State-of-the-Art Masonry Facade Evaluation & Repair Techniques

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Learning Objectives

Upon completing this program, the participant should:

1. Be familiar with the application of Infrared Thermography (IRT) and Surface Penetrating Radar (SPR), test methods for application to masonry construction as evaluation tools for existing construction.

2. Understand the technical aspects of the tests and have a working knowledge of the test methods.

3. Understand the capabilities and limitations of reinforced masonry veneer and post-tensioned masonry.

Non-destructive Evaluation Topics

Infrared thermography (IRT)

Surface penetrating radar (SPR)

Masonry Repair Topics

Reinforced masonry veneer

Post-tensioned masonry

NDT Uses With Masonry Construction

Location of voids in grouted reinforced masonry.

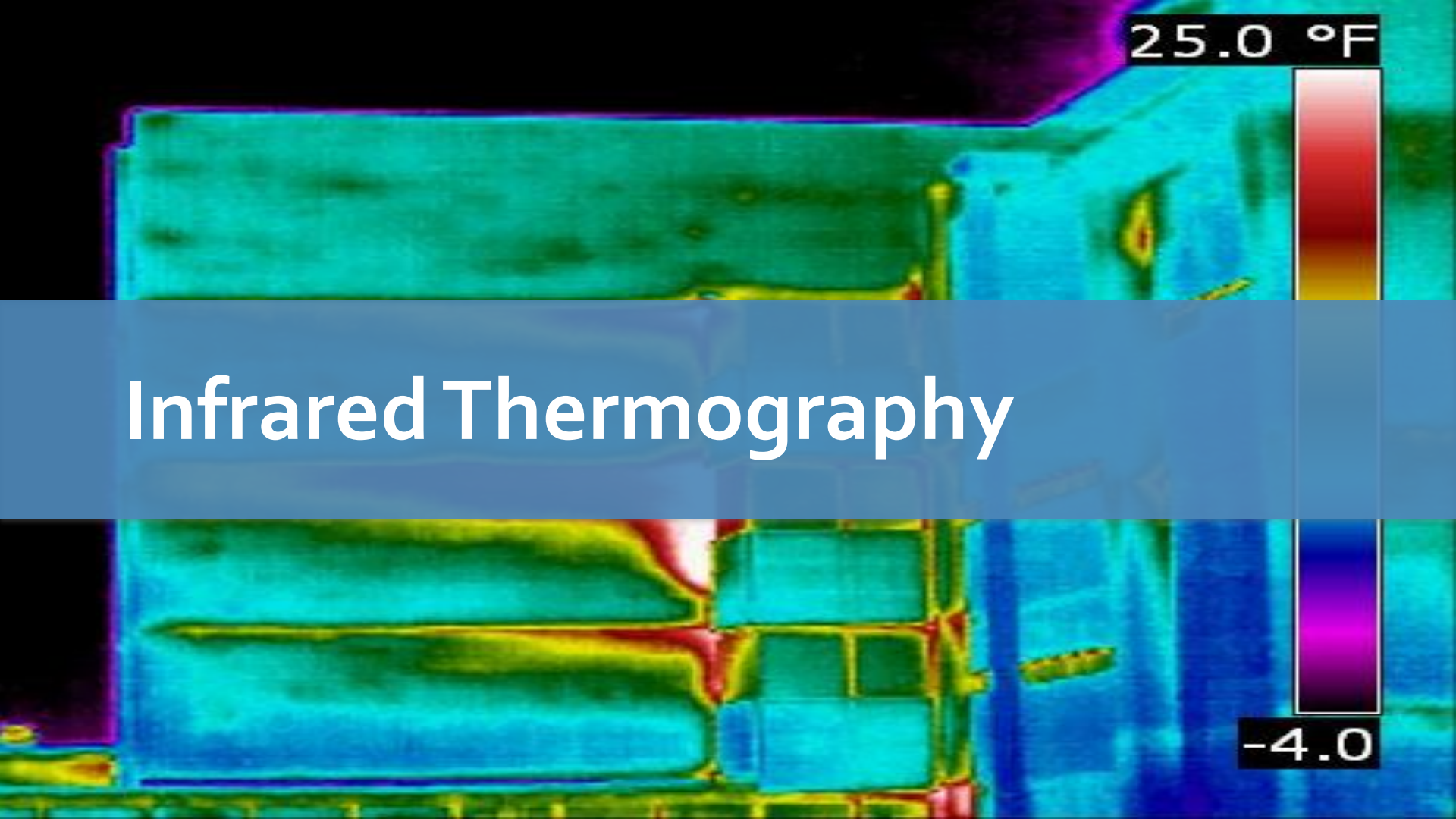
Location, position, & spacing of structural reinforcement.

Location & spacing of veneer anchors and joint reinforcement.

Location of embedded conduits, pipes, chases, etc.

Location of air leakage.

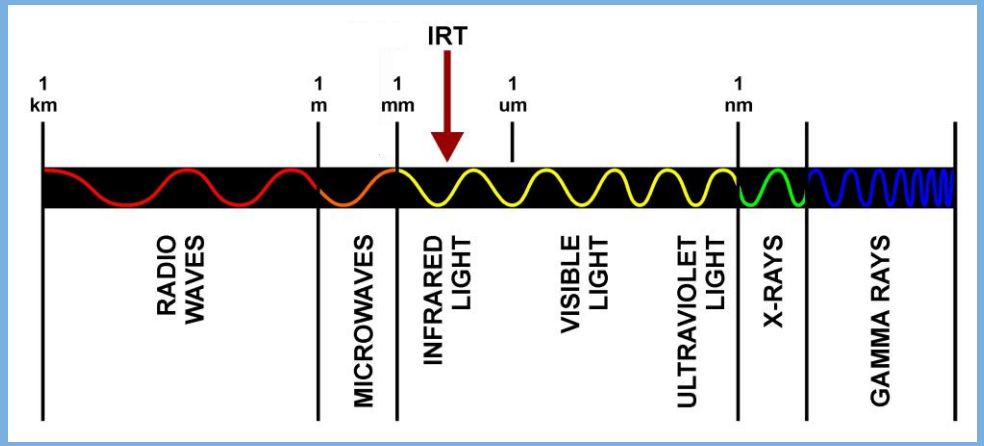
Define wall geometry.



Infrared Thermography

Infrared Thermography

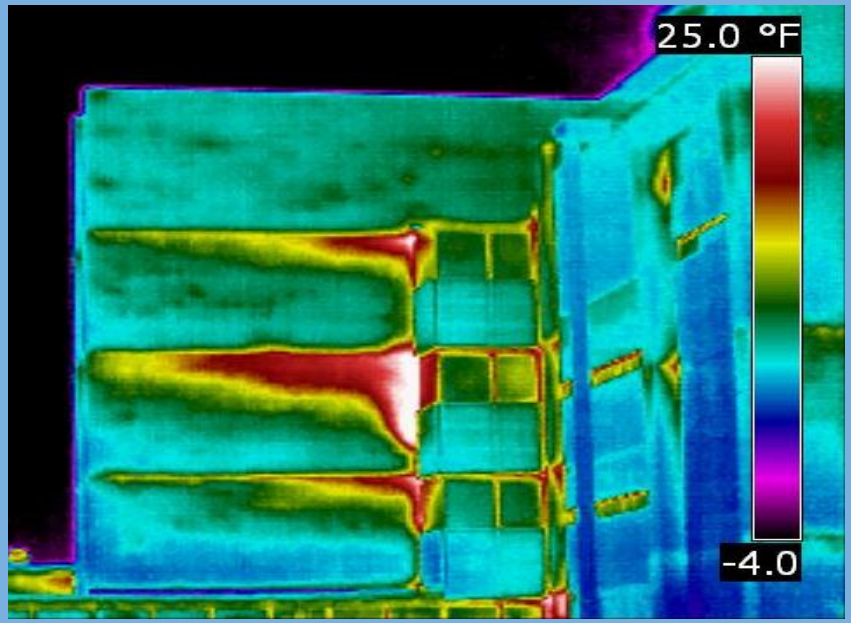
Operates in the long wave infrared range of the electromagnetic spectrum (8-14 um)



Infrared Thermography

Converts differing amounts of infrared energy to corresponding intensities of visible light

Image is influenced by temperature and emissivity of object



Infrared Thermography

ADVANTAGES:

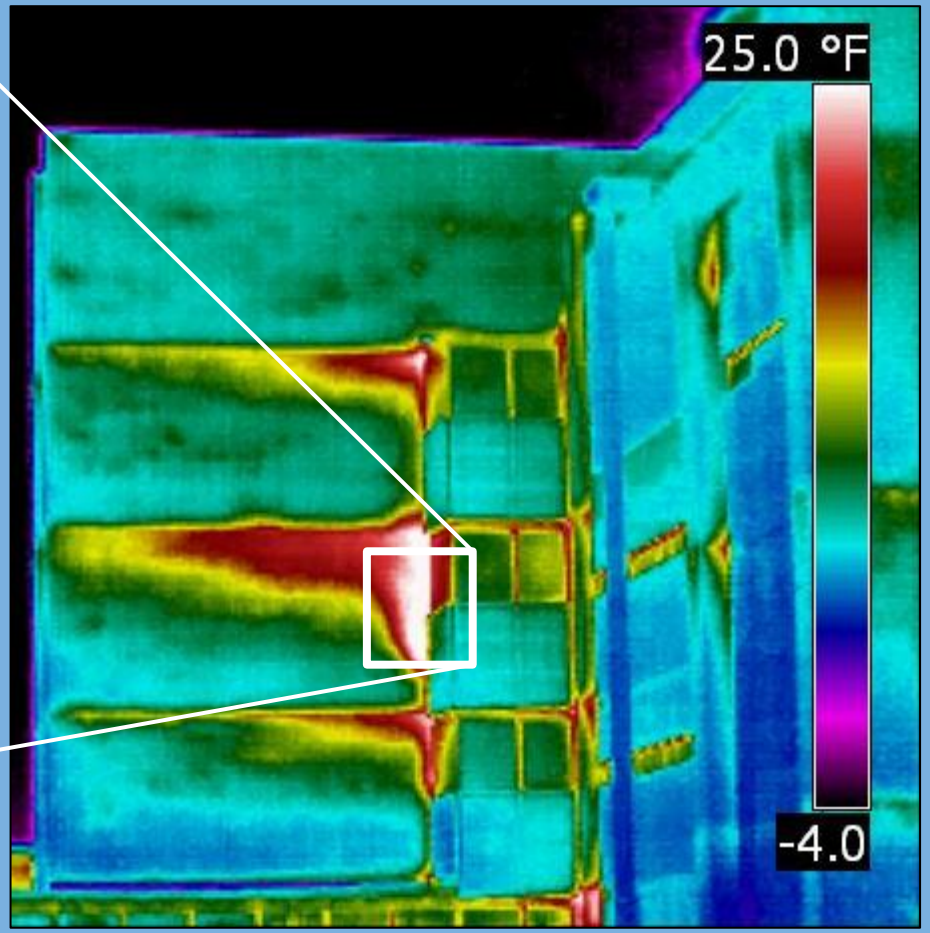
- Completely non-destructive with very rapid data collection
- Digital data record to memory card

DISADVANTAGES:

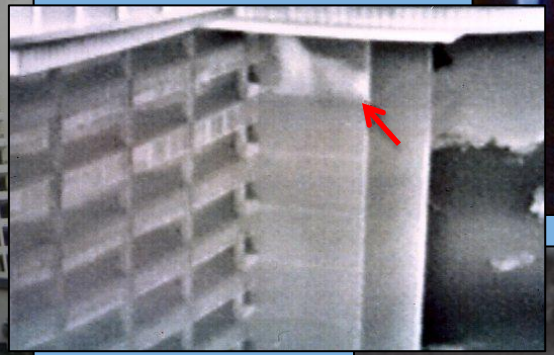
- Completely dependent on environmental conditions
- Data can be obscured by building components
- Not effective for some types of masonry construction

