American Concrete Institute®
Advancing concrete knowledge

Practical Design of Concrete Buildings

ACI Spring 2011 Convention
April 3 - 7, Tampa, FL

ACI WEB SESSIONS

ACI Web Sessions

The audio for this web session will begin momentarily and will play in its entirety along with the slides.

However, if you wish to skip to the next speaker, use the scroll bar at left to locate the speaker's first slide (indicated by the icon in the bottom right corner of slides 9 and 35). Click on the thumbnail for the slide to begin the audio for that portion of the presentation.

Note: If the slides begin to lag behind the audio, back up one slide to re-sync.

ACI WEB SESSIONS

ACI Web Sessions

ACI is bringing you this Web Session in keeping with its motto of "Advancing Concrete Knowledge." The ideas expressed, however, are those of the speakers and do not necessarily reflect the views of ACI or its committees.

Please adjust your audio to an appropriate level at this time.

ACI WEB SESSIONS

ACI Web Sessions

ACI Web Sessions are recorded at ACI conventions and other concrete industry events. At regular intervals, a new set of presentations can be viewed on ACI's website free of charge.

After one week, the presentations will be temporarily archived on the ACI website or made part of ACI's Online CEU Program, depending on their content.

ACI WEB SESSIONS

ACI Online CEU Program

ACI offers an easy-to-use Online CEU Program for anyone who needs to earn Continuing Education credits.

Once registered, you can download and study reference material. After passing a 10-question exam on the material, you will receive a certificate of completion that you can present to local licensing agencies.

Visit **www.concrete.org/education/edu_online_CEU.htm** for more information.

ACI WEB SESSIONS

ACI Conventions

ACI conventions provide a forum for networking, learning the latest in concrete technology and practices, renewing old friendships, and making new ones. At each of ACI's two annual conventions, technical and educational committees meet to develop the standards, reports, and other documents necessary to keep abreast of the ever-changing world of concrete technology.

With over 1,300 delegates attending each convention, there is ample opportunity to meet and talk individually with some of the most prominent persons in the field of concrete technology. For more information about ACI conventions, visit www.aciconvention.org.

ACI WEB SESSIONS

ACI Web Sessions

This ACI Web Session includes 2 speakers presenting at the ACI spring convention held in Tampa, FL April 3 – 7, 2011.

Additional presentations will be made available in future ACI Web Sessions.

Please enjoy the presentations.

ACI WEB SESSIONS

American Concrete Institute®
Advancing concrete knowledge

Practical Design of Concrete Buildings

ACI Spring 2011 Convention
April 3 - 7, Tampa, FL

ACI WEB SESSIONS

John Turner is the Greater Southwestern Region Manager for the Concrete Reinforcing Steel Institute. John is a structural engineer with experience in design and repair of wood, reinforced concrete, and steel structures, including buildings in moderate seismic zones and hurricane prone regions.

Mr. Turner holds a bachelor of science in safety engineering from Texas A&M University and a master's of science in civil engineering from Texas Tech University. He maintains designation as a Certified Safety Professional and is a licensed Professional Engineer (structural) in Texas. Prior to his current structural engineering career, John was a safety and fire protection engineer, including work on the Space Shuttle Main Engine Testing Program at Stennis Space Center, Mississippi. John has developed and presented adult education programs for about 20 years, including several years as an instructor for the OSHA Training Institute and Texas Engineering Extension Service.

ACI WEB SESSIONS

Optimizing Economy

Simplifying Loads, Optimizing Members, and Leveling the Design

ACI WEB SESSIONS

Economy By Design

"*Engineering is more than an exact applied science of rules to follow. Rather, it is a complicated integration of skill and resourcefulness. And, proficient engineering is a balanced combination of formula, knowledge and creativity.*"

- Kopf Consulting Group, Marietta, GA

ACI WEB SESSIONS

Design for Simplicity

- More engineering, less computing
- Saving labor in exchange for simplicity
- Getting a robust, not excessive, structure
- Reducing CA & errors
- Designing for economy and value

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Balancing Act

- Production, on the desk and in the field
- Engineering judgment
- Cost of design
- Cost of construction
- Owner, architect needs
- Contractor / CM issues

Working Smarter

- Make design decisions for value
- Avoid VE by engineering for value
- Repetition of components, not calculations
- Use the tools wisely
- Don’t complicate when simple will do

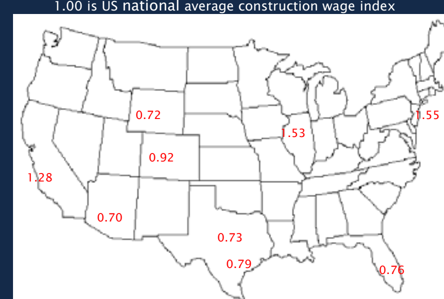
Costs in Construction

- Labor
- Materials
- Formwork

- Fabrication
- Transportation
- Time

Relative Wage Rates

1.00 is US national average construction wage index



2009 wage data from US Bureau of Labor Statistics

Specific Strategy

- Design and detailing to reduce cost
- More material, less complexity, lower cost
- Laying out loads and members
- Leveling design
- BIM, complexity, and construction costs
- LEED and "green construction" and complexity
- CA: RFI's, change orders & observations

Representational Analysis

- Structures work differently than planned:
  - Moments redistribute
  - Load paths vary
  - Variation in construction
  - Variations in loading
- Precision v. Accuracy
- A sharper pencil and more calcs don’t make it stronger
- Analysis is ONLY a tool to get a good design

