IT4 – Shear Wall Design

Update April 04, 2018

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Voting Members

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David Fields, Magnusson Klemencic, Seattle, WA

S. K. Ghosh, S. K. Ghosh Associates, Palatine, IL (Chair)

Gino Kurama, University of Notre Dame, Notre Dame, IN

Andy Taylor, KPFF, Seattle, WA

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Corresponding Members

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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.

Meetings Held

1. August 29-30, 2016, KPFF, Seattle, WA (two-day meeting) Gracious host: Andy Taylor, KPFF

Topics to be pursued tentatively chosen

2. November 2-3, 2016, KPFF, Seattle, WA (two-day meeting) Gracious host: Andy Taylor, KPFF

First day devoted to concrete-related topics

3. April 3, 2017 (web meeting)

Spent two hours discussing progress and planning actions for the near future

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Meetings Held

4. May 12, 2017 (web meeting)

5. June 29, 2017 web meeting)

6. August 15-16, 2017, KPFF, Seattle, WA (two-day meeting) Gracious host: Andy Taylor, KPFF Tentative outline of Resource Paper agreed to

7. November 6, 2017 (web meeting)

8. January 23-24, 2018, KPFF, Seattle, WA (two-day meeting) Gracious host: Andy Taylor, KPFF

Meetings Held

9. March 20, 2018 (web meeting)

Upcoming Meetings

10. May 29, 2018 (web meeting)

11. September 5-6, 2018, KPFF, Seattle, WA (two-day meeting) Gracious host: Andy Taylor, KPFF

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: December 2018

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Ductile Coupled Shear Walls

Bertero wrote in 1977: “Use of coupled walls in seismic-resistant design seems to have great potential. To realize this potential it would be necessary to prove that it is possible to design and construct “ductile coupling girders” and “ductile walls” that can SUPPLY the required strength, stiffness, and stability and dissipate significant amounts of energy through stable hysteretic behavior of their critical regions.”

Thus, discussion needs to focus on not on just coupled walls, but **ductile coupled walls** consisting of **ductile shear walls** and **ductile coupling beams**.

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 (NBCC)

- **Ductile coupled shear wall** — a shear wall system that complies with [specified detailing requirements] and has ductile shear walls connected by ductile coupling beams where at least 66% of the base overturning moment resisted by the wall system is carried by axial tension and compression forces resulting from shear in the coupling beam(s).