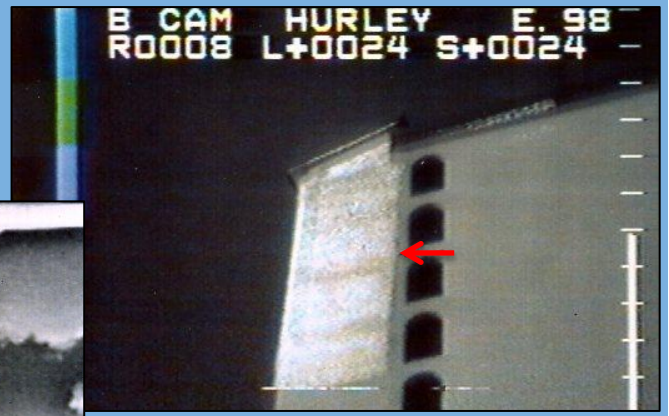
Air Leakage Surveys

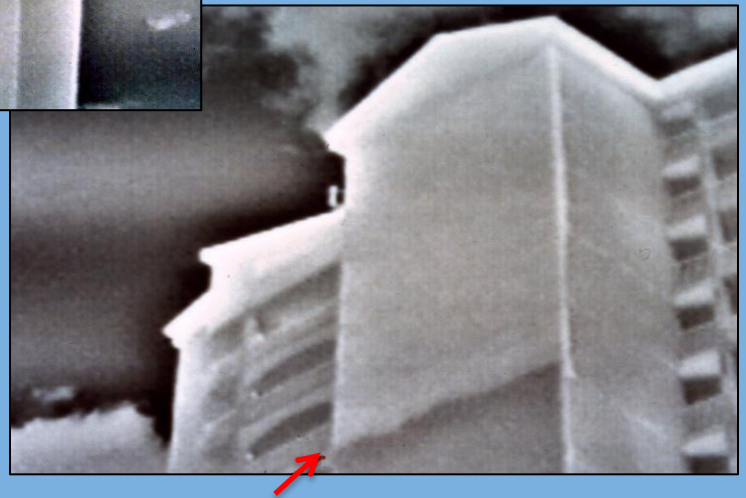
Discontinuity in air barrier



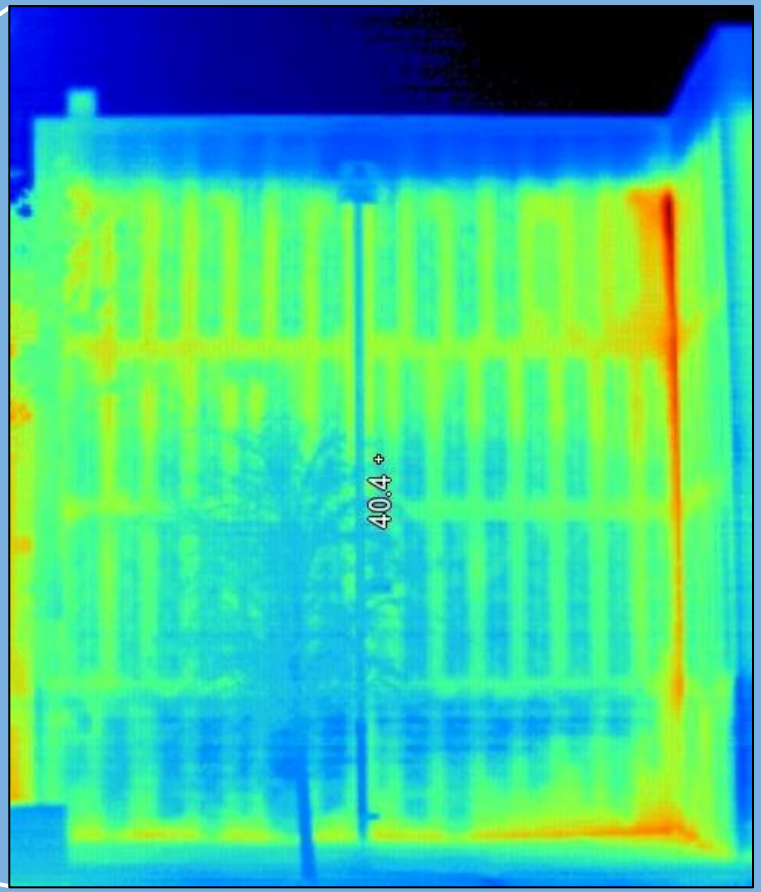
Stucco Delamination from Concrete Walls

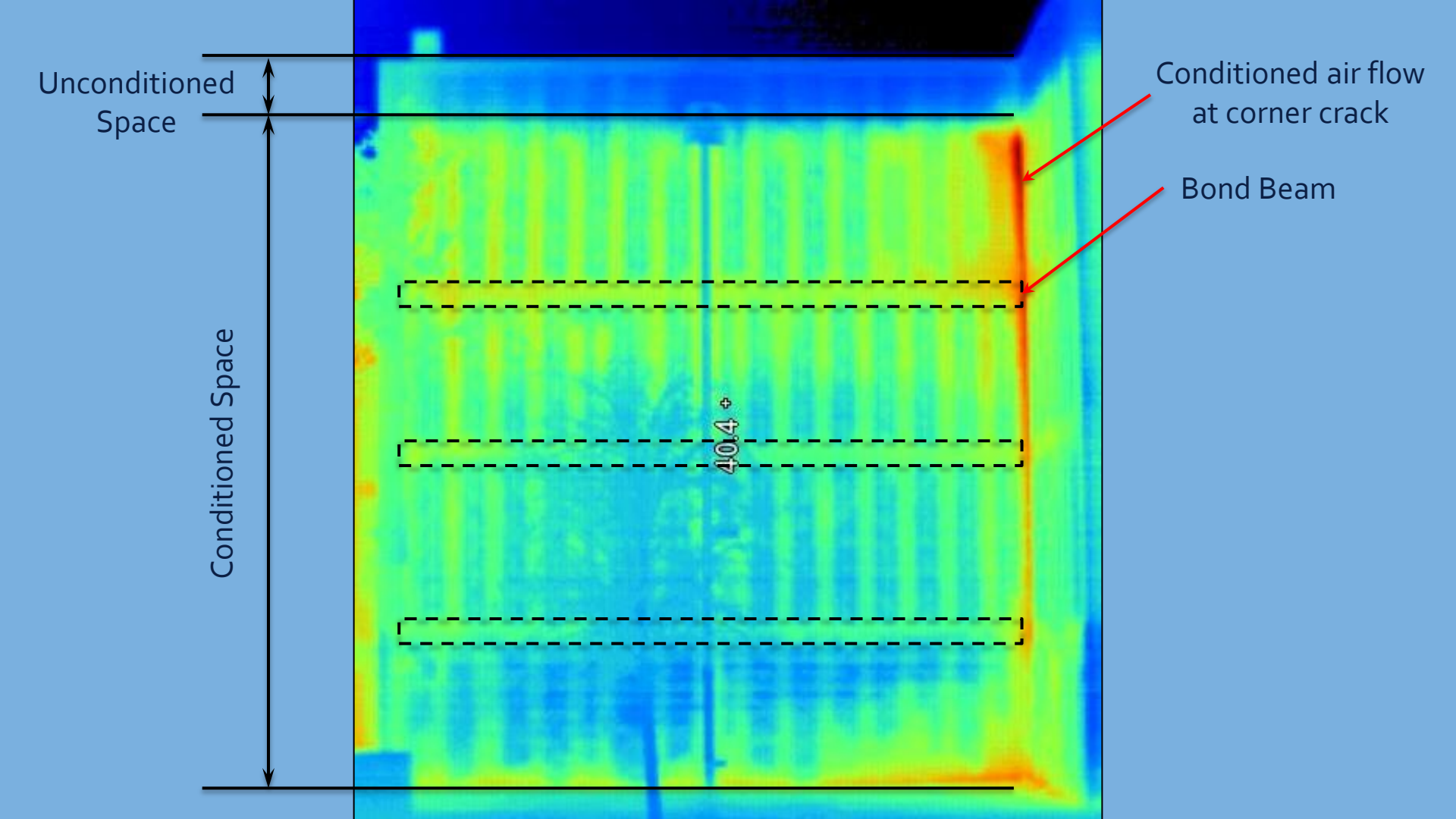






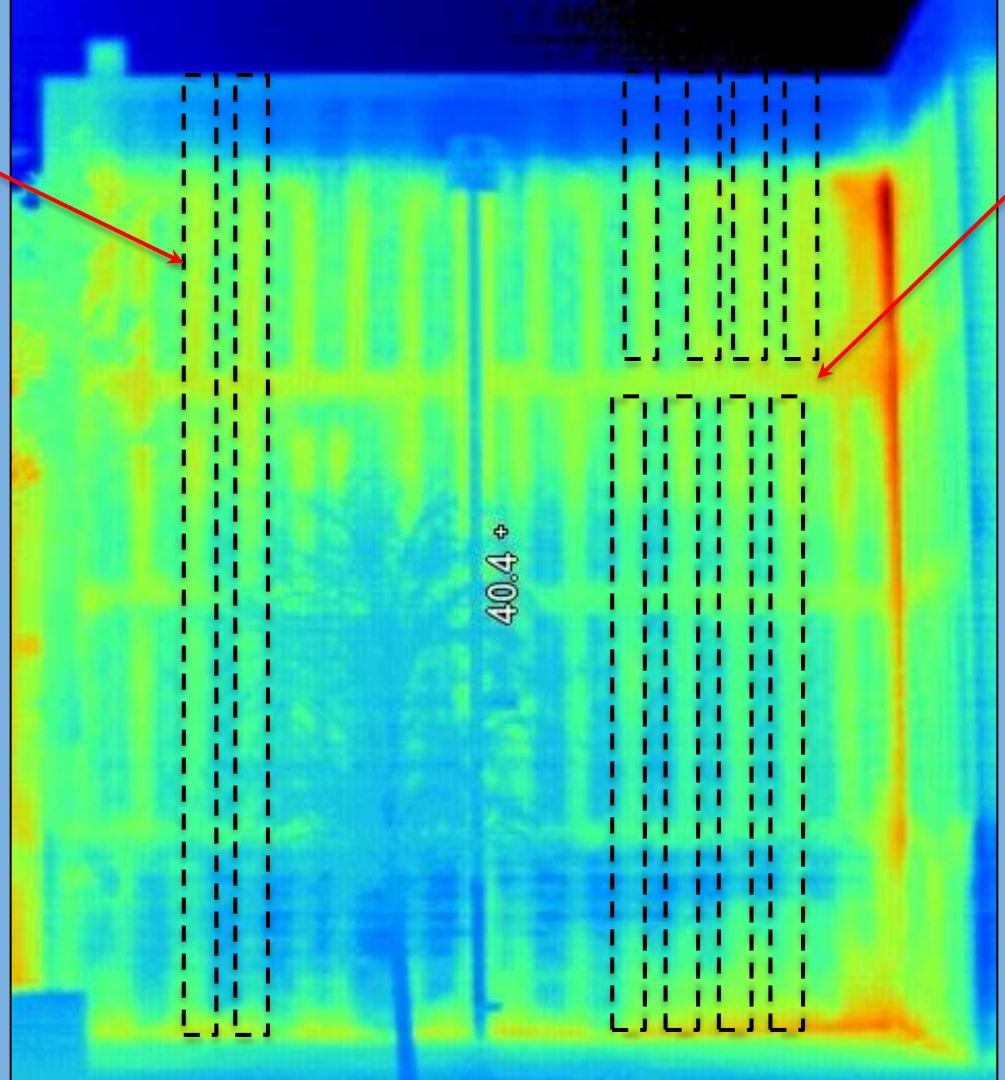
Single Wythe Concrete Masonry Walls




Unconditioned Space
Conditioned Space
Conditioned air flow at corner crack
Bond Beam
40.4