Gravity

- This is where savings will be found.
- You will save more with uniformity than minimization.
- Don't complicate things because you can (i.e., "all it takes is one click…")

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Simplifying Loads

- Uniform floor loads
  - With concrete structures, incremental increases in design live loads are insignificant
  - Redistribution will happen
  - Loading will probably look nothing like the architect's plan (precision has low value)
  - Plan for ongoing use of the structure "adaptive reuse"

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Simplifying Layout

- Make floors uniform
- Make columns uniform
- Reduce beam marks
- Minimize changes from level to level
- Less design time = lower formwork cost
- Avoid weak stories and plan irregularities *in the structure*

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Software

- Easy to complicate the design
- Provides an exact answer
- Lean structure based on material
- Easy to point and click…incorrectly
- Sizing and schedules REQUIRE manual fixes
- Has no sense of proportion
- Garbage In – Garbage Out
- Use its strengths, work around weaknesses

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Data In

- Uniform loads
  - except: RTU + drifts + joists
- Limit parameters to get better output
  - Beam sizes: eliminate "bad" ones
  - Rebar sizes: allow fewer sizes; even or odd
  - Restrict rebar to one size per beam
- Keep member sizes as uniform as possible

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Data Out

- Run, look at schedules, modify settings, run again
- Recognize when things went wrong
- Output moments, shears, and hand select

- Level before detailing or scheduling
- Do not use schedules without leveling

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Leveling

- Once the plan is "complete", step back and look at the result:
  - Does it look more complicated than needed?
  - Do you have/need sections cut *everywhere*?
  - How many shop drawings will this require?
  - Can you envision the construction process?
  - Can you count the number of beams/marks?
  - Do details look constructible?

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Leveling

- Look at members and decide if there are natural groups of similar members:
  - Moment demand & length
  - Shear
  - A_s , A_v & section
  - Same beam in same location on each floor
  - Uniformity across bays
  - Material costs are low, so don't over-think it

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Concrete

- Material cost is low per increment
- Excess material requires more reinforcing, larger footings, larger columns
- Too little concrete is inefficient
- Lean structures can be vulnerable
- Admixtures v. aggregate v. cement
- Supplemental cementitious materials

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Formwork

- Accounts for 30-50% of the cost for the concrete structure
- Small changes are just often as costly as big ones – consistency saves

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Formwork v. Materials

- Minimizing material quantities guarantees "inefficient" designs.

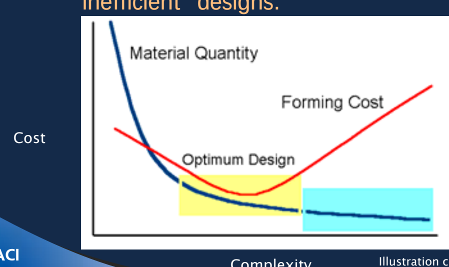

Illustration courtesy CECO

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Beam Size Economy

- Uniform width and depth
- Constant size from span to span
- Wide, flat beams
- Beam width, greater than column width
- Consider upturned spandrels for depth

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Column Size Economy

- Consistent size
- Consistent reinforcement
- Discontinue bars, then reduce bar size
- Rebar stock is:
  - 20, 40 & 60 foot straight
  - Coil (4000 lbs) in #3, #4 & #5

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Slab Economy

- Uniform reinforcing (bar size @ spacing)
- Uniform bottom of slab
- Drop panel depth (2-1/4”, 4-1/4”, 6-1/4”)

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Uniformity Reduces CA

- Simplify
- Level

- Smaller schedules = fewer shop drawings
- Easier observations, quicker inspections
- Easier QA/QC
- Less rework and fewer RFIs

ACI WEB SESSIONS

Questions or Comments?

ACI WEB SESSIONS

Javeed Munshi has 20 years of engineering experience in design, evaluation and construction of concrete structures including heavy industrial (fossil and nuclear) power structures, bridges, underground structures (tunnels) and environmental concrete structures. He is widely published and has conducted concrete design seminars and training for the American Concrete Institute (ACI), the Portland Cement Association (PCA), and the Concrete Reinforcing Steel Institute (CRSI). He has served as an expert for peer review of many projects. He is member of several ACI Committees including ACI Committee 307, Concrete Chimneys; 349, Concrete Nuclear Structures; 350, Environmental Engineering Concrete Structures; 359, Concrete Components for Nuclear Reactors (Joint ACI-ASME); 374, Performance-Based Seismic Design of Concrete ; and 437, Strength Evaluation of Existing Concrete Structures. Dr. Munshi is a licensed professional engineer in states of New York and Wisconsin and a licensed structural engineer in Illinois.

ACI WEB SESSIONS

Seismic Detailing

Special Session on Simplified Concrete Design, ACI 314, 2011 Spring Convention, Tampa FL

Javeed Munshi

Principal Engineer, Bechtel Power Corp.

