PC UFC Briefing
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Masonry and Cold-Formed Steel Requirements

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APPLIED RESEARCH ASSOCIATES, INC.

Masonry Requirements

- Composite Construction
  - ◊ Masonry is often used in composite construction, such as masonry load-bearing walls with wood floor systems.
  - ◊ For masonry/wood composite construction, the application of both the requirements of this chapter and those provided for wood in Chapter 7 are required.

Masonry Requirements

- Composite Construction, cont'd
  - For example, for masonry load-bearing walls with wood floors, the floor system and roof system would be required to meet the internal tie requirements of Chapter 7, while the masonry walls would be required to meet the tie (vertical, peripheral, and wall) requirements or AP requirements of this chapter.

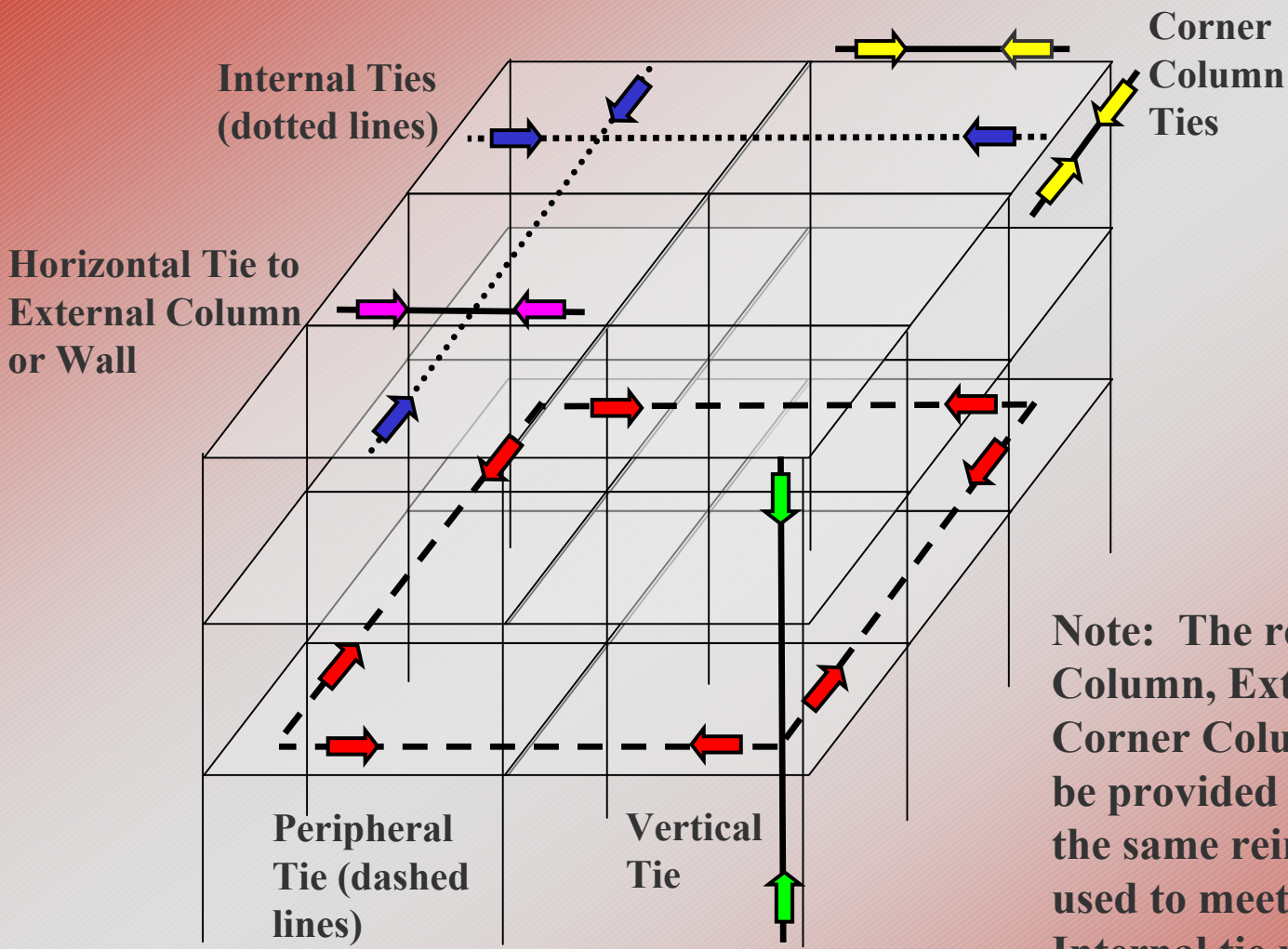
Masonry Requirements

- Material Properties for Masonry
  - ◊ All over strength factors for masonry are equal to 1.0.

Masonry Tie Force Requirements

- Masonry Tie Force Requirements
  - ◊ General
    - Peripheral, internal, and column or wall ties must be provided at each floor level and at roof level, but where the roof is of lightweight construction, no such ties need be provided at that level.
    - Horizontal ties may be provided by structural members or by reinforcement that is provided for other purposes.

Masonry Tie Force Requirements



Note: The required External Column, External Wall, and Corner Column tie forces may be provided partly or wholly by the same reinforcement that is used to meet the Peripheral or Internal tie requirement.

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Masonry Tie Force Requirements

- Strength Reduction Factor Φ for Masonry Tie Forces
  - ◊ Use the strength reduction factors Φ for development and splices of reinforcement and for anchor bolts as specified in Section 3-1 of *Building Code Requirements for Masonry Structures* from ACI (ACI 530-02).

