# *IT4 – Shear Wall Design*

Update August 16, 2018

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# *Purpose*

The IT has the broad mandate of identifying possible areas of improvement in current design practices for shear walls of concrete, masonry, steel, and wood and of formulating specific improvements.

# *Expected Work Product(s)*

The IT will develop Part 1 proposals and accompanying Part 2 commentary dealing with any topic on which the IT is able to progress to that point. All other findings of the IT and work leading to those findings will be recorded in a Part 3 Resource Paper.

# *Part 1 of the 2021 NEHRP Provisions*

Proposed modifications to ASCE 7-16 Table 12.2-1, adding line items on Bearing Wall Systems, Building Frame Systems, and Dual Systems featuring Ductile Reinforced Concrete Coupled Walls.

First Ballot target: April 2019

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# *Ductile Coupled Shear Walls*

Ductile shear wall – same as special structural wall complying with ACI 318-14 Sections 18.10.2 through 18.10.6.

Ductile coupling beam – coupling beam complying with ACI 318-14 Section 18.10.7.

# *Ductile Coupled Shear Walls Approved by ACI 318H*

- Ductile Coupled Wall – An assembly of special structural walls linked by coupling beams. Coupling beams in this system shall have length/height greater than or equal to 2.0 in all cases in the direction considered. Coupling beams in this system shall have length/height less than or equal to 5.0 at no less than 90% of the levels of the building in the direction considered.

# *Ductile Coupled Shear Walls Approved by ACI 318H*

- Ductile Coupled Wall (Contd.) –Coupling beams in this system shall be detailed so that the flexural capacity of the beam is fully developed at each end. Special structural walls in this system shall have total wall segment height to wall segment length exceeding 2.0.

# EARTHQUAKE FORCE-RESISTING STRUCTURAL SYSTEMS OF CONCRETE — ASCE 7-16

| BASIC SEISMIC FORCE-RESISTING SYSTEM | DETAILING REF. SECTION | *R* | $\Omega_0$ | $C_d$ | SYSTEM LIMITATIONS AND BUILDING HEIGHT LIMITATIONS (ft) BY SEISMIC DESIGN CATEGORY | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | B | C | D | E | F |
| ***A. Bearing Wall Systems*** | | | | | | | | | |
| 1. Special reinforced concrete shear walls | 14.2 | 5 | $2^1/_2$ | 5 | NL | NL | 160 | 160 | 100 |
| **2. Ductile Coupled Reinforced Concrete Shear Walls** | **14.2** | **?** | **?** | **?** | **NL** | **NL** | **?** | **?** | **?** |
| ~~2~~3. Ordinary reinforced concrete shear walls | 14.2 | 4 | $2^1/_2$ | 4 | NL | NL | NP | NP | NP |
| ~~3~~4. Detailed plain concrete shear walls | 14.2 | 2 | $2^1/_2$ | 2 | NL | NP | NP | NP | NP |
| ~~4~~5. Ordinary plain concrete shear walls | 14.2 | $1^1/_2$ | $2^1/_2$ | $1^1/_2$ | NL | NP | NP | NP | NP |
| ~~5~~6. Intermediate precast shear walls | 14.2 | 4 | $2^1/_2$ | 4 | NL | NL | 40[1] | 40[1] | 40[1] |
| ~~6~~7. Ordinary precast shear walls | 14.2 | 3 | $2^1/_2$ | 3 | NL | NP | NP | NP | NP |

[1]Increase in height to 45 ft is permitted for single-story storage warehouse facilities.