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ACI 314R - Seismic Detailing

- Document is deemed to comply with:
  - ACI 318-08
  - ASCE 7-05
  - IBC 2006
- Use the document in its entirety

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ACI 314R

- Low Risk (SDC A and B)
- High Risk (SDC C-F)
- Low-rise (small to medium height)
- 5 - story

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ACI 314R Structural System

- No restriction on structural system
- Seismic load to be carried by shearwalls
- Seismic design/details per Ch 11

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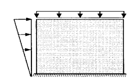
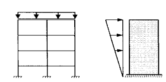
STRUCTURAL SYSTEMS

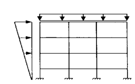
- Loadbearing Wall



- **Building Frame**



- Moment-Resisting Frame



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ACI 314R- Frames

- Low Risk – Frames designed for lateral load
- High Risk – Frames designed for 25% of lateral load

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ACI 314R-Structural System

- Dual building frame system
- **R = 5**
- Minimum wall area required in both orthogonal directions
- Shearwalls designed for 100% base shear
- Frames designed for 25% base shear
- Essential requirements – Bar size limited to No. 8

ACI WEB SESSIONS

Response Modification Factor and Deflection Amplification factor

Concrete Structural Systems in ASCE 7-05 - SDC D, E, F

CONCRETE STRUCTURAL SYSTEMS - SDC D, E, and F	R	Ω_0	C_d	Height limit D	Height limit E	Height limit F
MOMENT RESISTING FRAME SYSTEM using Special Moment Frames of RC (SMF)	8	3	5 ½	NL	NL	NL
DUAL SYSTEM using Special RC Shear Walls w/ SMF	7	2 ½	5 ½	NL	NL	NL
DUAL SYSTEM using Special RC Shear Walls w/ IMF	6 ½	2 ½	5	160	100	100
BUILDING FRAME SYSTEM WITH OMF OF RC using Special RC Shear walls	6	2 ½	5	160	160	100
BEARING WALL SYSTEM using Special RC Shear Walls	5	2 ½	5	160	160	160

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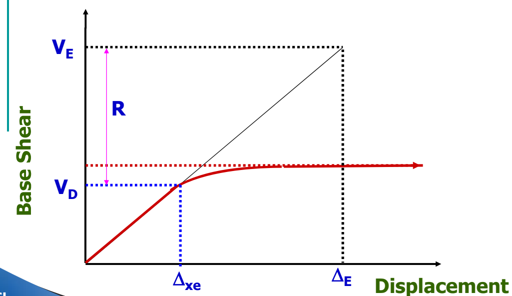
Design Philosophy



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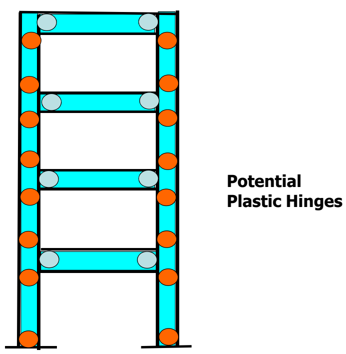
Seismic Design Philosophy



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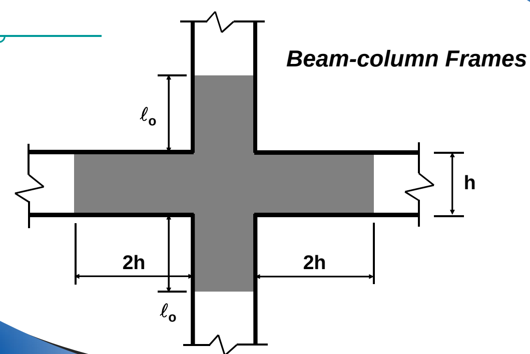
Locations of Potential Plastic Hinging



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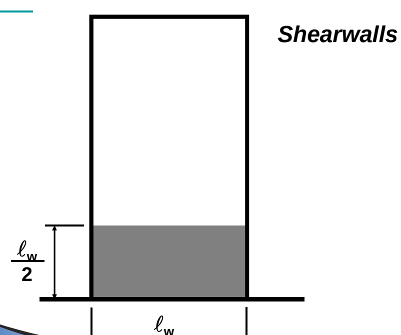
Locations of Potential Plastic Hinging



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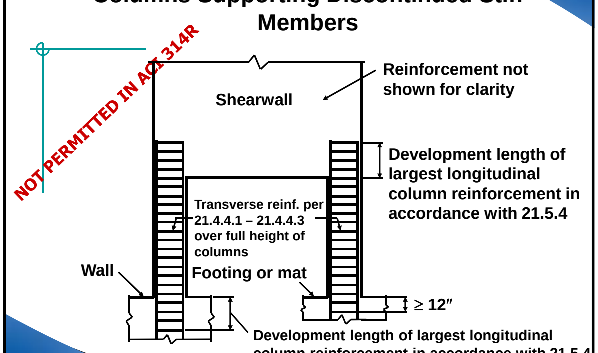
Columns Supporting Discontinued Stiff Members



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Flexural Members

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Splice Failure

1985 Mexico City

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Beam Hinging

1985 Mexico City

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ACI 318-High Seismic Risk

- Factored axial compressive force ≤ $A_g f'_c/10$
- Clear span ≥ 4 × effective depth
- Width to depth ratio ≥ 0.3
- Width ≥ 10 in.

  ≤ width of supporting member + distances on each side of supporting member not exceeding ¾ of the depth of the flexural member

(21.3. 1)

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SAME IN ACI 314R

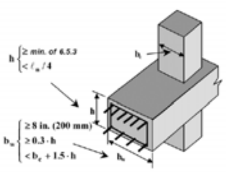
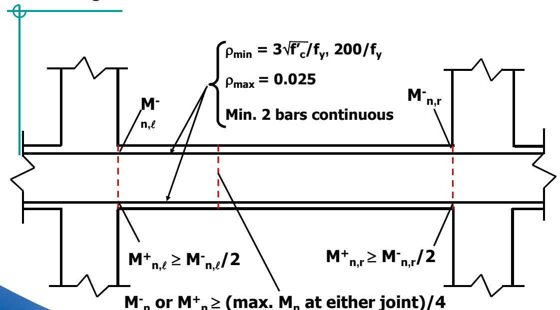


Fig. 8.22—Limits on girder depth and width.

