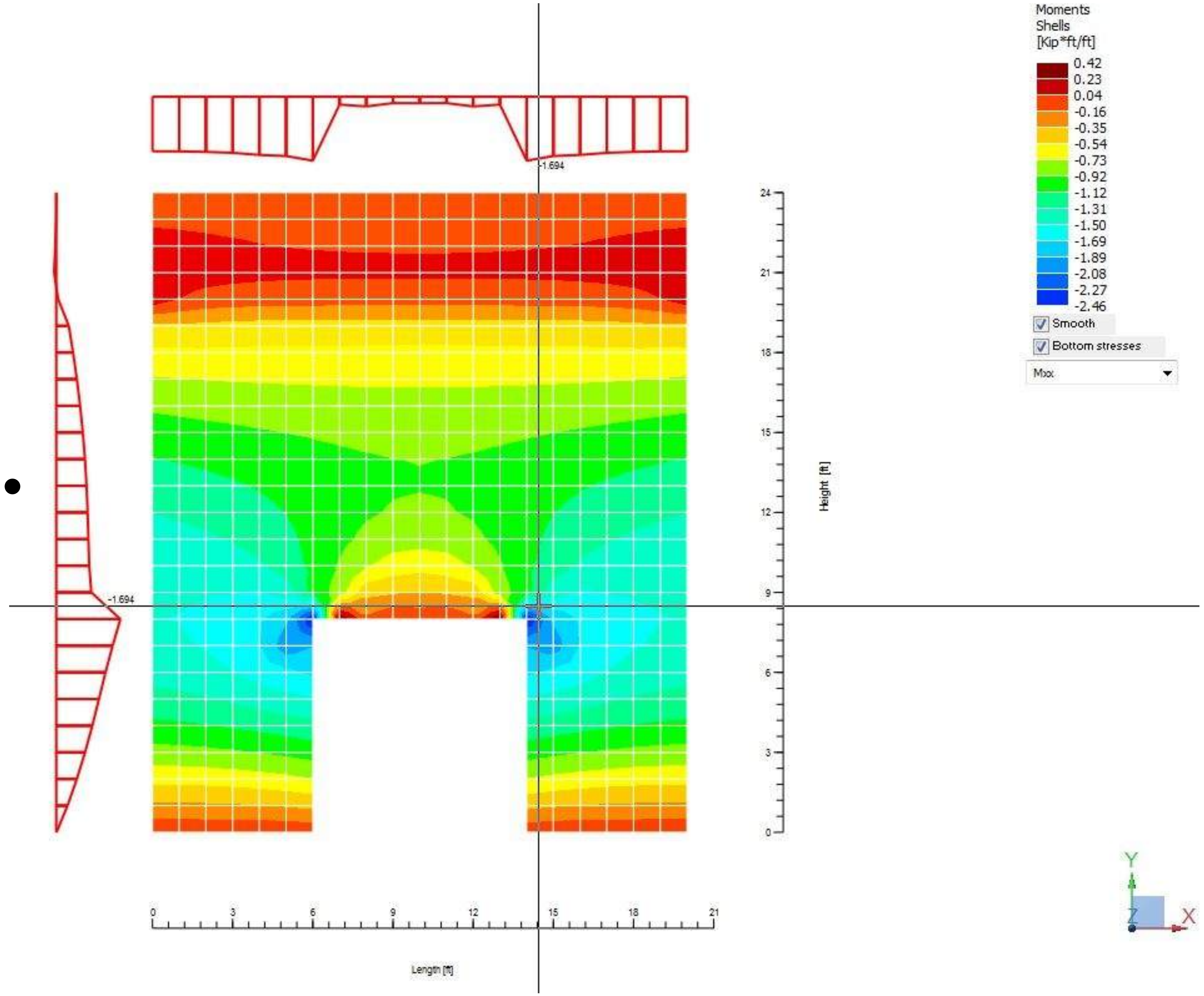
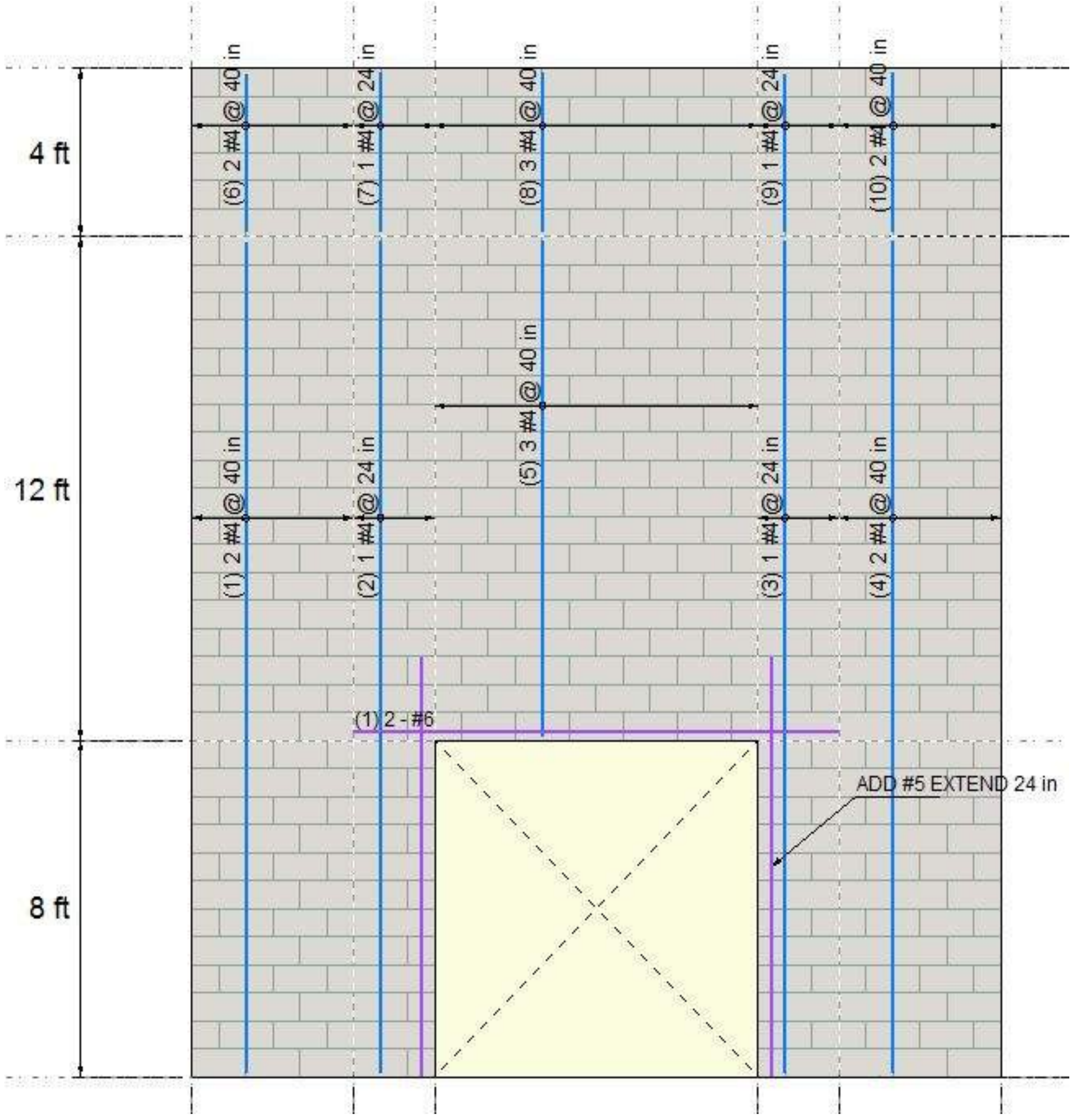