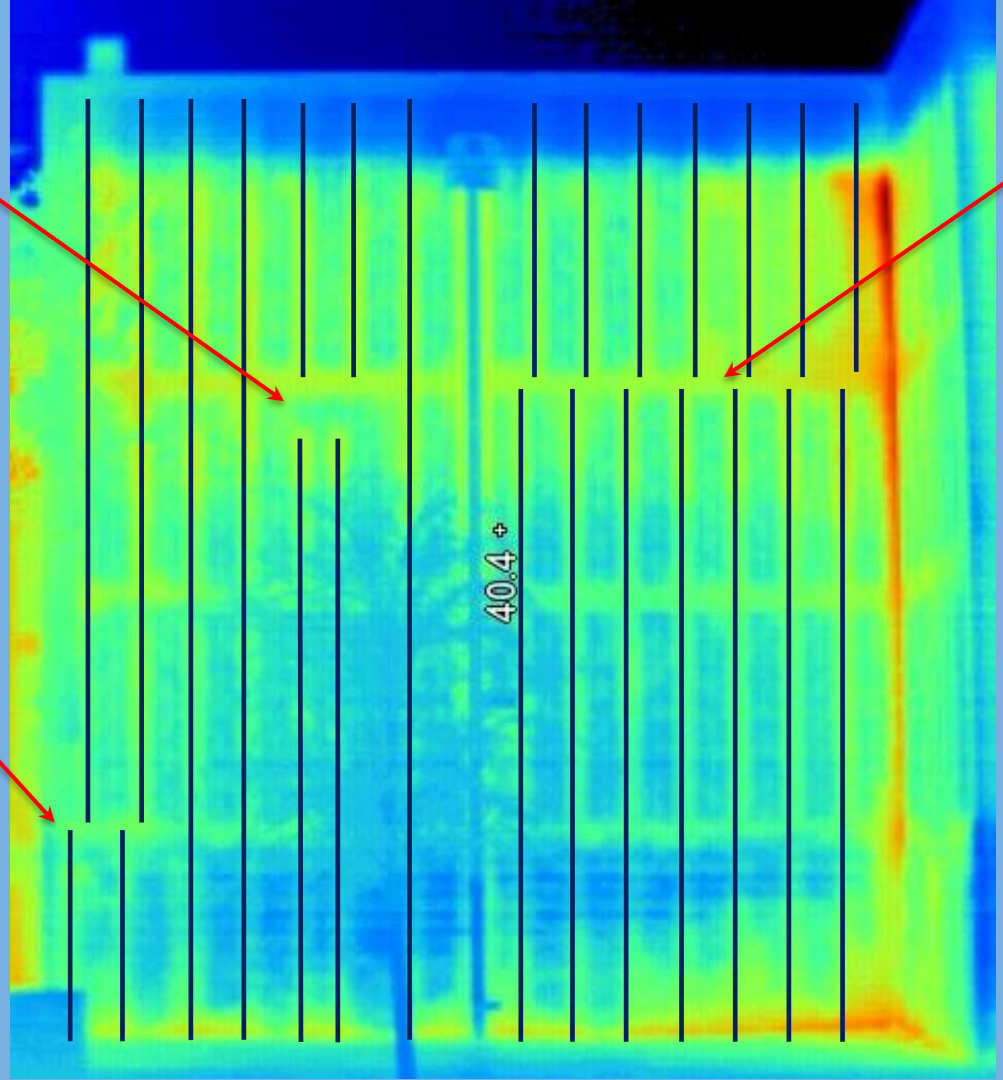
Grouted vertical cell

Cells misaligned at bond beam



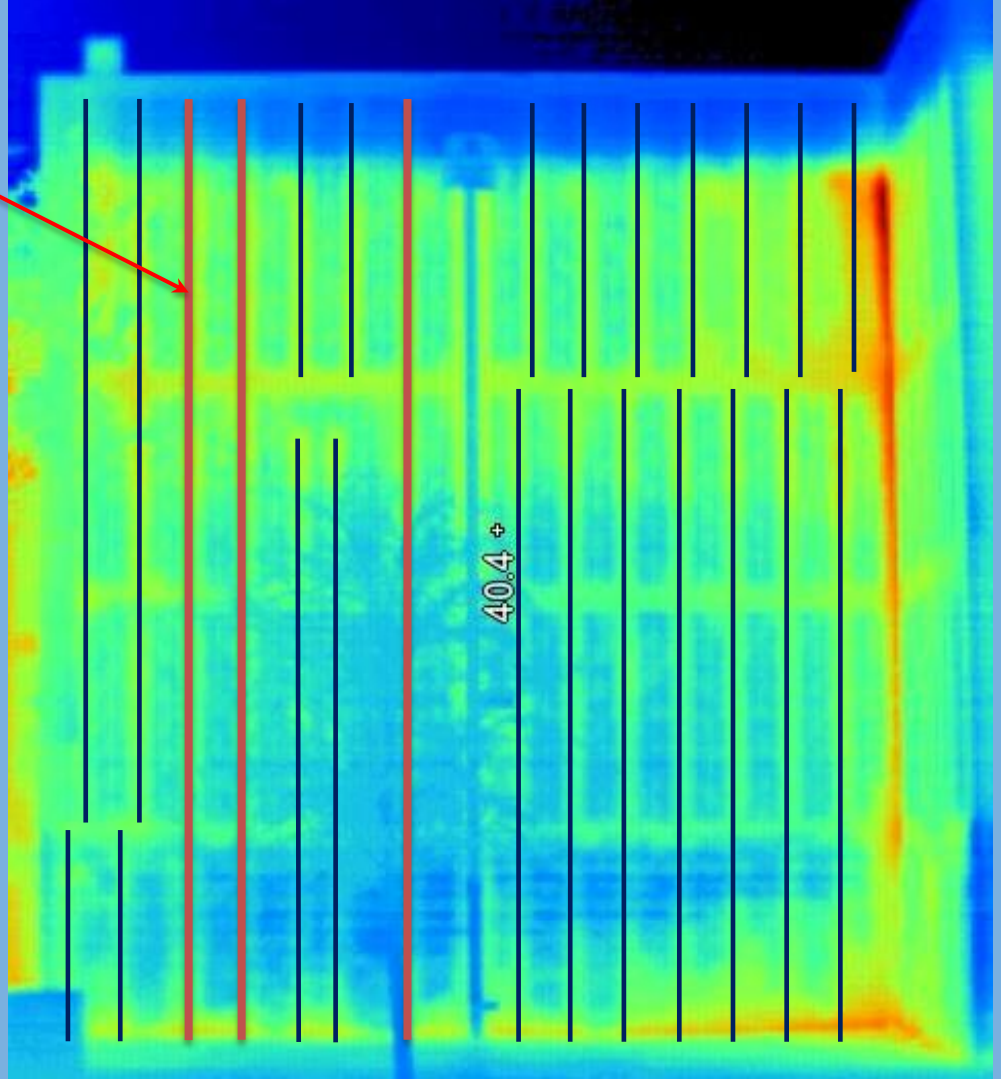
Void in vertical cell

Cells misaligned at bond beam



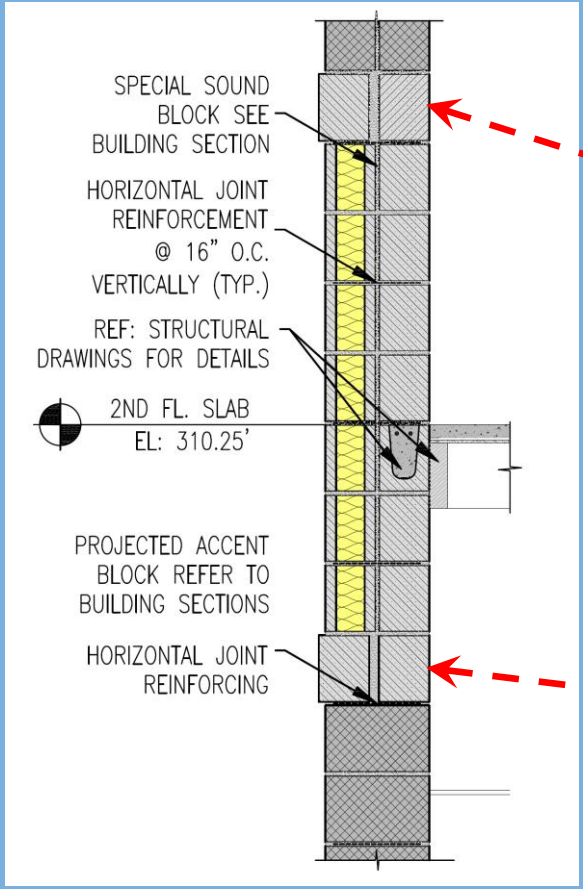
Cells misaligned at bond beam

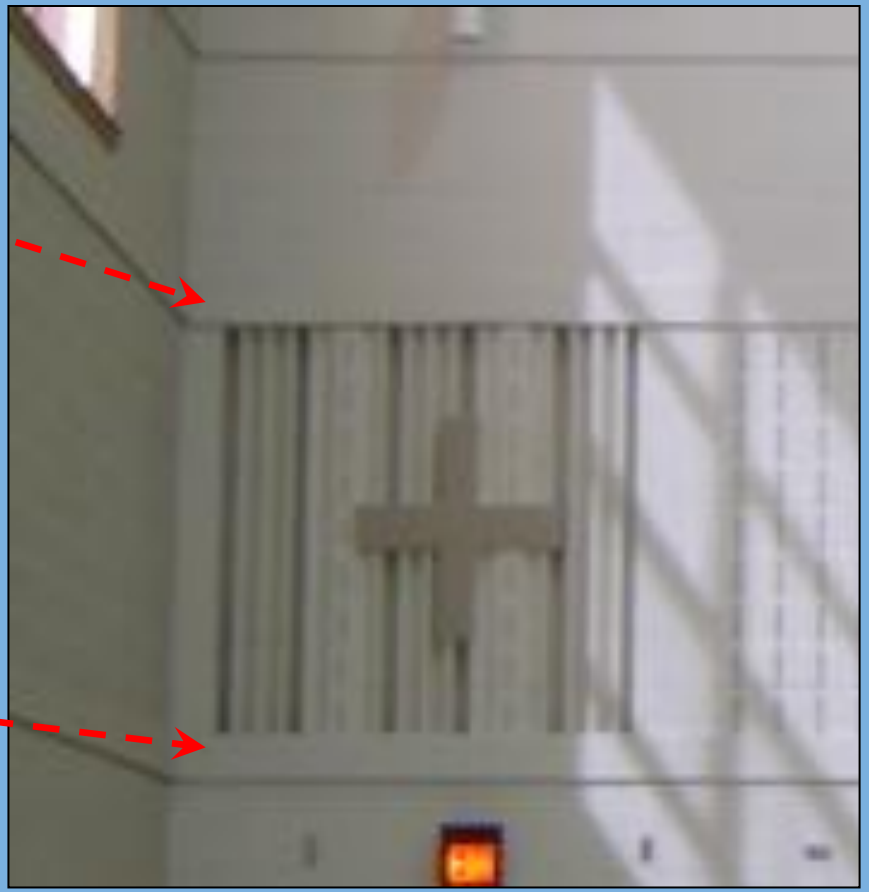
Continuous bars

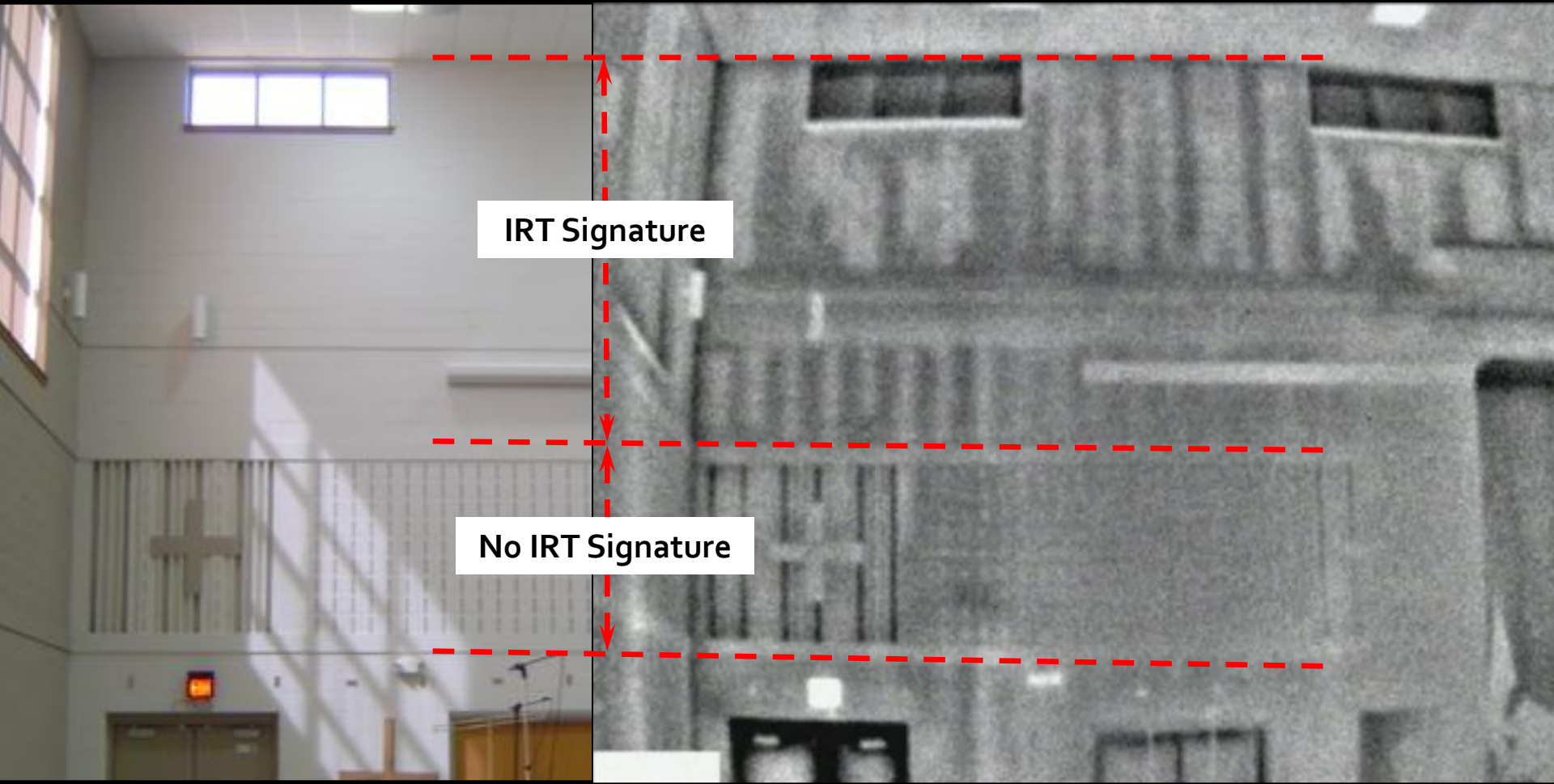


Potentially only 3 continuous reinforcing bars in wall section

Double Wythe Concrete Masonry






IRT Signature
No IRT Signature

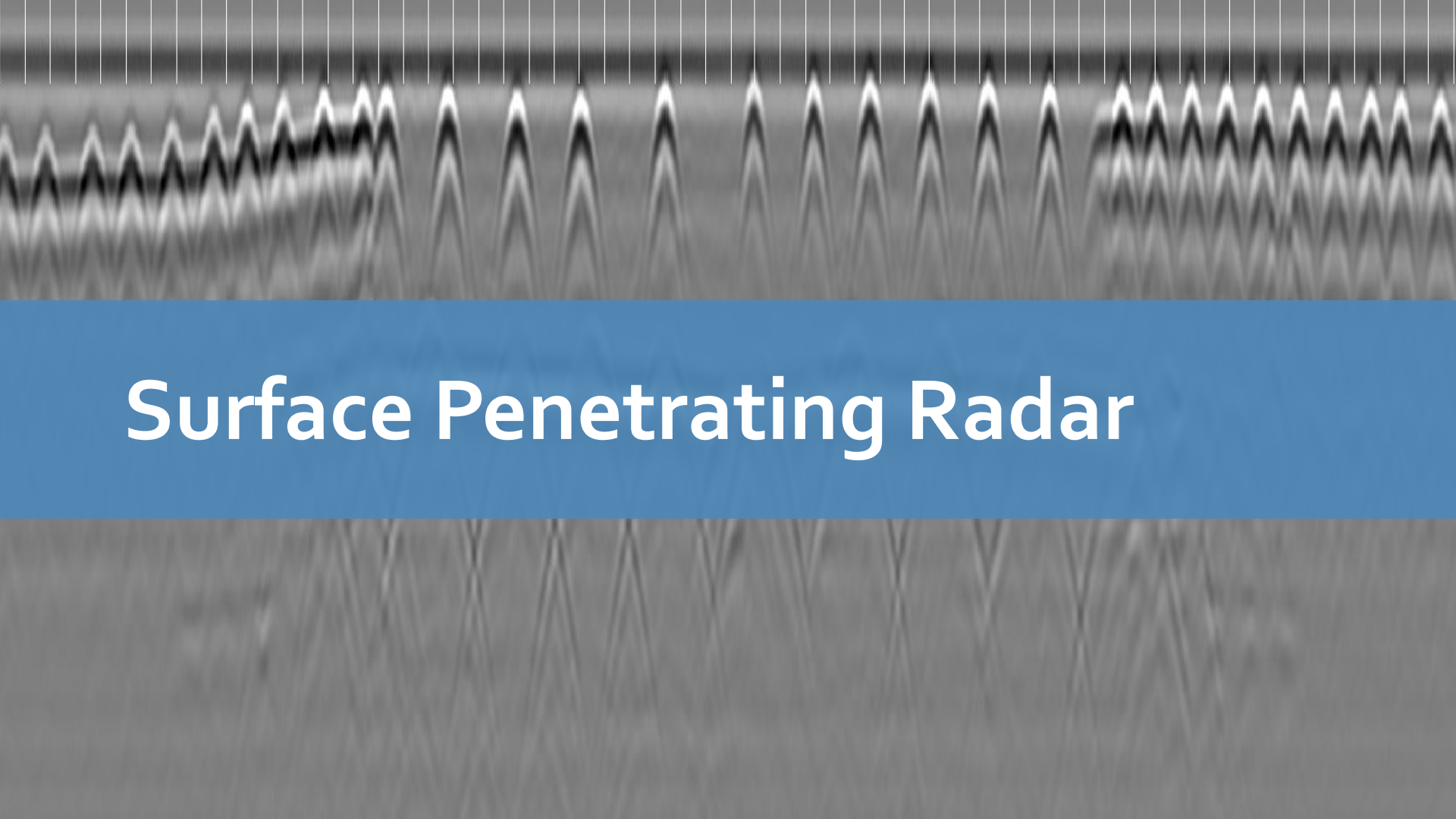
IRT SCAN
CMU WALL

Infrared Thermography Summary

Data can be gathered quickly provided there is an adequate thermal window/differential.

No data related to reinforcement installation is obtained, reinforcement data must be gathered by other NDT methods.

Can be used as part of a QA/QC program during construction.



Surface Penetrating Radar

Surface Penetrating Radar

ADVANTAGES:

Continuous data collection at walking speed with real time visual output

Does not disturb finishes - penetrates surface coatings, carpet, etc.

Requires access from only one side

Separate antennas available for different penetration depths

Very sensitive to steel and air

No radiation hazard - transmitted power is less than a CB radio

Surface Penetrating Radar

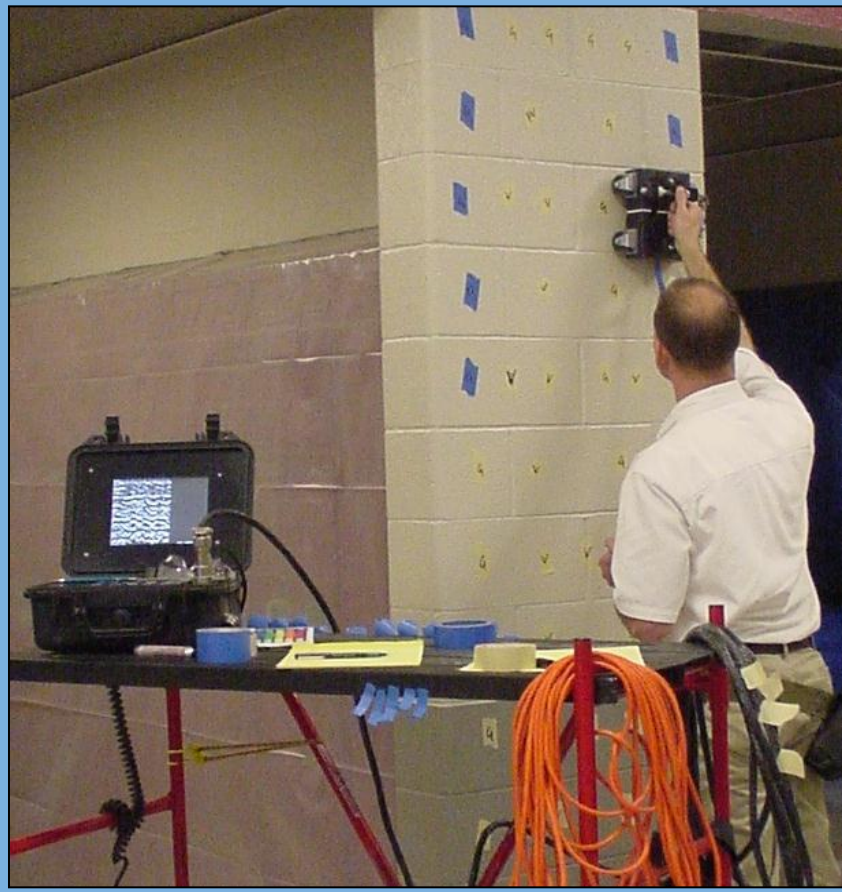
DISADVANTAGES:

Very sensitive to steel & air

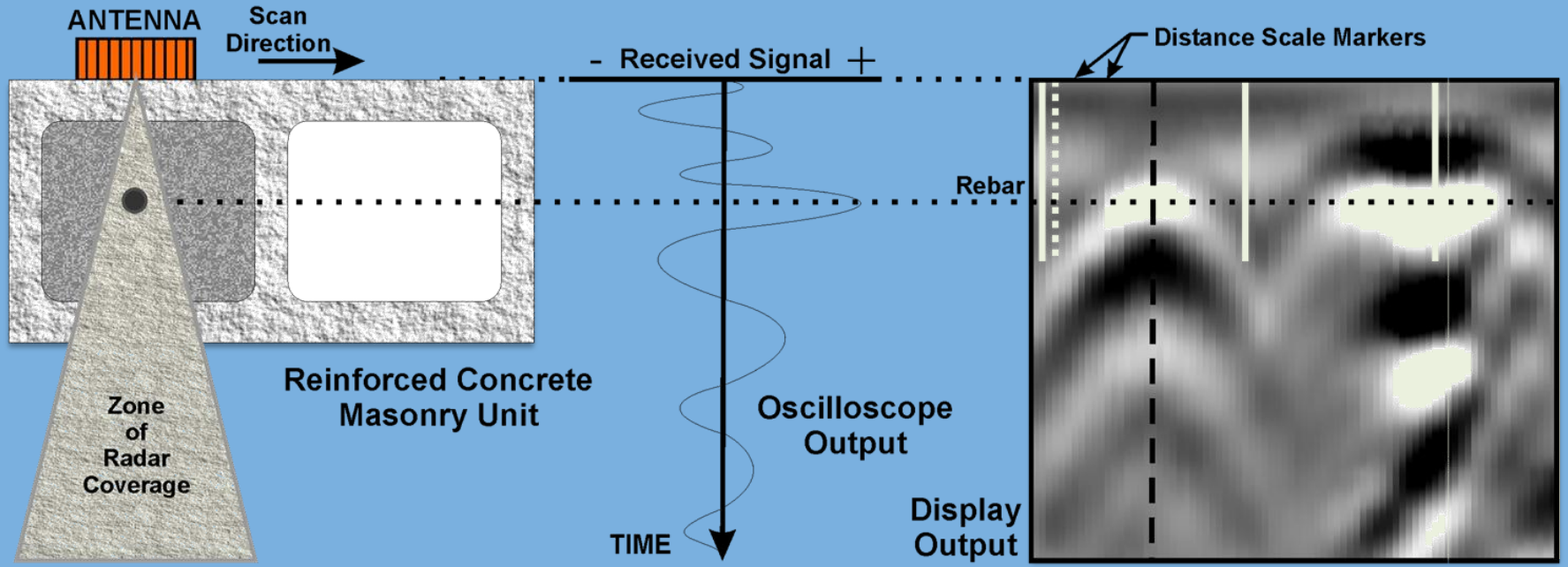
Post-tensioning, rebar, and steel conduits produce similar signals