11.1.2.1—***Dimensional requirements.*** Minimum width, b_w, of girders should be 10 in. (250 mm), and the girder should comply with of 8.7.2.

ACI WEB SESSIONS

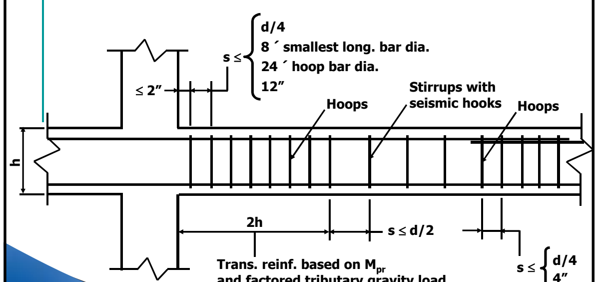
ACI 318 High Seismic Risk – Longitudinal Reinf. Same in ACI 314R



(21.3.2.1, 21.3.2.2)

ACI WEB SESSIONS

ACI 318 High Seismic Risk – Transverse Reinf.



(21.3.3, 21.3.2.3, 21.3.4)

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SIMILAR IN ACI 314R

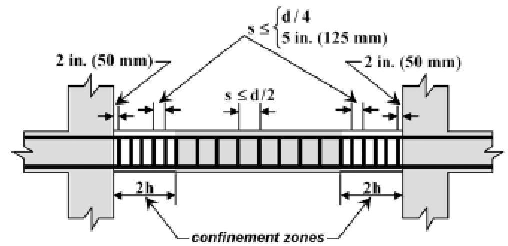

Fig. 11.1—Confinement stirrup spacing.

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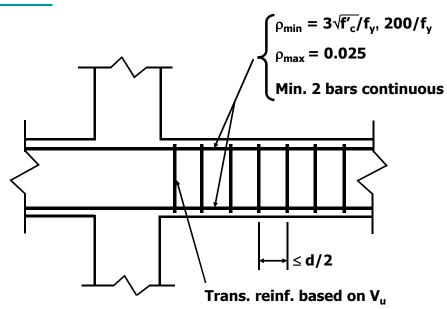
Frame members not part of LFRS - Case A:

$M_u \le \phi M_n$, $V_u \le \phi V_n$



(21.11.2.1)

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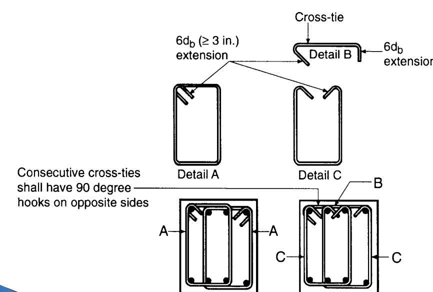
ACI 318 High Seismic Risk – Hoop Reinforcement



(21.3.3.6)

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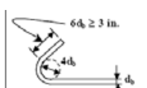
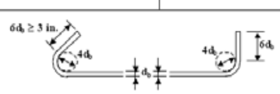
SAME IN ACI 314R

(d) For hoops (confinement stirrups and ties) in seismic zones	A 135°-bend plus minimum a $6d_b$ extension at free end of bar, but not less than 3 in. (75 mm)	
(e) For crossties in seismic zones	A 135°-bend plus minimum a $6d_b$ extension at one free end of bar, but not less than 3 in. (75 mm), and	A 90°-bend plus minimum a $6d_b$ extension at the other free end of bar
		

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T Beams – Not Addressed

21.4.2.2 – T-beam Construction

- **Slab reinforcement within an effective width defined in 8.10 shall be assumed to contribute to the flexural strength M_g if the slab reinforcement is developed at the critical section for flexure**

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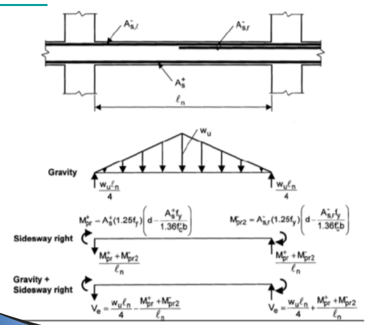
SHEAR REQUIREMENTS-SAME IN ACI 314R



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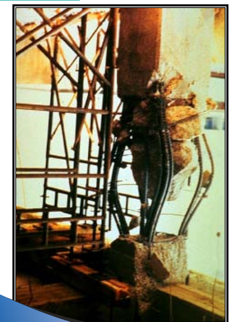
Column Crushing



- Poor distribution of longitudinal reinforcement
- Widely spaced ties

1985 Mexico City

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Tie Failure

- Concentration of longitudinal bars in corners
- Widely spaced 90-deg ties

1985 Mexico City

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ACI 318 High Seismic Risk – Same for ACI 314R

- Factored axial compressive force > $A_g f'_c/10$
- Shortest cross-sectional dimension ≥ 12 in.
- Ratio of shortest cross-sectional dimension to perpendicular dimension ≥ 0.4

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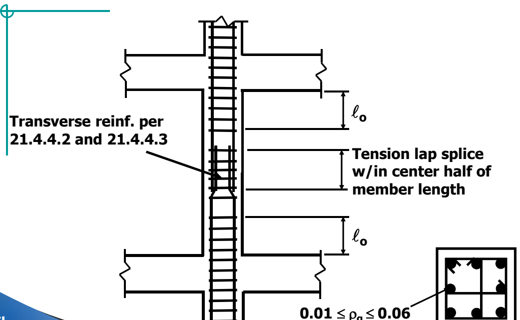
(21.4. 1)

