STRUCTURAL CONSIDERATIONS IN RESIDENTIAL CONSTRUCTION PART 3

Topics for the Inspector from a Structural Perspective

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RESIDENTIAL CODE - UDC

- Applicability
  - One or two family dwellings
- Does not apply to:
  - Multifamily
  - Accessory Buildings
  - Farm Buildings
  - Indian Reservations
- The Code does not restrict size of structure
  - Large and complex homes may be at risk of having structural deficiencies
- The Code does restrict the applicability of certain sections
  - Tall walls
  - Partial height basement walls

EXAMPLE: LARGE SCALE HOME

- Designed in 2015, this home exceeds 30,000 sf.
- Several unique design considerations that required extensive engineering analysis in lieu of prescriptive methods, including:
  - Deck Design
  - Tall Wall Design
  - Basement retaining wall design
  - Lateral Analysis (not covered today)

DECK DESIGN

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DECK DESIGN: REFERENCES

- Wisconsin
  - Chapter 321.225 – UDC
  - Chapters SPS320 to 325 Appendix B
  - Chapters SPS320 to 325 Appendix C

- Other
  - American Wood Council (AWC), 2013: Prescriptive Residential Wood Deck Construction Guide – DCA 6
  - Simpson Strong Tie: Deck Connection and Fastening Guide

DECK DESIGN

- Chapter 321.225 - UDC

SPS 321.225 Decks. (1) Decks attached to dwellings and any detached decks that serve an exit shall comply with the applicable provisions of subchs. II to X of ch. SPS 321, including all of the following:

(a) Excavation requirements under s. SPS 321.14;

(b) Footing requirements under s. SPS 321.15 (2) (f);

(c) Frost penetration requirements under s. SPS 321.16;

(d) Load requirements under s. SPS 321.02;

(e) Stair, handrail and guard requirements of s. SPS 321.04.

(f) Decay protection requirements of s. SPS 321.10.

(2) A deck that complies with the standards in ch. SPS 325 Appendix B, and ch. SPS 325 Appendix C, if applicable, shall be considered as complying with sub. (1).

RESIDENTIAL DECKS: TOPICS

- Topics
  - Loads
  - Beam to Post Connections
  - Stability
    - Tie backs
    - Ledger connection
    - Knee braces
    - Cantilevered steel posts

DECK DESIGN - FAILURES

- Code Compliance issues:
  - Ledger connection
  - Tie-back
  - Beam to Post connection
  - Stability bracing
- Recent study found 33,000 persons were injured over a five year period due to structural failures of decks or balconies. Half were “serious” injuries

DECK DESIGN: LOADS

- Live Load Requirement, UDC Ch321.02

Table 321.02–1

Component	Live Load (pounds per sq. ft.)
Floors	40
Garage floors	50
Exterior balconies, decks, porches . .	40
Ceilings (with storage)	20
Ceilings (without storage)	5

Commercial decks are designed for a load which matches the occupancy loading which is typically 100 psf

DECK DESIGN: LOADS

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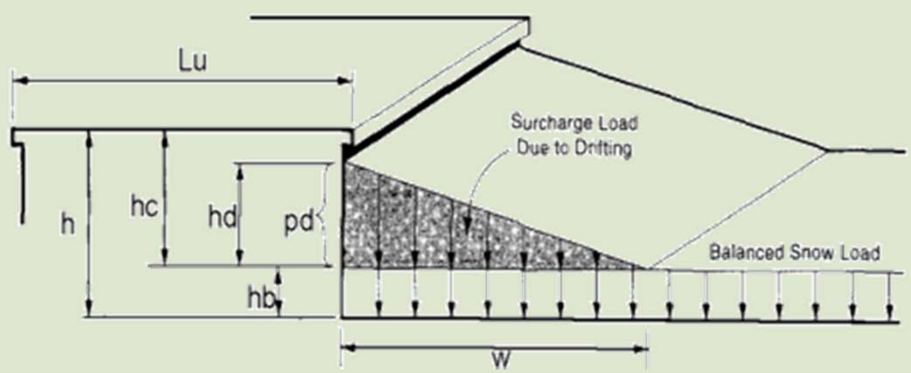
Loads that require consideration that are often overlooked:
From Section 1: General Requirements Appendix B

9. A deck constructed in accordance with these standards is not approved for concentrated loads that exceed 40 pounds per square foot (psf), such as from privacy screens, planters, built–in seating, hot tubs, stairs for multiple–level decks, or from snow–drift loads or sliding–snow loads. Engineering analysis is needed for these loads.

This is EVERY deck adjacent to a home.
Compare to IBC/ASCE 7-05 Snow Drift & Sliding Snow
Example of 30' wide house adjacent to deck

Leeward Snow Drifts - from adjacent higher roof

Upper roof length	lu =	15.0 ft
Snow density	g =	20.5 pcf
Balanced snow height	hb =	2.05 ft
	hc =	5.95 ft
hc/hb >0.2 = 2.9	**Therefore, design for drift**	
Adjacent structure factor	=	1.00
Drift height	hd =	2.00 ft
Drift width	w =	8.00 ft
Surcharge load:	pd = γ*hd =	**41.0 psf**
Balanced Snow load:	=	42.0 psf
		83.0 psf

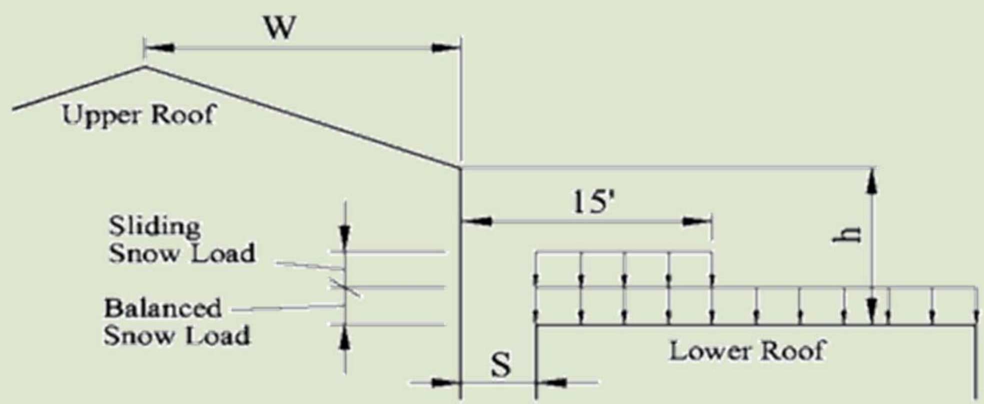


DECK DESIGN: LOADS

Sliding Snow
Example of 30’ wide house adjacent to deck

Sliding Snow - onto lower roof

Sliding snow = 0.4 Pf W =	231.0 plf
Distributed over 15 feet =	15.4 psf
hd + hb =	2.80 ft
hd + hb < =h therefore sliding snow =	**15.4 psf**
Balanced snow load =	42.0 psf
Uniform snow load within 15' of higher roof =	57.4 psf



Sliding and Drifting snow
Should be applied simultaneously
Ptotal = 15.4 psf + 83 psf = 98.4 psf (max)

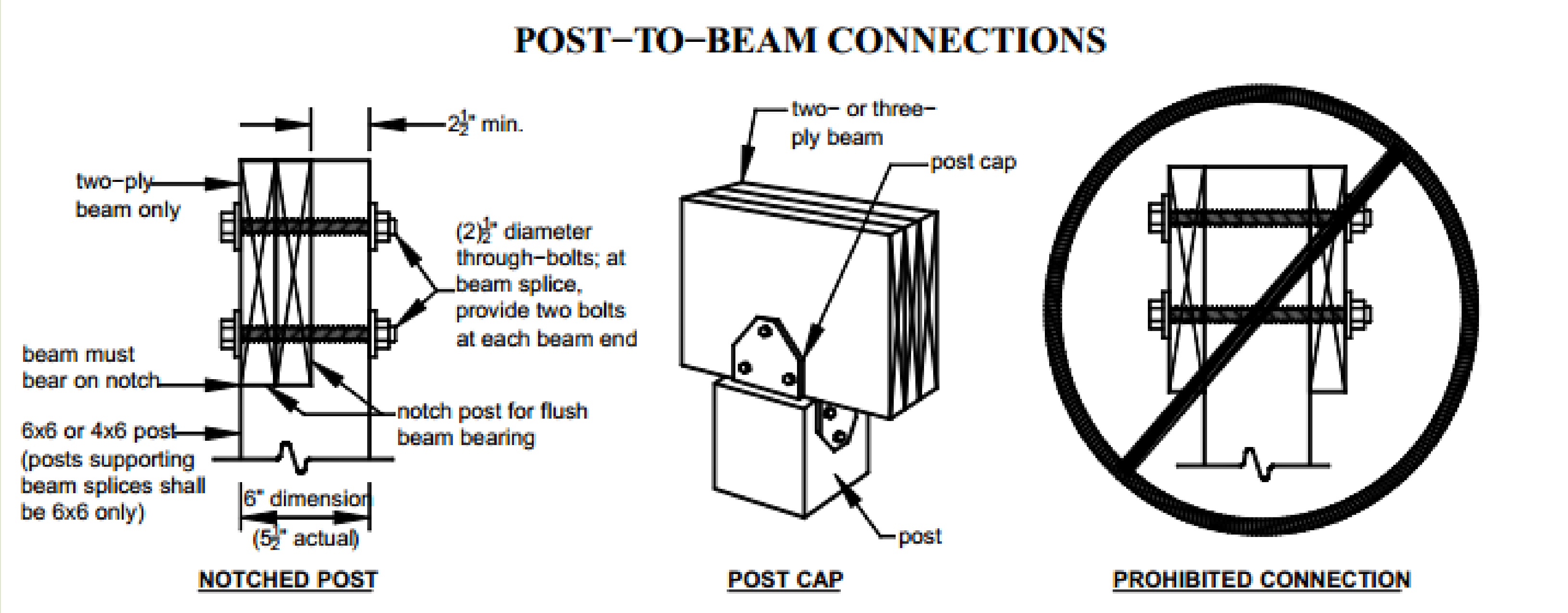
This is more than DOUBLE the 40 psf base requirement

POST TO BEAM CONNECTIONS

- Permissible Connections
  - Minimum post size is dictated by post height and beam connection. Locations of beam splices require 6x6 (min)

Table 2
MAXIMUM POST HEIGHT

Post Size	Maximum Height
4"x4"	6'
4"x6"	8'
6"x6"	14'