Masonry Tie Force Requirements

- Proportioning of Ties
  - ◊ Reinforcement that is provided for other purposes, such as flexure or shear, may be regarded as forming part or whole of the required ties

Masonry Tie Force Requirements

- Continuity and Anchorage of Ties
  - ◊ Splices in longitudinal reinforcing bars that provide tie forces must be lapped, welded or mechanically joined, per Section 3-2 of ACI 530-02.
  - ◊ Splices must not be located near connections or mid-span.

Masonry Tie Force Requirements

- Continuity and Anchorage of Ties
  - ◊ Reinforcing bars that provide tie forces must be tied at right angles to other reinforcing bars using 135 degree hooks with a six-diameter (but not less than 3 in) extension.
  - ◊ Each load-bearing wall must be tied continuously from the lowest to the highest level.

Masonry Tie Force Requirements

- Internal Ties
  - ◊ General
    - Internal ties must be anchored to peripheral ties at each end, or, they must continue as wall or column ties.
    - They must be effectively continuous through the entire length of the slab, beam or girder.
    - Internal ties may be provided:
      - uniformly throughout the floor or roof width, or
      - concentrated, with a 6 m (19.7 ft) maximum horizontal tie spacing) or
      - within walls no more than 0.5 m (1.6 ft) above or below the floor or roof and at 6 m (19.7 ft) maximum horizontal spacing (in addition to peripheral ties spaced evenly in the perimeter zone).

- Internal Ties, cont'd
  - Two Way Spans

In English units and in both directions in a two way span, the internal ties must resist a required tie strength (in kip/ft width) equal to the greater of:

a) $\frac{(1.0D + 1.0L)}{156.6} \frac{L_a}{16.4} \frac{1.0}{3.3} F_t$ (kip/ft)

or

b) $\frac{1.0}{3.3} F_t$ (kip/ft)

where: D = Dead Load (lb/ft^2), L = Live Load (lb/ft^2)

L_a = Lesser of: i) the greatest distance in the direction of the tie between the centers of columns or other vertical load-bearing members where this distance is spanned by a single slab or by a system of beams and slabs, or, ii) 5h. (ft)

h = Clear story height (ft)

F_t = "Basic Strength" = Lesser of (4.5 + 0.9 Ns) or 13.5

N_s = Number of stories including ground and basement

Masonry Tie Force Requirements

- Internal Ties, cont'd
  - ◊ One Way Spans
    - In the direction of the span in a one way span, the internal ties must resist the greater of the tension forces specified in a) and b) of the previous section.
    - In the direction perpendicular to the span, the internal ties must resist a tension of F_t.

Masonry Tie Force Requirements

- Peripheral Ties
  - ◊ Peripheral ties must resist a tension equal to 1.0 F_t.
  - ◊ Peripheral ties must be placed within 1.2 m (3.9 ft) of the edge of a floor or roof or in the perimeter wall and must be anchored at re-entrant corners or changes of construction.

Masonry Tie Force Requirements

- Horizontal Ties to External Columns and Walls
  - ◊ *In English units,* each external column and every 3.3 ft length of external wall carrying vertical load must be anchored or tied horizontally into the structure at each floor and roof level with a capacity of force equal to:

    2.0 Ft or $(h/8.2)\ F_t$, whichever is smaller (kip)

    where: h = Clear story height (ft)
    F_t = "Basic Strength" = Lesser of $(4.5 + 0.9\ N_s)$ or 13.5
    N_s = Number of stories including ground and basement

  - ◊ Corner columns must be tied in both directions.

Masonry Tie Force Requirements

- Horizontal Ties to External Columns and Walls, cont'd
  - ◊ Wall ties, where required, must be spaced uniformly along the length of the wall or concentrated at centers not more than 5 m (16.4 ft) apart and not more than 2.5 m (8.2 ft) from the end of the wall.
  - ◊ External column and wall ties may be provided partly or wholly by the same reinforcement as peripheral and internal ties.

Masonry Tie Force Requirements

- Vertical Ties
  - ◊ Wall Requirements
    - Columns and walls which are load-bearing and are required to have vertical ties must meet the requirements in the table on next page.
    - Vertical ties must be positioned at a maximum of 5 m (16.4 ft) on center, along the wall, and 2.5 m (8.2 ft) maximum from any free end of any wall (i.e., there is no return at the wall end).

Masonry Tie Force Requirements

Requirements for Full Vertical Ties in Masonry Construction

Property	Requirement
Minimum thickness of a solid wall or one load-bearing wythe of a cavity wall	150 mm (5.9 in)
Minimum characteristic compressive strength of masonry	5 N/mm^2 (725 psi)
Maximum ratio h_a/t	20
Allowable mortar designations	S, N

Masonry Tie Force Requirements

- Vertical Ties, cont'd
  - ◊ Wall Requirements, cont'd
    - Vertical ties must extend from the roof level to the foundation.
    - They must be fully anchored at each end and at each floor level and any joint must be capable of transmitting the required tensile forces.

Masonry Tie Force Requirements

- Vertical Ties, cont'd
  - ◊ Wall Requirements, cont'd
    - For full vertical tying to be considered effective:
      - Precast or in-situ concrete or other heavy floor or roof units must be anchored, in the direction of their span, to adjacent spans, in such a manner as to be capable of resisting a horizontal tensile force of F_t, in kN per meter width (kips per 3.3 ft width), where F_t was given earlier.
      - The wall must be constrained between concrete surfaces or other similar construction, excluding wood, capable of providing resistance to lateral movement and rotation across the full width of the wall.