Loss of resolution vs. penetration depth (deeper penetration less resolution)

Signal interpretation requires SPR experience and knowledge of construction materials & methods



Surface Penetrating Radar



Surface Penetrating Radar

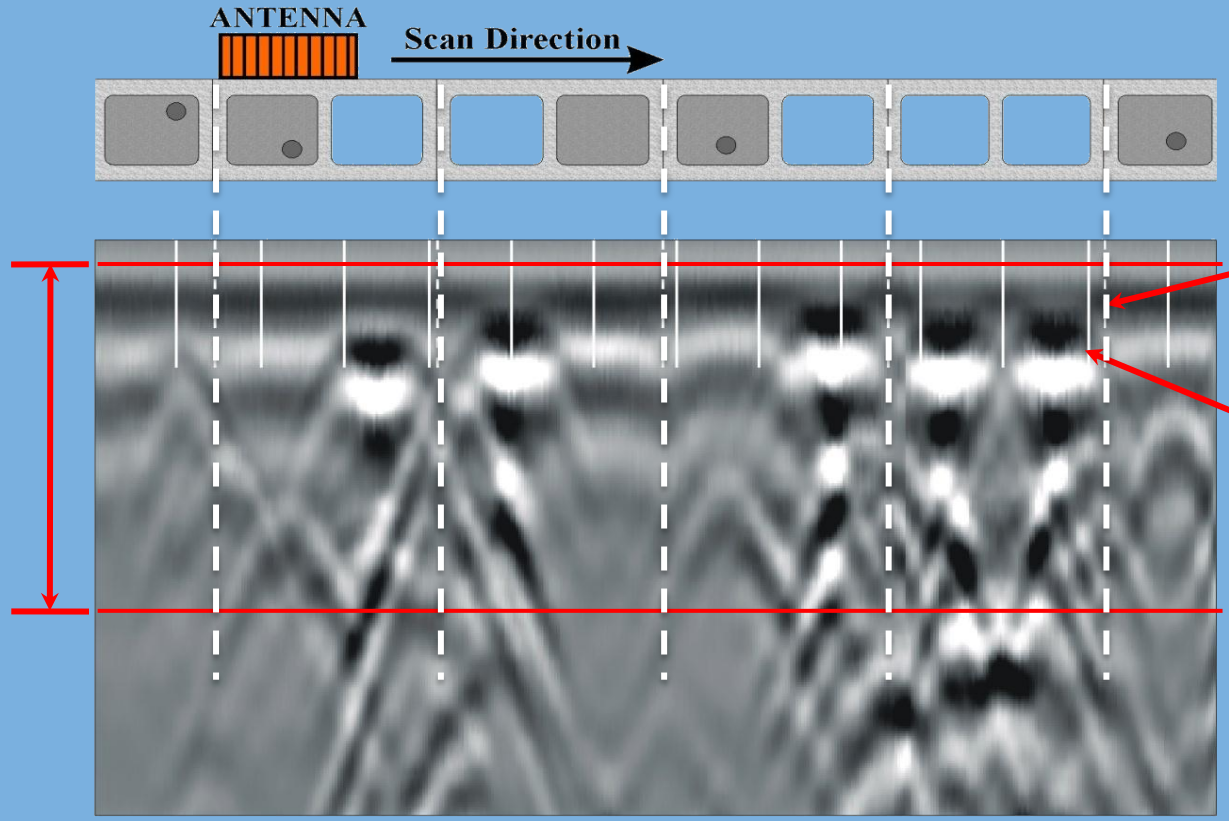
MASONRY APPLICATIONS:

- Reinforcing bar location, depth, & slice length
- Voids in grouted cells or collar joints
- Joint reinforcement location & depth
- Conduit and chase location

DISADVANTAGES:

- Cannot penetrate air spaces or cavities
- Water in wall can obscure readings
- Masonry unit cores or cells can obscure readings

Anatomy of A Radar Signal In Masonry

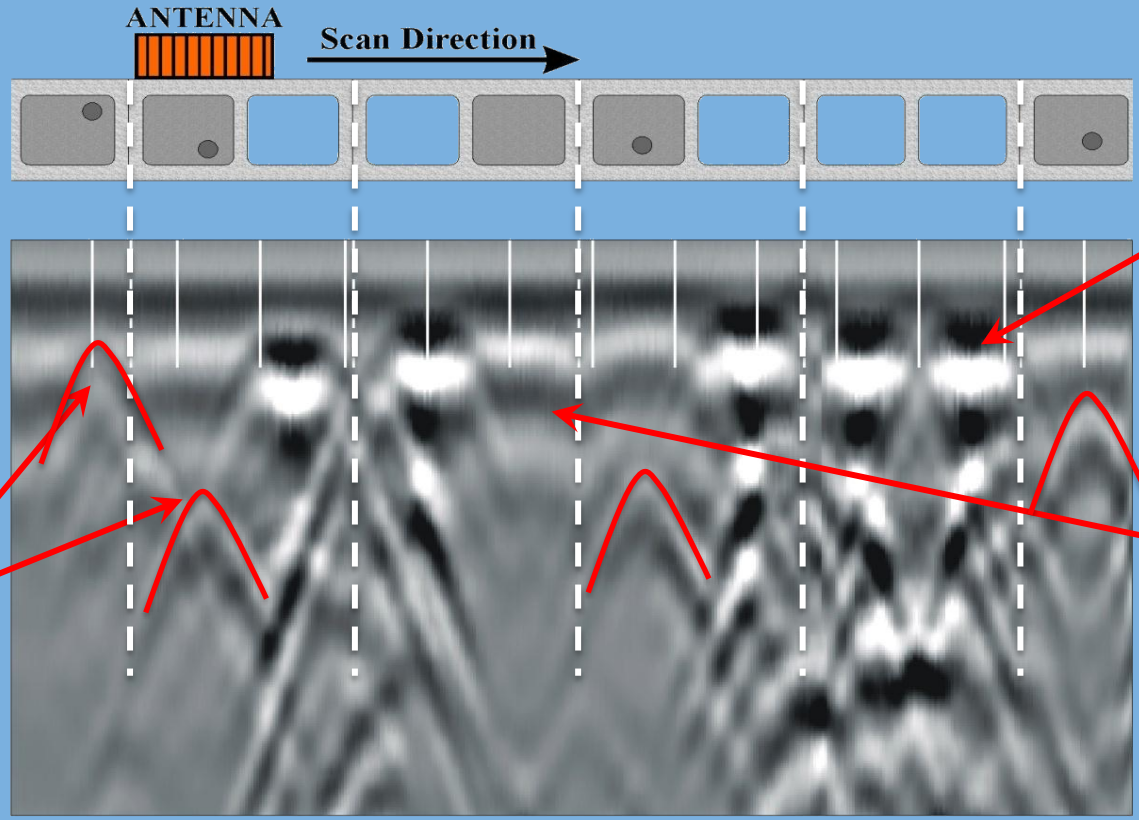


Wall Thickness

Manually Applied Tick Mark

Automatic Horizontal Tick Mark

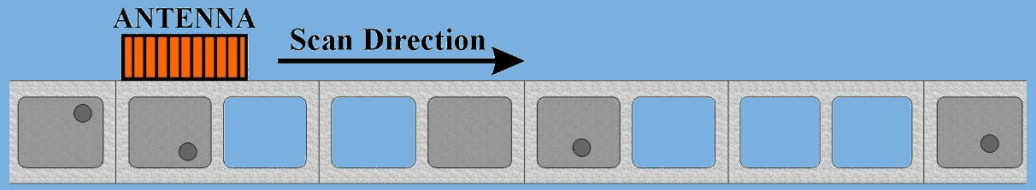
Anatomy of A Radar Signal In Masonry



Void Cell
No Grout
(B-W-B)

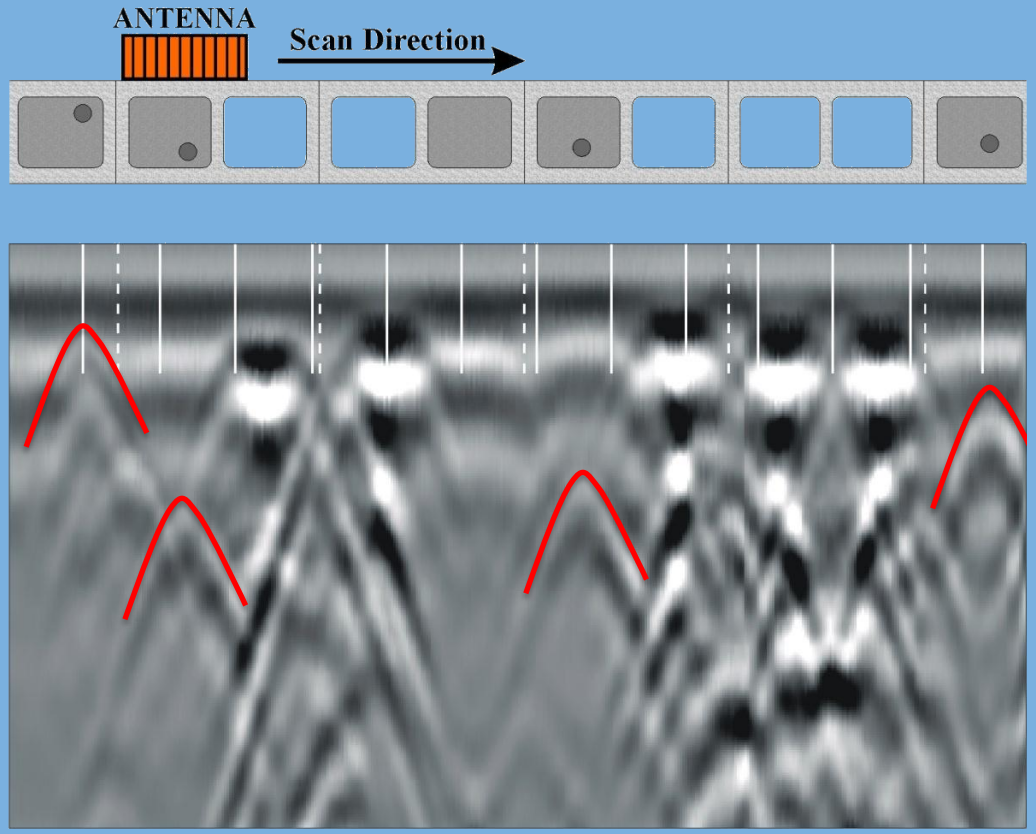
Grouted
Cell & Rebar
(W-B-W)

Grouted
Cell No
Rebar



SPR TESTING
CMU WALL

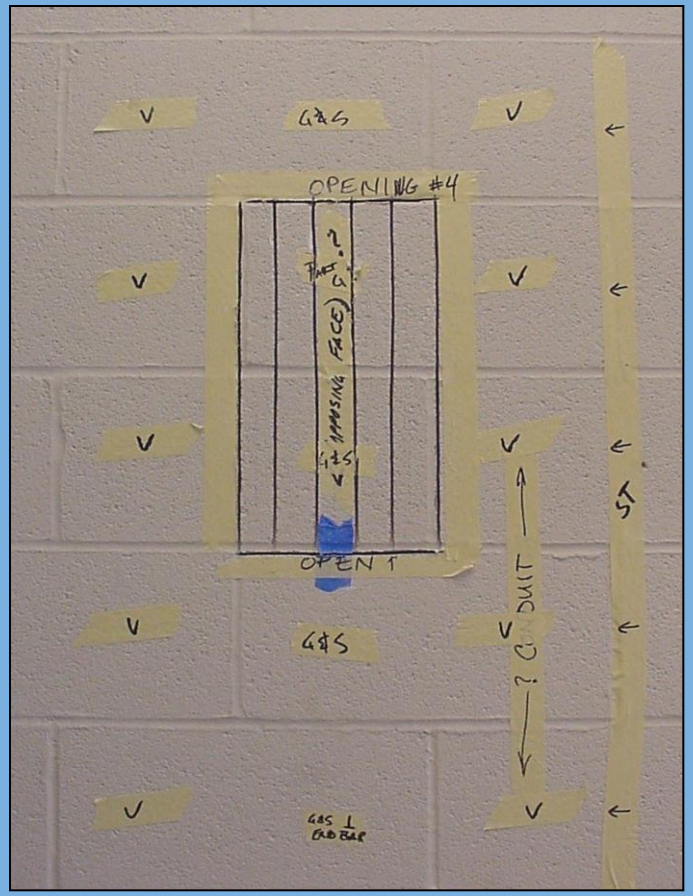
Back Face of Wall

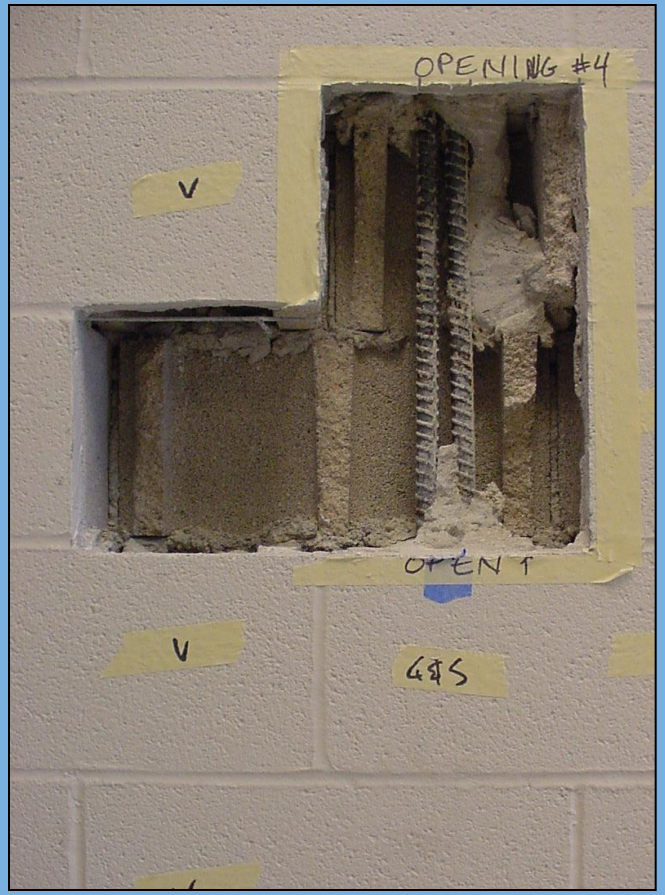

ANTENNA
Scan Direction

Loadbearing Masonry High School
Lancaster, PA

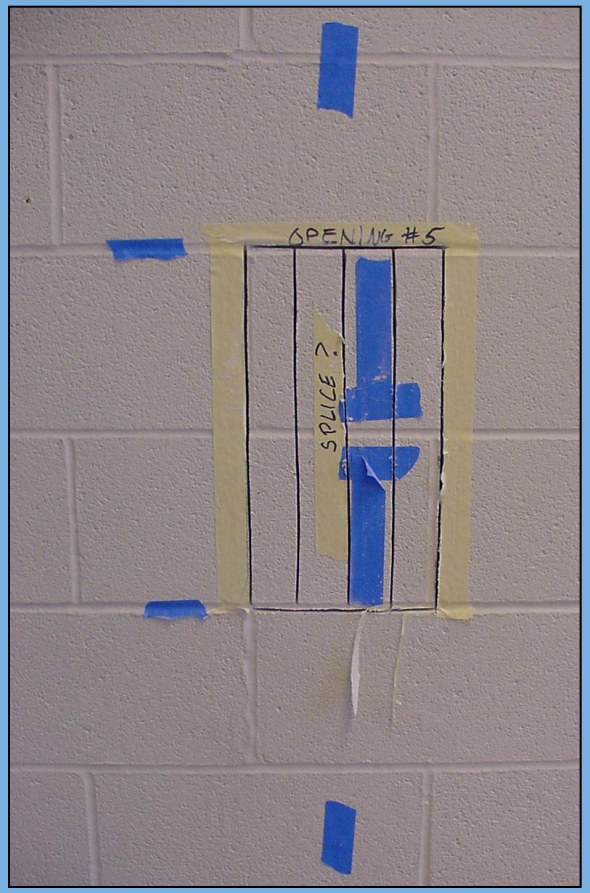
- Identify grouting & reinforcing deficiencies using surface penetrating radar (SPR)
- Development of as-built drawings using SPR data