DECK STABILITY (LATERAL SUPPORT)

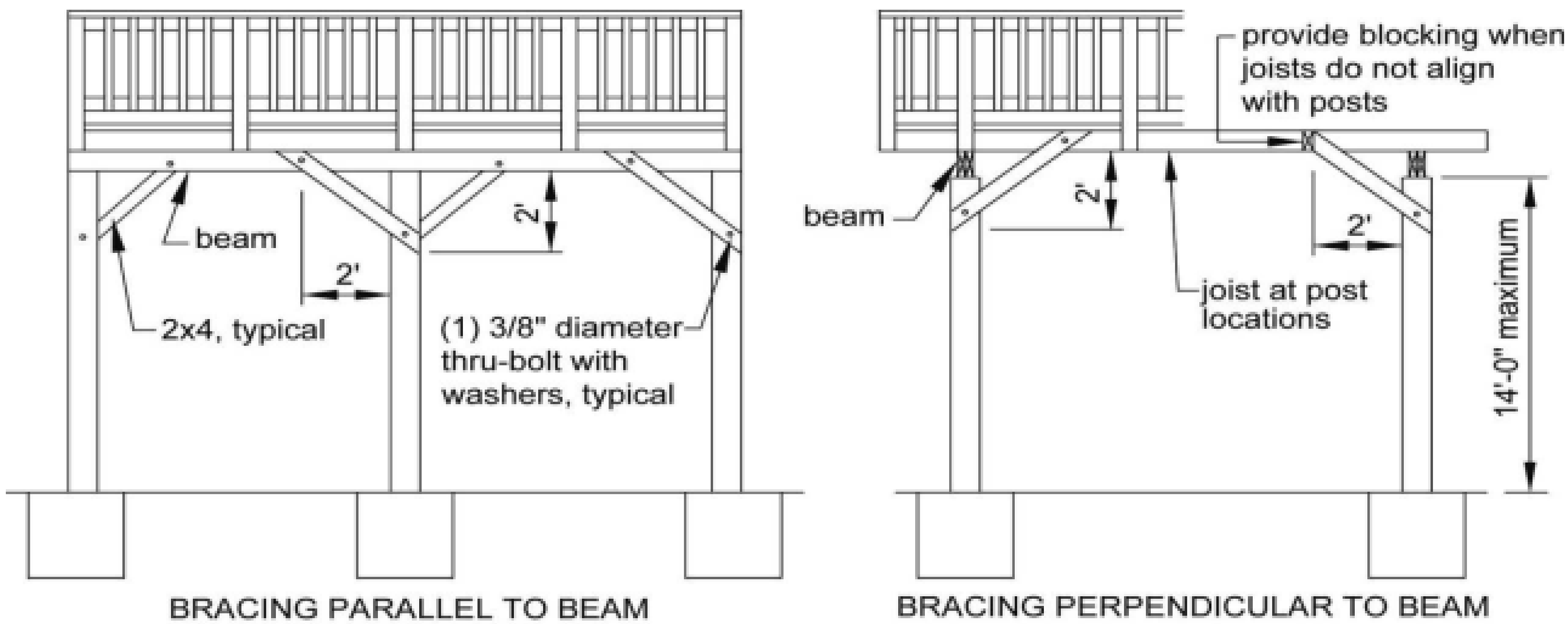
- Decks greater than 2' above grade shall be provided with diagonal bracing

- Methods of Obtaining deck stability
- Wood Framing
  - Diagonal Bracing
  - Attachment to house
- Steel posts
  - Cantilever from frost depth pier and footing.

WOOD FRAMING - STABILITY

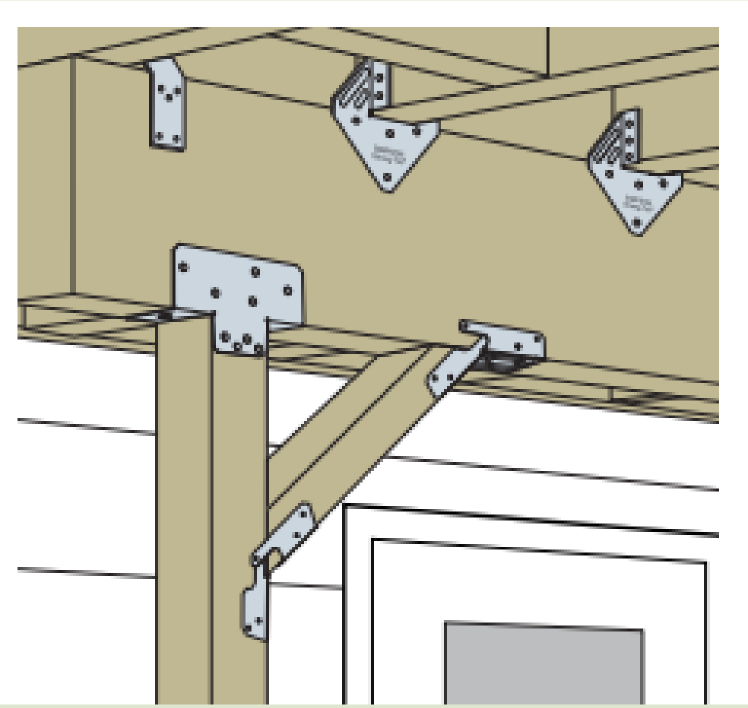
- Diagonal (Knee) Bracing:
  - Required at any perimeter column where deck does not attach to a structure

Figure 18
DIAGONAL BRACING REQUIREMENTS



DIAGONAL (KNEE) BRACING

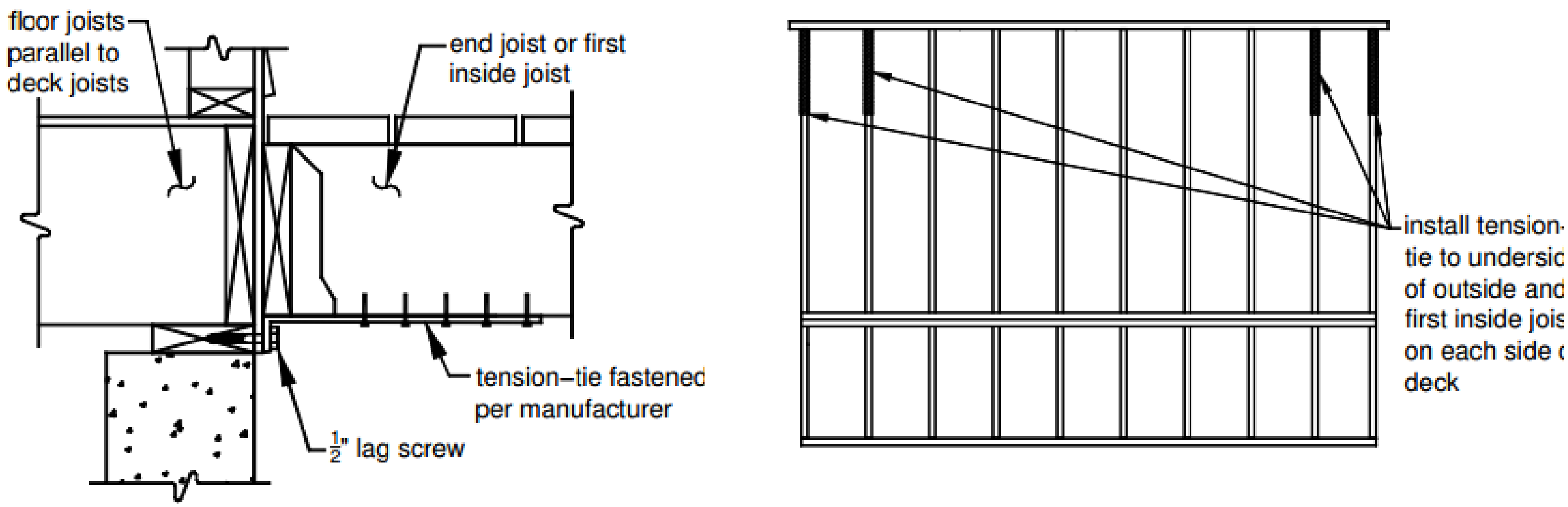
- **Simpson Proprietary Product:**



WOOD FRAMING STABILITY

- Tension Tie Attachment

Figure 19
TENSION–TIE CONNECTION, WITH LEDGER BOARD



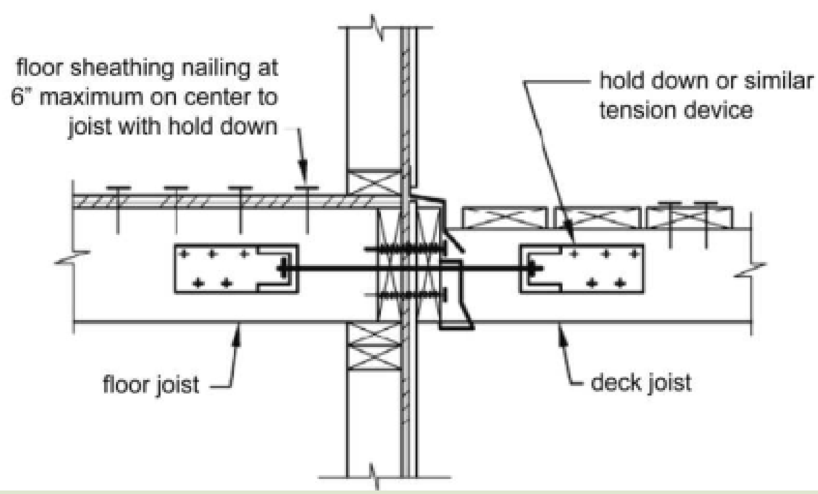
Tension–tie requirements. Tension ties, if used instead of perpendicular bracing as described above, must comply with all of the following, but are not permitted for free–standing decks:

1. The deck joists and floor joists must be parallel.
2. At least 4 ties must be installed, at the end joist and first inside joist at each end of the deck as shown in Figure 19. A set of tension–ties must be installed for each structurally independent section of a multi–level deck.
3. Approved tension–ties include the LTS19–TZ from USP or DTT1Z from Simpson Strong–Tie.
4. The minimum capacity of each tension–tie is 750 pounds.