RAM Elements

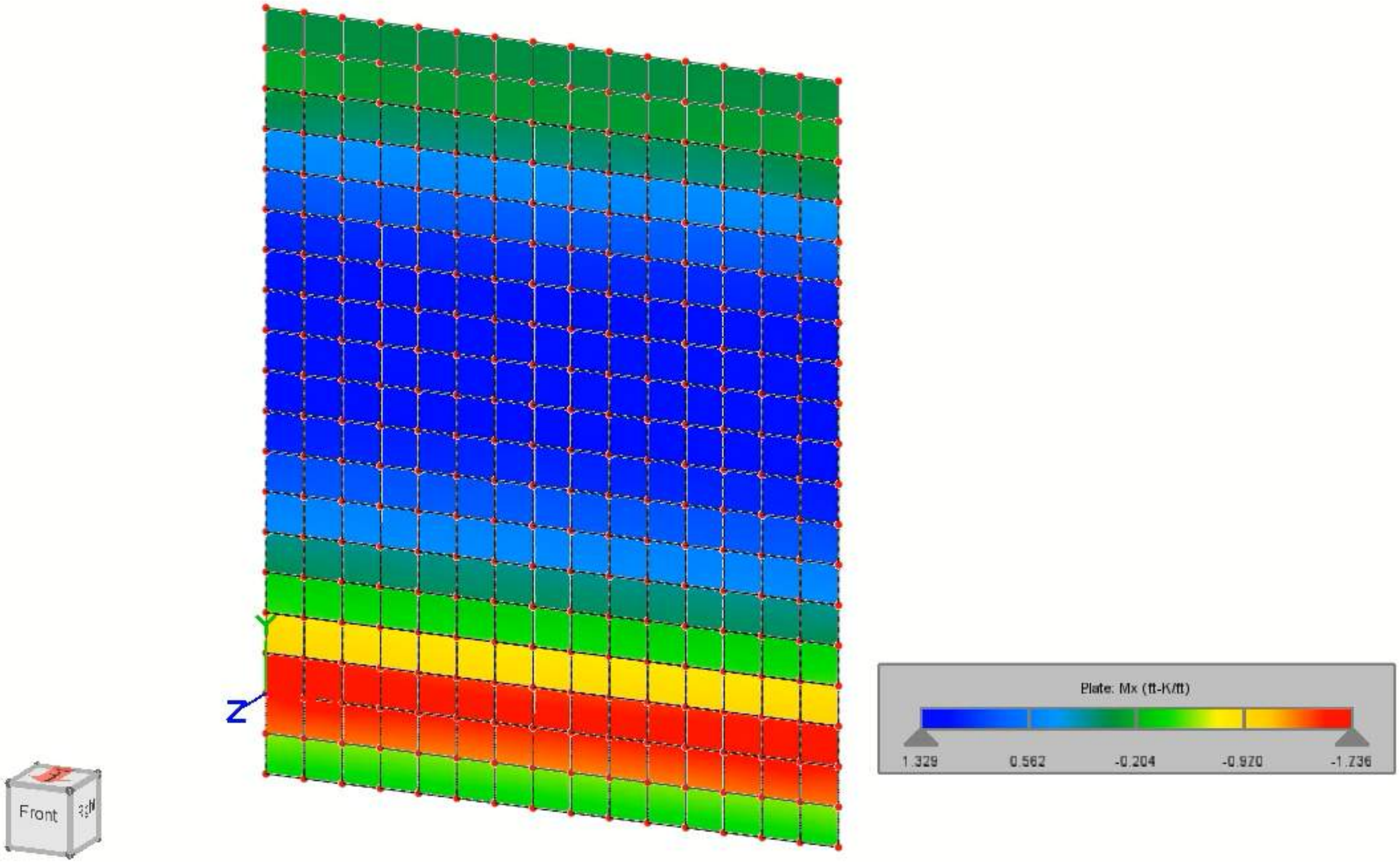
Moment Distribution (vertical)