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|---|---|---|---|---|---|---|---|---|---|
| | | | | | B | C | D | E | F |
| ***B. Building Frame Systems*** | | | | | | | | | |
| 4. Special reinforced concrete shear walls | 14.2 | 6 | $2^1/_2$ | 5 | NL | NL | 160 | 160 | 100 |
| **5. Ductile Coupled Reinforced Concrete Shear Walls** | **14.2** | **?** | **?** | **?** | **NL** | **NL** | **?** | **?** | **?** |
| ~~5~~6. Ordinary reinforced concrete shear walls | 14.2 | 5 | $2^1/_2$ | $4^1/_2$ | NL | NL | NP | NP | NP |
| ~~6~~7. Detailed plain concrete shear walls | 14.2 and 14.2.3.2 | 2 | $2^1/_2$ | 2 | NL | NP | NP | NP | NP |
| ~~7~~8. Ordinary plain concrete shear walls | 14.2 and 14.2.2.7 | $1^1/_2$ | $2^1/_2$ | $1^1/_2$ | NL | NP | NP | NP | NP |
| 89. Intermediate precast shear walls | 14.2 | 5 | $2^1/_2$ | $4^1/_2$ | NL | NL | $40^1$ | $40^1$ | $40^1$ |
| ~~9~~10. Ordinary precast shear walls | 14.2 | 4 | $2^1/_2$ | 4 | NL | NP | NP | NP | NP |

[1]Increase in height to 45 ft is permitted for single-story storage warehouse facilities.

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|---|---|---|---|---|---|---|---|---|---|
| | | | | | B | C | D | E | F |
| ***D. Dual Systems with Special Moment Frames*** | | | | | | | | | |
| 3. Special reinforced concrete shear walls | 14.2 | 7 | $2^1/_2$ | $5^1/_2$ | NL | NL | NL | NL | NL |
| **4. Ductile Coupled Reinforced Concrete Shear Walls** | **14.2** | **?** | **?** | **?** | **NL** | **NL** | **NL** | **NL** | **NL** |
| 45. Ordinary reinforced concrete shear walls | 14.2 | 6 | $2^1/_2$ | 5 | NL | NL | NP | NP | NP |

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|---|---|---|---|---|---|---|---|---|---|
| | | | | | B | C | D | E | F |
| ***E. Dual Systems with Intermediate Moment Frames*** | | | | | | | | | |
| 2. Special reinforced concrete shear walls | 14.2 | $6^1/_2$ | $2^1/_2$ | 5 | NL | NL | 160 | 100 | 100 |
| **3. Ductile Coupled Reinforced Concrete Shear Walls** | **14.2** | **?** | **?** | **?** | **NL** | **NL** | **?** | **?** | **?** |
| ~~3~~4. Ordinary reinforced concrete shear walls | 14.2 | $5^1/_2$ | $2^1/_2$ | $4^1/_2$ | NL | NL | NP | NP | NP |
| ***F. Shear Wall-Frame Interactive System with Ordinary Reinforced Concrete Moment Frames and Ordinary Reinforced Concrete Shear Walls*** | 12.2.5.10 and 14.2 | $4^1/_2$ | $2^1/_2$ | 4 | NL | NP | NP | NP | NP |

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# *Ductile Coupled Shear Walls FEMA P-695 Study*

- If coupled concrete shear walls are to gain acceptance by ASCE 7 into the *R*-factor table, a P-695 study is required.

# *Ductile Coupled Shear Walls*
# *FEMA P-695 Study*

A P-695 study of ductile coupled reinforced concrete shear walls is currently underway.

It is being carried out by Negin Tauberg and Kristijan Kolozvari of California State University, Fullerton, and John Wallace, UCLA.

The PUC-appointed peer review team consists of Ron Hamburger, Charlie Kircher, Anindya Dutta, and Steve McCabe.

The study is funded by the Pankow Foundation. Additional funding from the ACI Foundation is expected.

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# *Ductile Coupled Shear Walls*
# *FEMA P-695 Study*

There is also an ACI 318/ACI 318H/Pakow Foundation advisory group consisting of: S.K. Ghosh, Jim Harris, Ron Klemencic, John Hooper, David Fields, Andy Taylor and Laura Lowes.

