SEAW Earthquake Engineering Committee	**WHITE PAPER 1-2009**

Special Reinforced Concrete Shear Walls as Building Frame Systems for Mid- and High-Rise Buildings	**Date: November 9, 2009**
ABSTRACT: The intent of this White Paper is to recommend design and performance criteria for designating seismic force-resisting systems consisting of special reinforced concrete shear walls (SRCSW) as building frame systems for mid- and high-rise buildings per the provisions of ASCE 7-05 Section 12.2.	**Task Group Members:** *Cheryl Burwell, P.E., S.E., Chair* *Douglas Beck, P.E., S.E* *Phil Brazil, P.E., S.E* *Dave Fields, P.E., S.E* *Martin Maingot, P.E., S.E* *Kai Ki Mow, P.E* *Peter Somers, P.E., S.E* *Andrew Taylor, P.E., S.E* *Tom Xia, P.E., S.E*

COMMITTEE STATEMENT:

- *The recommendations in this White Paper represent the opinion of the task group and the Earthquake Engineering Committee. It should only be used as reference by engineers and building officials in conjunction with their own judgment and the actual project design assumptions.*

I. INTRODUCTION:

ASCE 7-05 Section 12.2.1 defines two types of seismic force-resisting systems consisting of special reinforced concrete shear walls (SRCSW): bearing wall system and building frame system. A building frame system is defined by ASCE 7-05 Section 11.2 as "a structural system with an essentially complete space frame providing support for vertical loads. Seismic force resistance is provided by shear walls or braced frames." ASCE 7-05 Section 11.2 also defines a bearing wall system as "a structural system with bearing walls providing support for all or major portions of the vertical loads. Shear walls or braced frames provide seismic resistance." However, even for buildings without the essentially complete space frame, it is common practice to use the seismic response coefficients based on a building frame system rather than a bearing wall system for the SRCSW system. It is often argued that the response modification coefficient, *R*, associated with a building frame system may more accurately reflect the expected ductility performance of the building.

The Earthquake Engineering Committee (EEC) of the Structural Engineers Association of Washington (SEAW) believes that alternate criteria are needed to define where the seismic response coefficients associated with a building frame system may be applied to the SRCSW system. The intent of this White Paper is to limit its recommendations to mid- and high-rise buildings.

II. RECOMMENDATIONS:

As an alternative to the ASCE 7-05 definition of a building frame system, the SEAW EEC recommends that a SRCSW system meet one of the following three design and/or performance criteria, in order to use the seismic response coefficients associated with a building frame system:

1. Design and detail the SRCSW system and the floor and roof systems as follows:

   a) Provide confined vertical load carrying elements within the SRCSW system for the full height of the shear walls. Size the vertical elements per ACI 318-05 Section 10.3.6 based on the assumed load path of 1b below for gravity load combinations of ACI 318-05 Section 21.11.2. Confine the vertical elements in accordance with ACI 318-05 Sections 21.4.4.1(c) and 21.4.4.3, with the vertical confinement spacing not to exceed 8 inches. Special boundary elements, as defined by ACI 318-05 Section 21.7.6, are deemed to satisfy these size and confinement requirements.

   b) Design the floor and roof systems to span between the columns and the confined vertical load carrying elements within the SRCSW system assuming the remaining portions of the shear walls do not participate in vertical support of the floor and roof systems. For this design only, use the gravity load combinations of ACI 318-05 Section 21.11.2. The vertical loads associated with the unconfined portions of the shear walls need not be supported by the floor and roof systems. Beam reactions resulting from less than 300 square-feet of tributary area for that reaction occurring within a horizontal distance of 15 feet from a vertical load-carrying element designed per 1a above need not be directly supported by vertical load-carrying elements. However these reactions should be accounted for in the design of the adjacent vertical load-carrying elements.