Quick Example



RAM Elements

final reinforcement layout


Y
Z
Front
Plate: Mx (ft-K/ft)
1.329
0.562
-0.204
-0.970
-1.736

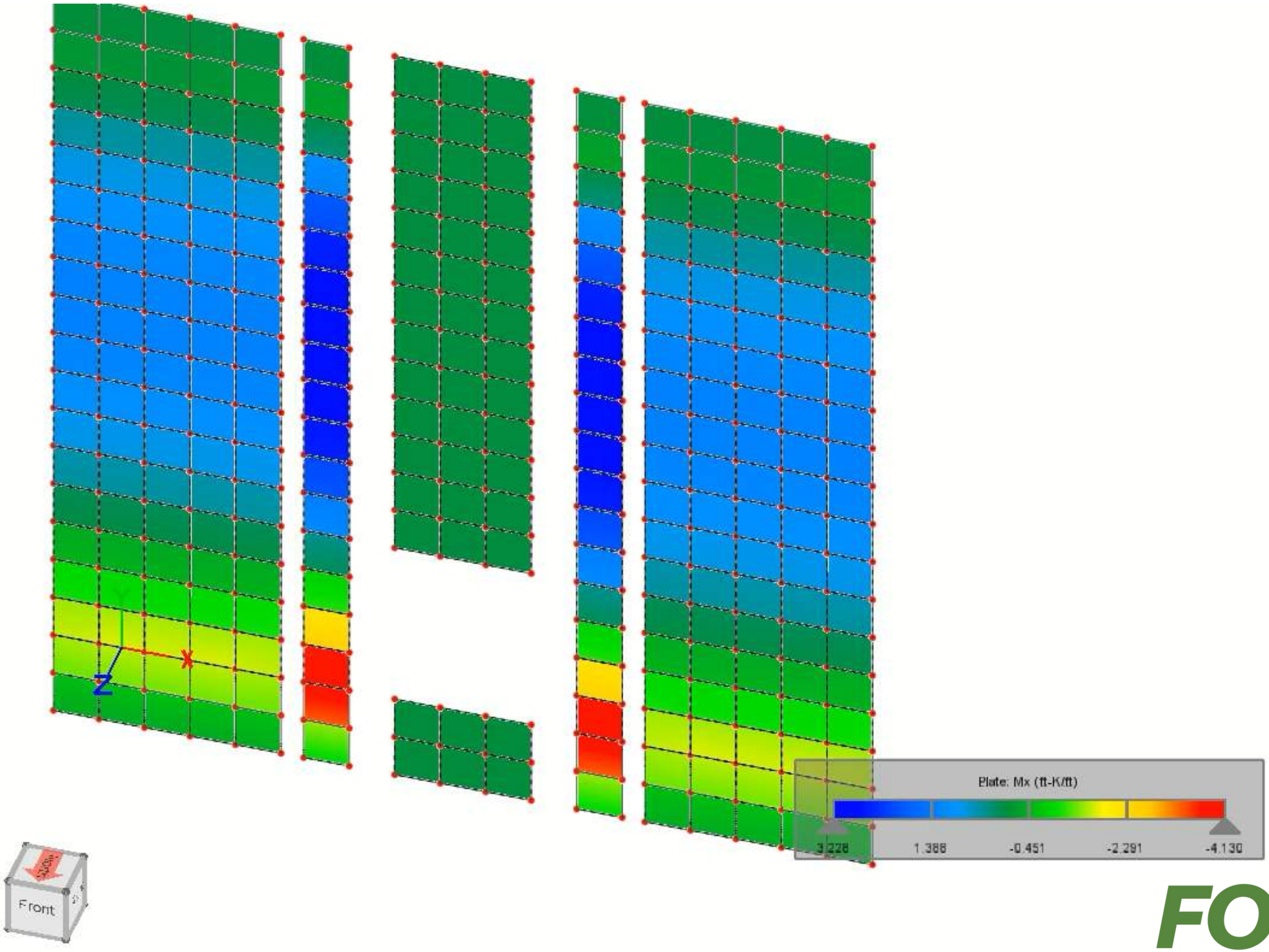
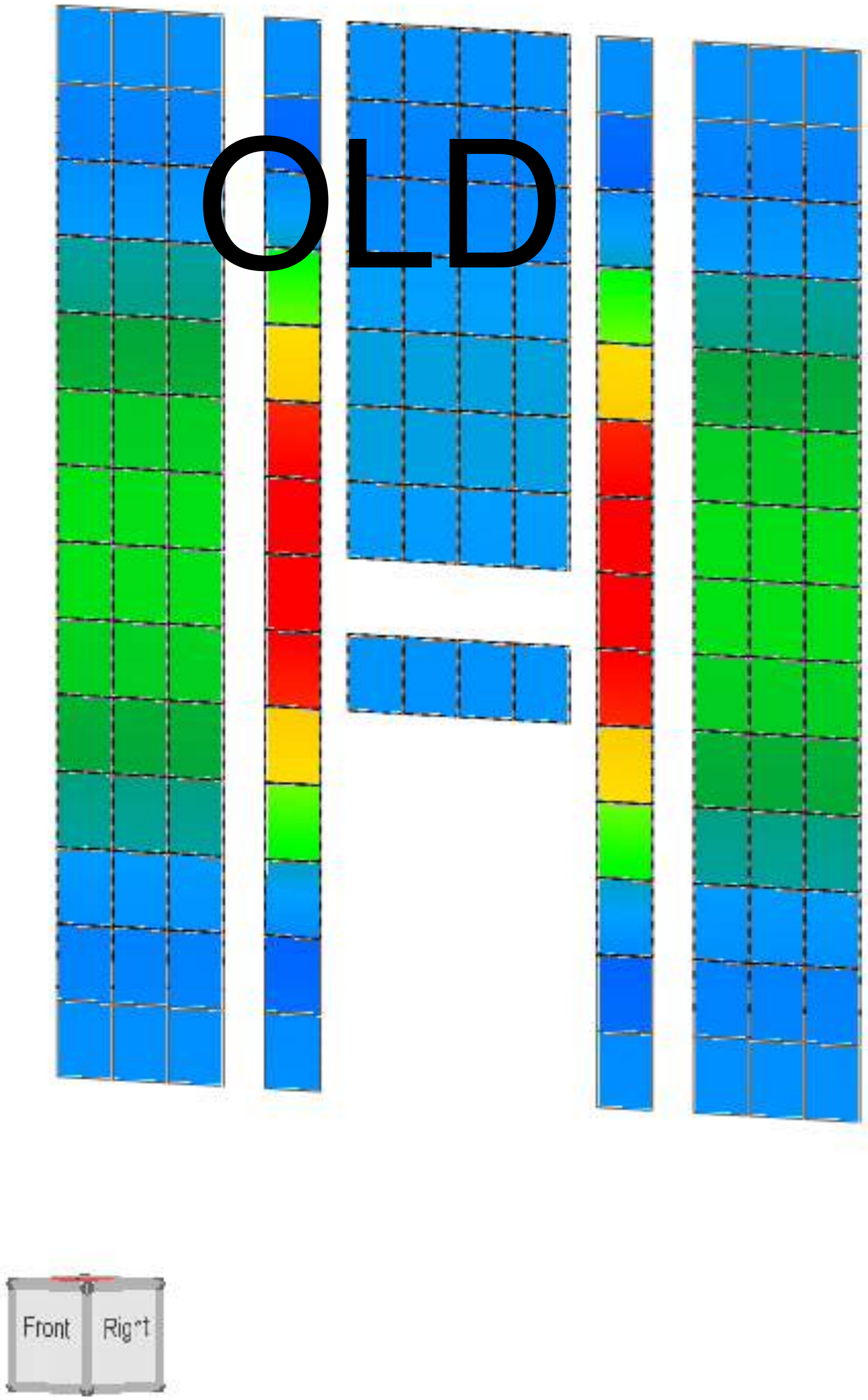
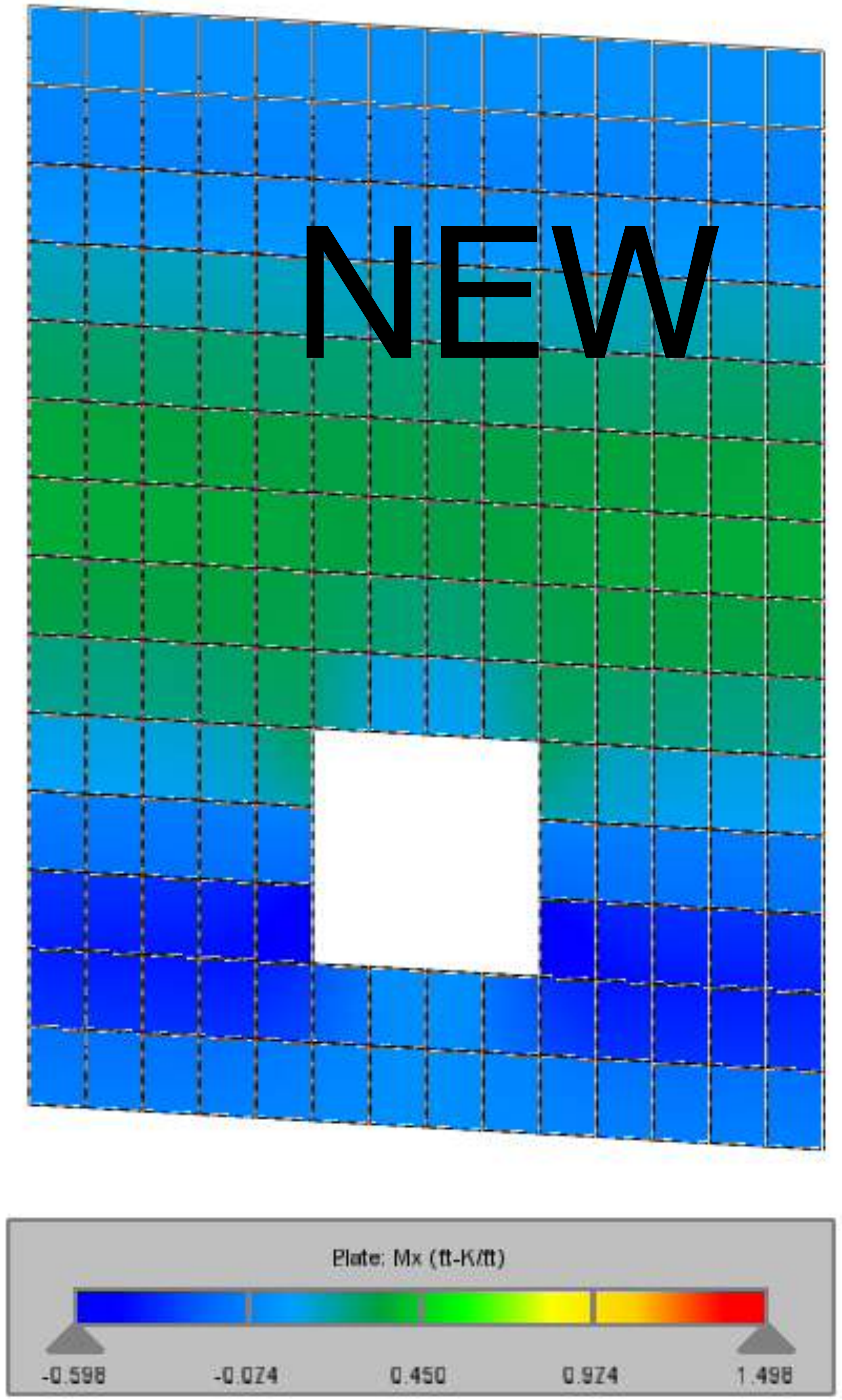


Plate: Mx (ft-K/ft)
3.228
1.388
-0.451
-2.291
-4.130
Front


OLD
Front


NEW
Plate: Mx (ft-K/ft)
-0.598
-0.074
0.450
0.974
1.498

Quick Example

BASED ON FEA TOOLS (NEW)

Typical Wall Steel

- (1)#4 @40"o.c. vert

Jamb

- (1)#4
- 24in strip

Lintel

- (2)#4 top and bottom
- 16in deep

BASED ON HAND CALCS (OLD)