Masonry Tie Force Requirements

- Vertical Ties, cont'd
  - Required Vertical Tie Force

    In English units, if the minimum requirements in Table 6-1 are met, a column or every 3.3 ft length of a load-bearing wall must provide a required tensile capacity equal to:

    $6.2 \times 10^{-4} \; A \; (h_a/t)^2$ or 22.5 whichever is larger (kips)

    where: A = Horizontal cross sectional area of the column or wall including piers, but excluding the non-load-bearing wythe, if any of an external wall for cavity construction. (ft^2)

    h_a = Clear height of a column or wall between restraining surfaces (ft)

    t = Wall thickness (ft)

Masonry Tie Force Requirements

- Load-Bearing Walls and Columns with Deficient Vertical Tie Forces
  - ◊ If it is not possible to provide the required vertical tie force in any of the load-bearing elements, then the Alternate Path method is applied for each such deficient element.
  - ◊ Remove each deficient member from the structure, one at a time in each story in turn, and perform an AP analysis to verify that the structure can bridge over the missing member.

Masonry Tie Force Requirements

- Load-Bearing Walls and Columns with Deficient Vertical Tie Forces, cont'd
  - ◊ The specific details of the AP method for masonry construction are provided in the next section.
  - ◊ The amount of member to be removed from the structure is given in the next slide.

Masonry Tie Force Requirements

Removal of Deficient Masonry Vertical Tie Members

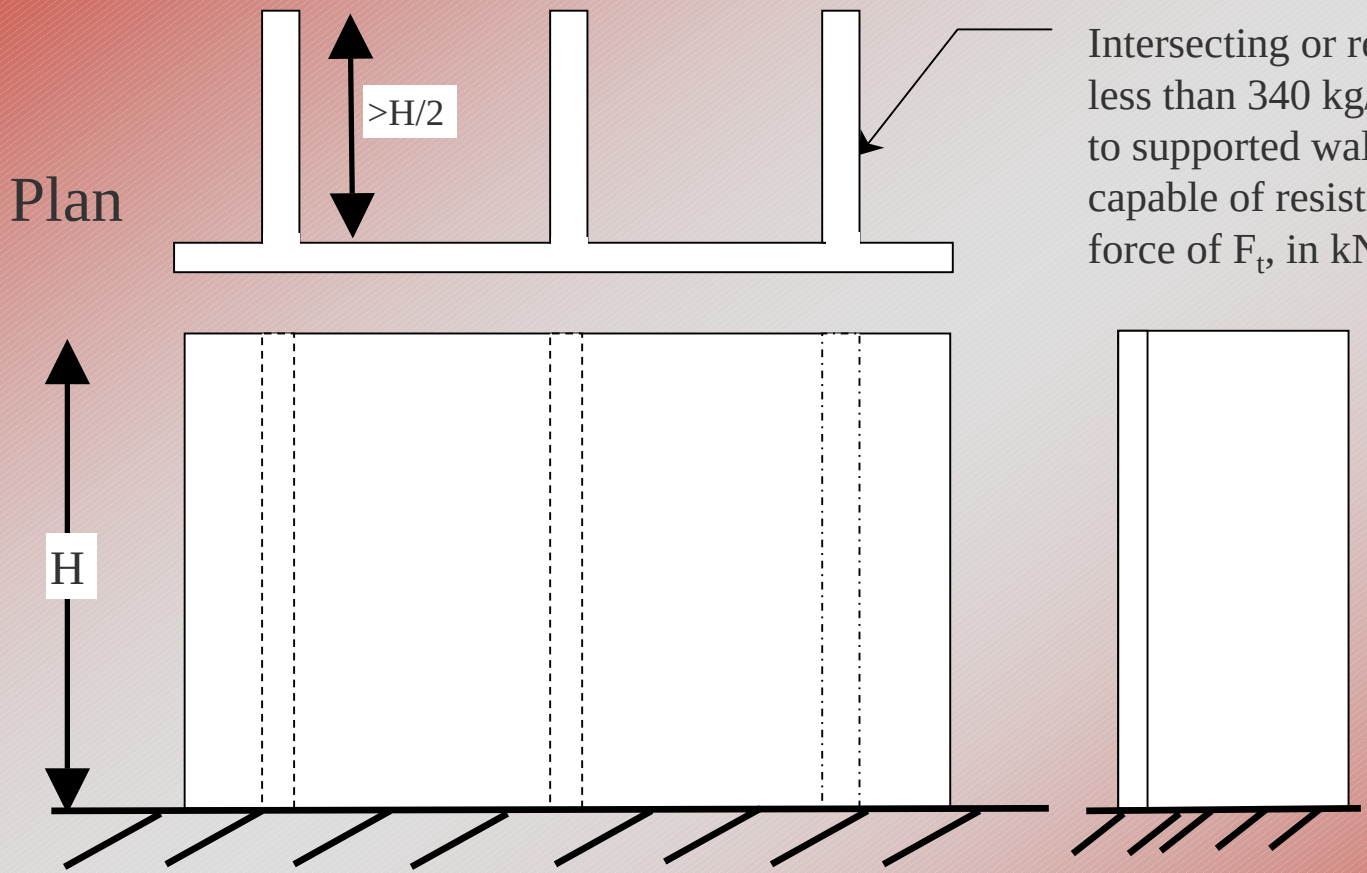
Vertical Load-bearing Element Type	Definition of Element	Extent of Structure to Remove if Deficient
Column	Primary structural support member acting alone	Clear height between lateral restraints
Wall Incorporating One or More Lateral Supports[A]	All external and internal load-bearing walls	Length between lateral supports or length between a lateral support and the end of the wall
Wall Without Lateral Supports	All external and internal load-bearing walls	For internal walls: length not exceeding 2.25 H, anywhere along the wall where H is the clear height of the wall. For external walls: Full length.

Masonry Tie Force Requirements

- Lateral Support Definitions
  - ◊ Using the definition of F_t, lateral supports may be provided three ways:
    1) An intersecting or return wall tied to a wall to which it affords support, with connections capable of resisting a force of F_t in kN per meter height of wall (0.45 F_t in kips per foot height of wall), having a length without openings of not less than H/2 at right angles to the supported wall and having an average weight of not less than 340 kg/m^2 (70 lb/ft^2).