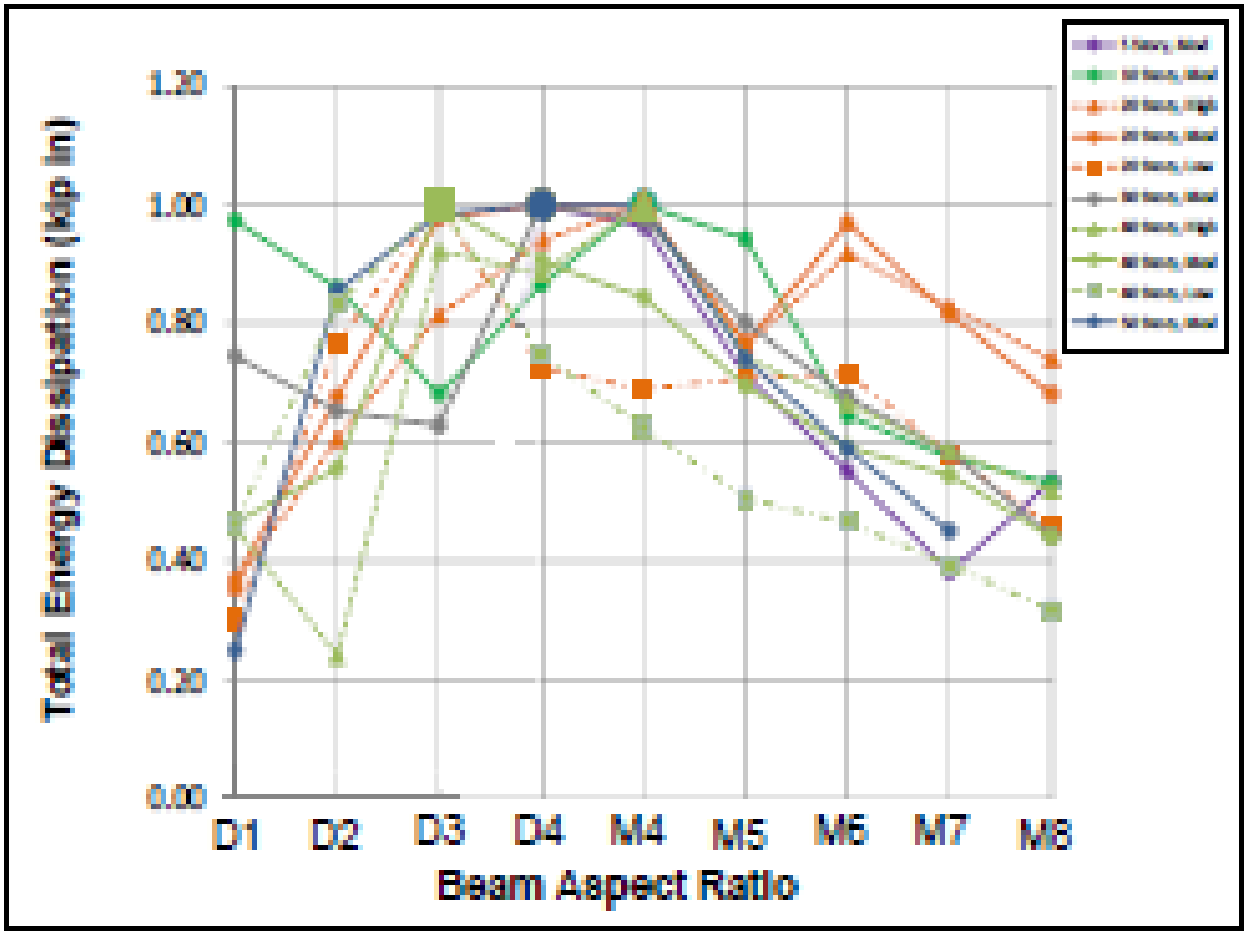
Ductile Coupled Shear Walls

- Ron Klemencic of Magnusson Klemencic Associates (MKA) suggested that since we are going to ask for higher *R*-values for coupled shear wall systems, the definition for a coupled shear wall system should probably be based on energy dissipation.

Ductile Coupled Shear Walls

- As the result of quite a bit of work done at MKA, an energy dissipation-based definition for coupled shear walls was developed and balloted within ACI 318H.

Ductile Coupled Shear Walls



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Ductile Coupled Shear Walls

- ACI 318-14
- Section 2.3 Terminology
- Ductile Coupled Structural Wall: Special structural walls conforming to 18.10 linked by coupling beams conforming to 18.10.7 with aspect ratios (length/height) between 2.0 and 5.0.

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.

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.

A kickoff meeting of the investigators, the peer review team, and the advisory group was held on November 10th. A second meeting is being planned for the near future.

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Ductile Coupled Shear Walls
FEMA P-695 Study

Kelly Cobeen 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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Composite Steel Plate Shear Walls with Coupling

- Michel Bruneau and Amit Varma to report on progress of their P-695 study

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: March 2019

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Tentative Outline of IT4 Resource Paper

1. Introduction

   a. Scope (rocking shear walls not included)

   b. Mechanics of shear walls (ductile mechanisms only – rocking shear walls not included) – *Sabelli/Taylor 10/23/17*

   c. Design of concrete shear walls

      i. Cast-in-place – *Ghosh/Lehman 10/23/17*

         – Non-prestressed

         – Post-tensioned - *Kurama 10/23/17*

      ii. Precast - *Kurama 10/23/17*

Tentative Outline of IT4 Resource Paper

1. Introduction

d. Design of masonry shear walls - *Bennett 10/23/17*

e. Design of steel plate shear walls - *Berman 10/23/17*

f. Design of composite steel plate shear walls – *Berman/Lehman 10/23/17*

g. Cold-formed steel shear walls – *Allen/Zeydel 10/23/17?*

h. Design of wood shear walls – *Cobeen/Line 10/23/17*

Concrete Shear Walls
Shear Design of RC Shear Walls

i. ACI determination of required shear strength
   – *Ghosh 10/23/17*

ii. ϕ-factor used in shear design of shear walls – *Ghosh 10/23/17*

iii. Flexural overstrength – *Lowes 10/23/17*

iv. Dynamic amplification – *Lowes, Kurama 10/23/17*

Concrete Shear Walls
Shear Design of RC Shear Walls

v. Shear strength of concrete under high rate of loading – *Kurama 10/23/17*

vi. Effect of compressive stress on shear strength – *Kurama 11/13/17*

vii. Shear migration to compression pier and shear-compression interaction in a coupled shear wall system – *Lehman/Kurama 10/23/17*

Masonry Shear Walls

a. Partially grouted shear walls - *Bennett 10/23/17*
   i. Shear strength
   ii. Ductility

b. Coupled masonry shear walls - *Bennett 10/23/17*
   i. Slab coupled
   ii. Lintel coupled
   iii. Shear walls with openings

Steel Plate Shear Walls

a. Special steel plate shear walls –
Fahenstock/Sabelli 11/13/17

b. Special coupled steel plate shear walls –
Fahenstock/Sabelli 11/13/17

c. Special composite steel plate shear walls –
Bruneau/Berman 12/31/17

d. Special coupled composite steel plate shear walls
Bruneau/Berman 12/31/17

Wood Shear Walls

a. Methods for computing deflections in stacked shear walls – *Cobeen/Line 10/23/17*

b. Combined compression and shear failures in shear walls – *Cobeen/Line 11/13/17*

c. Capacity-based design – *Cobeen/Line 12/31/17*

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

ω_v shall be taken as 1.0, except for walls with $h_w/l_w \geq 2.0$, where ω_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