Typical Wall Steel

- (1)#4 @32"o.c. vert

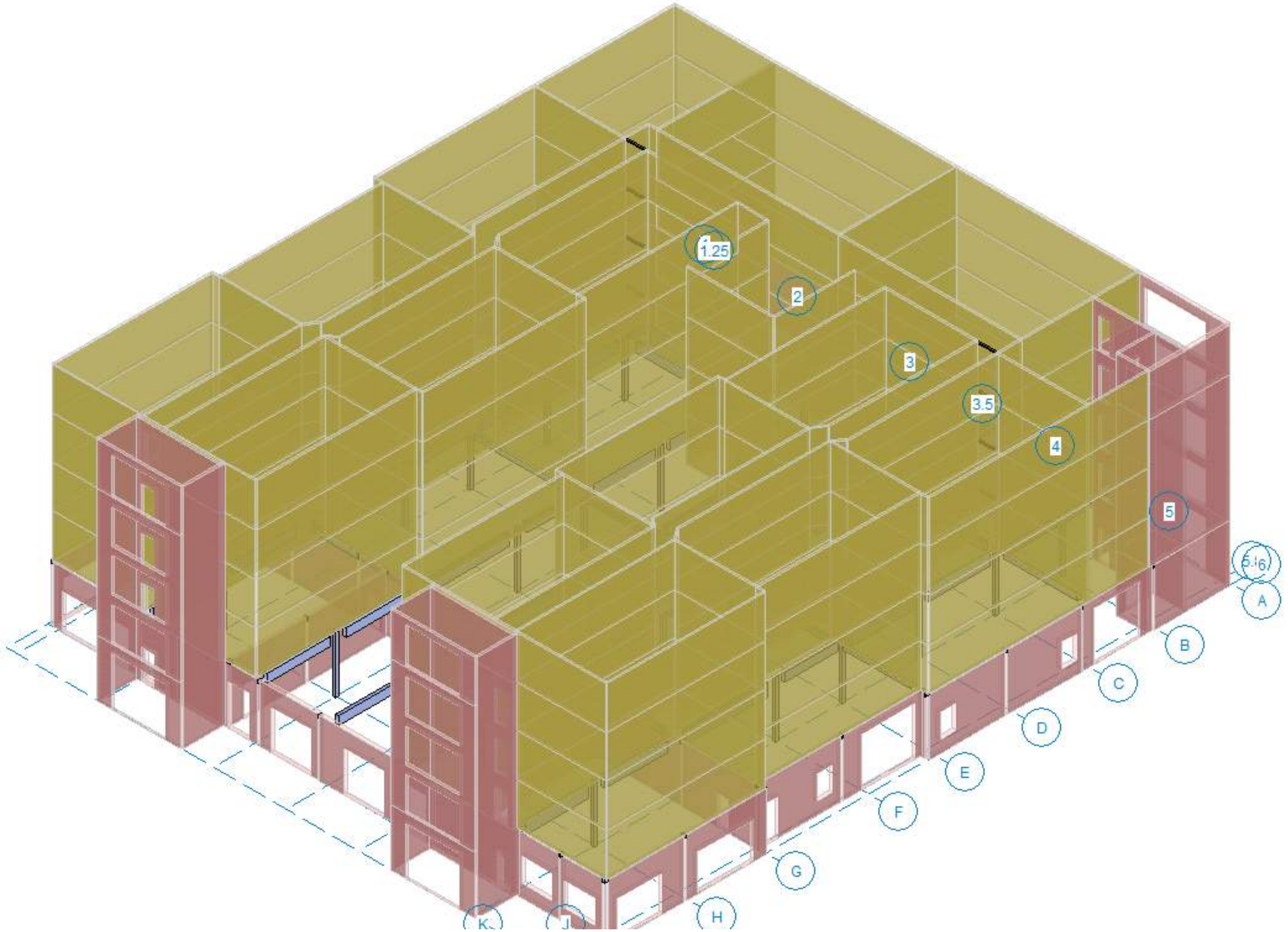
Jamb

- (2)#4 each cell (6 total)
- 24in strip

Lintel

- (2)#6, 40in deep (w/o arching)
- 1-#4, 16in deep (w/ arching)

3D finite Element Software Model

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Animate ALL the Mode Shapes
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Joint Reactions
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Member Forces
Member Stresses
Member Torsion
Member Deflections
Suggested Design
Design Results
Seismic Detailing
Concrete Reinforcing
Plate Stresses
Plate Forces
Plate Corner Forces
Solid Stresses
Solid Principals
Wall Panel Design
Material TakeOff
Frequencies
Mode Shapes
Connection Results
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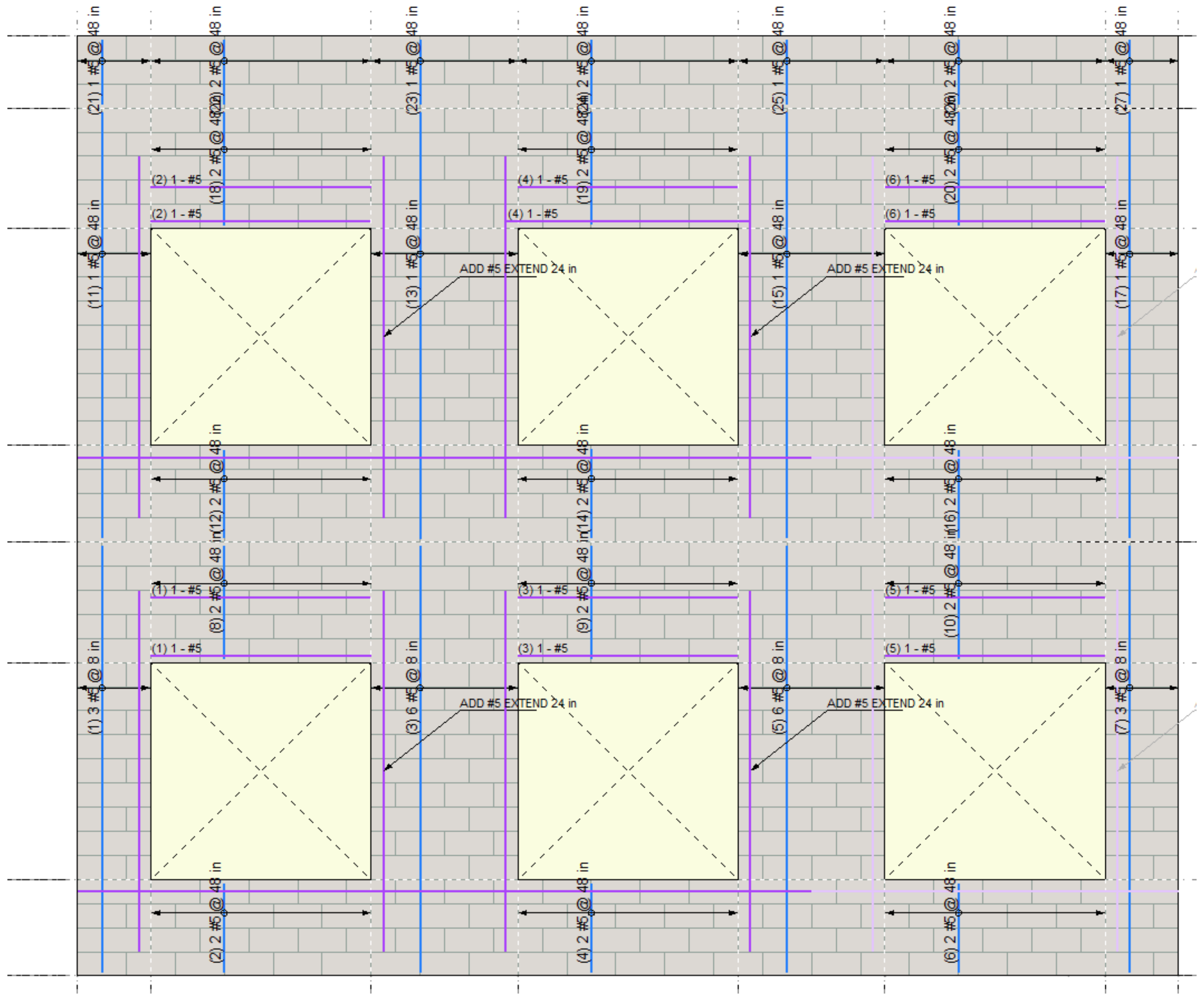
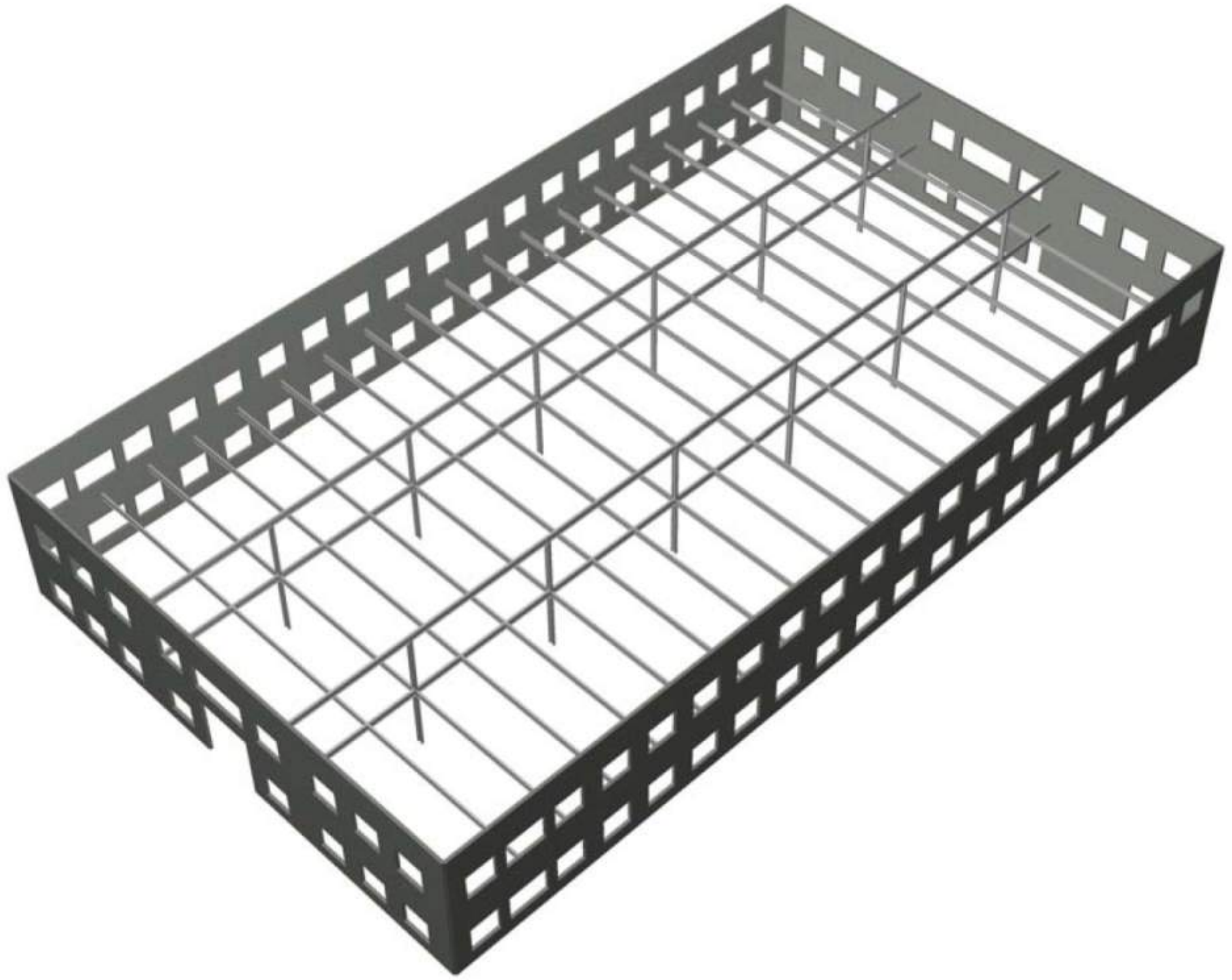
tips for masonry design with software