WOOD FRAMING STABILITY

5. Tension ties which are not available in a G−185 zinc coating require a barrier membrane separating the tension tie and the preservative−treated joist. The barrier membrane must be recommended for this location by its manufacturer.
6. Tension−ties must be attached to the underside of the joists in accordance with the manufacturer's instructions. Tension−ties must be attached to the exterior wall with lag screws as shown in Figure 19. Lag screws must penetrate a minimum of 3 inches into the sill plate or top plate of a wood−framed wall.
7. Where attaching to a concrete wall, lags screws may be replaced with adhesive or expansion anchors and a 1/2 inch threaded rod, with a withdrawal capacity of at least 750 pounds. The anchor must be installed in accordance with the manufacturer's instructions.

Figure 20
HOLD−DOWN TENSION DEVICE, WITH LEDGER BOARD

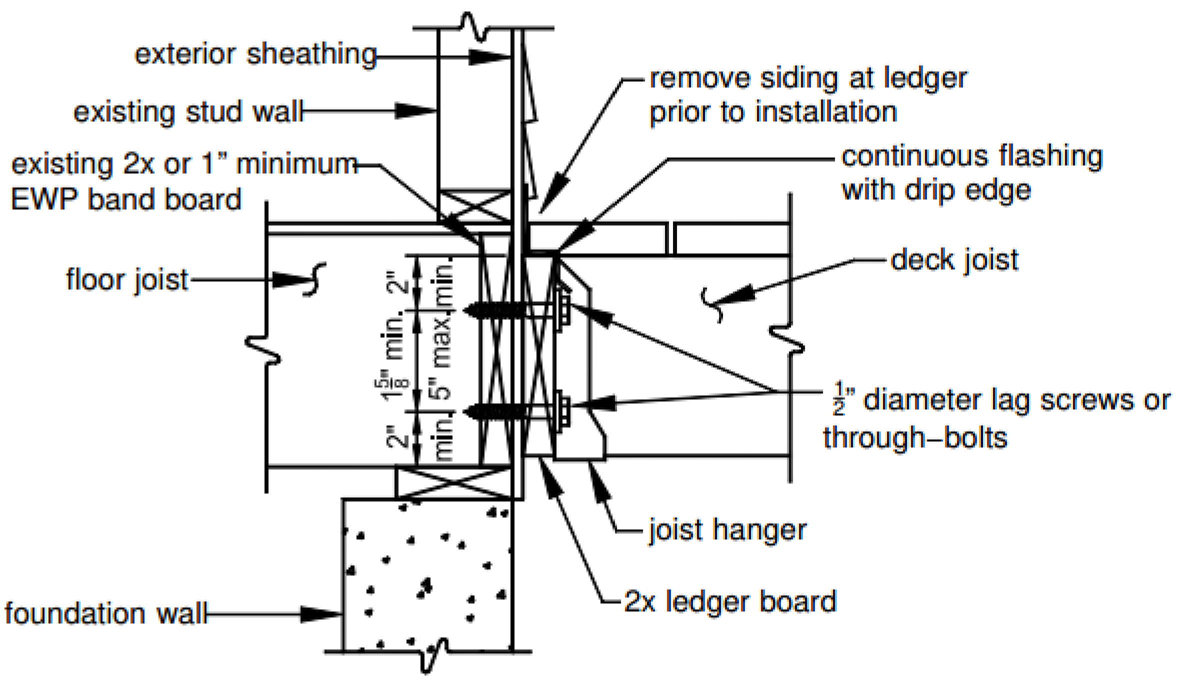


LEDGER ATTACHMENT

- Example of typical attachment

Figure 11

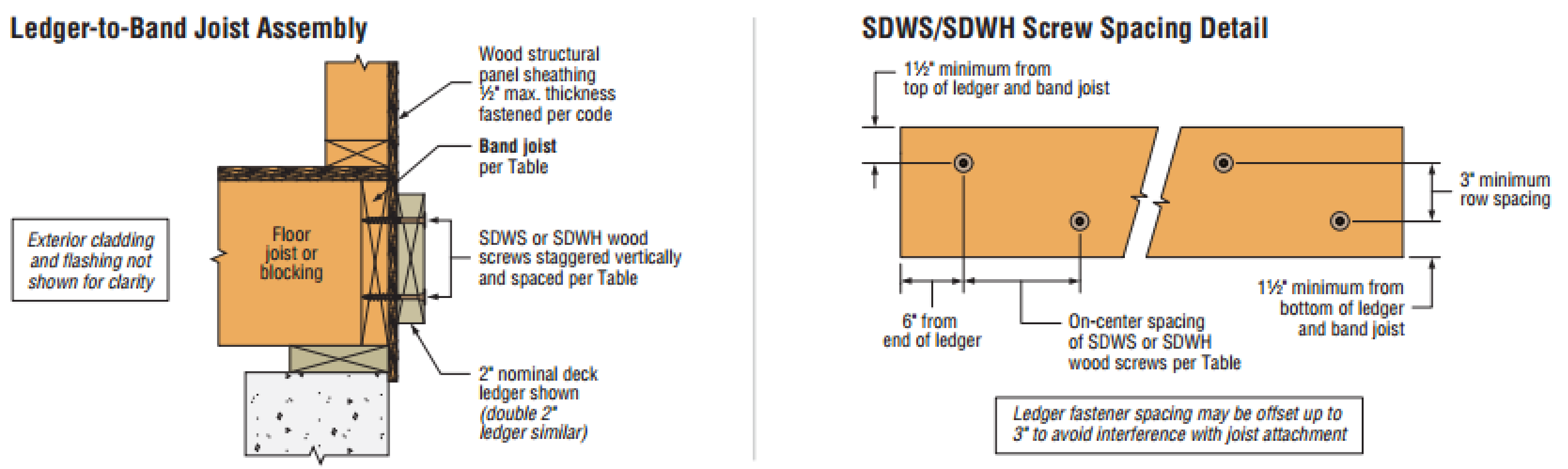
ATTACHMENT OF LEDGER BOARD TO BAND BOARD OR BAND JOIST



Attachments not allowed : to brick or stone veneer, or to cantilevered floor framing

LEDGER ATTACHMENT

- See Figure 15 in Appendix B or also proprietary tables



2012 and 2009 IRC Compliant Strong-Drive® SDWS
Structural Wood Screw Spacing for a Sawn Lumber Deck Ledger to Band Joist

DECK STABILITY: CANTILEVERED STEEL

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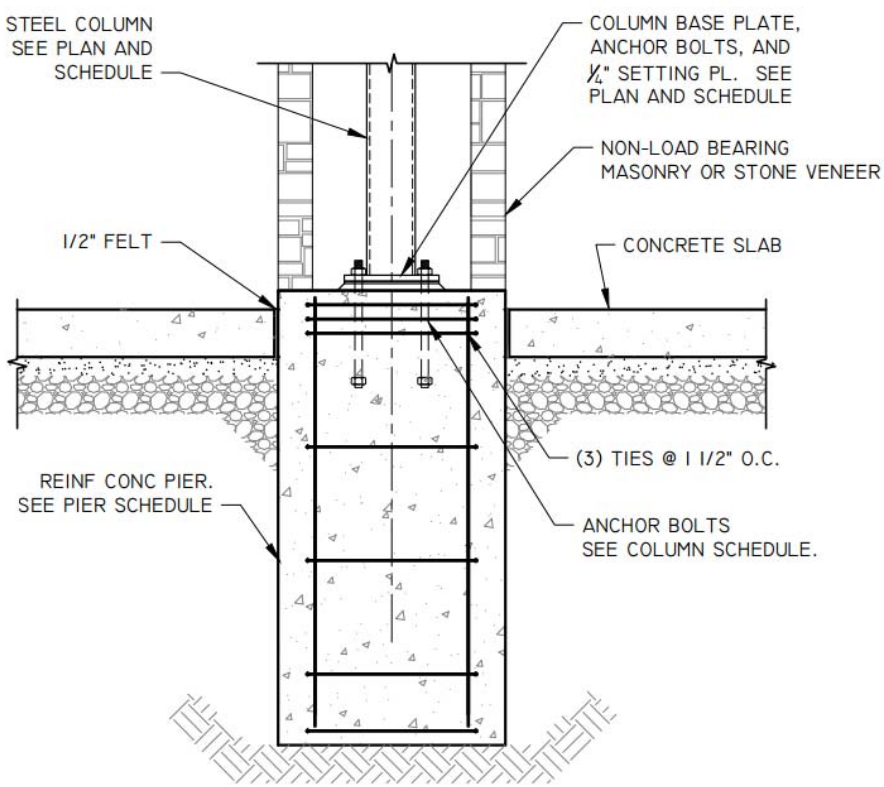
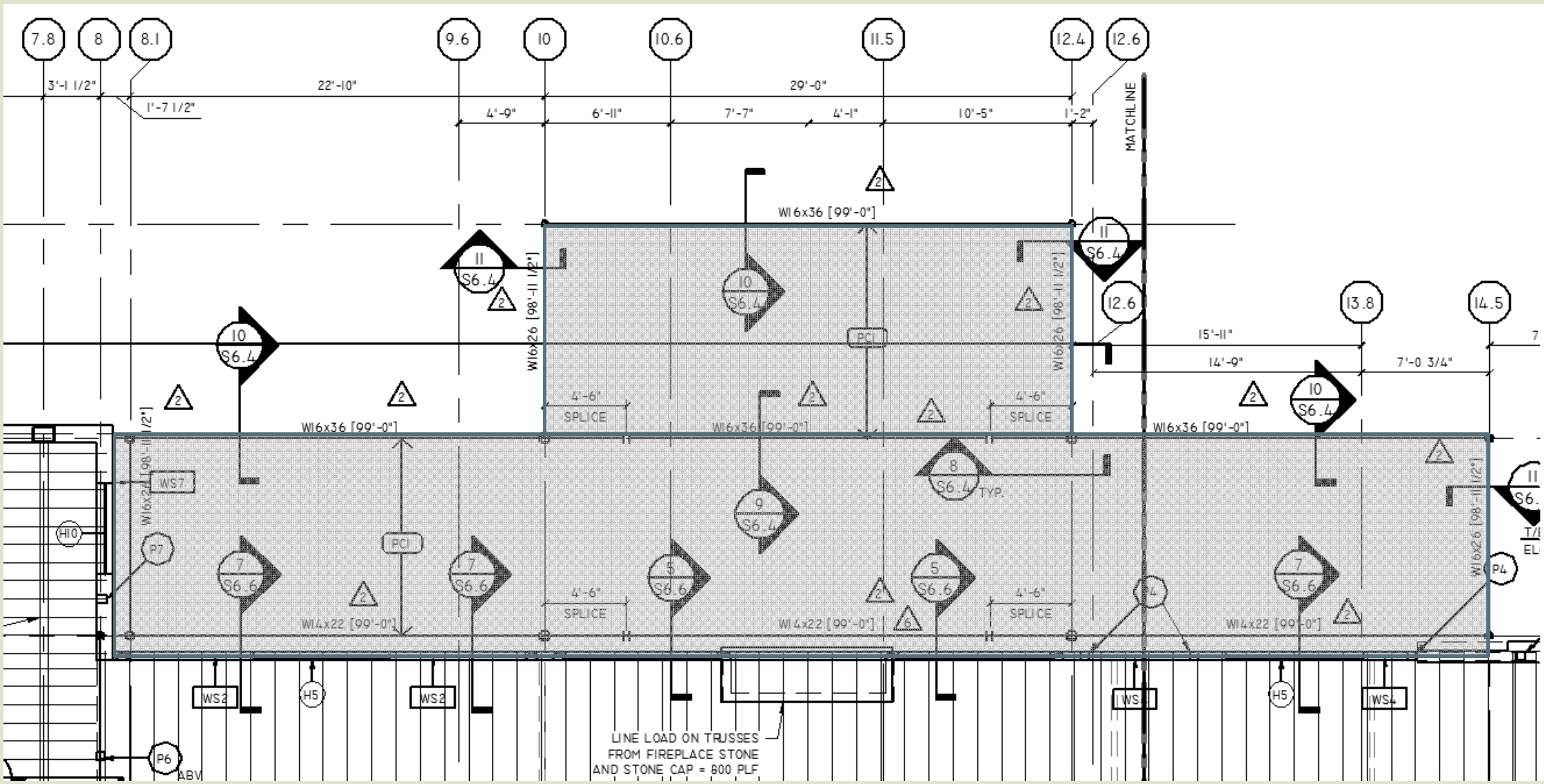
- An Engineered Design with Steel posts can eliminate the need for the tension tie to the structure as well as the knee braces
- The steel posts can be designed to cantilever from the concrete pier or sonotube footing.