Masonry Tie Force Requirements

- Lateral Support Definitions, cont'd



Intersecting or return wall of not less than 340 kg/m^2 (70lb/ft^2), tied to supported wall with connections capable of resisting a horizontal force of F_t, in kN per meter height

Masonry Tie Force Requirements

- Lateral Support Definitions, cont'd

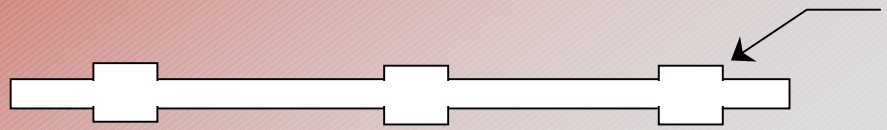
  2) A pier or stiffened section of the wall [not exceeding 1 m (3.3 ft) in length], capable of resisting a horizontal force of 1.5 F_t kN per meter height of wall (0.45 F_t in kips per foot height of wall).

  3) A substantial partition at right angles to the wall having an average weight of not less than 150 kg/m^2 (30.9 lb/ft^2), tied with connections capable of resisting a force of 0.5 F_t kN per meter height of wall (0.15 F_t in kips per foot height of wall) and having a length without openings of not less than H at right angles to the supported wall.

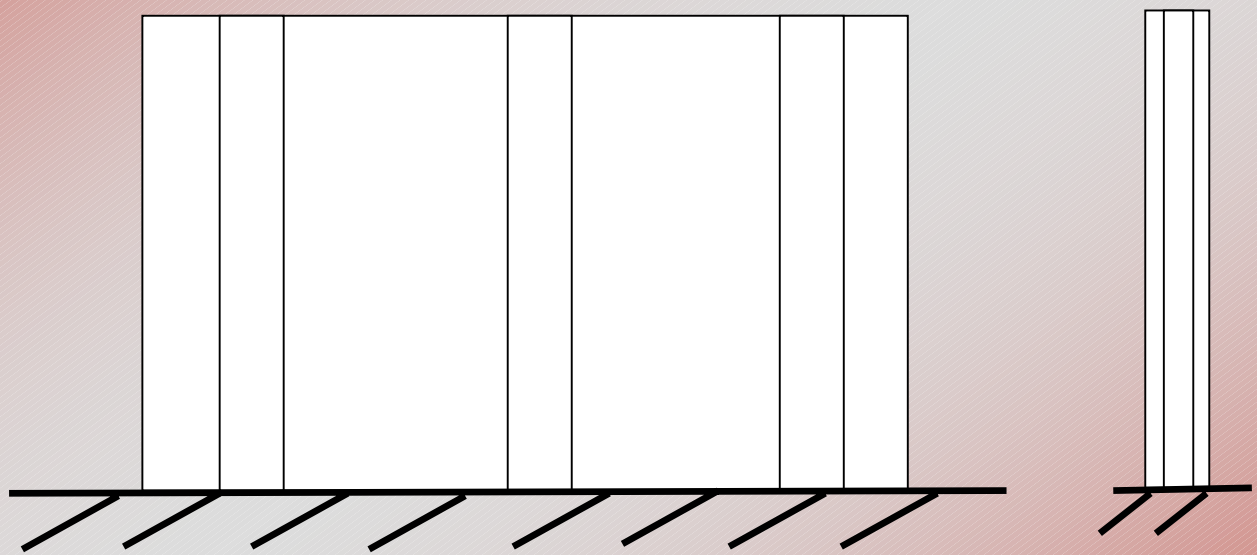
Masonry Tie Force Requirements

- Lateral Support Definitions, cont'd

Plan



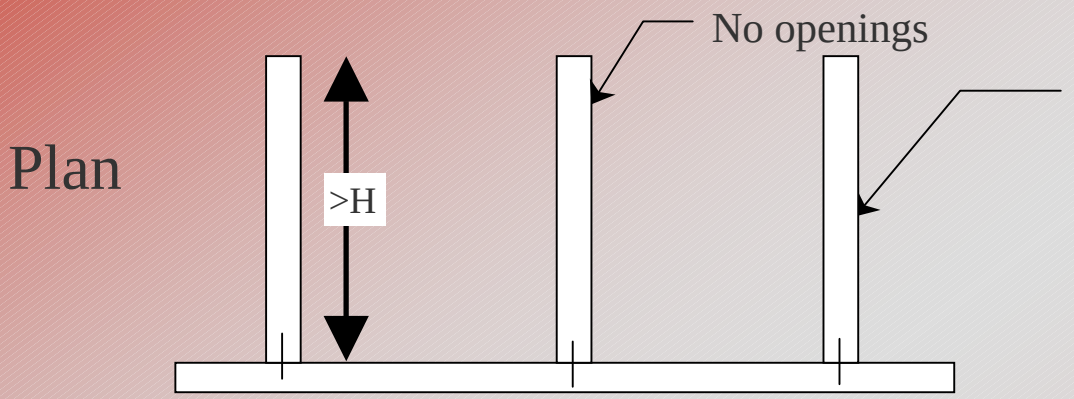
Pier or stiffened section < 1 m long, capable of resisting a horizontal force of 1.5 F_t, in kN per meter height



