Shear Wall/Hold-Down Cyclic Testing

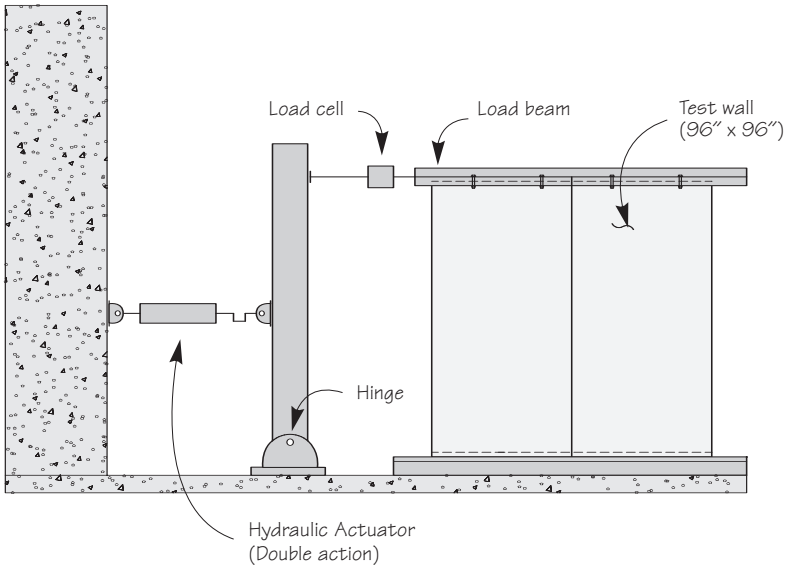
June 2004

As a manufacturer of structural hardware and accessories used in the resistance of earthquake forces, *USP Structural Connectors®* is dedicated to providing the design professional with timely technical information that will aid in the creation of the most cost efficient and structurally sound building designs. To this end, we have recently completed a series of cyclic tests of wood panel sheathed, conventionally framed shear walls. The shear wall panels were anchored to the test bed by use of commercially available hold-downs, manufactured by the test sponsor, *USP Structural Connectors®*, installed on the inside face, near the bottom of the wall end post. The testing, conducted at the University of California, Irvine, Structures Lab, proceeded in accordance with the Structural Engineers Association of Southern California (SEAOSC) "Standard Method of Cyclic (Reversed) Load Test for Shear Resistance of Framed Walls for Buildings", January 1997. Representatives of EQE International, Inc., Irvine, California, witnessed the testing as an independent third party engineer, provided analysis of the data, and wrote the test report.

This testing was performed for the following purposes:

- To provide the sponsor's technical staff with insight as to the overall performance of wood framed shear walls in a cyclic test environment.
- To provide comparative data, using USP hold-downs, for other shear wall and hold-down testing being conducted (COLA, APA, CUREe, etc).
- To provide performance data relative to the end post design practice of neglecting combined bending stresses thought to be induced by use of eccentric hold-down devices.
- To test the limiting capacity and deformation performance of the hold-down devices. Plywood sheathing and fastener combinations were selected to provide allowable shear values resulting in development of at least the allowablecapacity, with as much as a 50% overstress permitted in some hold-downs.
- To provide research data for future new product development.

A total of 27 shear wall panel assemblies were cyclically tested. This total was comprised of 2 samples each of 13 different USP hold-downs connected to wall end posts (See Table 1 for a complete description of all test samples). Additionally, one wall sample was tested using the "Ben Schmid" hold-down for control purposes. Wall panels were all 8 feet tall and of two basic configurations; 1 to 1 aspect ratio with sheathing on one side only or, 2 to 1 aspect ratio with sheathing on both sides. Plywood sheathing and nailing used in the test panels were selected from 1997 UBC Table 23-II-I-1 to provide allowable shear capacity to develop at least the allowable uplift capacity of the hold-down. In order to maximize the possible effects of bending due to hold-down eccentricity, end posts were sized primarily by consideration of tension on the gross section. Combined tension and bending due to eccentricity of the hold-down anchor bolt was not considered in post sizing.