- Finite Element Analysis (FEA) identifies true wall behavior
  - More accurate analysis
  - More accurate design
- Reinforcement where you need it, less where you don’t need it
- Save design time
- Make better use of materials, saves owner material costs when
  - More economical design

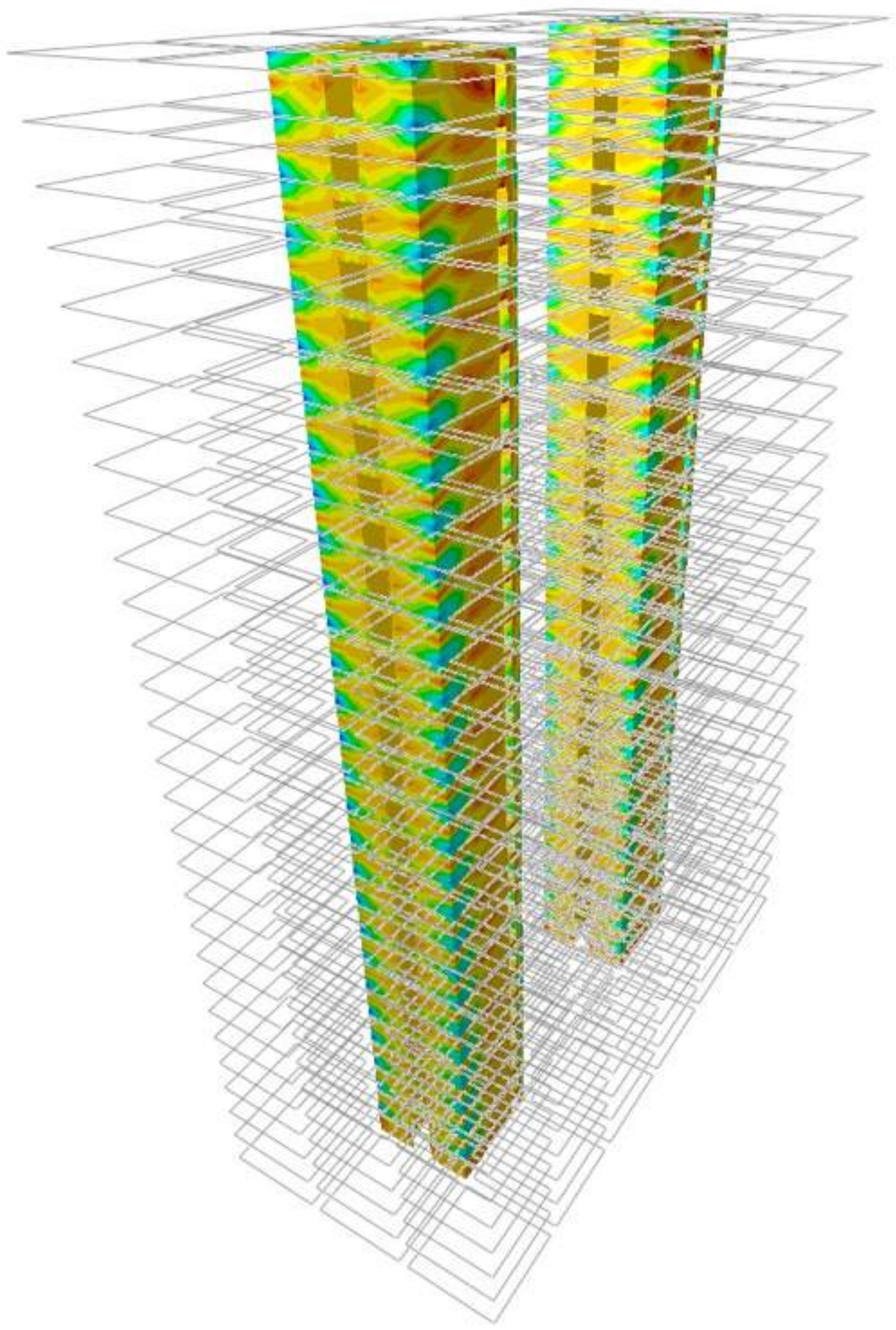
Achieving Economical Design