ACI 318 High Seismic Risk – Reinforcement



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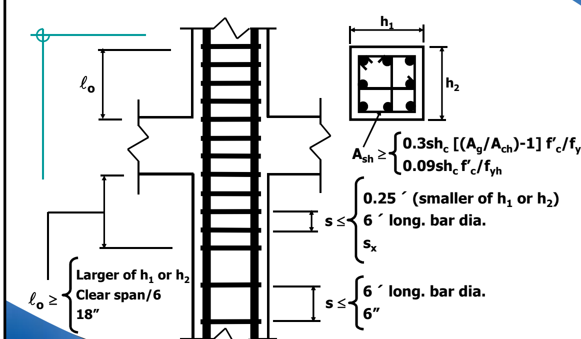
(21.4.3)

ACI 318 High Seismic Risk – Rect. Hoop



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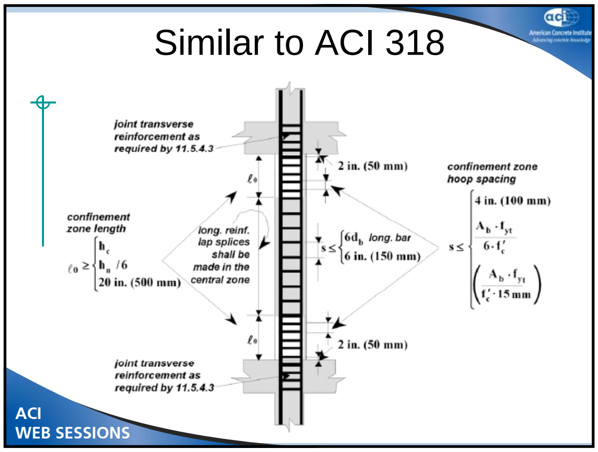
(21.4.4)


Similar to ACI 318
joint transverse reinforcement as required by 11.5.4.3
2 in. (50 mm)
confinement zone hoop spacing
4 in. (100 mm)
confinement zone length
long. reinf. lap splices shall be made in the central zone
6d_b long. bar
6 in. (150 mm)
20 in. (500 mm)
2 in. (50 mm)
joint transverse reinforcement as required by 11.5.4.3
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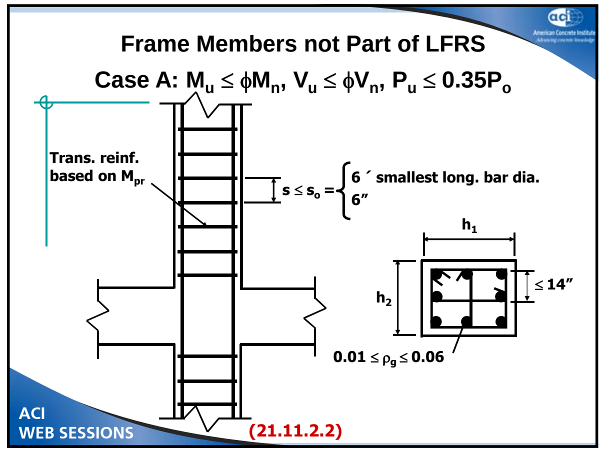
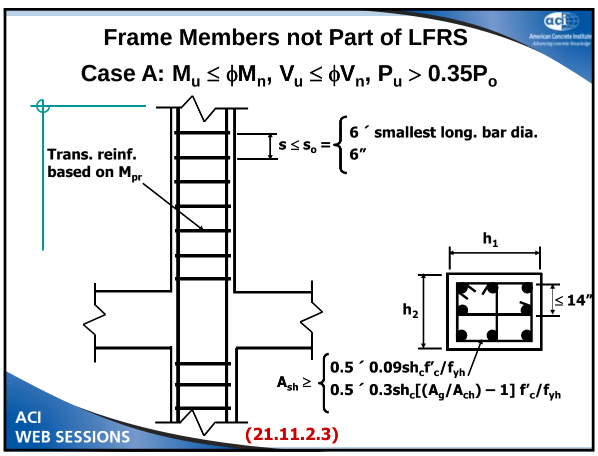
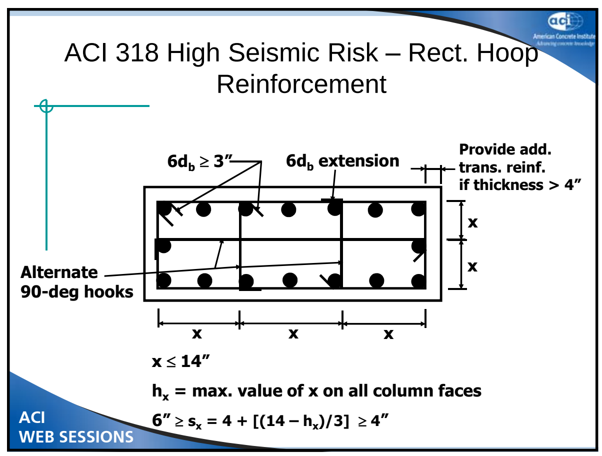
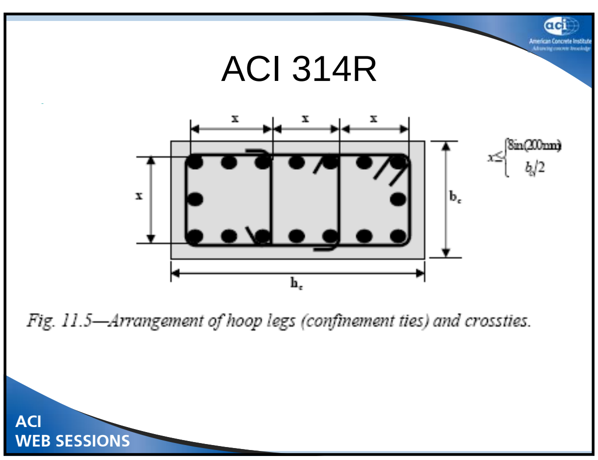