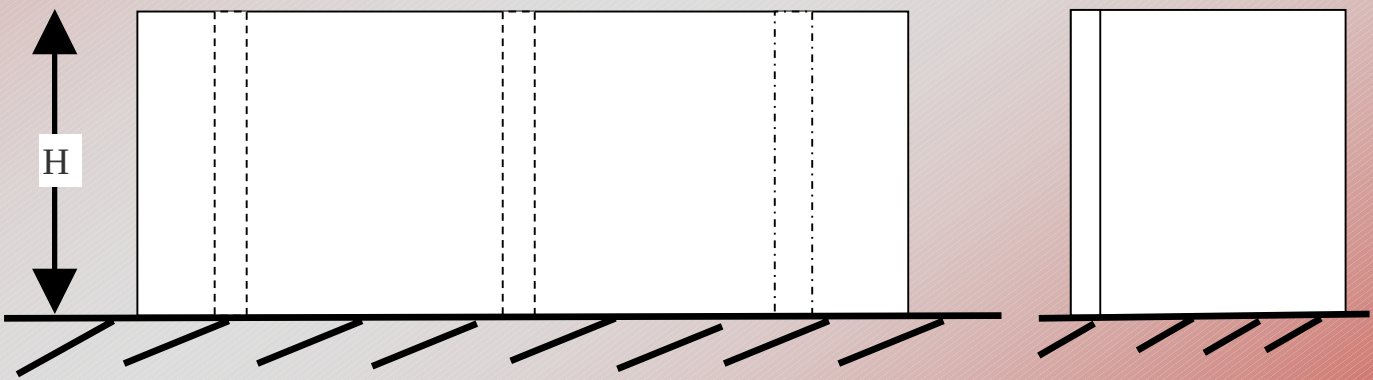
Elevation

Masonry Tie Force Requirements

- Lateral Support Definitions, cont'd



Substantial partition of mass not less than 150 kg/m^2 (30.9 lb/ft^2) so tied to be capable of resisting a horizontal force of 0.5 F_t, in kN per meter height and having a length without openings of not less than H at right angles to the supported wall.



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AP Method for Masonry

- Alternate Path Method for Masonry
  - The Alternate Path method must be used to verify that the structure can bridge over removed elements.
  - The general procedure provided in Section 3-2 in the UFC must be followed.

AP Method for Masonry

- Acceptability Criteria for Masonry
  - ◊ The acceptability criteria are provided in Table 6-2 and the design strengths must be calculated per ACI 530-02.
  - ◊ The subsequent actions for the AP model after violation of the acceptability criteria are detailed in the following slides.

AP Method for Masonry

Acceptability Criteria and Subsequent Action for Masonry

Structural Behavior	Acceptability Criteria	Subsequent Action for AP Model
Element Flexure	ΦM_n[A]	Section 6-3.1.1
Element Axial	ΦP_n[A]	Section 6-3.1.2
Element Shear	ΦV_n[A]	Section 6-3.1.3
Connections	Connection Design Strength[A]	Section 6-3.1.4
Deformation	Deformation Limits, defined in Table 6-4	Section 6-3.2

[A] Nominal strengths are calculated with the appropriate material properties and over-strength factor Ω; all Φ factors are defined per Chapter 3 of ACI 530-02

AP Method for Masonry

- Flexural Resistance of Masonry
  - For masonry, the flexural design strength is equal to the nominal flexural strength multiplied by the strength reduction factor Φ.
  - Calculate the nominal flexural strength per ACI 530-02 procedures.

AP Method for Masonry

- Flexural Resistance of Masonry, cont'd
  - ◊ For Linear Static Analysis:
    - If the required moment exceeds the flexural design strength and if the reinforcement layout is sufficient for a plastic hinge to form and undergo significant rotation, add an equivalent plastic hinge to the model, by inserting a discrete hinge at the correct location within the member.
    - For a connection with a plastic hinge, insert the hinge at the offset from the member end; use engineering analysis and judgment to determine the offset length, which must be less than ½ the depth of the member from the face of the column.
    - Apply two constant moments, one at each side of the new hinge, in the appropriate direction for the acting moment.

AP Method for Masonry

- Flexural Resistance of Masonry, cont'd
  - ◊ For Nonlinear Static and Dynamic Analysis:
    - The software must be capable of representing post-peak flexural behavior.
    - The designer must ensure that shear failure will not occur prior to developing the full flexural design strength.

AP Method for Masonry

- Flexural Resistance of Masonry, cont'd
  - ◊ If the structural element is not able to develop a constant moment while undergoing continued deformation, remove the element when the required moment exceeds the flexural design strength.
  - ◊ Redistribute the loads associated with the element per Section 3-2.4.3.

AP Method for Masonry

- Axial Resistance of Masonry
  - The acceptability criteria for axial loads is based on the axial design strength, as calculated in Chapter 3 of ACI 530-02, using the appropriate strength reduction factor Φ.
  - If the element violates the criteria, remove the element and redistribute the loads associated with the element per Section 3-2.4.3.

AP Method for Masonry

- Shear Resistance of Masonry
  - The acceptability criteria for shear is based on the shear design strength of the cross-section, per Chapter 3 of ACI 530-02, using the appropriate strength reduction factor Φ.
  - If the element violates the shear criteria, remove the element and redistribute the loads associated with the element per Section 3-2.4.3.

AP Method for Masonry

- Connections
  - ◊ Design strengths for connections are calculated using ACI 530-02, including the appropriate strength reduction factor Φ.
  - ◊ If the connection violates a criteria, remove it from the model.
  - ◊ If both connections at the ends of an element fail, remove the element and redistribute the loads associated with the element per Section 3-2.4.3.

AP Method for Masonry

- Deformation Limits for Masonry
  - ◊ The Deformation Limits are given in Table 6-4.
  - ◊ Note that Table 6-4 does not contain deformation limits for connections; thus, the deformation limits are applied only to the structural elements.

AP Method for Masonry

Deformation Limits for Masonry

	AP for Low LOP		AP for Medium and High LOP	
Component	Ductility (μ)	Rotation, Degrees (θ)	Ductility (μ)	Rotation, Degrees (θ)
Unreinforced Masonry[A]	-	2	-	1
Reinforced Masonry[B]	-	7	-	2

[A] Response of unreinforced masonry walls is also limited by D/h, the maximum member displacement to thickness ratio. This ratio is limited to 0.75. Compare this limit with the rotation limits and use the most restrictive condition. Also, all of these deformation limits apply to European clay tile and single, double and triple wythe brick.