2. Design flexure controlled shear walls as follows:

   a) Limit the combination of factored gravity and lateral design axial loads on individual shear wall segments to a maximum of $0.35A_g f'_c$ unless a ductility assessment using a moment-curvature analysis is performed to justify a higher axial load level.

   b) Demonstrate that the nominal shear strength of each wall is greater than the wall shear demand corresponding to the development of the nominal flexural strength of the wall.

3. Alternative rational design methods may be proposed by the Engineer as a substitute to the recommended methods given above for review and approval by the Building Official.

III. COMMENTARY:

These recommendations are intended to apply to mid- and high-rise buildings that fall somewhere between the ASCE 7-05 definitions for bearing wall and building frame systems as this issue is typically encountered in taller buildings. A definition for mid- and high-rise buildings is intentionally not provided in this White Paper since there is not a standard definition related to the structural systems. It is recommended that the Engineer and the Building Official determine the appropriate application of this White Paper. The mid- and high-rise buildings addressed here typically consist of concrete or steel gravity framing with core shear walls and/or individual shear wall segments that carry a significant portion of the building's gravity loads. These systems have been designed using R=6.0, but text of ASCE 7-05 does not support this criterion. However, research and experience suggest that R=6.0 can be appropriate for design as indicated in the 2008 SEAOC Blue Book. This White Paper provides guidance for the design professional in considering where the use of R=6.0 can be reasonable by following one of the three recommendation methods.

The first method provides guidelines for designing a "system with an essentially complete space frame providing support for vertical loads." It is our opinion that this effective gravity system need not be "fully" complete as the shear walls even in traditional building frame systems support their own self-weight and a nominal amount of floor and roof load. Section 1b describes a method for checking the floor/roof framing to span between gravity load-carrying elements, and section 1a describes a method for designing these load-carrying elements. The intent of Section 1b is to provide vertical support elements at locations with primary floor/roof framing members carrying significant gravity loads, hence the beam reaction 300 square-foot tributary area limit. The recommended loading for this design approach utilizes the gravity load combination for deformation compatibility checks in ACI 318 Section 21.11.2, which are intended as a secondary check. For the load-carrying element, or "column" design, the intent is to size and reinforce a column within the shear wall to support the required loads using the axial load design provisions of ACI 318-05 Section 10.3.6. Other aspects of typical column design (for example minimum longitudinal reinforcement, tie spacing, slenderness checks, and P-M interaction) are not intended to apply to this design. The recommended confinement criteria are those associated with shear walls where boundary elements are not required, but the longitudinal reinforcing ratio is greater than 400/fy in accordance with ACI 318-05 Sec. 21.7.6.5. This confinement recommendation provides a medium level of confinement, less than a special boundary zone, but more than a typical wall element.

Note that this first method is not intended to be a substitute for compliance with the gravity load combinations in 2006 IBC Section 1605 for the shear walls and floor and roof systems.

The second method contains guidelines for providing improved seismic behavior that could be considered more consistent with the higher *R* factor for the building frame system. The recommendations for limiting axial load and for avoiding shear-controlled behavior are not required by ACI 318, but rather are recommendations in the SEAOC Blue Book for better shear wall performance and ductility.

The third method allows design professionals to develop and propose alternate criteria for justifying the higher *R* factor. For example this method could involve a design similar to, but different in the details of, what is recommended for Methods 1 or 2 or involve a performance-based design approach to rationalize the *R* factor used.

The recommendations in this White Paper are not intended to be required for systems traditionally considered building frame systems (for example a low-rise, large floor plate buildings with several isolated shear walls), nor are the recommendations intended to allow buildings traditionally considered bearing wall systems (for example low-rise box-type concrete buildings) to be designed as building frame systems.

The above recommendations were developed by the SEAW EEC using the following reference documents:

ASCE 7 "Minimum Design Loads for Buildings and Other Structures", 2005 Edition.

ACI 318 "Building Code Requirements for Structural Concrete", 2005 Edition.

SEAOC Blue Book "Seismic Design Recommendations of the SEAOC Seismology Committee", 2008 Edition.