Wall Reinforcement & Grouting

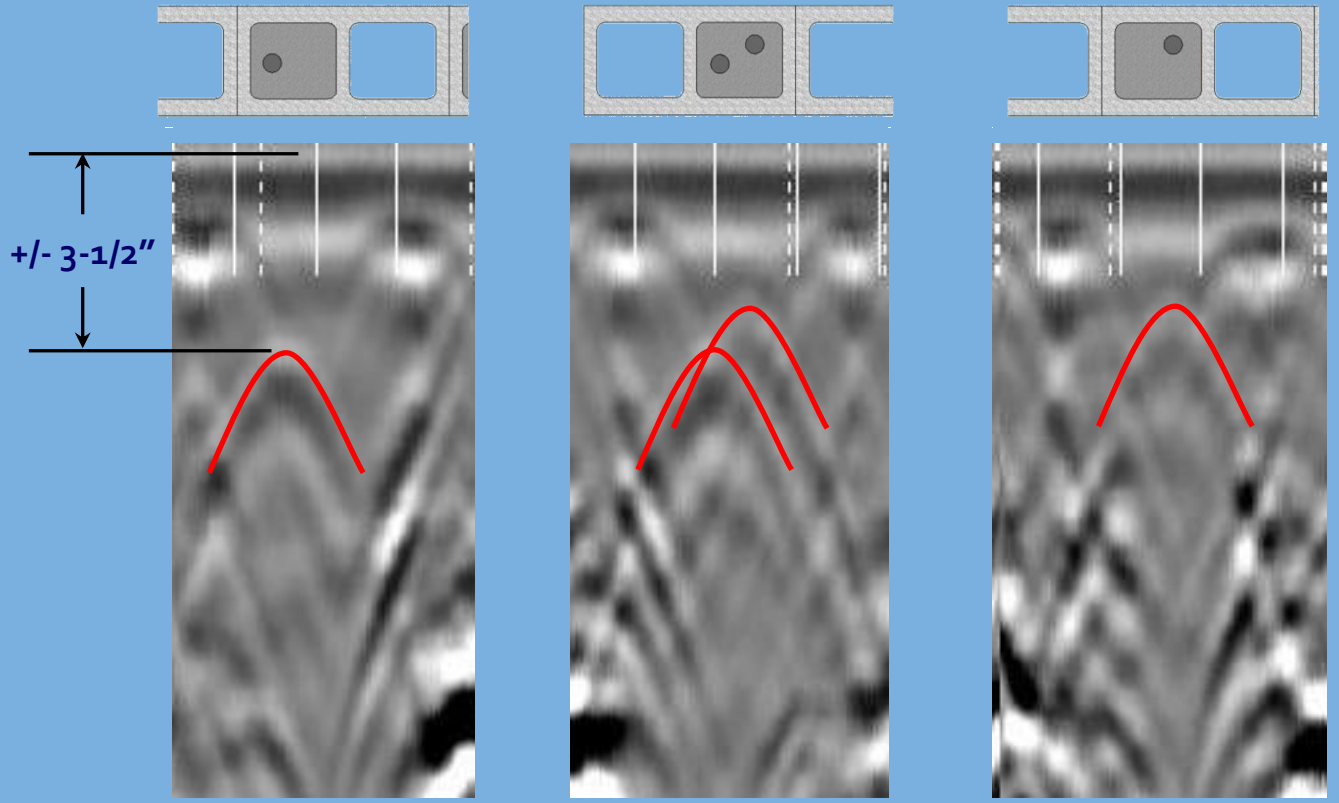




Wall Reinforcement & Splices



Wall Reinforcement & Splices



Course Above Splice

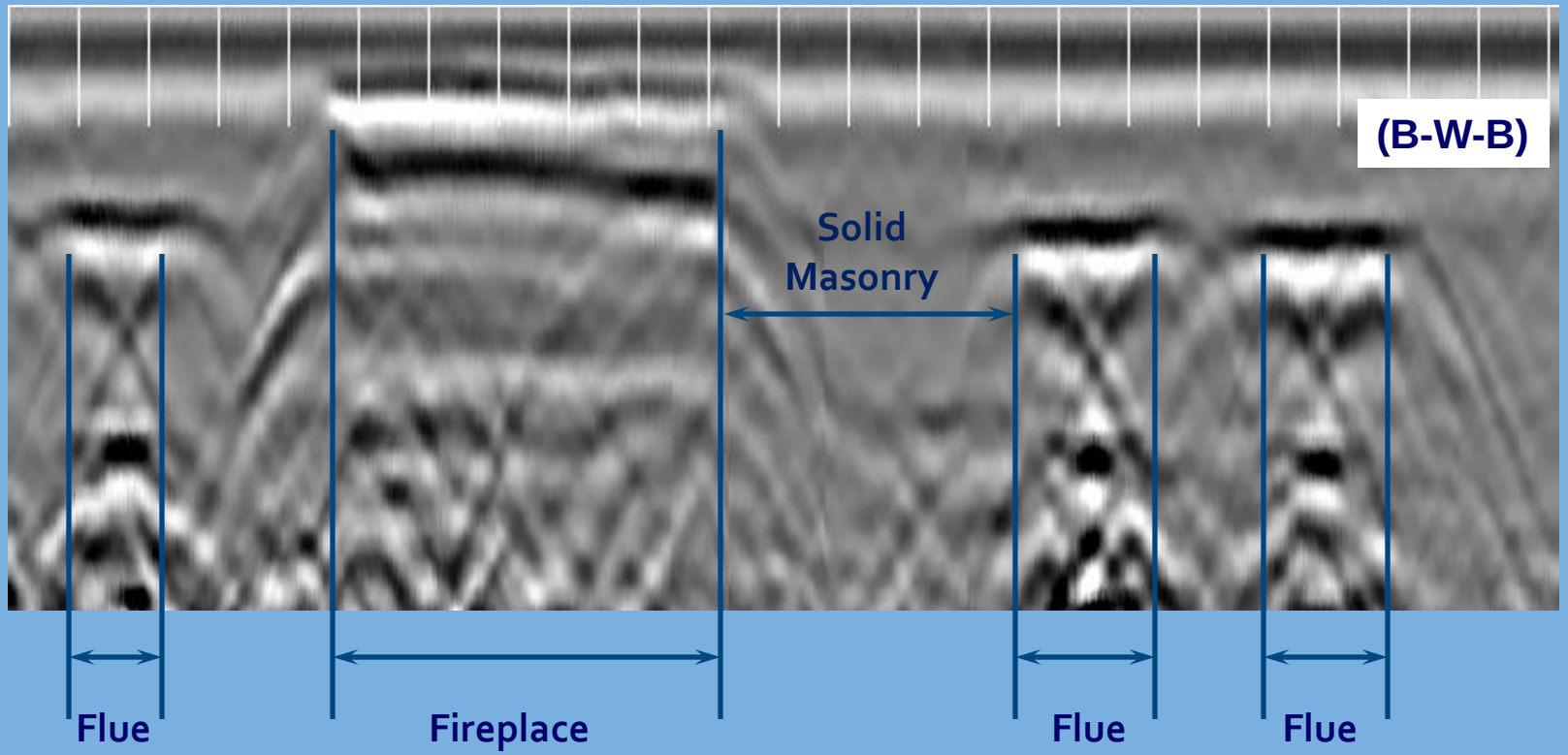
Course At Splice

Course Below Splice

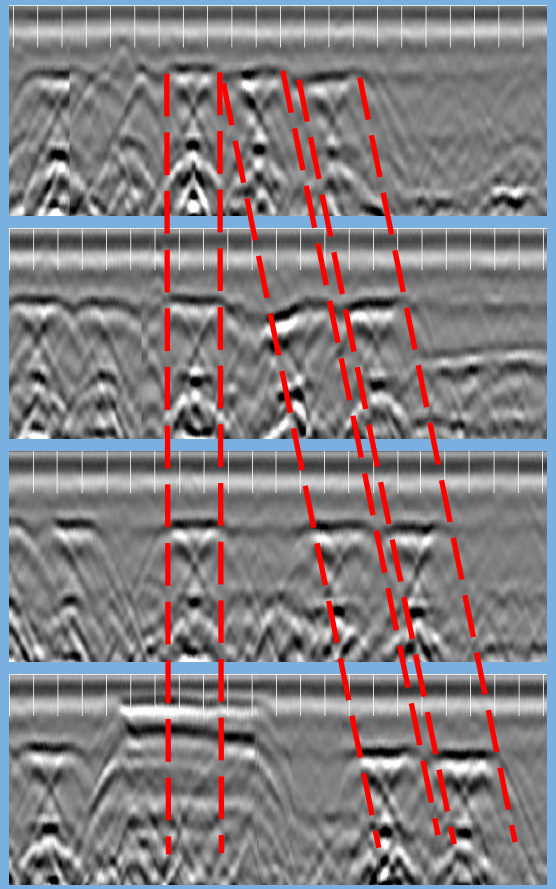
Multi-Wythe Masonry

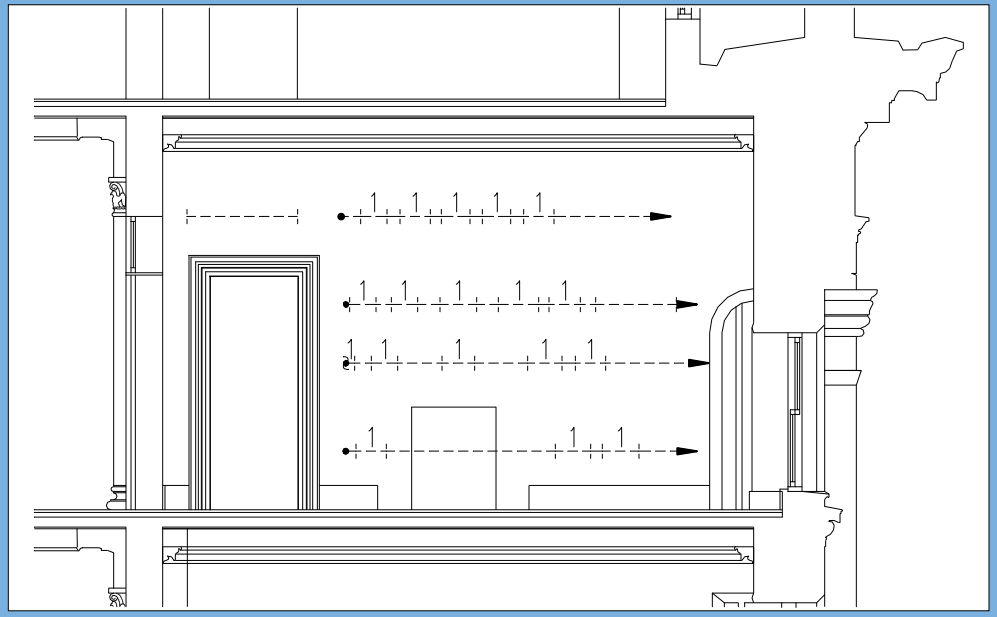
Multi-Wythe Masonry

Multi-Wythe Masonry



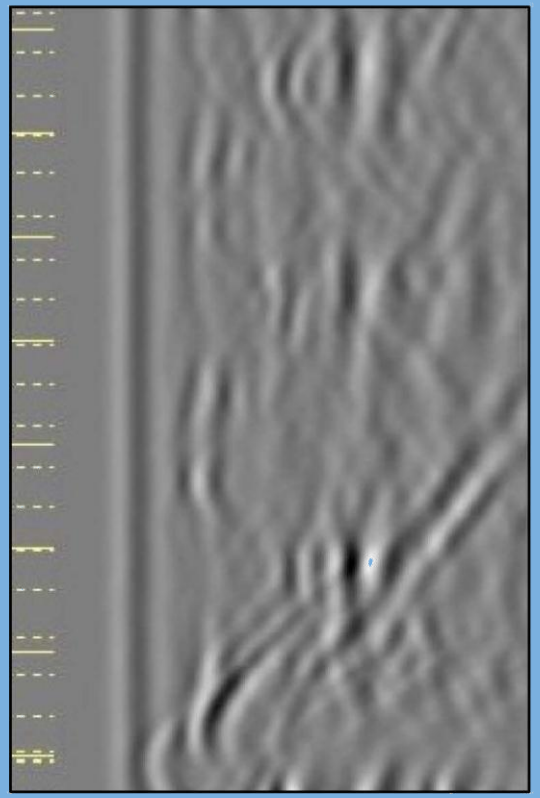
Multi-Wythe Masonry





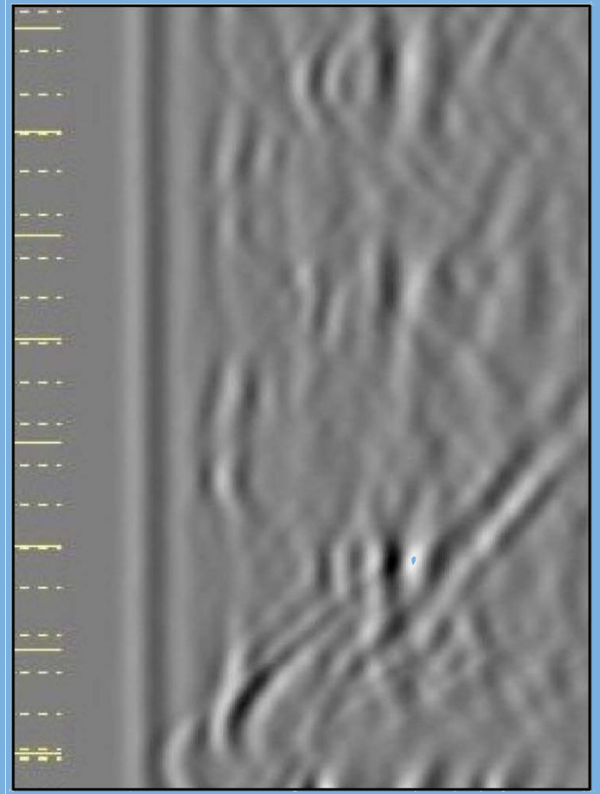
Partial Wall Elevation

Location of Flemish Bond Headers

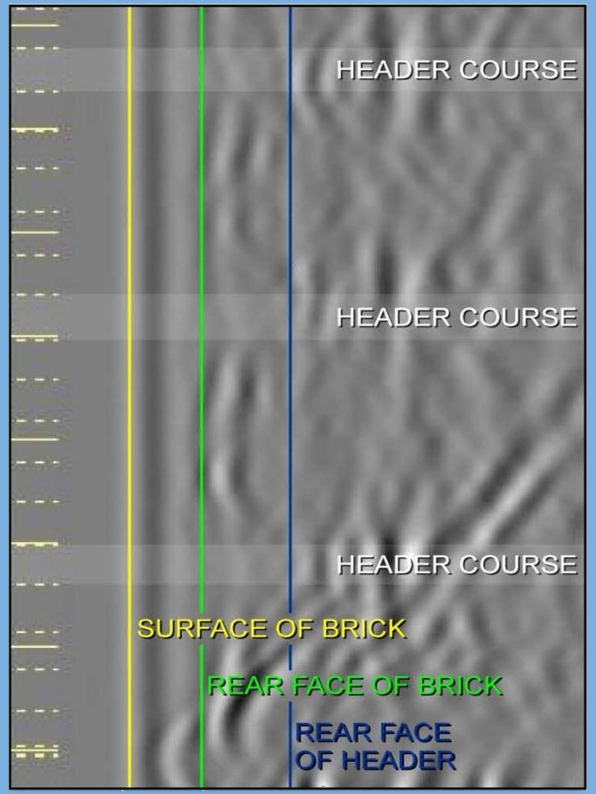


Raw SPR Signal

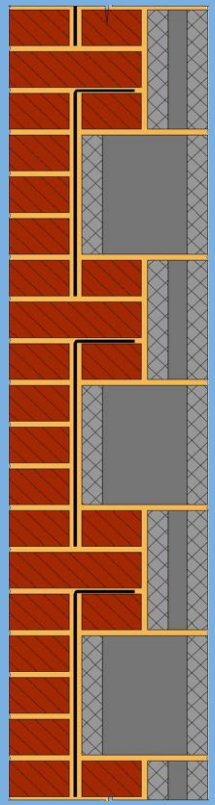
Location of Flemish Bond Headers



Raw SPR Signal



Signal Interpretation



Wall Section

Surface Penetrating Radar Summary

Detecting Targets

Radar waves attenuate in air, making it difficult to detect targets within large (deep) air voids. For example, **rebar located in the hollow cell of a CMU will not usually be detected by SPR.**