[B] The ultimate resistance is based on the moment capacity using 90% of F_y for reinforcement.

AP Method for Masonry

- Additional Ductility Requirements
  - For MLOP and HLOP structures, all ground floor columns and load-bearing walls must be designed such that the shear capacity is greater than the flexural capacity, including compression membrane effects where appropriate.
  - Methods for calculating the compression membrane effects can be found in Park and Gamble 1999 and UFC 3-340-01.

Cold-Formed Steel Requirements

Cold-Formed Steel Requirements

- This section provides the specific requirements for designing a cold-formed steel building to resist progressive collapse.
- As cold-formed steel construction is similar to wood frame, near-identical requirements are used. These values might be adjusted in the future, with additional research and analysis.

Cold-Formed Steel Requirements

- Composite Construction
  - For composite construction, the application of both the requirements of this chapter and those provided for the other materials are required.
  - If wood floor diaphragms are used, the floor system and roof system would be required to meet the internal tie requirements of Chapter 7, while the steel stud walls would be required to meet the tie (vertical, peripheral, and wall) requirements or AP requirements of this chapter.

Cold-Formed Steel Requirements

- Material Properties for Cold-Formed Steel
  - ◊ All over-strength factors for cold-formed steel are equal to 1.0.

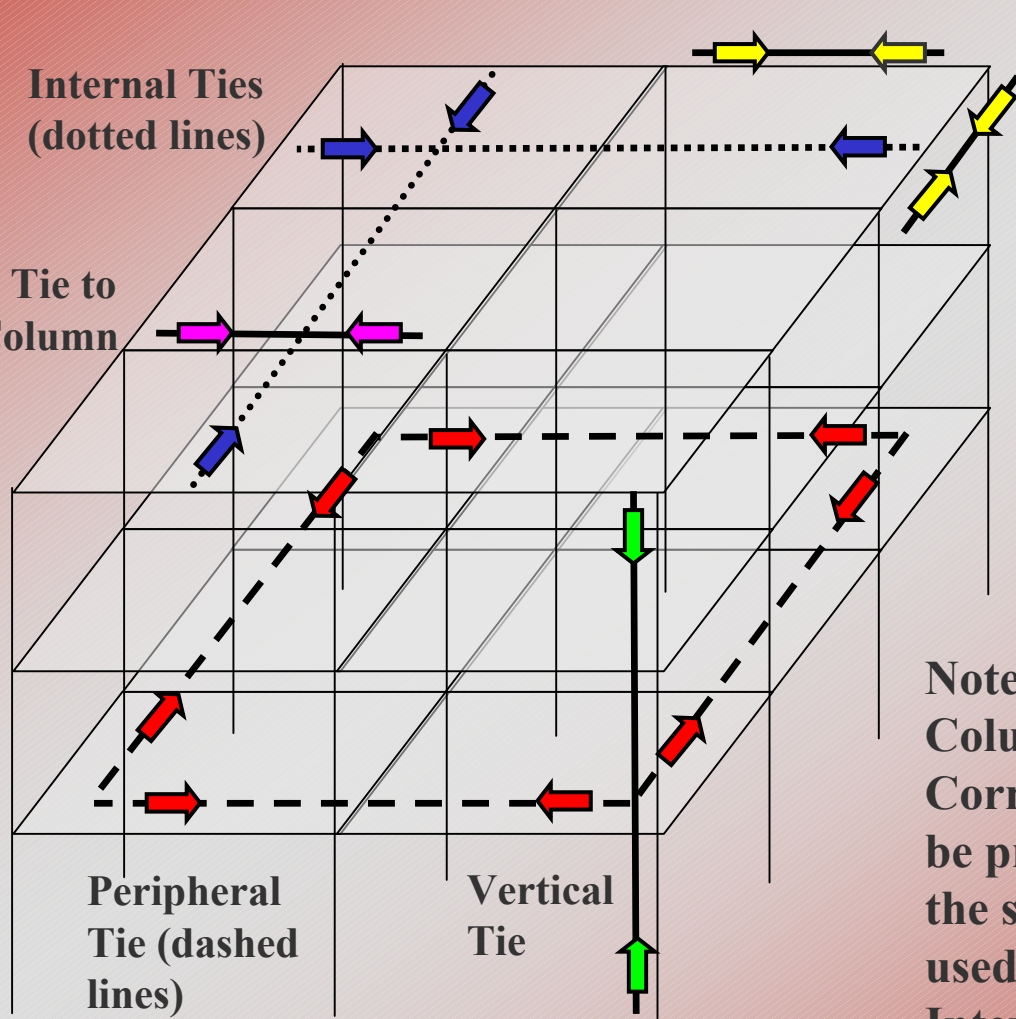
Cold-Formed Steel Force Requirements

- Cold-Formed Steel Tie Force Requirements
  - The following sections provide the necessary information to calculate the tie force demands for the various required ties.

Cold-Formed Steel Force Requirements

- General
  - ◊ Cold-formed steel construction is analogous to closely spaced columns and beams with nominal tie resistance provided at each joist to wall stud junction.
  - ◊ Peripheral, internal, vertical, and horizontal ties to columns and walls are required.
  - ◊ Structural members and connections that are provided for other purposes may be regarded as forming part or whole of the required ties.
  - ◊ Ties must, whole or in part, be spread evenly in the diaphragm or must be grouped at or in beams, walls or other appropriate positions.

Cold-Formed Steel Force Requirements



Note: The required External Column, External Wall, and Corner Column tie forces may be provided partly or wholly by the same reinforcement that is used to meet the Peripheral or Internal tie requirement.