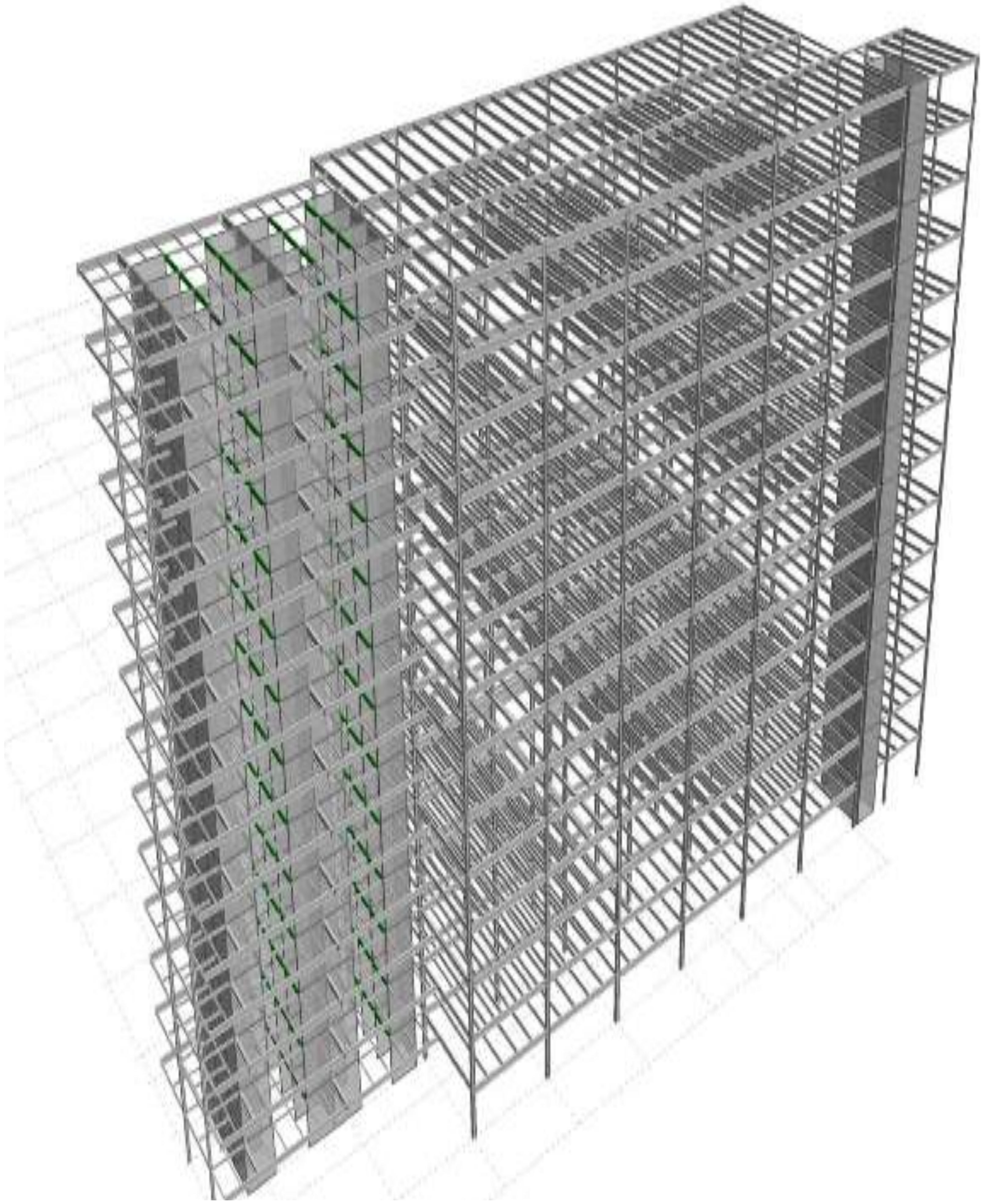
Reason for FEA

Understand Performance Needed for this 28 Story Load Bearing Masonry



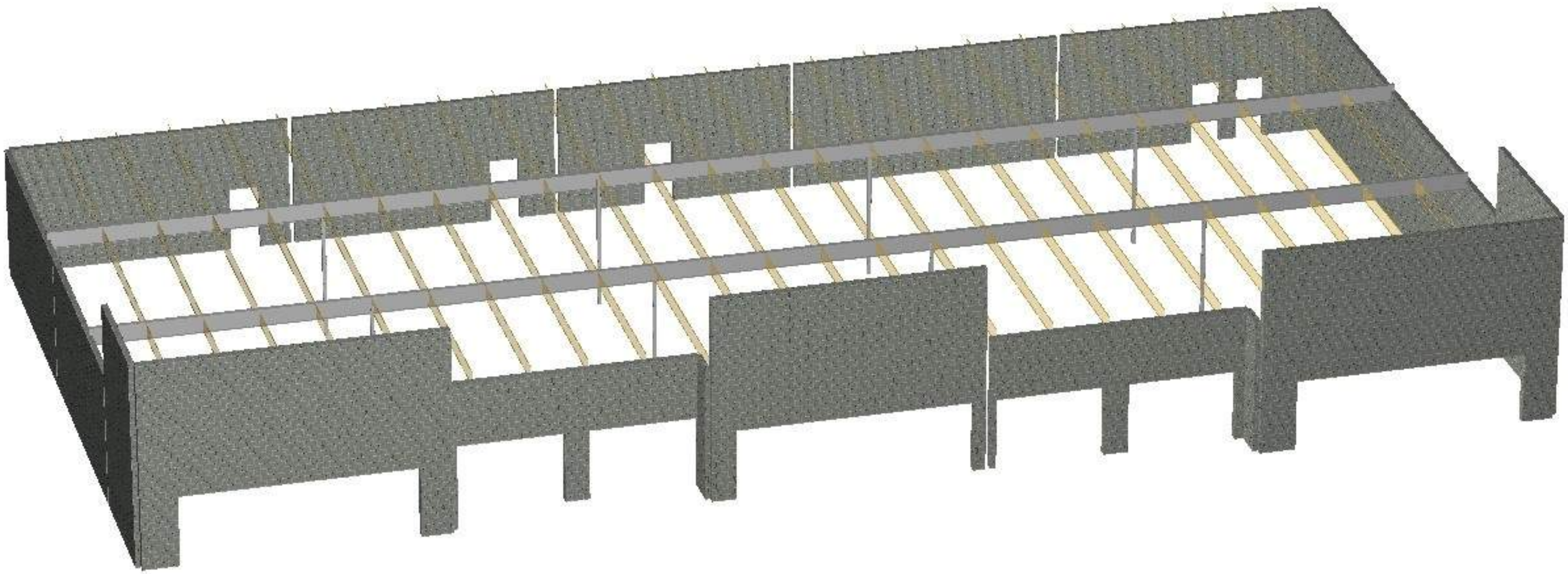
Reason for FEA

Determine Lateral Needs for this Mid-Rise in Missouri



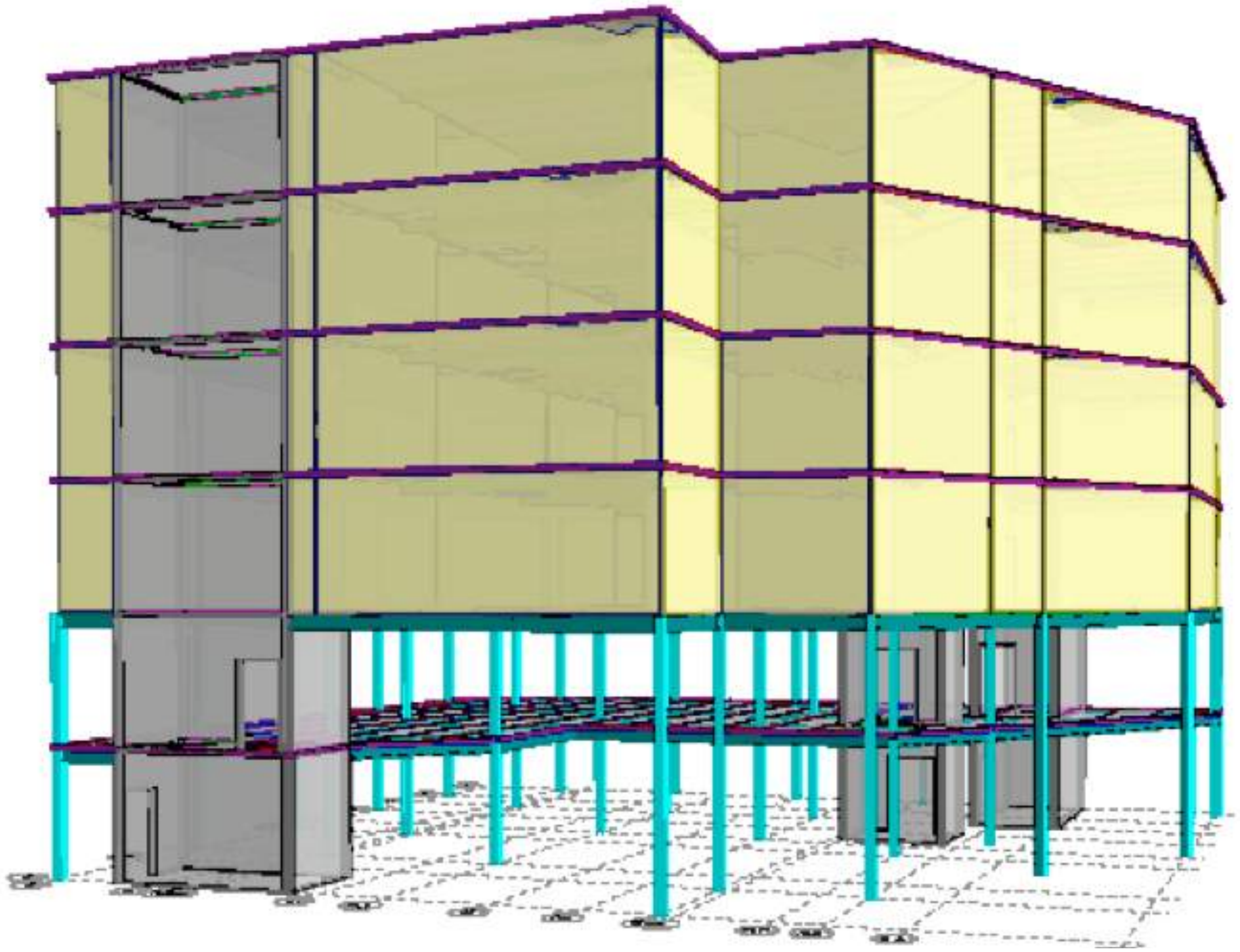
Reason for FEA

FEA Help Gain Understanding for Deep Lintels in “Moment Frames”