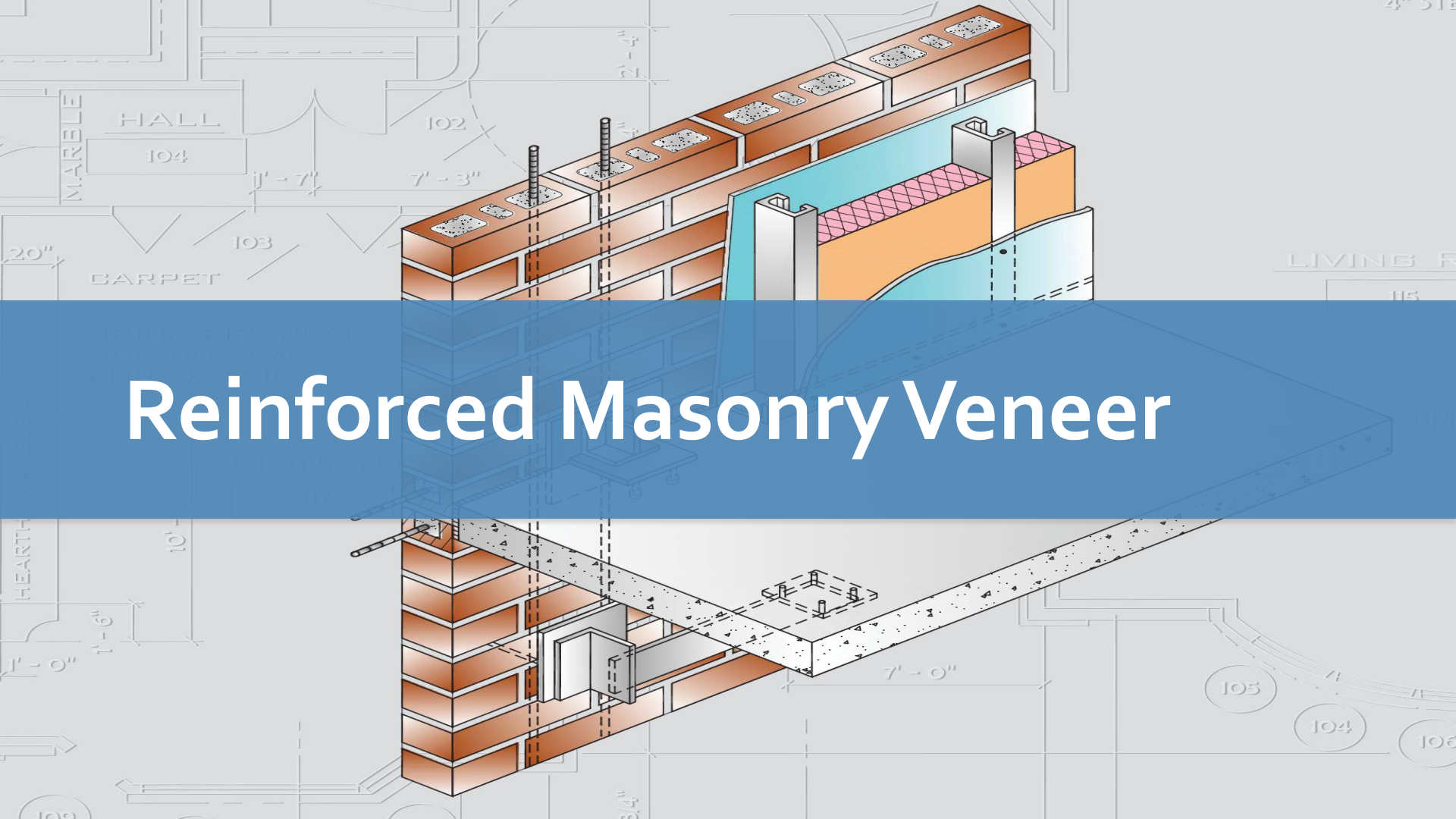
Because radar cannot penetrate metal, hollow steel objects, such as conduits, **generate the same signal as a solid steel rebar** or an unbonded monostrand tendon (provided the diameters are similar).

Embedded **steel reinforcement as small as 9 gage diameter** can be detected due to the reflective property of metals and other conductive materials.

Masonry Repair Topics

Reinforced masonry veneer

Post-tensioned masonry



Reinforced Masonry Veneer

Reinforced Masonry Veneer

Reduces the structural requirements for veneer back-up walls.

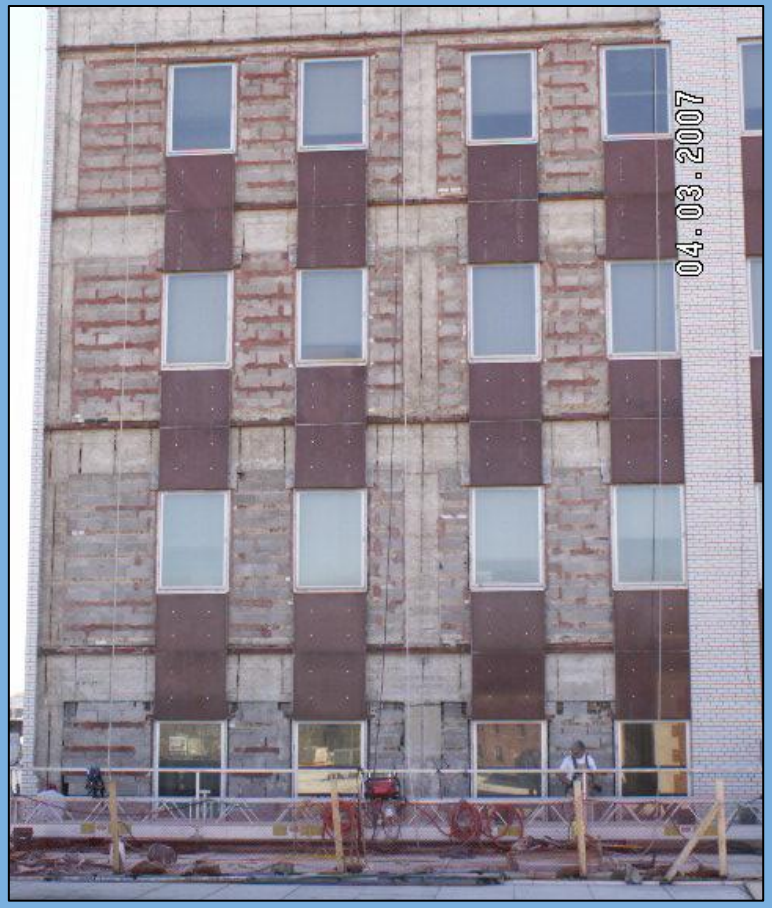
- ι/600 for steel studs
- Thinner concrete masonry units

Typically lighter than precast concrete and brick faced concrete panels.

Can be built in place using standard masonry construction techniques.

Reduced number of anchor connections resulting in a more continuous moisture and air barrier.

Reinforced Masonry Veneer



Often Advantageous for composite walls requiring exterior wythe replacement.

Desire to install air space, air and water barrier.

Airspace negates composite action between wythes.

Back-up strength or frame connections suspect or of inadequate capacity for non-composite wall system.

Reinforced Masonry Veneer

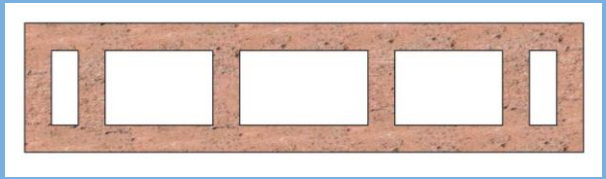
Inner wythe connection to frame suspect.

Reinforced Masonry Veneer

Inner wythe construction quality suspect.

Reinforced Masonry Veneer

Typical Wall Weights:



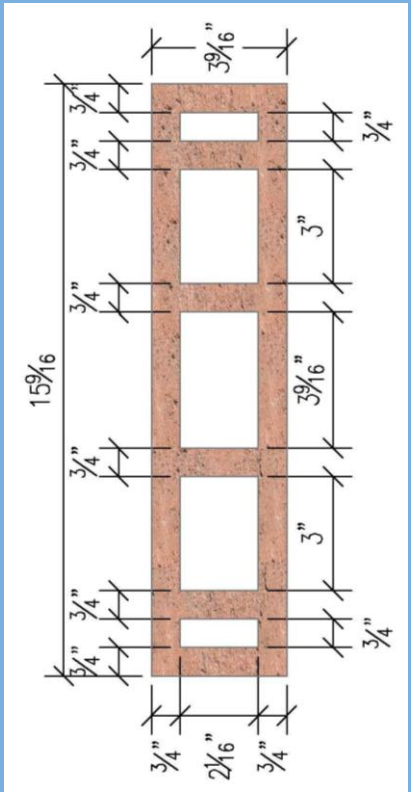
4″ x 4 ″ x 16 ″ Unit

WEIGHT OF WALL	4 x 4 x 16		6 x 4 x 16	
	psf	Kg/m^2	psf	Kg/m^2
Hollow	25	122	30	146
Grout @ 48″ o.c. (1.2 m)	28	137	38	186
40″ o.c. (1.0 m)	29	142	39	190
32″ o.c. (.81 m)	30	146	40	195
24″ o.c. (.61 m)	31	151	42	205
16″ o.c. (.41 m)	33	161	45	220
Solid	38	186	56	273

Typical ASTM C216 solid face brick wall weight: 40 psf

Reinforced Masonry Veneer

Strength Design Reinforcement Limits:



Diameter ≤ 1/8 nominal member thickness

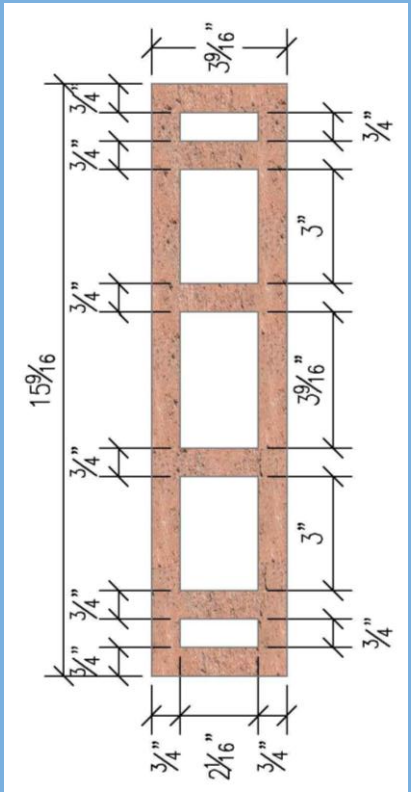
Diameter ≤ 1/4 least clear dimension of cell

Bar area ≤ 4% of grout space area

9 bar or smaller

Reinforced Masonry Veneer

Strength Design Reinforcement Limits:



Diameter $\leq$ 1/8 nominal member thickness: 1/8 x (4″) = 0.5″

Diameter $\leq$ 1/4 least clear dimension of cell: 1/4 x (2″) = 0.5″

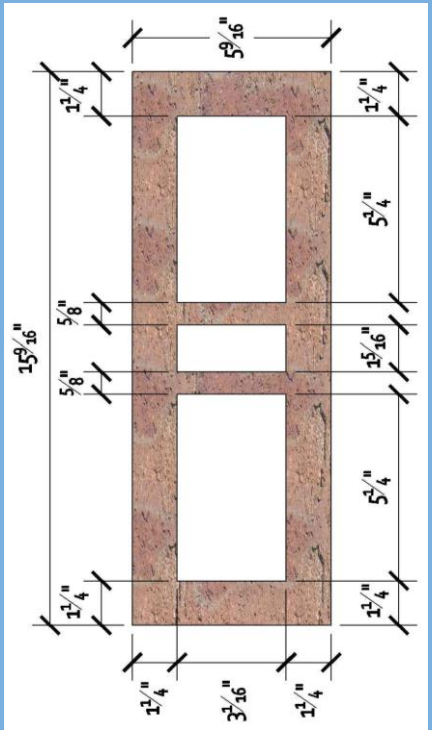
Bar area $\leq$ 4% of grout space area: 0.04 x (3″ x 2″) = 0.24 in^2

9 bar or smaller

Bar Size #	Diameter in	Area in^2
3	3/8	0.11
4	1/2	0.20
5	5/8	0.31
6	3/4	0.44

Reinforced Masonry Veneer

Strength Design Reinforcement Limits:



Diameter $\leq$ 1/8 nominal member thickness: 1/8 x (6″) = 0.75″

Diameter $\leq$ 1/4 least clear dimension of cell: 1/4 x (3″) = 0.75″

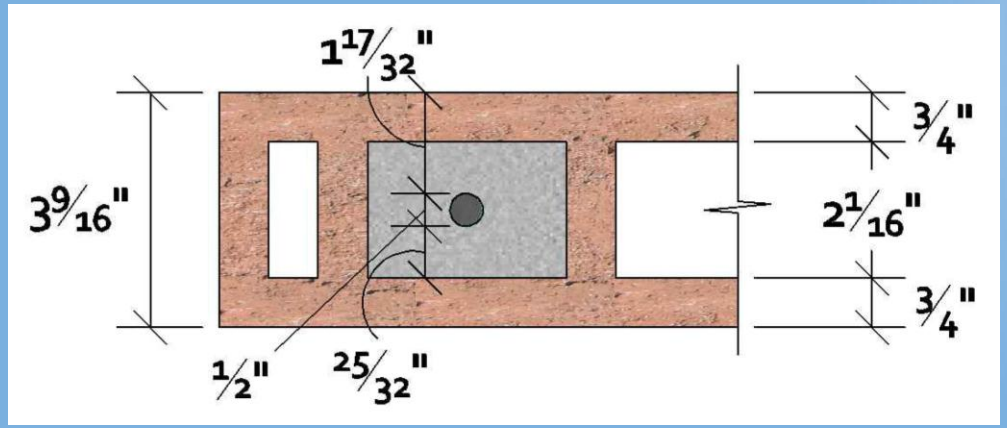
Bar area $\leq$ 4% of grout space area: 0.04 x (5.25″ x 3″) = 0.63 in^2

9 bar or smaller

Bar Size #	Diameter in	Area in^2
3	3/8	0.11
4	1/2	0.20
5	5/8	0.31
6	3/4	0.44

Reinforced Masonry Veneer

Cover Requirements:



Bar size ≤ #5: 1-1/2″

Bar size ≥ #5: 2″

Grout cover:

Fine grout: ¼″

Coarse grout: ½″

Reinforced Masonry Veneer

2009 IBC Strength Design

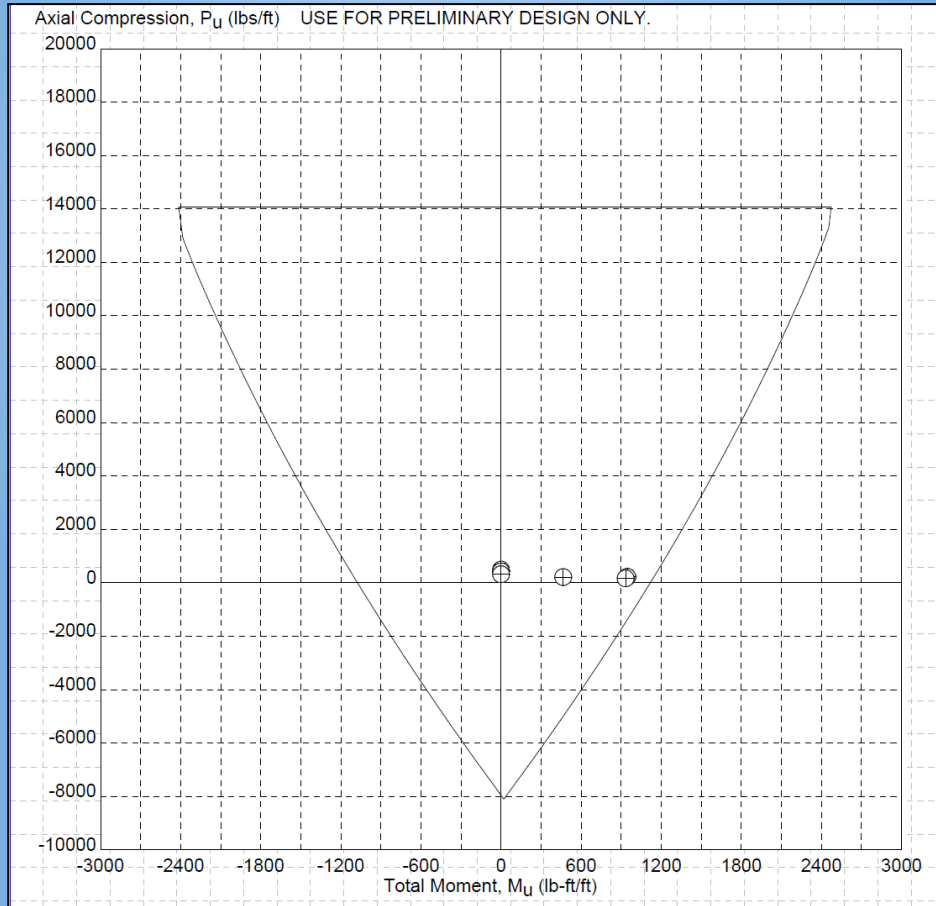
Masonry Unit: 4" partially grouted

Reinforcement: #4 @ 16" o.c.