**Kristijan Kolozvari to report on progress of P-695 study.**

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# *Composite Steel Plate Shear Walls with Coupling*

- *Engineering News Record*, September 27, 2017: Steel Core System Could Transform Office Tower Construction
- "The coupled steel-plate composite wall system—a sandwich of plates filled with concrete liberated of reinforcing steel—provides the strength, stiffness, safety and serviceability of a reinforced concrete core but is not burdened by rebar congestion and complex formwork, …" The links between the walls are provided by composite dual-plate coupling beams.

# *Composite Steel Plate Shear Walls with Coupling*

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# *Composite Steel Plate Shear Walls with Coupling*

- "The CSPSW-WC system is currently being tested at Purdue University (Amit Varma) and the University at Buffalo (Michel Bruneau) with funding from AISC and the Pankow Foundation. AISC and the Pankow Foundation are also co-funding a FEMA P-695 study being conducted by Bruneau and Varma.
- The project seeks an *R*-factor developed from FEMA P-695 studies for Coupled Composite Plate Shear Walls - Concrete Filled, for inclusion in ASCE 7.
- This study on CSPSW-WC is being coordinated through IT4. It is expected that the study will be completed successfully on time, such that line items featuring this system may also be added to ASCE 7 Table 12.2-1.

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|---|---|---|---|---|---|---|---|---|---|
| | | | | | B | C | D | E | F |
| ***B. Building Frame System*** | | | | | | | | | |
| ~~13~~14. Steel and concrete Composite Plate shear walls | 14.3 | $6^1/_2$ | $2^1/_2$ | $5^1/_2$ | NL | NL | NL | NL | NL |
| **15. Composite Steel Plate shear walls with Coupling** | **14.3** | **?** | **?** | **?** | **NL** | **NL** | **?** | **?** | **?** |
| ~~14~~16. Steel and concrete Composite special shear walls | 14.3 | 6 | $2^1/_2$ | 5 | NL | NL | 160 | 100 | 100 |
| ~~15~~17. Steel and concrete Composite ordinary shear walls | 14.3 | 5 | $2^1/_2$ | $4^1/_2$ | NL | NL | NP | NP | NP |

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|---|---|---|---|---|---|---|---|---|---|
| | | | | | B | C | D | E | F |
| ***D. Dual Systems with Special Moment Frames*** | | | | | | | | | |
| ~~7~~8. Steel and concrete Composite Plate shear walls | 14.2 | $7^1/_2$ | $2^1/_2$ | 6 | NL | NL | NL | NL | NL |
| **9. Composite Steel Plate shear walls with Coupling** | **14.2** | **?** | **?** | **?** | **NL** | **NL** | **?** | **?** | **?** |
| ~~8~~10. Steel and concrete Composite special shear walls | 14.2 | 7 | $2^1/_2$ | 6 | NL | NL | NL | NL | NL |
| ~~9~~11. Steel and concrete Composite ordinary shear walls | 14.2 | 6 | $2^1/_2$ | 5 | NL | NL | NP | NP | NP |

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# *Composite Steel Plate Shear Walls with Coupling*

- **Amit Varma to report on progress of the P-695 study by him and Michel Bruneau**

# *Part 3 of the 2021 NEHRP Provisions*

Tentative Outline of IT 4 Resource Paper
(with assigned authors and tentative deadlines)
agreed to.

Segments are being are being developed.

First Ballot target: August 2019

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# *Shear Amplification: Concrete Shear Walls*

$$V_u' = \phi_0 V_u$$

$$\phi_0 = \omega_v \left(M_{pr,cs}/M_{u,cs}\right)$$

Unless a more detailed analysis is conducted, the ratio $(M_{pr,cs}/M_{u,cs})$ shall be taken greater than or equal to 1.5.

# *Shear Amplification: Concrete Shear Walls*

$\omega_v$ shall be taken as 1.0, except for walls with $h_w/l_w \geq 2.0$, where $\omega_v$ shall be calculated as:

$$\omega_v = 0.9 + n_s/10 \qquad \text{for } n_s \leq 6$$

$$\omega_v = 1.3 + n_s/30 \leq 1.8 \qquad \text{for } n_s > 6$$

Where $n_s$ is the number of stories above the critical section.

# *End*