Frame Members not Part of LFRS
Case A: $M_u \le \phi M_n$, $V_u \le \phi V_n$, $P_u \le 0.35P_o$
Trans. reinf. based on M_{pr}
$s \le s_o =$ 6 ´ smallest long. bar dia. / 6″
h_1
h_2
≤ 14″
$0.01 \le \rho_g \le 0.06$
(21.11.2.2)
ACI
WEB SESSIONS


Frame Members not Part of LFRS
Case A: $M_u \le \phi M_n$, $V_u \le \phi V_n$, $P_u > 0.35P_o$
Trans. reinf. based on M_{pr}
$s \le s_o =$ 6 ´ smallest long. bar dia. / 6″
h_1
h_2
≤ 14″
$A_{sh} \ge$ 0.5 ´ $0.09sh_cf'_c/f_{yh}$ / 0.5 ´ $0.3sh_c[(A_g/A_{ch}) - 1]\,f'_c/f_{yh}$
(21.11.2.3)
ACI
WEB SESSIONS


ACI 318 High Seismic Risk – Rect. Hoop Reinforcement
$6d_b \ge 3''$
$6d_b$ extension
Provide add. trans. reinf. if thickness > 4″
Alternate 90-deg hooks
x
x
x x x
$x \le 14''$
h_x = max. value of x on all column faces
$6'' \ge s_x = 4 + [(14 - h_x)/3] \ge 4''$
ACI
WEB SESSIONS


ACI 314R
x x x
x
b_c
h_c
$x \le$ 8in (200mm) / $b_c/2$
Fig. 11.5—Arrangement of hoop legs (confinement ties) and crossties.
ACI
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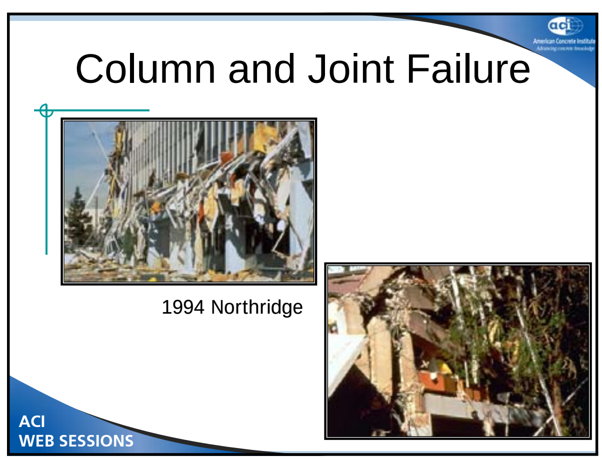

Column and Joint Failure
1994 Northridge
ACI
WEB SESSIONS

Interior Joint Failure

1985 Mexico City

- Longitudinal beam bars not confined within column longitudinal bars or ties

Interior Joint Failure

1985 Mexico City

- No intermediate ties in joint normal to outside face of joint

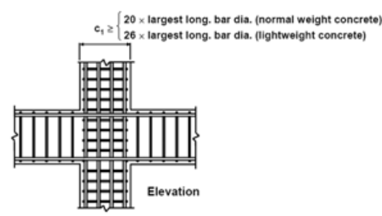
Corner Joint Failure

1985 Mexico City

- No transverse reinforcement through joint
- Insufficient anchorage for hooked bars
- Widely spaced ties outside of joint
- No intermediate ties in column

ACI 318/ACI 314R JOINTS

High Seismic Risk – Joint Detail



ACI 314R

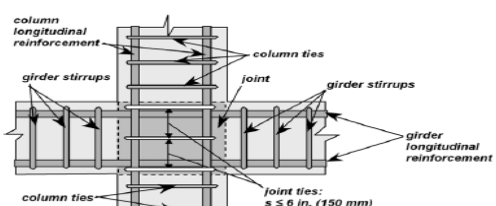
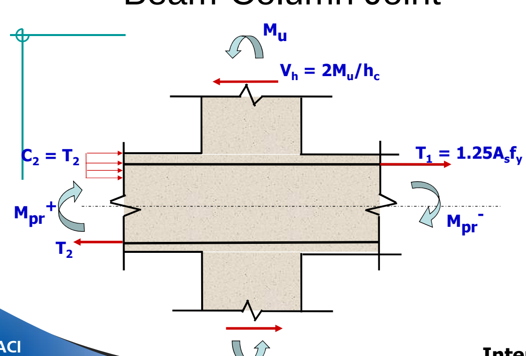


Fig. 10.14—Column ties in column-girder joints.

Beam-Column Joint



Interior

JOINTS

Nominal Shear Strength of Joint

- Joints confined on all 4 faces:

  $V_n = 20\sqrt{f'_c}\,A_j$

- Joints confined on 3 faces/2 opposite faces:

  $V_n = 15\sqrt{f'_c}\,A_j$

- For others:

  $V_n = 12\sqrt{f'_c}\,A_j$

ACI WEB SESSIONS

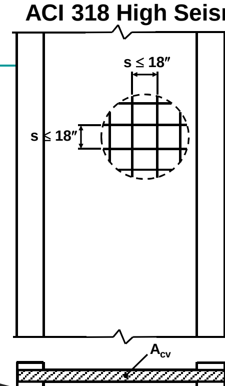
High Seismic Risk – Joint Detail

ACI WEB SESSIONS

Reinforced Concrete Structural Walls

ACI WEB SESSIONS

ACI 318 High Seismic Risk



Shear strength requirements per

Design for flexure and axial load

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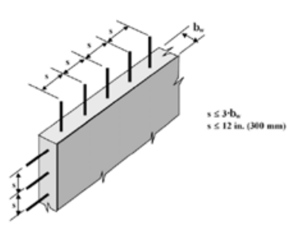

Fig. 12.5—Reinforcement spacing in reinforced concrete walls.