Reason for FEA

FEA Gives Us a Better Understanding of Shear Wall Group Capacity

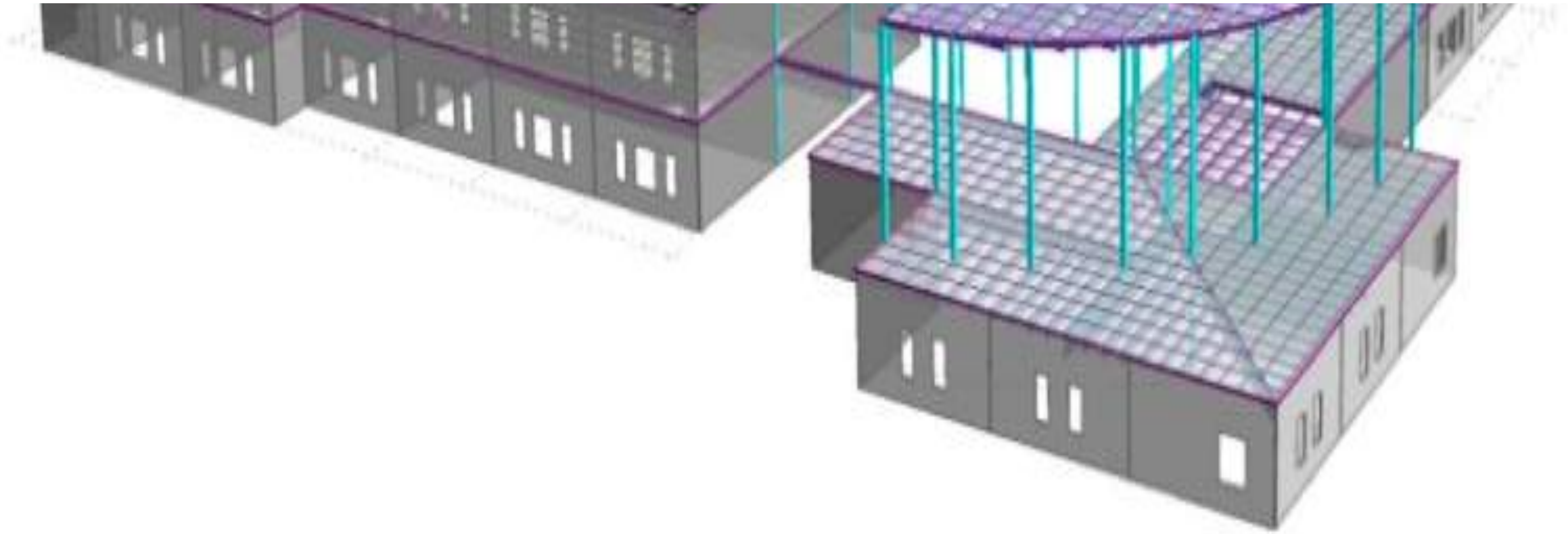


Reason for FEA

FEA Allows us to Look at PT Slabs, Concrete Buildings and Masonry Lateral as Hybrid System

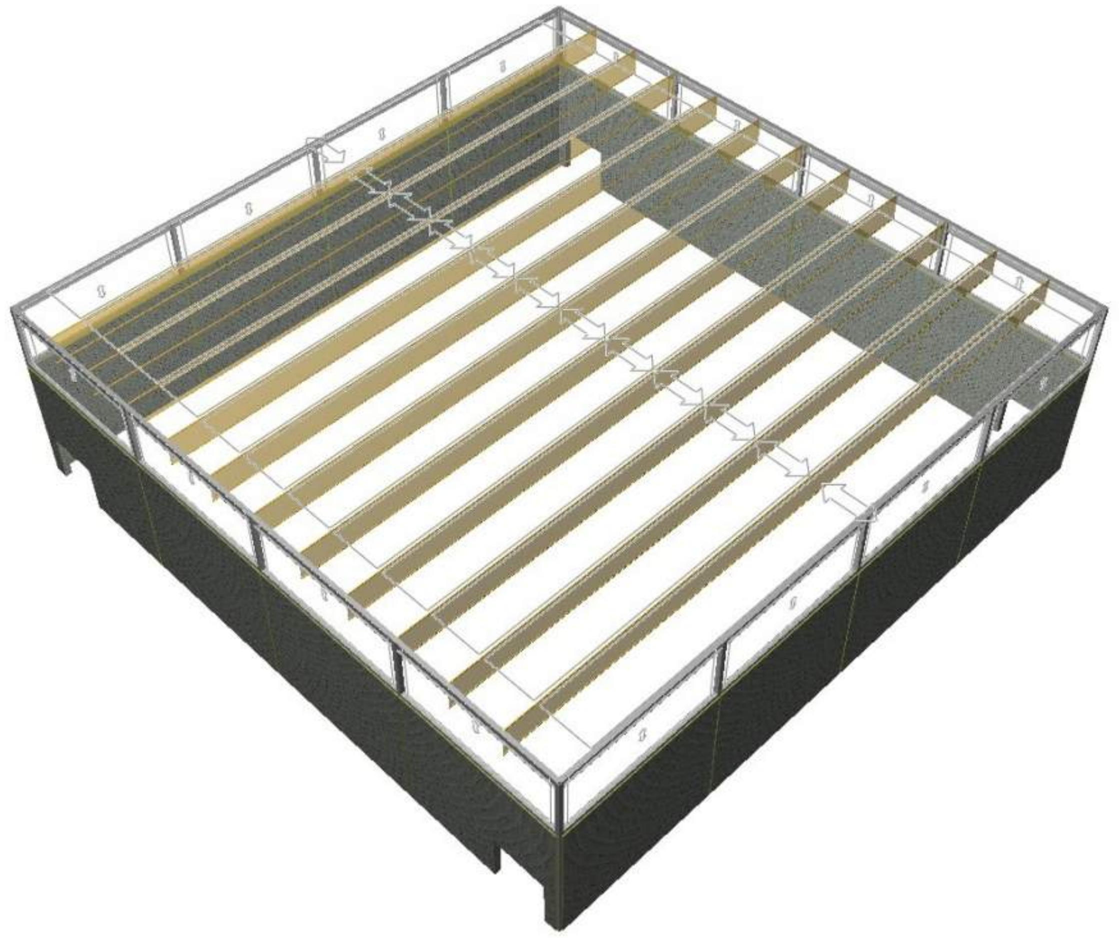
Reason for FEA

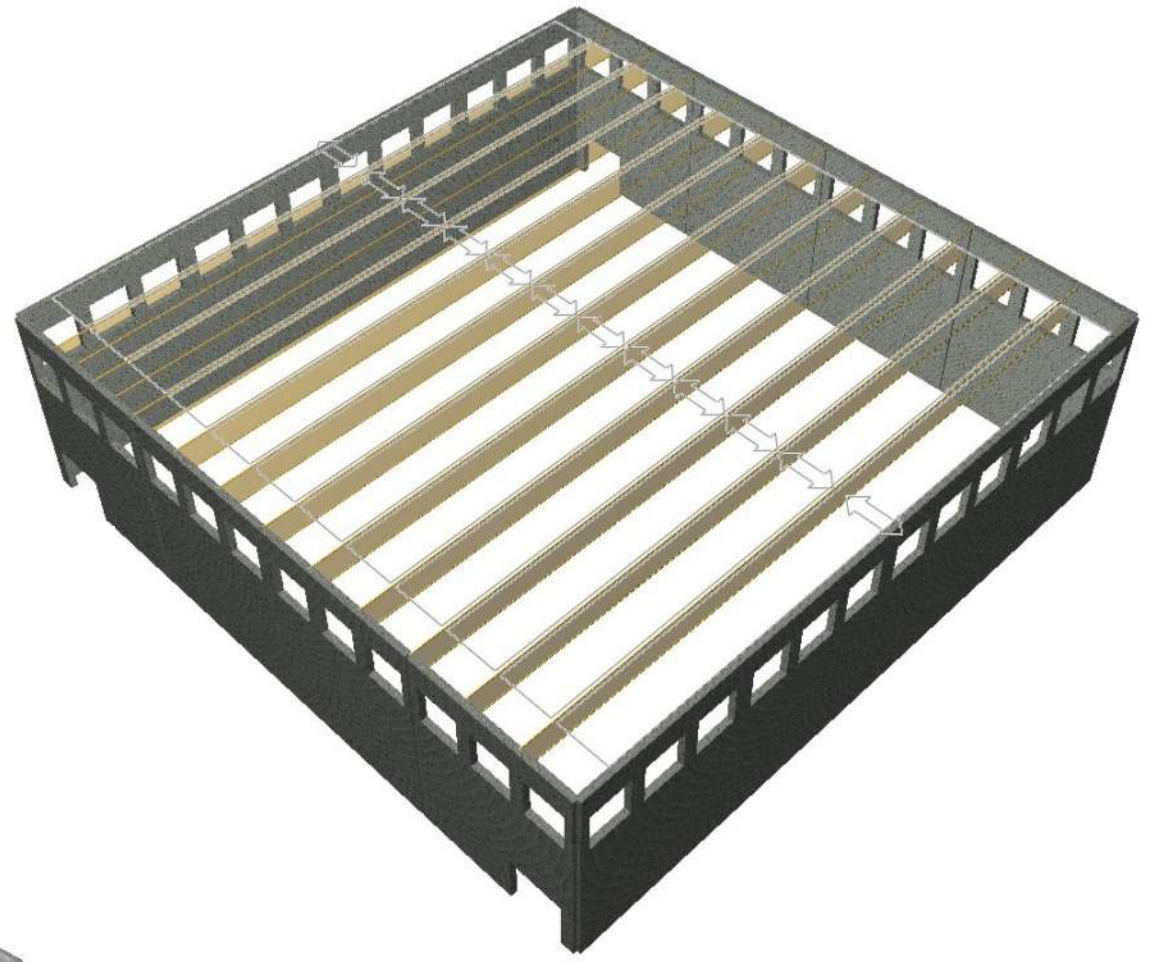
Whole Building Analysis
-Productive Solution for Large Scale