F_y = 60 ksi f'_m = 3,000 psi

As = 0.2 in² d = 1.71" H = 12'-8"

Wind Load: 28 psf Wall weight: 33 psf



Reinforced Masonry Veneer

2009 IBC Strength Design

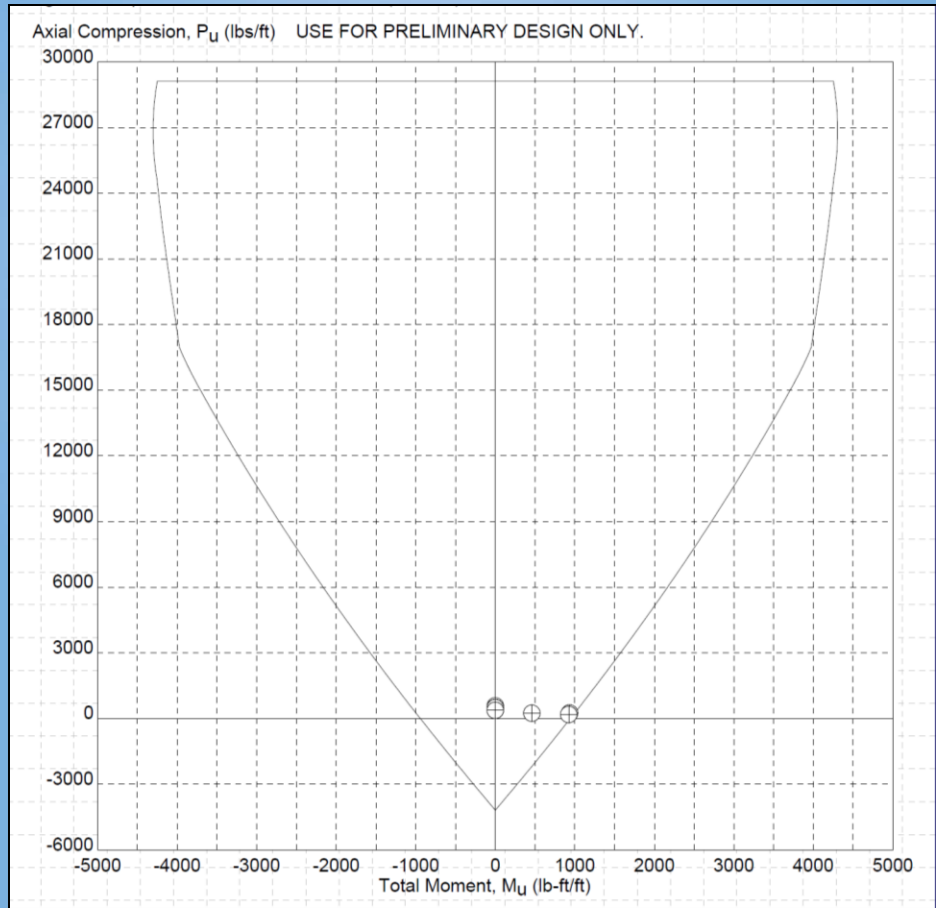
Masonry Unit: 6" partially grouted

Reinforcement: #5 @ 48" o.c.

F_y = 60 ksi f'_m = 3,000 psi

As = 0.31 in² d = 2.81" H = 12'-8"

Wind Load: 28 psf Wall weight: 38 psf



Reinforced Masonry Veneer

2009 IBC Strength Design

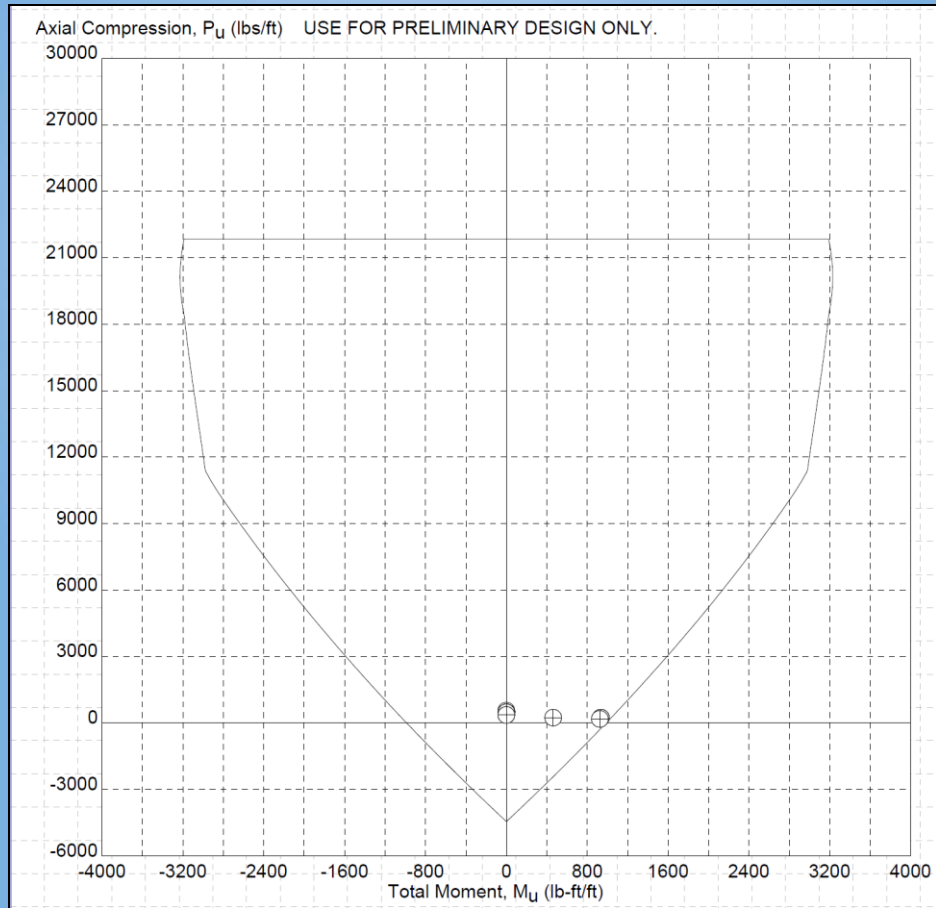
Masonry Unit: 6" partially grouted

Reinforcement: #6 @ 64" o.c.

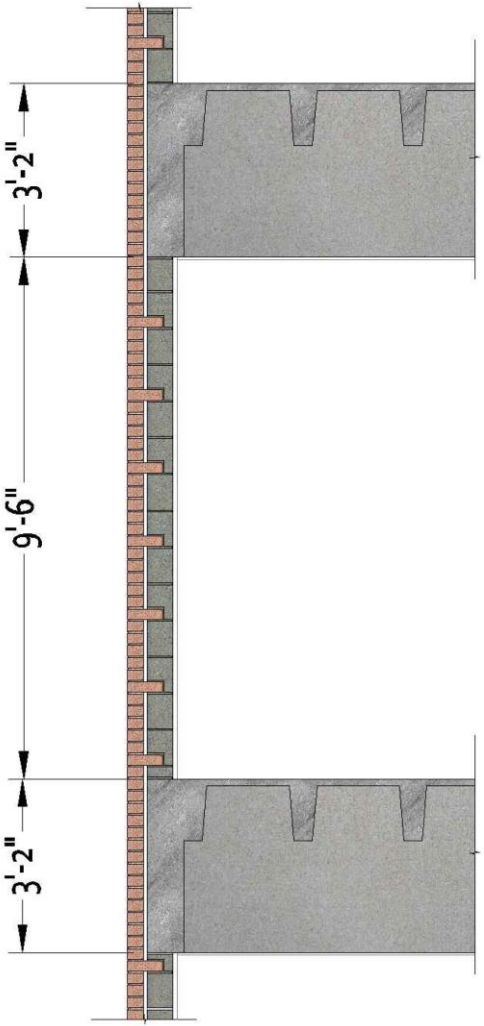
F_y = 60 ksi f'_m = 3,000 psi

As = 0.31 in² d = 2.81" H = 12'-8"