- Example:

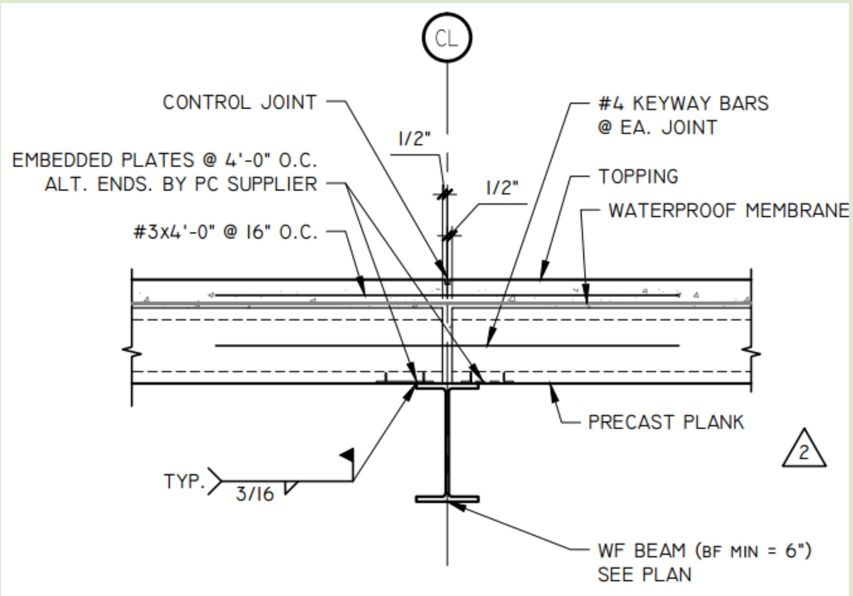


STEEL POST CANTILEVERED DECK: EXAMPLE 1

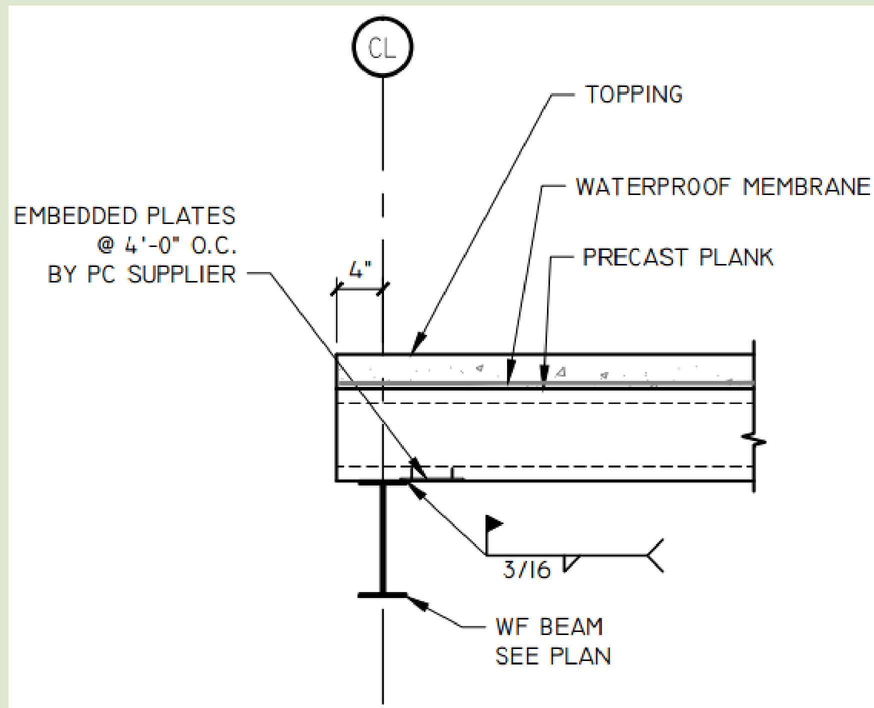


Area = 1200 sf +/-

DETAILS: EXAMPLE 2



Precast Deck with waterproof membrane, supported by steel beams and columns. Stability provided by cantilever steel column design.



STEEL POST CANTILEVERED DECK: EXAMPLE 2

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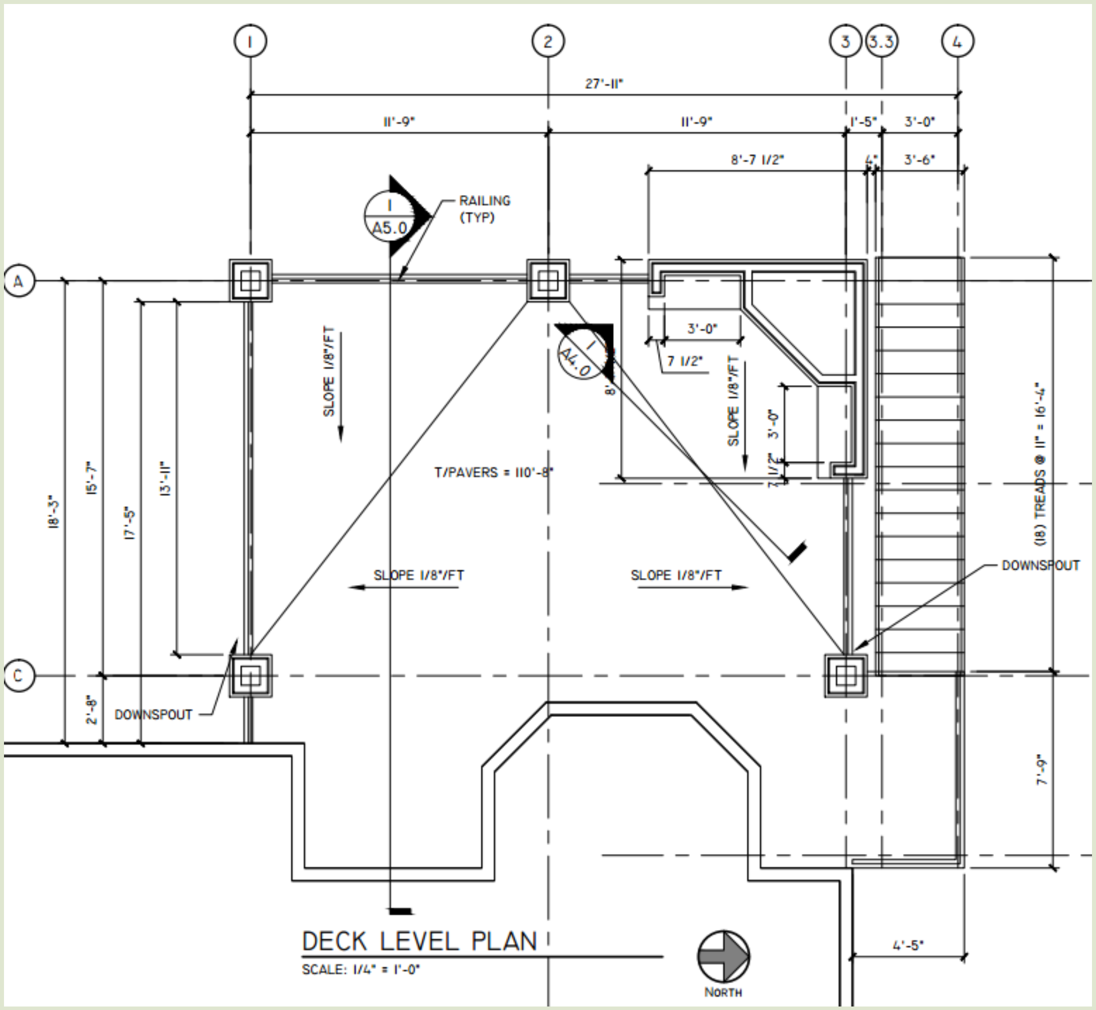
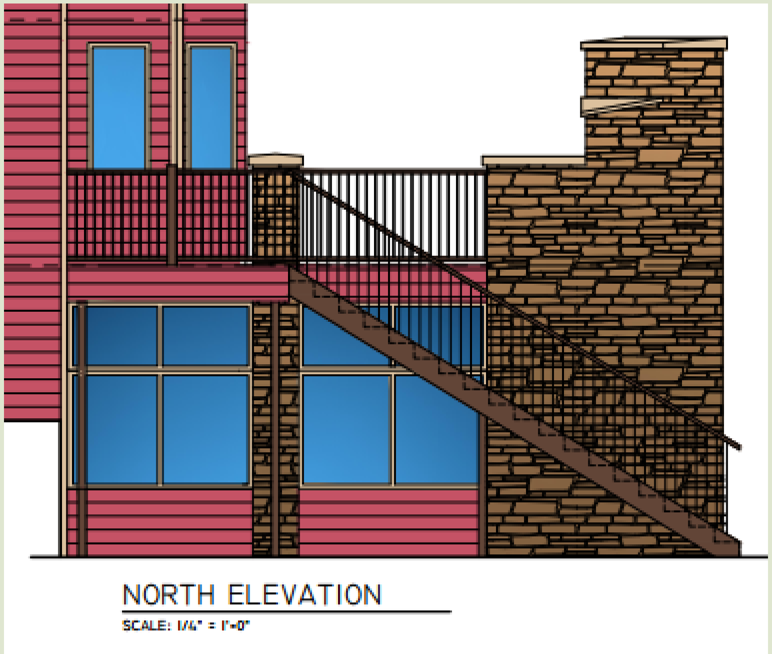