Reason for FEA

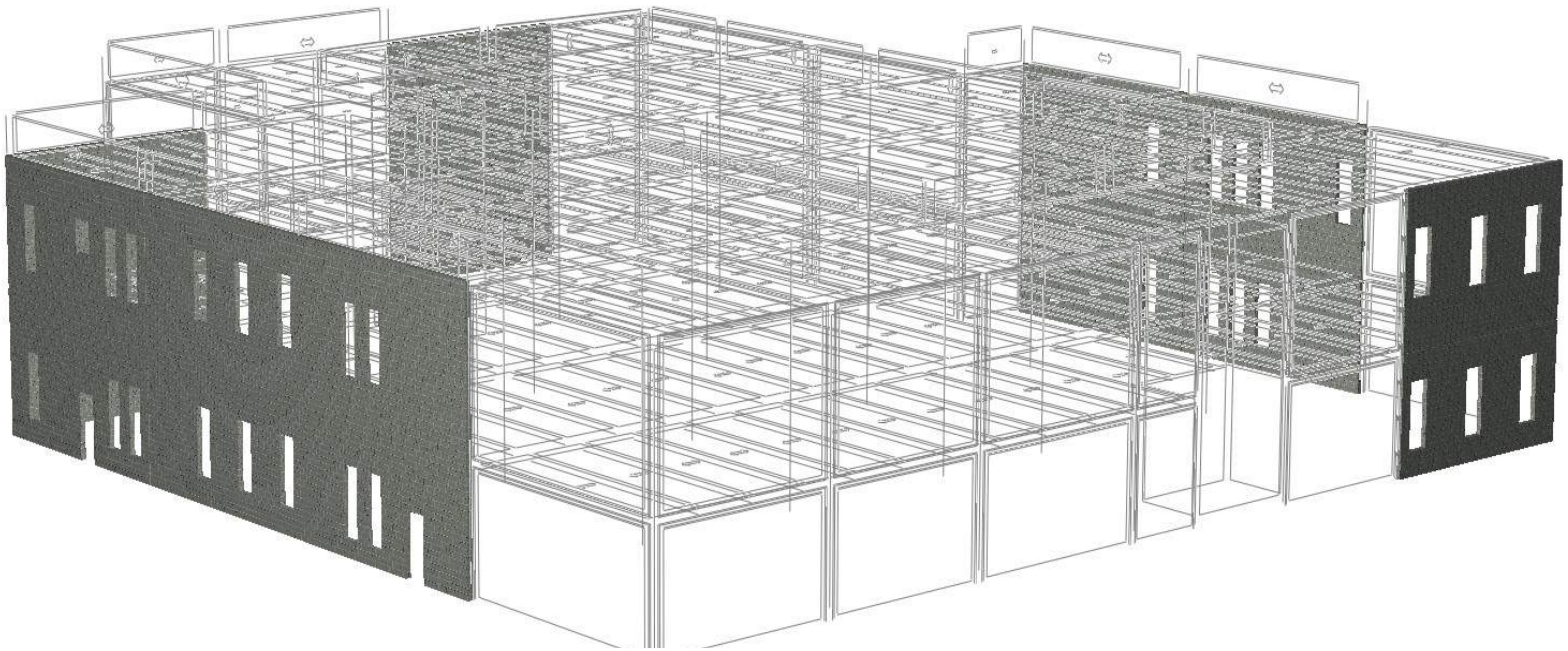
Options for Masonry Gymnasiums





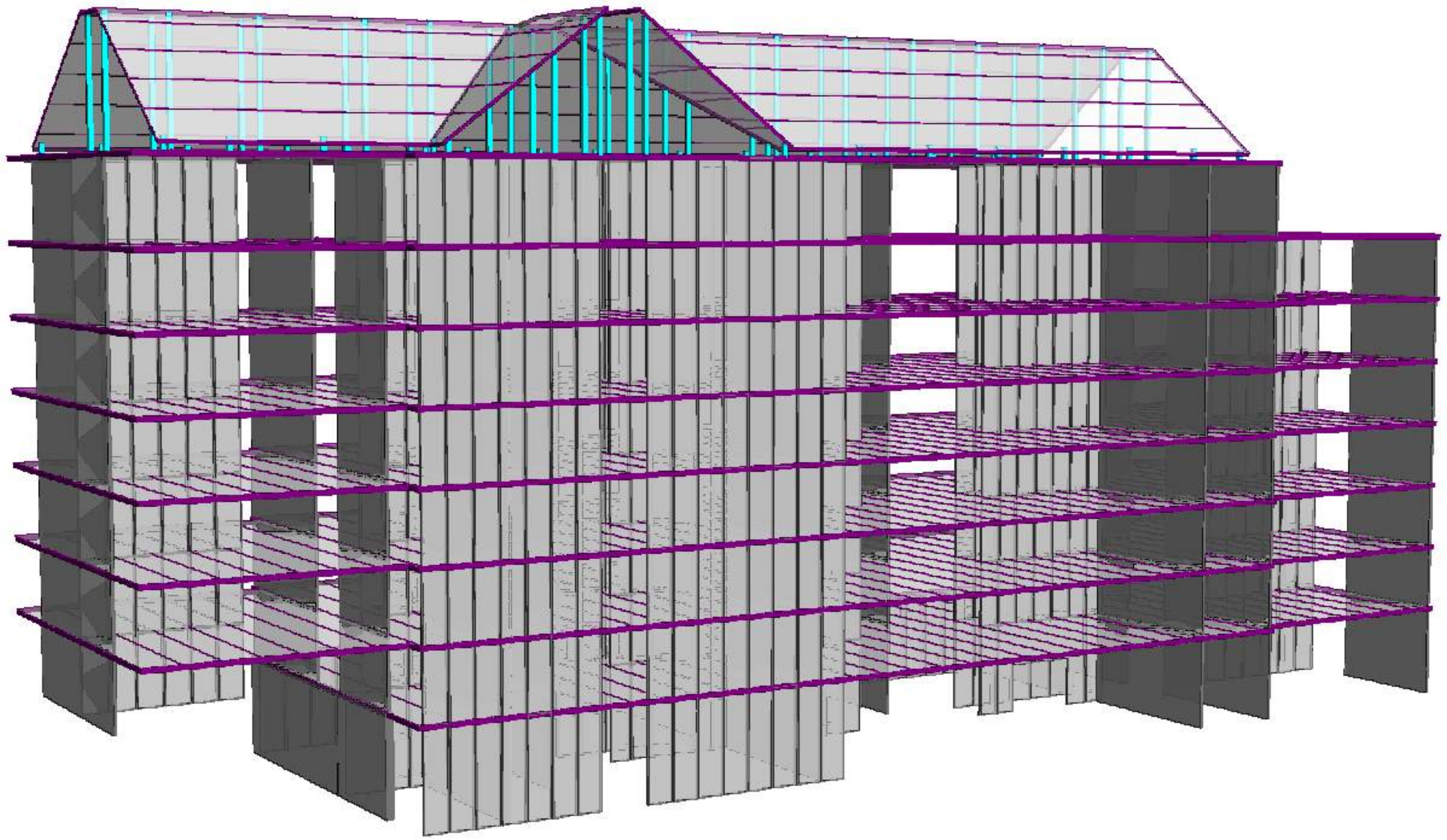
Reason for FEA

Hybrid (Steel/Masonry), Perforated Shearwalls, & Tornado Design



Reason for FEA

Load Bearing, Lateral Resistance, High-Strength Masonry



Reason for FEA

Software Review

MASONRY INSIGHTS

Software Review for Structural Masonry Design of Masonry

Numerous design programs support masonry analysis and design, for both component design and finite element analysis (FEA) and design. As engineers, it is important to not only know what programs are available and when to use them, but also the common issues with software and how to avoid them.

Below are examples for modifying FEA elements to properly model masonry:

- How to account for partial grouting in masonry
- Incorporating masonry control joints (CJ)
- How to account for cracking in masonry

All items are available on the FORSE website: http://website.forsei.com/find/masonry/

List of finite element analysis/design software reviewed by FORSE

We recommend using FEA programs for walls that are either complicated or have a reasonably high load demand, which includes: walls with relatively large openings, shear walls with openings, masonry wall groups used with stair and elevator shafts, exterior walls with high loads, multistory masonry walls, and storm shelter walls. FEA programs are required for understanding the true load on all masonry lintels.

1. **RAM Elements** - Masonry Wall module

   Quick start guide: IMI - RAM Elements V8i Manual for Masonry Analysis and Design (pdf)

2. **RISA Floor/ RISA 3D**

   Quick start guide: IMI - RISA-3D Workflow Manual for Masonry Analysis and Design (pdf)

3. **ETABS** - Masonry walls are all modeled as grouted solid. When the actual wall being modeled is solid, ETABS can be used without issue; if it is partially grouted, modification factors need to be used.

   Quick start guide: *Not yet available.*

IMI quick start guides are found at: http://imiweb.org/masonry-software/