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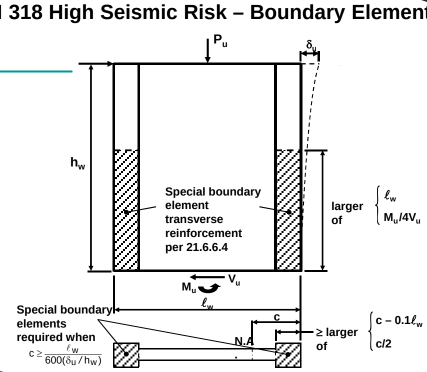
ACI 318 High Seismic Risk – Boundary Elements



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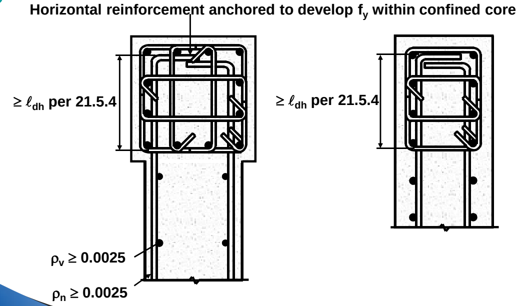
Boundary Element Layout

Horizontal reinforcement anchored to develop f_y within confined core



ACI 314R - Boundary Element where compressive stress >0.2f'c

Provide Boundary Element or Confinement over the Whole Wall

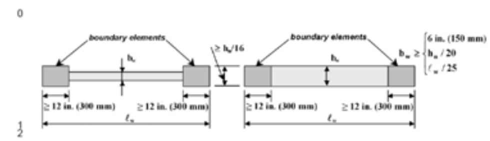


Fig. 11.13—Boundary element dimensions.

ACI 314R

$$0.0025 \leq \rho_{vw} \left(= \frac{A_{st}}{b_w \ell_w} \right) \leq 0.06 \qquad (12\text{-}2)$$

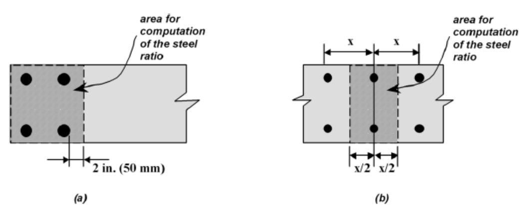


Fig. 12.6—CalculationVertical reinforcement ratio calculation.

Short Column Failure

1985 Mexico City

ACI 314R

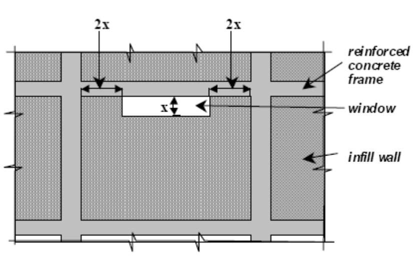
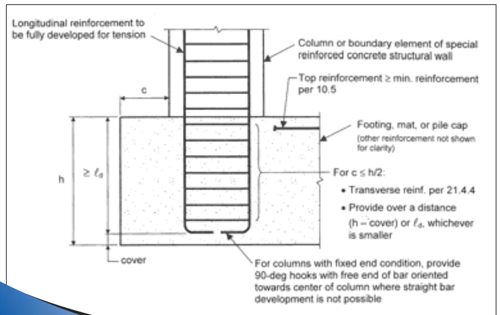


Fig. 11.15—Alternative to account for the short or captive column effect.

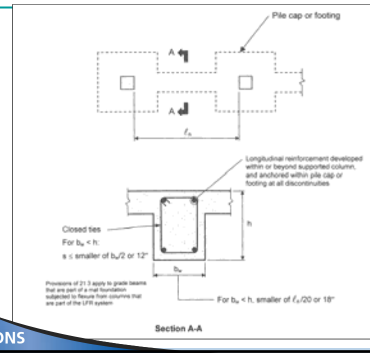
Foundations

ACI 318 High Seismic Risk – Footings, Foundation Mats, and Pile Caps



ACI WEB SESSIONS

ACI 318 High Seismic Risk – Grade Beams



ACI WEB SESSIONS

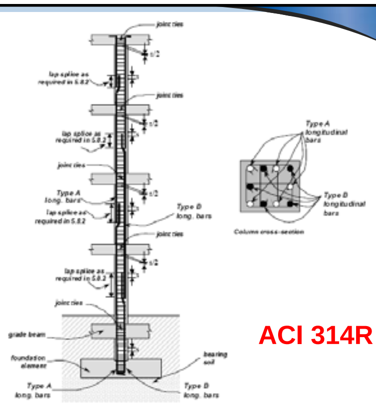


Fig. 10.9(a), (b)—Typical column reinforcement layout in high seismic zones.