- Elevated deck flush with main level
- Living space below at lower level walk-out
- Mix of wood and steel framing.
- Owner did not want appearance of k-bracing

STEEL POST CANTILEVERED DECK: EXAMPLE 2



FOUNDATION PLAN: EXAMPLE 2

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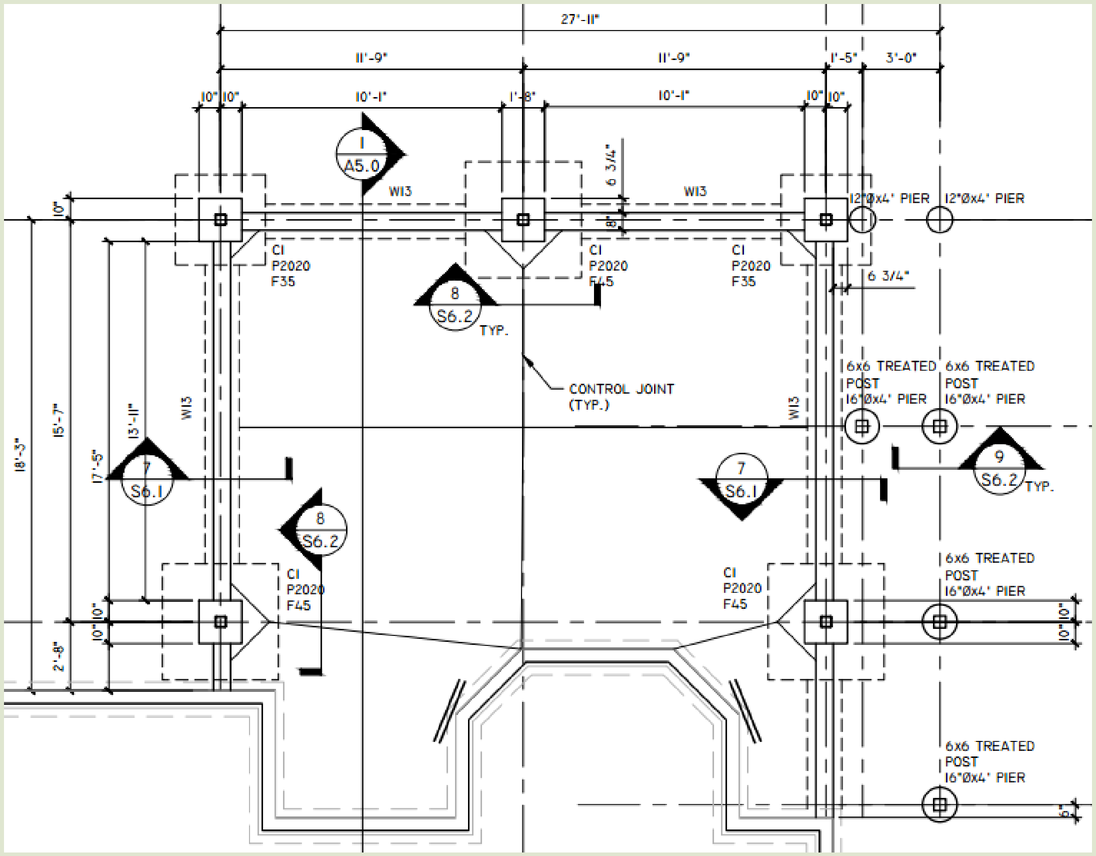
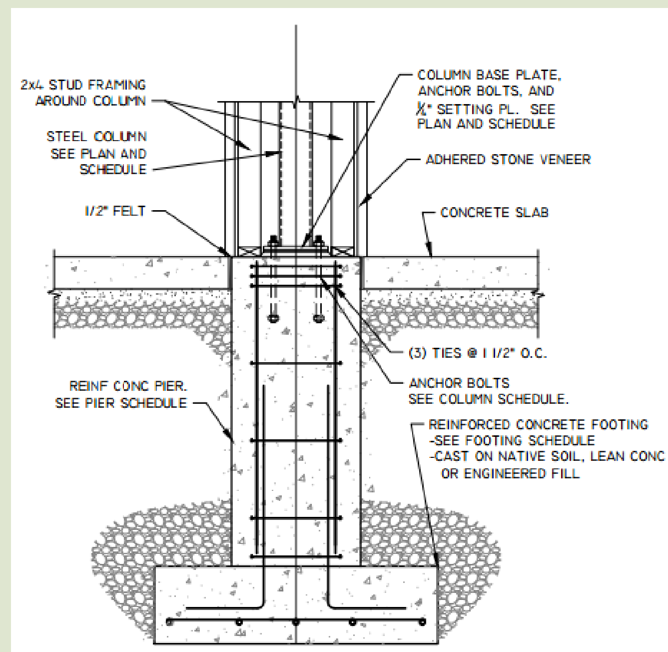
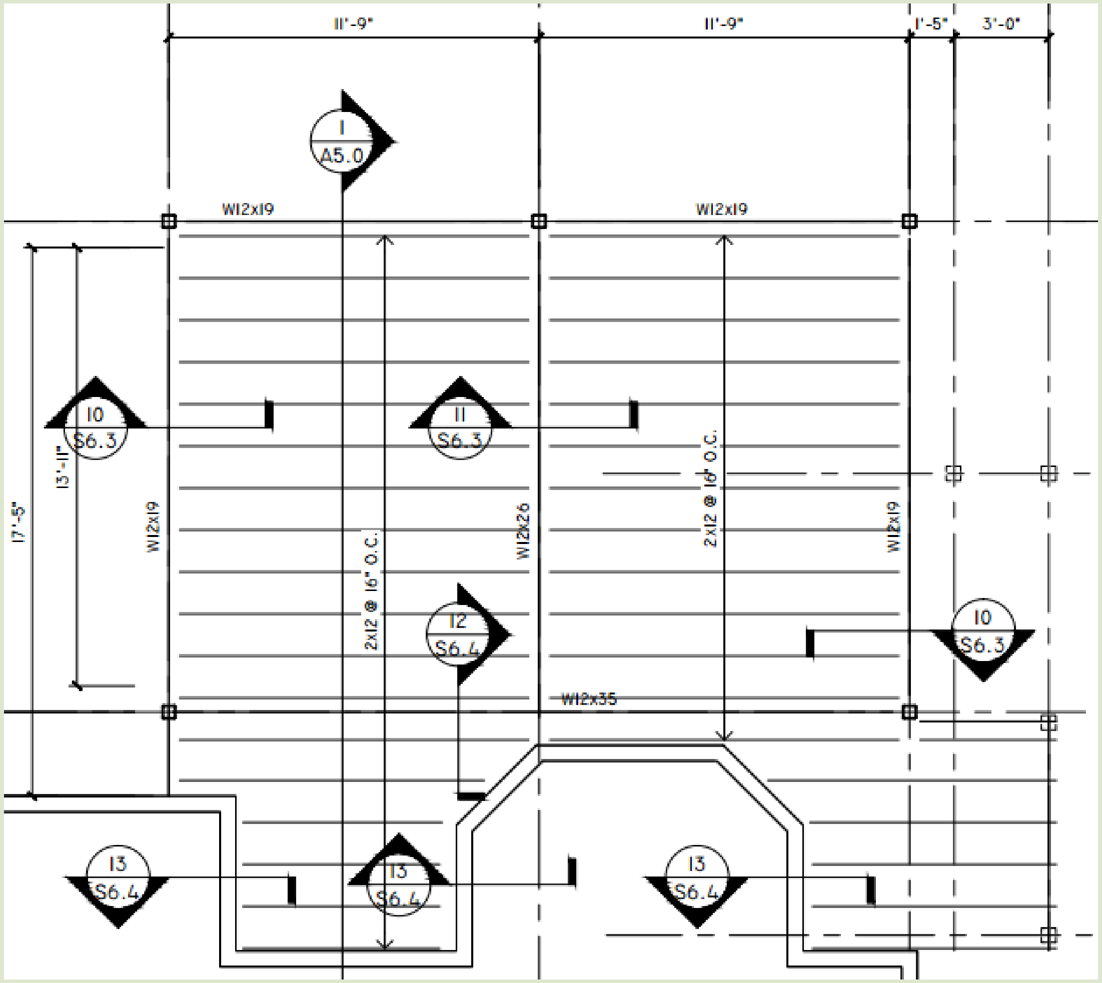


