

## SEAOC Blue Book – Seismic Design Recommendations Anchor Bolts in Light-Frame Construction at Small Edge Distances

| <b>ASCE 7-05<br/>reference section(s)</b> | <b>2007 CBC<br/>reference section(s)</b>   | <b>Other standard<br/>reference section(s)</b>  |
|---|--|---|
| Ch 12 Seismic Design Requirements         | 1613 Earthquake Loads<br>1911 Anchorage to Codes-<br>Allowable Stress Design<br>1912 Anchorage to Concrete-<br>Strength Design | ACI 318-05 Appendix D<br>ACI 318-08 Appendix D<br>ACI 355.2<br>NDS <sup>®</sup> -05 Table 11E |

### Introduction

The subject of this article is the anchorage of wood-frame sill plates on structural walls in light-frame construction. Wood-frame shear walls have traditionally been connected to concrete foundations with cast-in anchor bolts or post-installed anchors in accordance with varied local practices. At shear wall locations, substantial loads are assumed to load the anchor bolts in pure shear parallel to the concrete edge. For the purposes of this article the following are assumed:

- Typical cast-in place “L-bolt,” minimum 7-inch embedment
- Bolt diameter of nominal ½ inch through ¾ inch
- Standard or 3-inch square plate washer with standard nut
- Bolts assumed to act in pure shear, loaded parallel to free edge of concrete
- Bolt corner distance minimum 8 inches
- Preservative-treated wood sill plate (2x4, 2x6, 3x4, 3x6, etc.)
- Typical wood-frame construction with redundant anchor bolts
- Foundation minimum  $f'c=2500$  psi, conventional or pre-stressed concrete.

The change of model codes in California in January 2007 from the 1997 UBC to the 2006 IBC required a number of fundamental changes to the accepted design practices of wood-frame sill plate anchorage in light-frame structures. A significant change to design practice was also necessary to apply the IBC provisions for the seismic design of anchor bolt connections occurring near a concrete edge. These changes have been a source of much discussion and frustration for code users in high seismic areas subject to the IBC and ACI codes.

Two sensitive assumptions that affect the ACI Appendix D calculation are the ductility parameter and the cracked concrete parameter. The ductility parameter of IBC 1908.1.16 [D3.3.5] alone requires a 60 percent reduction to the connection capacity in concrete if the attachment to concrete is not ductile at the concrete design strength. (ACI 318-08 has reduced the reduction to 50 percent in light-frame construction.) The resultant low concrete capacity values indicate that a failure of the connection is expected to occur in the concrete long before it occurs in the anchor bolt or the wood sill plate, which is counter-intuitive. The SEAOC Seismology Committee performed a literature search of anchor bolt testing for wood sill plates with small concrete edges distances and discovered very limited research was available. The SEAOC Seismology Committee then decided to embark on an anchor bolt testing program. Using the Tyrell Gilb facility in Stockton, California, members of the SEAOC Seismology Light-frame Subcommittee conducted the first test program of its kind where the behavior of light-frame wood sill plate anchorage at small edge distances was targeted. Additionally, the test program included non-destructive impact-echo readings to continuously monitor the progression of any delaminations in the concrete. The results of this testing program are published in the document “Report on Laboratory Testing of Anchor Bolts Connecting Wood Sill Plates to Concrete with Minimum Edge Distances,” dated March 29, 2009. This report is available for download from the SEAONC website: [www.SEAONC.org/member](http://www.SEAONC.org/member).

The SEAOC test data show that the yield strength of the wood sill plate connection governs over the strength of the concrete in the subject connections. This component testing was necessary to determine the specifics of the connection behavior, particularly the large amount of yielding the bolts achieve above the concrete surface and the beneficial clamping effect due to the square plate washer.