Test setup for Cyclic load plywood shear wall tests

TECH BULLETIN

End posts used were all DF-L species randomly selected and either a standard and better 4x4 or No. 2 grade 4x6. Based on these sizes, over stresses of up to 60% in the UBC allowable perpendicular to grain bearing capacity (for deflection critical bearings) were permitted on the sill plates under the end posts, in order that the posts could be undersized for the potential bending stresses due to hold-down eccentricity.

We believe the results of this testing are particularly useful at this time for the following reasons:

• To date, very minimal amounts of cyclic shear wall test data have been made available to the design community; even less employing commercially available hold-downs.

• Current UBC wood structural panel shear wall values are not derived from cyclic load tests; monotonic, one directional load tests were used.

• Current UBC wood structural panel shear wall values are not derived from tests using typical eccentric hold-down devices applied near the bottom of the wall end post; a top of wall, end clamp was substituted.

• Manufacturers' hold-down allowable loads are not verified by cyclic tests of a shear wall system.

• The SEAOSC test protocol is generally regarded as the most severe test method of several available cyclic protocols.

• Shear wall and hold-down performance data, both load and deformation, derived from these tests are relevant to real shear wall construction tested in a severe cyclic environment.

Following is a presentation of the major observations and results of the testing:

1. No structural failure of any hold-down or its connection to the end post; average over-strength factor of 2.4 at the Strength Limit State (SLS); average over-strength factor of 1.7 at the Yield Limit State (YLS).

2. 26 of 27 shear wall panels failed by nail fatigue, sheathing edge tearing and nail withdrawal from framing at the fixed sill and adjacent end post areas; only one end post failure was observed despite calculated post overstress factors ranging from 2.6 to 11.4 due to combined effects of tension and bending due to hold-down eccentricity.

3. All wall groups, except one, achieved UBC allowable wall shear prior to YLS.

4. Tested wall SLS, on average, exceeded UBC shear wall allowable values by factors ranging from 1.8 to 2.2 for 1 to 1 aspect ratio walls, and from 1.5 to 1.8 for 2 to 1 aspect ratio walls.

5. 1 to 1 aspect ratio walls reached YLS at a drift ratio of approximately 0.5% and SLS at approximately 1.5%; 2 to 1 aspect ratio walls reached YLS at a drift ratio of approximately 1.0% and SLS at approximately 2.3%.

6. Sill plate crushing can contribute significantly to wall deflection.

For complete test results, refer to the test report and the summary tables 1 through 8. The report tables also contain considerable data about wall, hold-down, and connection deformation as well as a compilation of shear stiffness values for the walls.

In the test report, EQE International stated a number of conclusions and recommendations based on the testing. The most significant are:

1. The common engineering design practice of neglecting hold-down end-post eccentricity for design of sheathed plywood shear walls appears appropriate limited by the following caveats:

• The findings apply to single-story walls in conformance with the UBC. No cyclical load testing of two-story walls was performed to substantiate the additional overturning effects that might occur on stacked (multi-story) walls.

• The load duration factor for both seismic and wind design of end-posts should be limited to CD=1.33.

• Allowable tension stresses should be considered using the net end-post section (gross area - area of bolt holes and shear plates).

• Compression perpendicular-to-the-grain of the sill plate should be checked, and a larger end-post selected if required. Based on the observed performance of the sills, use of 73% of the allowable perpendicular to grain compression capacity for deflection critical bearings as specified in the 1997 UBC and 1997 NDS (Section 4.2.6) appears appropriate. Use CD=1.0.

• The actual wall overturning couple shall be resisted by hold-down anchor bolt using a reduced arm dimension, L' (base dimension - end-post dimension - hold-down eccentricity), as shown in Figure 4 of the test report.

• Edge-knots or generally large knots should be prohibited at the lower end of the end-posts, assuming that the hold-downs are installed as in the test panels, at bottom of the end-post. A knothole limitation over the lower 3-feet of the end post appears reasonable based on the test observations.