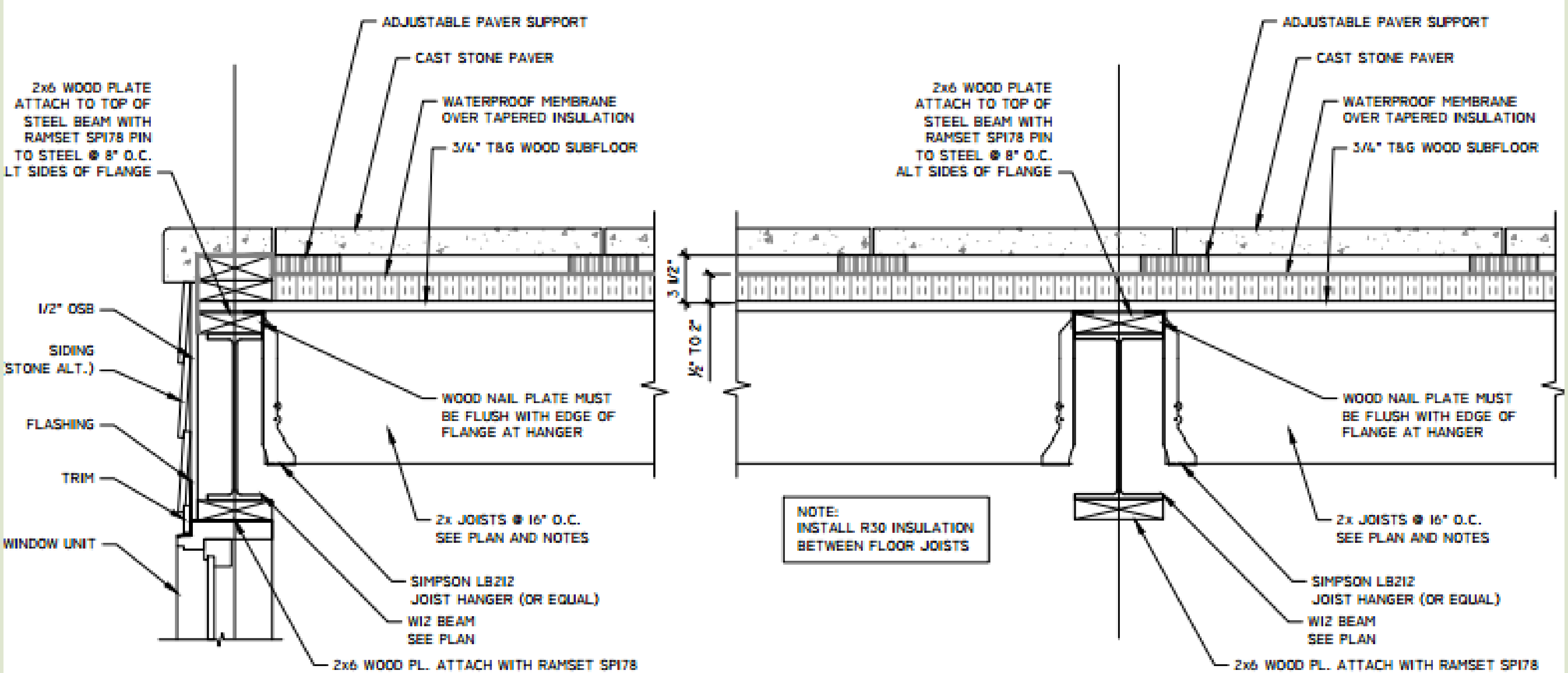


FRAMING PLAN: EXAMPLE 2

- Steel beams supported by cantilevered steel columns
- Wood Joists span between steel beams
- Living space below deck is enclosed, so a waterproof membrane is located on top of tapered insulation



FRAMING DETAILS: EXAMPLE 2



DECK DESIGN: ADDITIONAL CRITERIA

- Additional Criteria and regulations that must be considered in every deck design include:
  - Design for long term decay resistance including treated lumber, flashing at interface with rim joist, connection hardware.
  - Footings must be frost depth (Sect 2, UDC Appx. B)
  - Joist attachments to beams and ledgers (Sect 6, UDC Appx. B)
  - Elevated wood post attachments (Sect 2, UDC Appx. B)
  - Railing attachment (Sect 13, UDC Appx. B)
  - Stair Stringers (Sect 14, UDC Appx. B)

TALL WALLS

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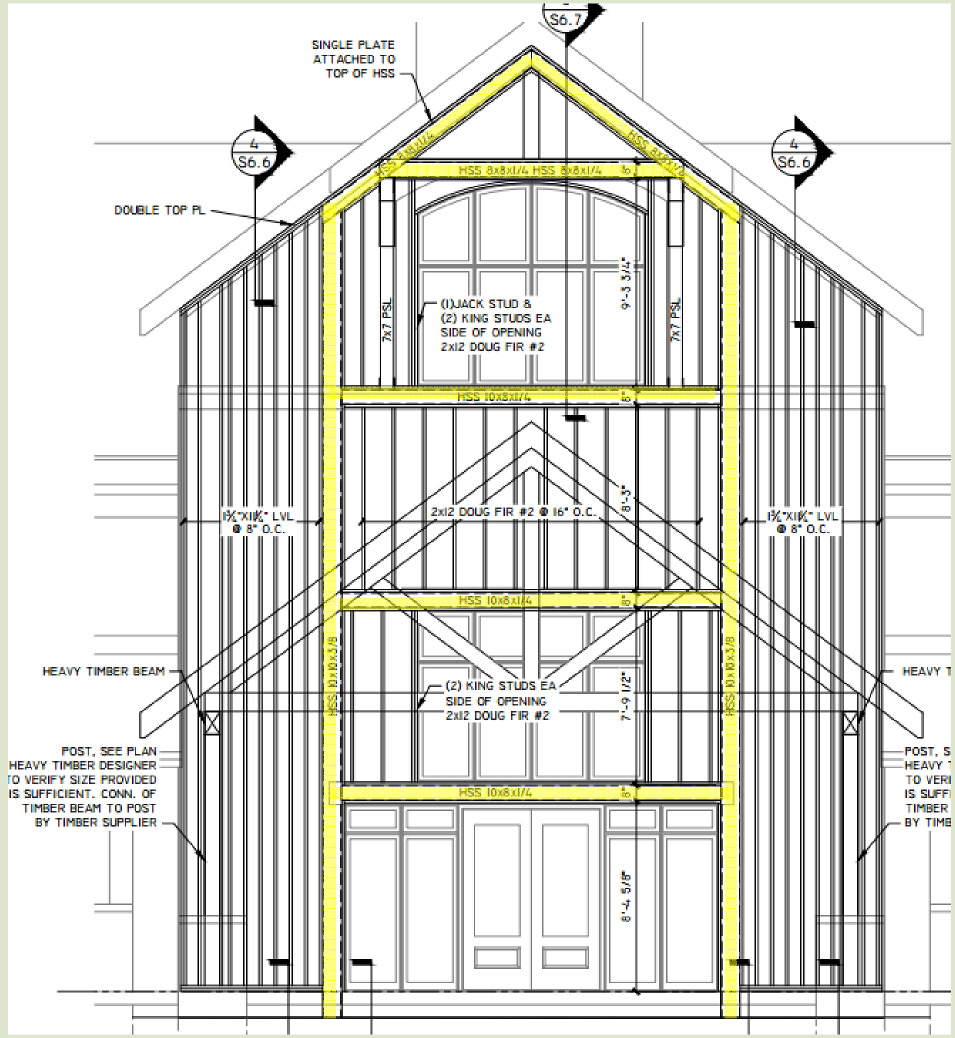
TALL WALL DESIGN

- Maximum allowable unbraced height for a load bearing wall is 10'-0" without additional engineering.
- Practical limits for wood tall walls
  - Deflection limitations for tall walls are not well defined, so limits of L/180 to L/720 can be applied. Limits typically based on finish materials, but should likely be L/480 to L/600 in most cases. Masonry and glass attachments require greater rigidity than siding and metal panel.
  - Exterior wall design typically controlled by wind or wind+gravity load
  - Interior wall design typically controlled by gravity design

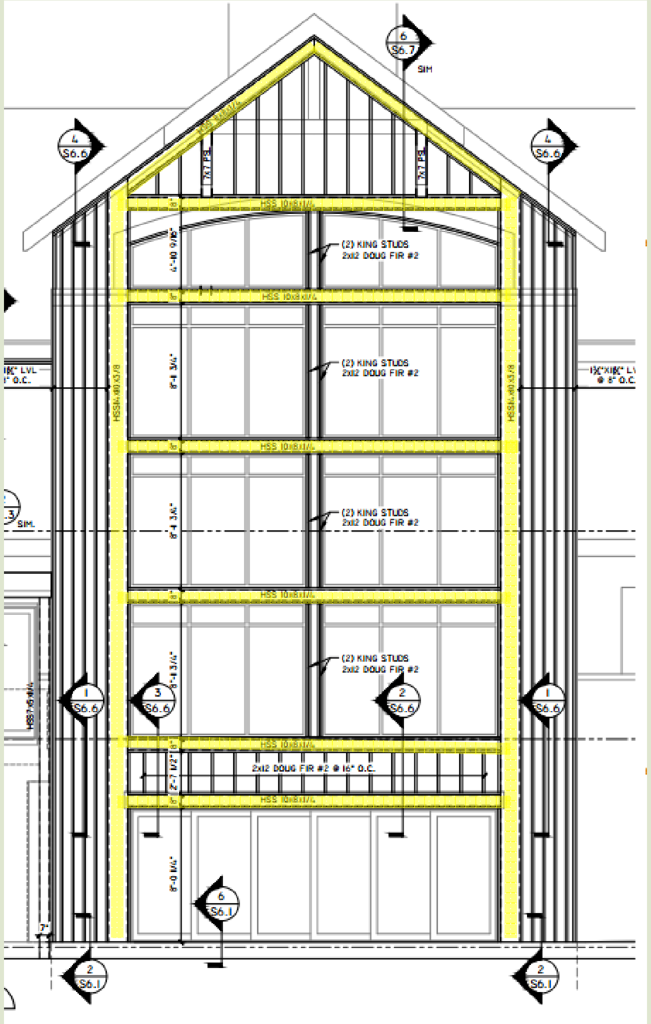
TALL WALL: EXAMPLE 1

- Overall max ht = 42'
- Unbraced ht = 42'
- Steel frame around area with windows
- Tall wall framed with 1 ¾"x11 ¼" LVL @ 8" o.c.