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Cold-Formed Steel Force Requirements

- Strength Reduction Factor Φ for Cold-Formed Steel Tie Forces
  - For the cold-formed steel members and connections that provide the design tie strengths, use the appropriate tensile strength reduction factors Φ from the 2002 version of the *AISI Standard North American Specification for the Design of Cold-Formed Steel Structural Members* from the American Iron and Steel Institute (AISI/COS/NASPEC 2001).
  - For example, use a strength reduction factor of 0.90 for welds with tension or compression normal to the effective area or parallel to the axis of the weld.

Cold-Formed Steel Force Requirements

- Continuity and Anchorage of Ties
  - ◊ All ties must be mechanically joined, such that the full axial capacity of the tie member can be developed.
  - ◊ At re-entrant corners or at substantial changes in construction, care must be taken to insure that the ties are adequately anchored or otherwise made effective.

Cold-Formed Steel Force Requirements

- Internal Ties
  - ◊ Distribution and Location
    - These ties must be distributed at each floor and roof level in two directions approximately at right angles.
    - They must be effectively continuous and must be anchored to peripheral ties at each end (unless continuing as horizontal ties to columns or walls).

Cold-Formed Steel Force Requirements

- Internal Ties, cont'd
  - ◊ Distribution and Location, cont'd
    - They must, whole or in part, be spread evenly in the diaphragm or must be grouped at or in beams, walls or other appropriate positions.
    - Spacings must not be greater than 1.5 l_r, where l_r is the greater of the distances between the centers of the frames or walls supporting any two adjacent floor spaces in the direction of the tie under consideration (i.e., approximately the span length associated with the tie).
    - In walls, they must be within 0.5 m (1.6 ft) of the top or bottom of the floor diaphragm

Cold-Formed Steel Force Requirements

- Internal Ties, cont'd
  - ◊ Required Tie Force Capacity

In English units and in each direction, internal ties must have a required tie strength (in kip/ft width) equal to the greater of:

a) $\frac{(1.0D + 1.0L)}{65} \quad \frac{l_r}{15} \quad \frac{1.0}{3.3} \quad F_t$ (kip/ft)

or

b) $\frac{1.0}{3.3} \quad F_t$ (kip/ft)

where: D = Dead Load (lb/ft^2), L = Live Load (lb/ft^2)

l_r = Greater of the distances between the centers of the columns, frames or walls supporting any two adjacent floor spaces in the direction of the tie under consideration (ft)

F_t = "Basic Strength" = Lesser of $(1.62 + 0.33n_o)$ or 4.92

n_o = Number of stories

Cold-Formed Steel Force Requirements

- Internal Ties, cont'd
  - ◊ Whenever walls occur in plan in one direction only (e.g. "cross wall" or "spine wall" construction), the value of l_r used when assessing the tie force in the direction parallel to the wall must be taken as either the actual length of the wall or the length which may be considered lost in the event of an accident, whichever is the lesser.
  - ◊ The length which may be considered lost must be taken as the length between adjacent lateral supports or between a lateral support and a free edge.

Cold-Formed Steel Force Requirements

- Peripheral Ties
  - ◊ At each floor level and roof level, an effectively continuous peripheral tie must be provided, capable of providing a required tensile strength equal to 1.0 F_t, located within 1.2 m (3.9 ft) of building edges or within the perimeter wall.

Cold-Formed Steel Force Requirements

- Horizontal Ties to External Walls and Columns
  - ◊ *In English units*, each external column and, if the peripheral tie is not located within the wall, every 3.3 ft length of external wall carrying vertical load must be anchored or tied horizontally into the structure at each floor and roof level with a tie with a required tie strength (in kips) equal to the greater of:

    a) the lesser of $2.0\ F_t$ or $(l_s/8.2)\ F_t$ (kip)

    or

    b) 3% of the largest factored vertical load, carried by the column or wall at that level, due to conventional design load combinations (kip)

    where: l_s = the floor to ceiling height (ft).

Cold-Formed Steel Force Requirements

- Horizontal Ties to External Walls and Columns, cont'd
  - ◊ Where the peripheral tie is located within the wall, provide horizontal ties adequate to anchor the internal ties to the peripheral ties.
  - ◊ Corner columns must be tied into the structure at each floor and roof level in each of two directions, approximately at right angles, with ties having a required tensile strength equal to the greater of a) or b) from the previous section.

Cold-Formed Steel Force Requirements

- Vertical Ties
  - ◊ Each column and load-bearing wall must be tied continuously from the lowest to the highest level.
  - ◊ The tie must be capable of resisting a tensile force equal to the largest factored vertical load received by the column or wall from any one story, due to conventional design load combinations.

Cold-Formed Steel Force Requirements

- Vertical Ties, cont'd
  - When a wall at its lowest level is supported by an element other than a foundation, a general check for structural integrity must be made (i.e., a careful check must be made and appropriate action taken to insure that there is no inherent weakness of structural layout and that adequate means exist to transmit the dead, live, and wind loads safely from the highest supported level to the foundations).

Cold-Formed Steel Force Requirements

- Load-bearing Elements with Deficient Vertical Tie Forces
  - ◊ If it is not possible to provide the required vertical tie force in any of the load-bearing elements, then the Alternate Path method is applied for each such deficient element.
  - ◊ Remove each deficient member from the structure, one at a time in each story in turn, and perform an AP analysis to verify that the structure can bridge over the missing member.
  - ◊ The amount of member to be removed from the structure is given in Table 8-1.