ACI 314R

ACI WEB SESSIONS

ACI 314R

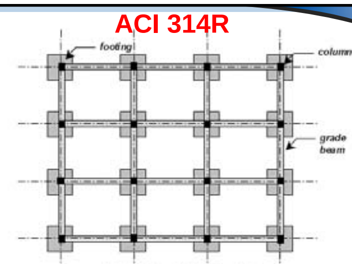
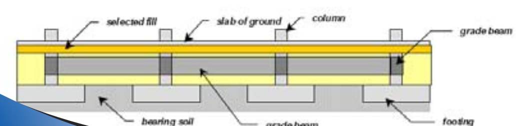


Fig. 14.20—Grid of grade beams.



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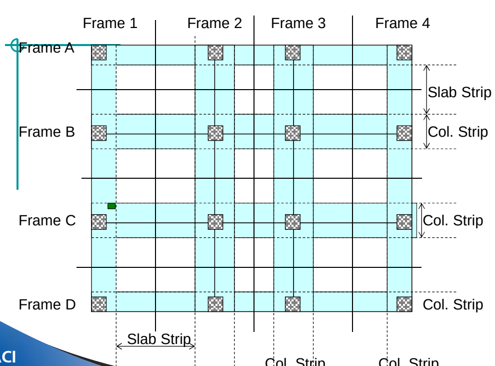
ACI 314R Grade Beams

- Designed for 25% column load (10% per IBC and ASCE 7-05)
- Min dimension = clear col spacing/20 (20 in max)
- Closed ties @ 12 in spacing

ACI WEB SESSIONS

ACI 318 – Two-way Slabs



ACI WEB SESSIONS

ACI 314R

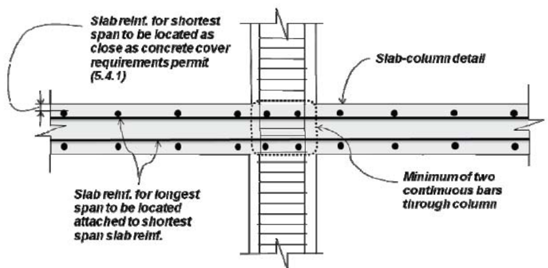
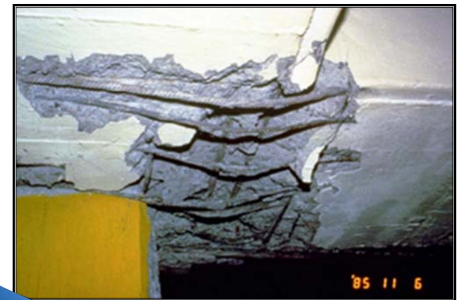


Fig. 9.3—Slab reinforcement detail.

ACI WEB SESSIONS

Bar Buckling in Waffle Slab



1985 Mexico City

ACI WEB SESSIONS

Waffle Slab Failure

1994 Northridge

ACI WEB SESSIONS

ACI 318 Intermediate Seismic Risk – Two-way Slabs

- Direct shear (V_u) and,
- *Shear induced due to portion of unbalanced moment* $(1-\gamma_f)M_s$ *transferred by eccentricity of shear*

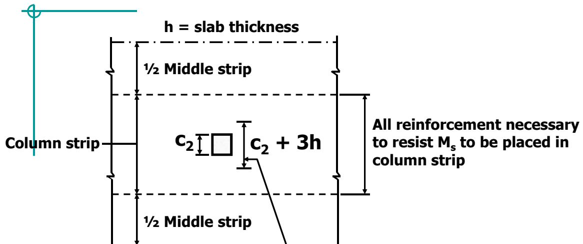
$$v_u = \frac{V_u}{A_c} \pm \frac{\gamma_v M_s c}{J_c} \qquad \text{(11.12.6 ACI 318)}$$

$$\gamma_v = 1 - \gamma_f$$

$$v_u \leq \phi v_c$$

ACI WEB SESSIONS

Intermediate Seismic Risk – Two-way Slabs



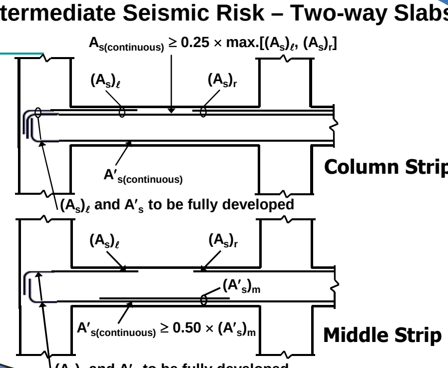
$A_s \geq$ { Reinforcement necessary to resist $\gamma_f M_s$; Reinforcement in column strip/2 }

Note: Applies to both top and bottom reinforcement

(21.12.6)

ACI WEB SESSIONS

Intermediate Seismic Risk – Two-way Slabs



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ACI 314R – Development and Splice

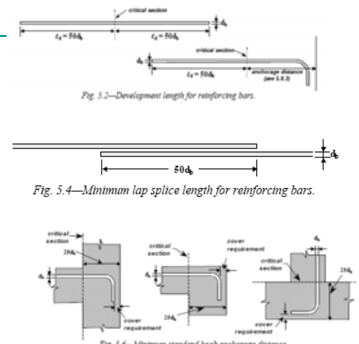

Fig. 5.2—Development length for reinforcing bars.

Fig. 5.4—Minimum lap splice length for reinforcing bars.

Fig. 5.6—Minimum standard hook anchorage distance.

ACI WEB SESSIONS

ACI 314R

- Focuses on analysis/design simplification
  - Only a small fraction of project cost
  - Conservative design
  - Detailing similar to that for ACI 318 for SDC D and above for Special Moment Frames/Shearwalls
- Computers and commercial software allow refinement of designs to achieve larger construction cost savings

ACI WEB SESSIONS

Thank You!

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