TALL WALL: EXAMPLE 2

- Overall max ht = 54’
- Unbraced ht = 42’
- Steel frame around area with windows
- Tall wall framed with 1 ¾”x11 ¼” LVL @ 8” o.c.
- Steel columns tied bask into floor diaphragm with straps



TALL WALL STEEL COLUMN TIE

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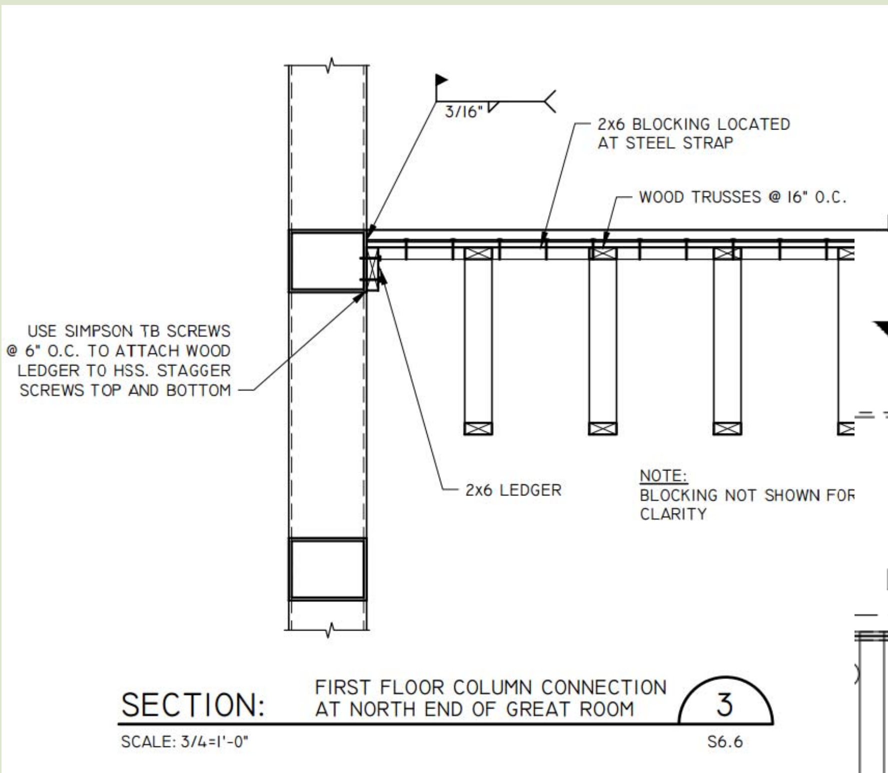
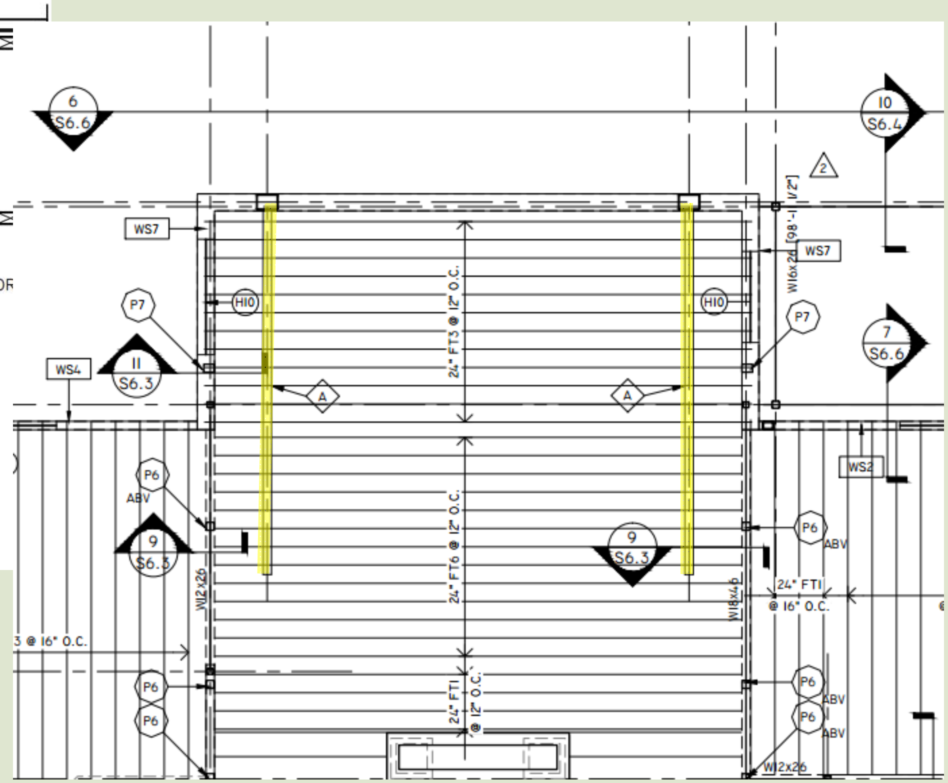


Straps transfer wind load into horizontal diaphragm which is transferred to shear walls or reaction at top of retaining wall



BASEMENT WALLS

BASEMENT WALL LOADS

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Loads

- Total horizontal load W=q*h^2/2
- q varies based on soil type
- Top reaction = W/3
- Bottom reaction = 2/3W

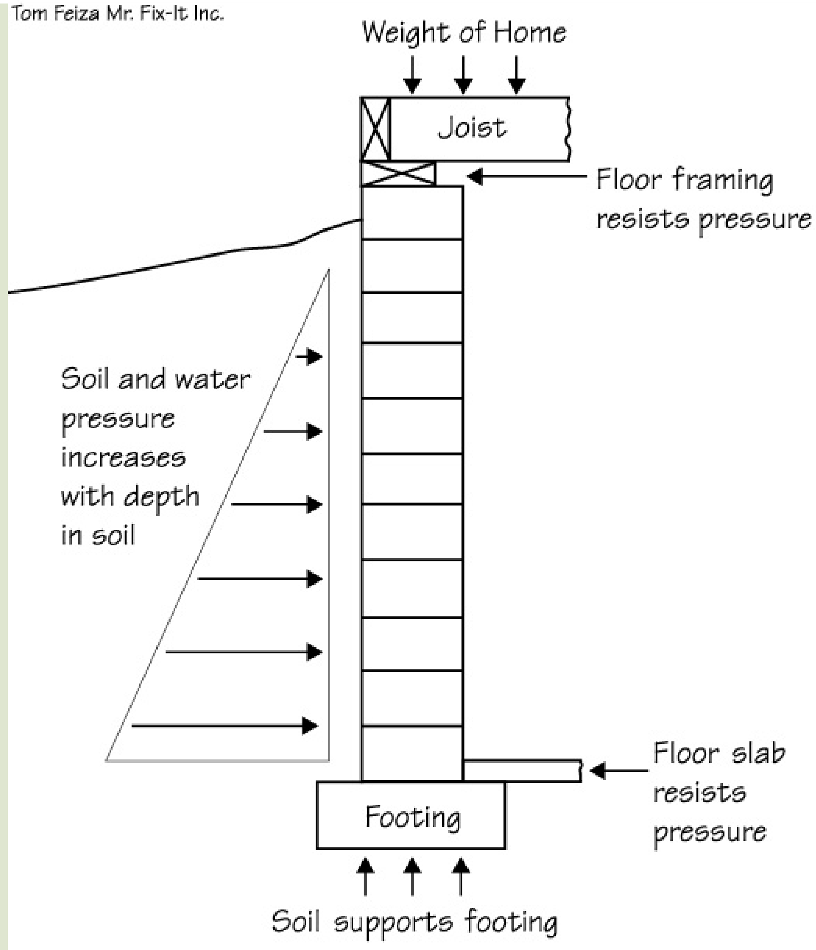
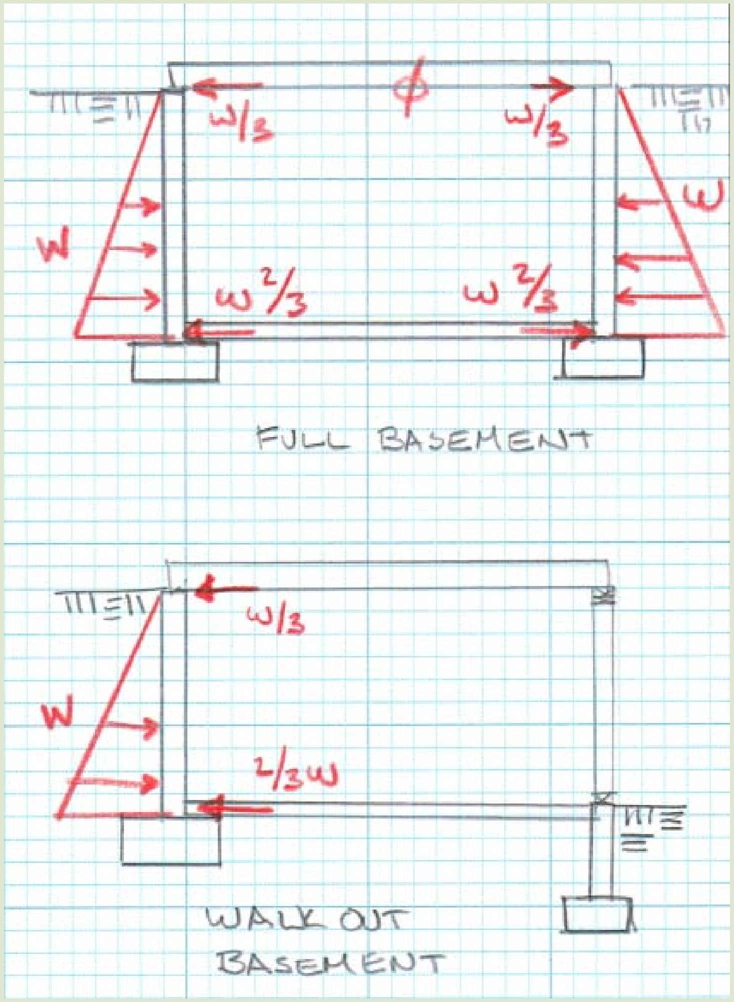


Image from Home Systems Data, Denver, USA
http://www.hsdi.us/library/

BASEMENT WALL DESIGN

- Typical basement wall design
  - Pinned at top and bottom
  - Balanced loads on either side create a net reaction of "zero" into perpendicular shear walls
- Walk-out basement
  - No resistance to top reaction at opposing wall
  - Resistance design must be handled via:
    - Diaphragm load transferred to perpendicular shear walls, or
    - Fixed base design (cantilever retaining wall)



THE FLOOR DIAPHRAGM: HOW IT WORKS

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- The reaction at the top of the wall acts on the floor diaphragm and is transferred into the walls parallel to the load which act as shear walls
- If the basement does not have any exposure, the system will act in equilibrium as the forces on either side of the diaphragm will be equal and opposite.
- If the basement is exposed on one side, the load will be unbalanced. Improper connections can lead to the outside exposed wall bowing outward. This is even more problematic where walls are partial height.