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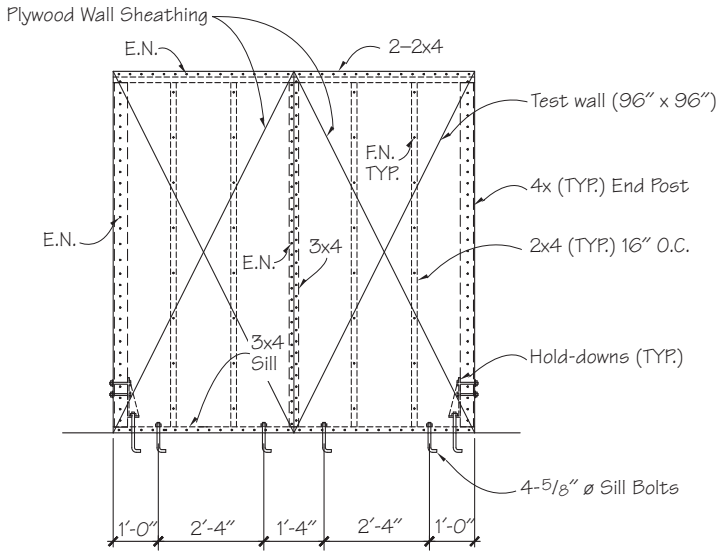
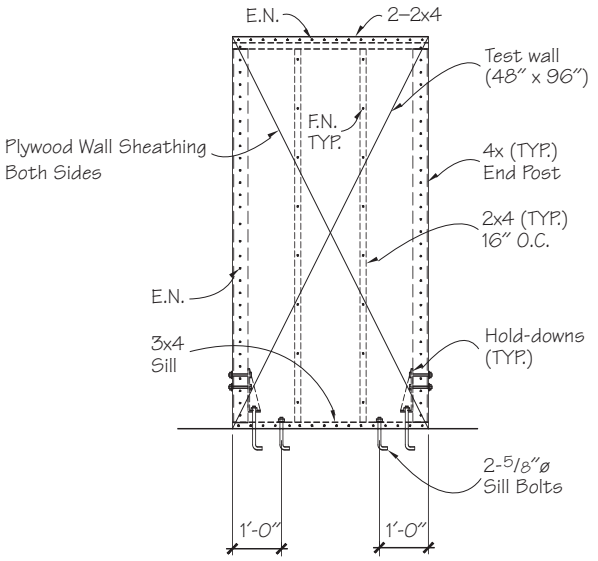