Cold-Formed Steel Force Requirements

Removal of Deficient Cold-Formed Steel Vertical Tie Members

Vertical Load-bearing Element Type	Definition of Element	Extent of Structure to Remove if Deficient
Column	Primary structural support member acting alone	Clear height between lateral restraints
External Wall	All load-bearing walls that form the perimeter and external face of the building but not room partitions	Length between intersecting walls (perpendicular partitions, return walls, internal room dividers), or between columns. Minimum length of wall to be considered 2.4 m (7.9 ft).
Internal Wall	All load-bearing walls within the building including room partitions	Length limited between intersecting walls or 2.25H, where H is the clear height between lateral supports (i.e. floor-to-floor).

AP Method for Cold-Formed Steel

- Alternate Path Method for Cold-Formed Steel
  - The Alternate Path approach is used to verify that the structure can bridge over removed elements.
  - The general procedure provided in Section 3-2 must be followed.

AP Method for Cold-Formed Steel

- Acceptability Criteria for Cold-Formed Steel
  - ◊ The acceptability criteria are provided in Table 8-2 and the required design strengths must be calculated per AISI/COS/NASPEC 2001.
  - ◊ The subsequent actions for the AP model after violation of the acceptability criteria are detailed in the following sub-sections.

AP Method for Cold-Formed Steel

Acceptability Criteria and Subsequent Action for Cold-Formed Steel

Structural Behavior	Acceptability Criteria	Subsequent Action for AP Model
Element Flexure	ΦM_n^A	Section 8-3.1.1
Element Combined Axial and Bending	AISI/COS/NASPEC 2001 Chapter C5 Interaction Equations	Section 8-3.1.2
Element Shear	ΦV_n^A	Section 8-3.1.3
Connections	Connection Design Strength[A]	Section 8-3.1.4
Deformation	Deformation Limits, defined in Table 8-3	Section 8-3.2

[A] Nominal strengths are calculated with the appropriate material properties and over-strength factor Ω; all Φ factors are defined per AISI/COS/NASPEC 2001.

AP Method for Cold-Formed Steel

- Flexural Resistance of Cold-Formed Steel
  - For cold-formed steel, the flexural design strength is equal to the nominal flexural strength, multiplied by the strength reduction factor Φ.
  - Calculate the nominal flexural strength per AISI/COS/NASPEC 2001 procedures.

AP Method for Cold-Formed Steel

- Flexural Resistance of Cold-Formed Steel, cont'd
  - For Linear Static Analysis:
    - If the required moment exceeds the flexural design strength and if the geometry and supports of the cold-formed steel member are sufficient for a plastic hinge to form and undergo significant rotation, add an equivalent plastic hinge to the model, by inserting a discrete hinge at the correct location within the member.
    - For a connection with a plastic hinge, insert the hinge at the offset from the member end; use engineering analysis and judgment to determine the offset length.
    - Apply two constant moments, one at each side of the new hinge, in the appropriate direction for the acting moment.

AP Method for Cold-Formed Steel

- Flexural Resistance of Cold-Formed Steel, cont'd
  - For Nonlinear Static and Dynamic Analysis:
    - The software must be capable of representing post-peak flexural behavior.
    - The designer must ensure that shear failure will not occur prior to developing the full flexural design strength.

AP Method for Cold-Formed Steel

- Flexural Resistance of Cold-Formed Steel, cont'd
  - ◊ If the structural element is not able to develop a constant moment while undergoing continued deformations, remove the element when the internal moment exceeds the flexural design strength.
  - ◊ Redistribute the loads associated with the element per Section 3-2.4.3.

AP Method for Cold-Formed Steel

- Combined Axial and Bending Resistance of Cold-formed Steel
  - ◊ The acceptability criteria for elements undergoing combined axial and bending loads is based on the interaction equations in Chapter C5 of AISI/COS/NASPEC 2001, using the appropriate strength reduction factor Φ and over-strength factor Ω.
  - ◊ If the element violates the criteria, remove the element and redistribute the loads associated with the element per Section 3-2.4.3.

AP Method for Cold-Formed Steel

- Shear Resistance of Cold-Formed Steel
  - ◊ The acceptability criteria for shear is based on the shear design strength of the cross-section, per Chapter C3 of AISI/COS/NASPEC 2001, using the appropriate strength reduction factor Φ and over-strength factor Ω.
  - ◊ If the element violates the criteria, remove the element and redistribute the loads associated with the element per Section 3-2.4.3.

AP Method for Cold-Formed Steel

- Connections
  - ◊ Design strengths for connections are calculated per AISI/COS/NASPEC 2001, using the appropriate strength reduction factor Φ and over-strength factor Ω.
  - ◊ If the connection violates the criteria, remove it from the model.
  - ◊ If both connections at the ends of an element fail, remove the element and redistribute the loads associated with the element per Section 3-2.4.3

AP Method for Cold-Formed Steel

- Deformation Limits for Cold-Formed Steel
  - The Deformation Limits are given in Table 8-3.
  - Note that Table 8-3 does not contain deformation limits for connections; thus, the deformation limits are applied only to the structural elements.

AP Method for Cold-Formed Steel

Deformation Limits for Cold-Formed Steel

	AP for Low LOP		AP for Medium and High LOP	
Component	Ductility (μ)	Rotation, Degrees (θ)	Ductility (μ)	Rotation, Degrees (θ)
Girts and Purlins	5	5	2	2
Metal Studs				
With studs connected top and bottom	3	2	1.8	1.3
With sliding connection	1	-	0.9	-
Corrugated Metal Deck	6	4	3	2
Standing Seam Metal Deck	6	4	3	2

AP Method for Cold-Formed Steel

- Additional Ductility Requirements
  - ◊ For MLOP and HLOP structures, all external ground floor columns and load- bearing walls must be designed such that the shear capacity is greater than the flexural capacity, including compression membrane effects if appropriate.
  - ◊ Methods for calculating the compression membrane effects can be found in Park and Gamble 1999 and UFC 3-340-01.