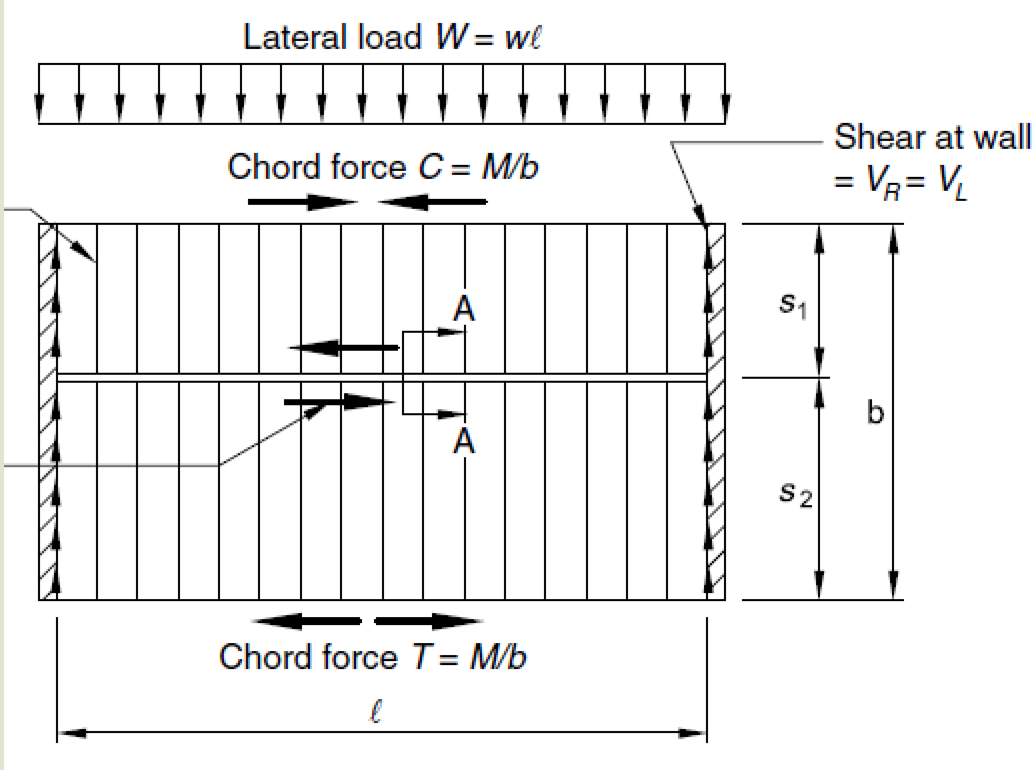
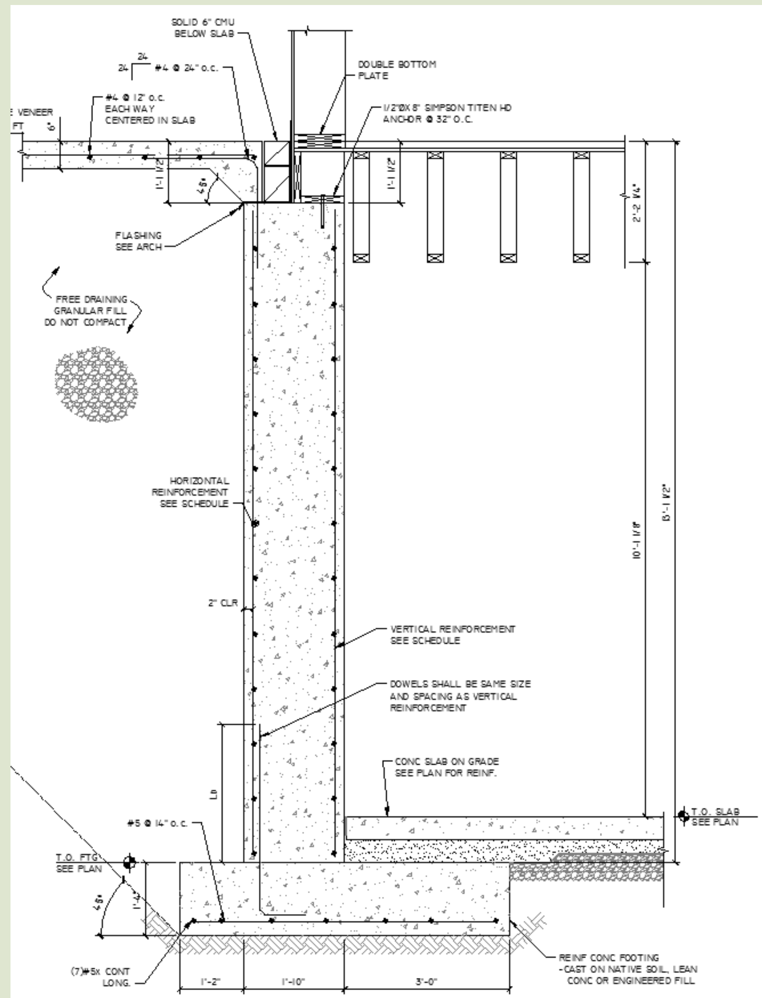


Image from: Precast/Prestressed Concrete Institute. 2010 PCI Design Handbook, 7th Edition. pp 4-56

BASEMENT WALLS WITH FULL EXPOSURE

- Unbalanced fill present for more than 140’ of the structure
- Due to height of the walls (13’), the weak diaphragm (wood) and the spacing of the perpendicular shear walls, shear wall resistance design was not feasible.
- Solution: Basement walls designed as cantilevered retaining walls at all locations where load was on only one side



TOP CONNECTION @ BALANCED SOIL CONDITION

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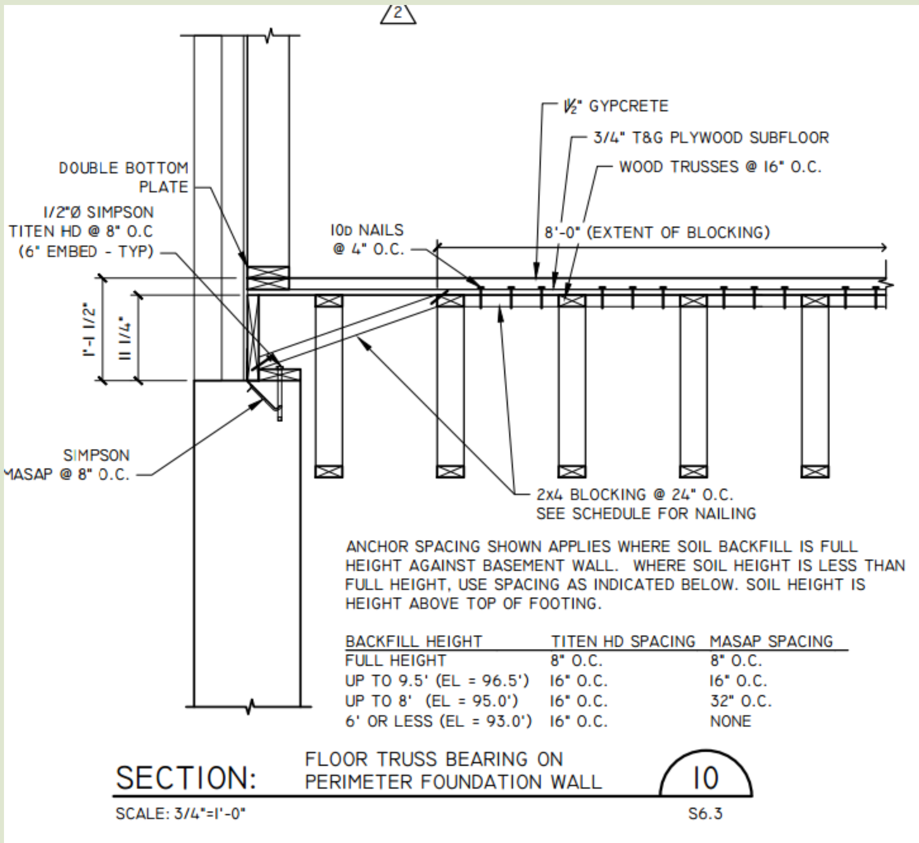

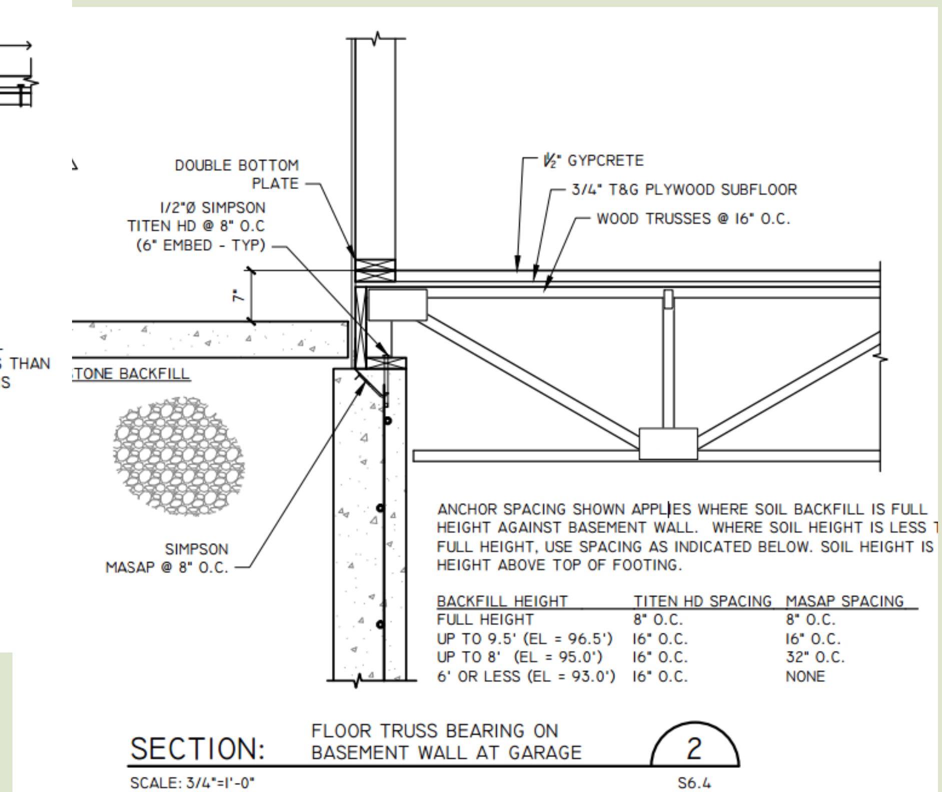

SUMMARY

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- Deck Design
  - Key design components are deck stability and complete load path
  - Design for long term corrosion resistance
  - Loads in tables likely not adequate due to snow drift
- Basement wall designs
  - Unbalanced load design requires careful analysis and does not meet the prescriptive design criteria of the UDC
- Tall Wall Design
  - Walls more than 10’ clear (unbraced) require engineered design.
  - Strength and serviceability requirements must be considered.
- Future Code changes?
  - Requirement for houses over a certain footprint per floor to be stamped by a licensed professional?

QUESTIONS?

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