8' x 8' Plywood test panel with Plywood Sheathing on One Sides



8' x 4' Plywood test panel with Plywood Sheathing on Two Sides

Table 1 - Plywood Shear Wall Test Panel Specimen Configuration

USP Group Designation	Number of Samples Tested for Group	Plywood Shear Wall and End-Post Specifications												USP Hold-Down Hardware Specifications							
																Bolts /Nails		Anchor Bolts			
		Sides Sheathed	STRUC I Plywood Thickness	Common Nail Size	Common Nail Spacing EN / FN		1997 UBC Allowable Shear Capacity, lb/ft-wall	UBC Allowable Shear Capacity, lb	Aspect Ratio, h/L	Panel Length (ft)	Sill Bolt No./Diameter		1997 UBC Sill Bolt ASD Shear Capacity (Mode III&IV CD = 1.6)	Nom. Std. & Better End Post Size	USP Structural Connectors Hold-Down Device	Seismic HD Capacity (USP Tech. Bulletin for the 1997 UBC)	Hold-Down to Post Connection No. Bolts/Nails & Diam./Pennyweight		Bolt End Distance	A.B. Diameter	Post A.B. Offset	Eccentricity from C.L. of End-Post Used
1	2	1	3/8	8d	4	12	430	*3,440*	1	8	4	5/8	*7,160*	4x4	**TD 2**	2,860	2	5/8	4 1/2	5/8	1 1/2	3 1/4
2	2	1	15/32	10d	4	12	510	*4,080*	1	8	4	5/8	*7,160*	4x4	**TD 5**	4,090	2	3/4	5 1/4	3/4	2 1/8	3 7/8
3	2	2	15/32	8d	3	12	1,100	*4,400*	2	4	2	5/8	*3,580*	4x4	**TD 9**	8,435	3	1	7	1 1/8	2 1/8	3 7/8
4	2	2	15/32	10d	2	12	1,740	*6,960*	2	4	2	5/8	*3,580*	4x6	**TD 12**	13,260	4	1	7	1 1/8	2 1/8	4 7/8
5	2	1	3/8	8d	4	12	430	*3,440*	1	8	4	5/8	*7,160*	4x4	**HTT 16 (10d)**	3,190	18	10d	Nails	5/8	1 3/8	3 1/8
6	2	1	15/32	10d	2	12	870	*6,960*	1	8	4	5/8	*7,160*	4x4	**HTT 22 (10d)**	5,370	32	10d	Nails	5/8	1 3/8	3 1/8
7	2	2	15/32	8d	3	12	1,100	*4,400*	2	4	2	5/8	*3,580*	4x4	**HTT 30 (16d)**	8,015	36	16d	Nails	7/8	1 3/8	3 1/8
8	2	2	15/32	10d	2	12	1,740	*6,960*	2	4	2	5/8	*3,580*	4x6	**HTT 50 (16d)**	9,810	56	16d	Nails	7/8	1 3/8	4 1/8
9	2	1	15/32	10d	2	12	870	*6,960*	1	8	4	5/8	*7,160*	4x4	**MTS 27B (16d)**	4,635	24	16d	Nails	3/4	1 5/8	3 3/8
10	2	1	15/32	10d	4	12	510	*4,080*	1	8	4	5/8	*7,160*	4x4	**TDX 5**[9]	4,025	2	3/4	5 1/4	3/4	2 1/16	3 7/8
11	2	1	15/32	10d	3	12	665	*5,320*	1	8	4	5/8	*7,160*	4x4	**TDX 6**	5,100	2	7/8	6 1/8	7/8	2	3 3/4
12	2	2	15/32	10d	3	12	1,330	*5,320*	2	4	2	5/8	*3,580*	4x6	**TDX 10**	10,380	4	7/8	6 1/8	7/8	2	4 3/4
13	2	2	15/32	10d	2	12	1,740	*6,960*	2	4	2	5/8	*3,580*	4x6	**TDX 14**[9]	13,570	4	1	7	1	2 1/8	4 7/8
14	1	2	15/32	10d	2	12	1,740	*6,960*	2	4	2	5/8	*3,580*	4x6	**SHD 7** [1]	7,608	2	3/4	6 1/2	7/8	1 1/2	4 1/4

NOTES: 1. SHD 7 provided and developed by Ben Schmid. SHD 7 hold-down capacity based on capacity of 2-2 5/8" diameter shear plates at the end-post.
2. All sheathing is APA rated STR I plywood of the thickness spec'd.
3. 15/32" plywood is 4-ply, 3/8" plywood is 3-ply
4. All framing lumber is DF-L, untreated.
5. Wall bottom sill plates are 3x4's, and center studs on 8' long walls are 3x4's, No. 2 & Better.
6. Framing members are 16" on center max.
7. Moisture content of framing lumber is 19% or less
8. All UNITS: in, lb, U.N.O.
9. These stock numbers were previously known as ADS models.

Shear Wall/Hold-down Cyclic Testing

2. The current ICBO published design values for the tested *USP Structural Connector*® hold-downs appear adequate for restraint of the one-story cyclic loaded plywood sheathed shear walls tested, provided code deflection limitations are included in the design and construction, and the following items are considered:

- These tests used high-strength hold-down anchor bolts (current practice is to use ASTM A 307 anchor bolts). Use high-strength hold-down anchor bolts or account for the use of A 307 anchor bolts in the design.
- The end-post should be sized for compression perpendicular-to-grain of the sill plate.
- Compressive deformation of the sill plate at the end-post should be included in the deflection calculations.
- Deformation through the body of the hold-down (i.e. bending at the bearing plates supporting the anchor-bolt and side plates) should be considered in the deflection calculations, using the hold-down deflection results from the testing herein.