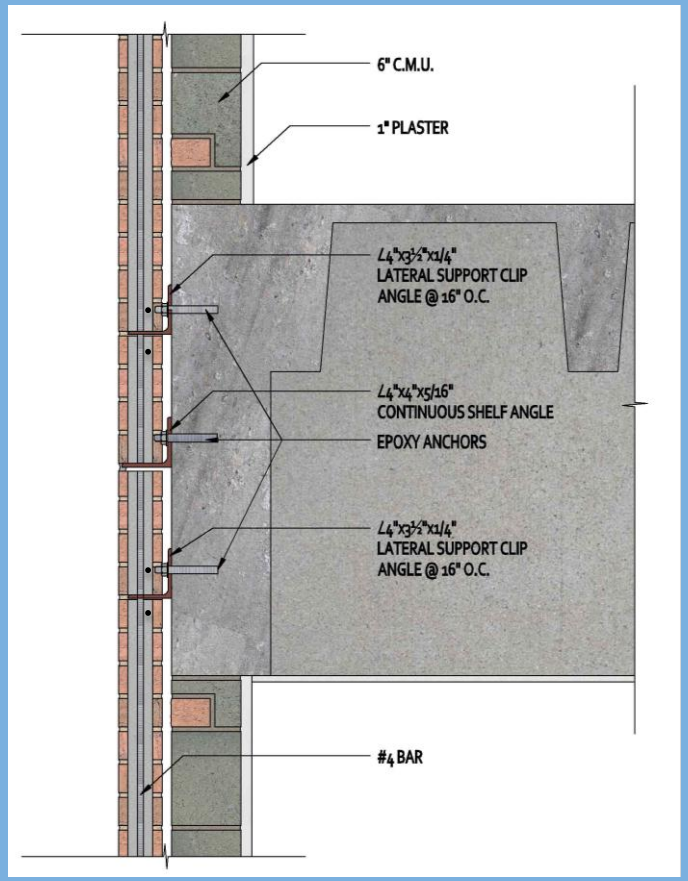
Wind Load: 28 psf Wall weight: 35 psf

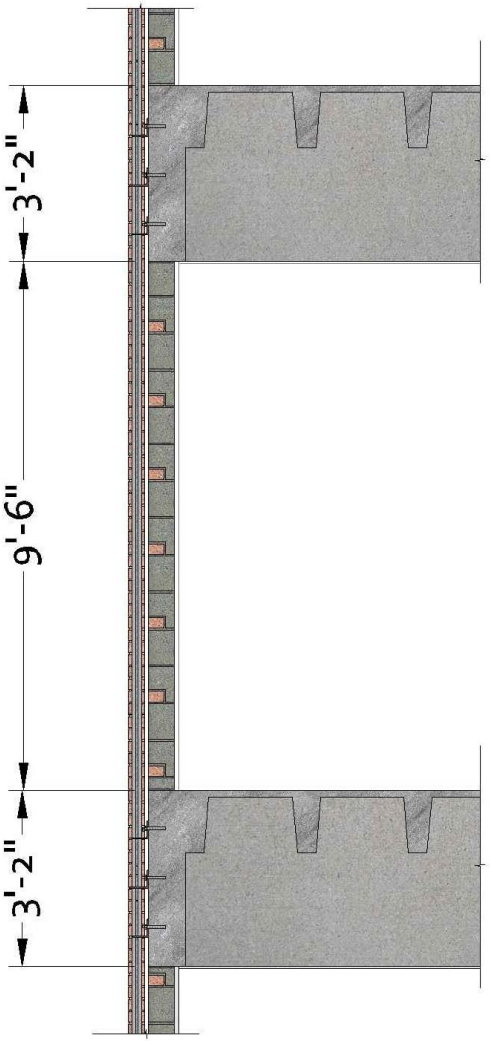


Reinforced Masonry Veneer

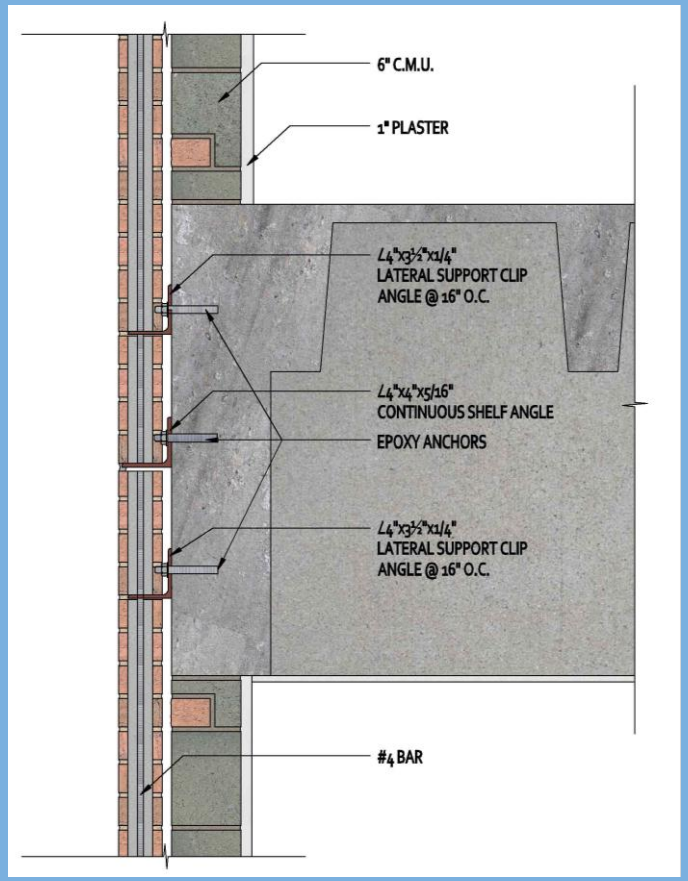


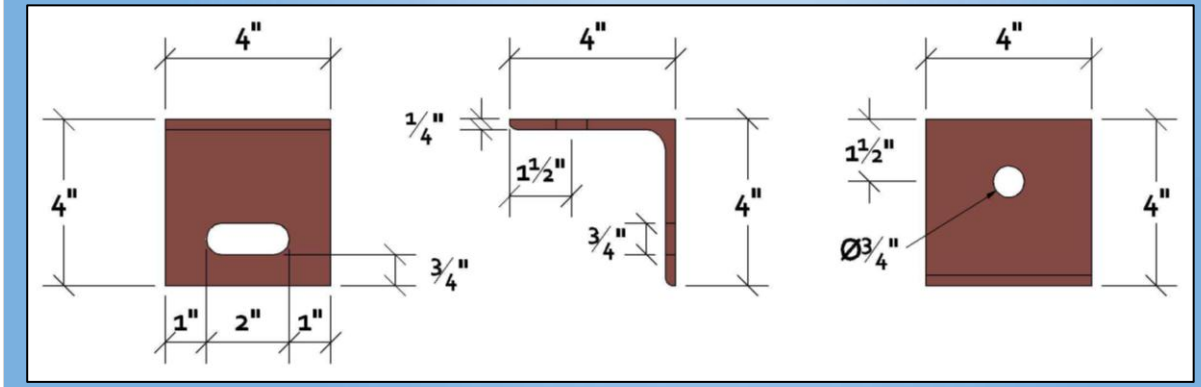
Reinforced Masonry Veneer



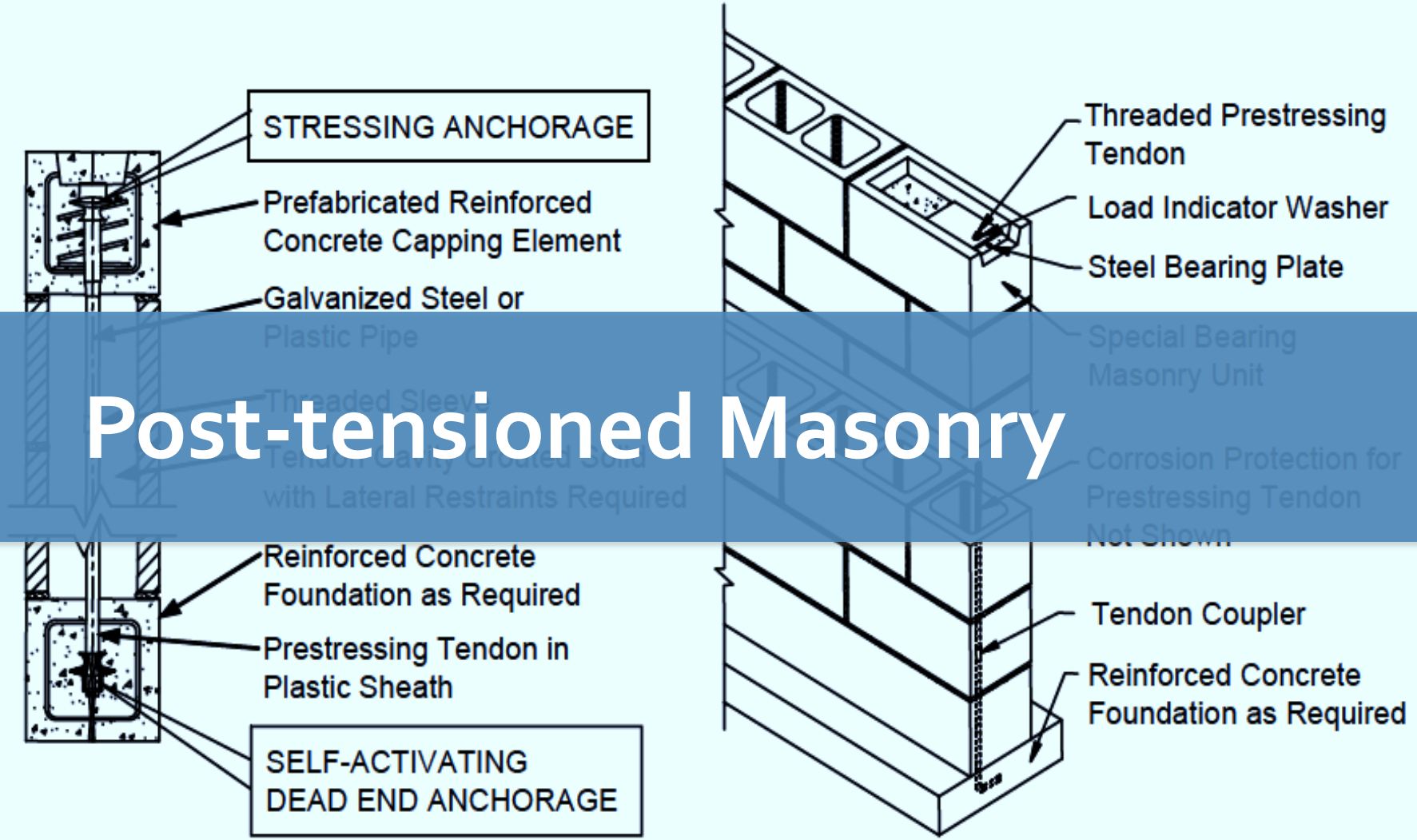


Reinforced Masonry Veneer





Lateral load clip angles.



Post-tensioned Masonry

Post-Tensioned Masonry

Advantageous Method When:

Hollow masonry walls

Cells are insulated preventing effective grouting

Conventional reinforcing and grouting would be too disruptive

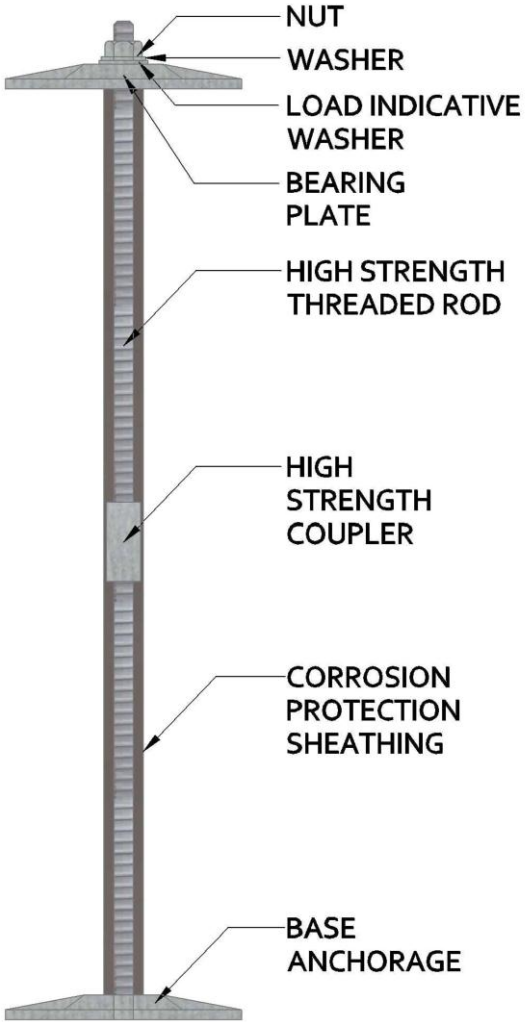
Post-Tensioned Masonry

Components:

Similar to conventional post-tensioned bar systems

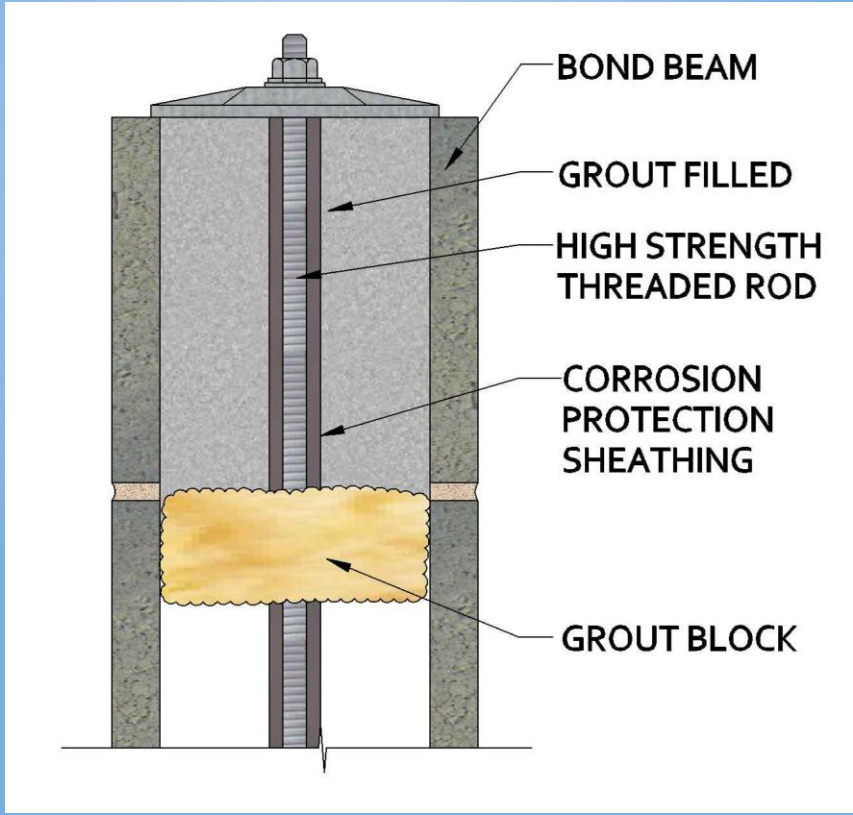
Compressive loads normally 5,000 to 16,000 lbs

7/16", 1/2", and 3/4'' diameter systems most common



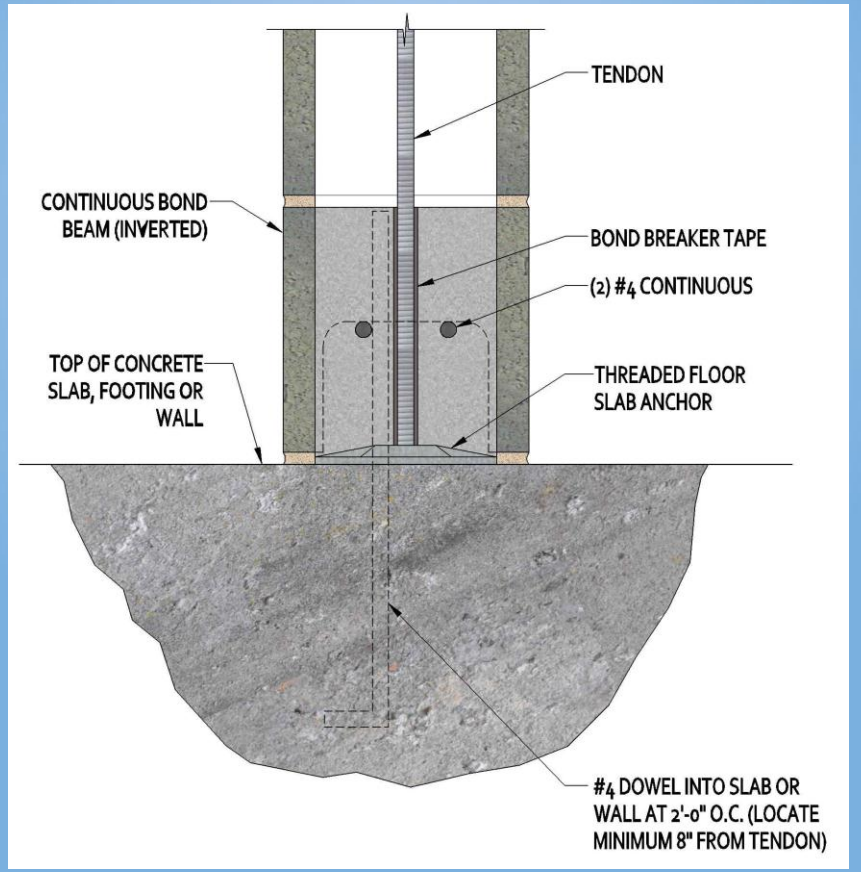
Post-Tensioned Masonry

Wall Top Detail:



Post-Tensioned Masonry

Base Detail:



Post-Tensioned Masonry

Typical Tensioning:

Proprietary Wall System (7/16" rod):

- Initial: 7,400 lbs
- After losses: 5,000 lbs

Generic Systems:

- Initial: 30,000 lbs
- After losses: 16,000 lbs

Post-Tensioned Masonry

Post-Tensioned Masonry

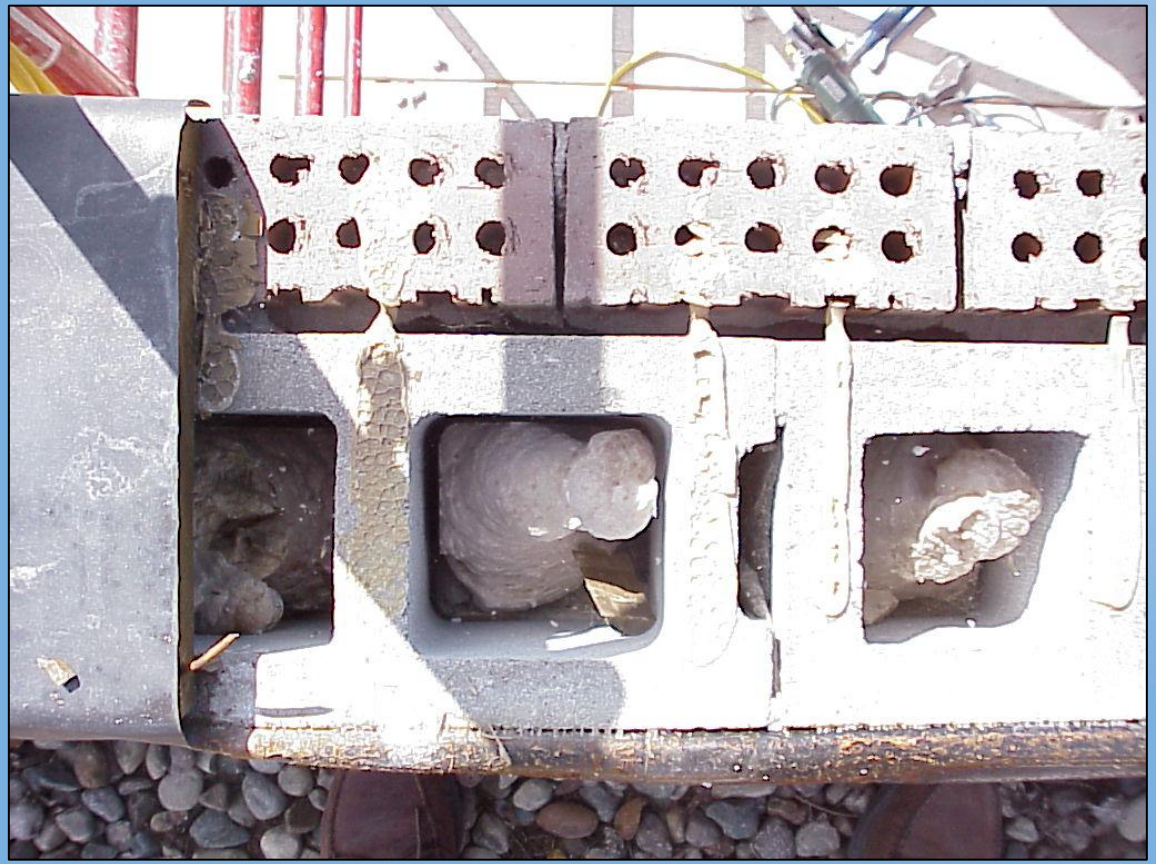
20,500 sq. ft. Commercial Building

Empirically designed

12″ CMU and 8″ CMU + 4″ Brick

22′ max. bearing height, 24′-8″ top of masonry

Post-Tensioned Masonry



CMU cells insulated with foam.

Post-Tensioned Masonry

CMU cells removed for base

CMU cells removed for coupler

Post-Tensioned Masonry

Coupler installation

Bar restrainer installation

Post-Tensioned Masonry

Protective sleeve

Bearing plate

Post-Tensioned Masonry

Tensioning rod

Tension verification

Post-Tensioned Masonry Relative Cost

Wall length: 500 Wall Height: 24’ CMU: 8”

Retrofit Reinforcing and Grout:

#5 bars @48” o.c.

$360,000 labor

$5,000 materials

$365,000 total

Retrofit Post Tensioning System:

1/2” rods @48” o.c.

$120,000 labor

$17,000 materials

$137,000 total

Thank You!

This concludes this ICRI sponsored presentation.

Any Questions?

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