The complete text of these conclusions and recommendations is included in USP's Technical Report (USP819-001). This report contains a complete overview of testing and is available to interested design professionals.

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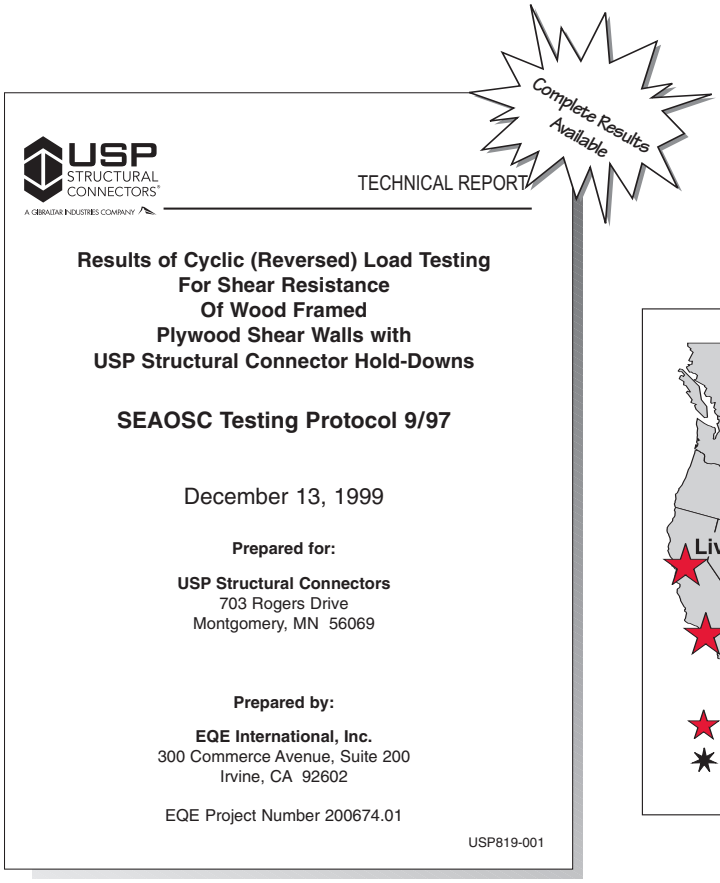
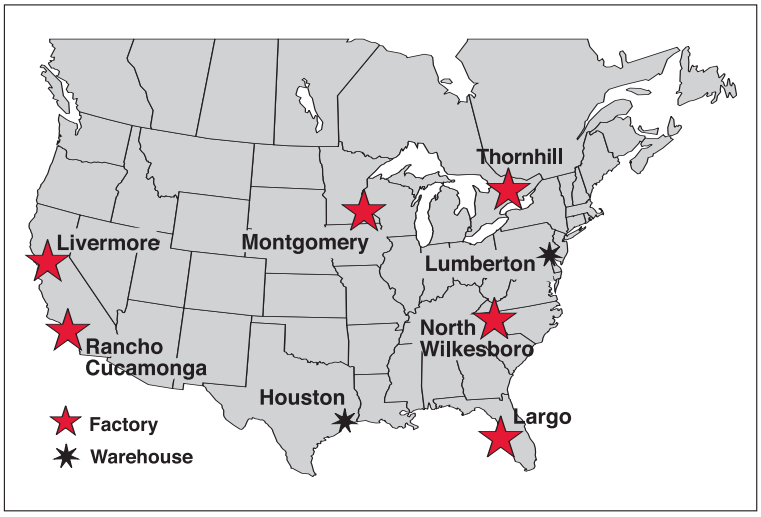


To order the USP Technical Report (USP819-001) you may call, fax, or visit our web site listed below.



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