Modifications to Post and Pier Foundation Retrofit for Residences with Sub-standard Crawl Space

Supplemental Recommendations based on observation of a

Post and Pier Retrofit applied to a Pearl City single family home

Prepared for

Sea Grant

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July 12, 2018

Introduction

In 2009, the authors prepared a report entitled "Structural Seismic Retrofits for Hawaii Single Family Residences with Post and Pier Foundations" for the Federal Emergency Management Agency, FEMA (FEMA, 2009). This Retrofit Report provides a methodology whereby a homeowner in Hawaii could determine the appropriate seismic retrofit for their post and pier foundation system. Three distinct retrofit approaches are available. Retrofit Option 1 involves reinforcement of the existing post and pier system. Retrofit Option 2 requires installation of wood shear walls, and Retrofit Option 3 requires installation of concrete masonry shear walls. The level of retrofit recommended for a particular residence depends on numerous factors including location, building size, number of stories and slope of the terrain.

This report highlights observations made during the inspection of a post and pier foundation retrofit applied to a home in Pearl City, Oahu, Hawaii. The availability of new holddown, connector and screw fasteners can simplify the original retrofit design. Also highlighted are the difficulties involved with applying the retrofit design to existing homes where the crawl space is less than the 24 inch minimum required by current building codes.

Building Description

The post and pier retrofit described in this report was applied to a single family home in Pearl City on the island of Oahu, Hawaii. The building is a traditional single-story wooden single-wall structure built in 1962 with a floor area of 1064 sqft. The majority of the building is supported by post and pier foundations as shown in Figure 1. The crawl space below the elevated floor is considerably less than the 24" required by current codes, making it difficult to install the post and pier retrofit described in the retrofit report (FEMA, 2009).

Figure 1: Single-wall home supported on post and pier foundations.

Recommended Retrofit Design

Based on the Retrofit Report (FEMA, 2009), this building qualifies for seismic retrofit using Retrofit Option 1, requiring reinforcement of the existing post and pier foundation. This is generally the simplest retrofit option because it does not involve any new foundations. Figure 3 shows two tables copied from the Retrofit Report that were used to determine the level of retrofit recommended for this building. The procedure is as follows:

- The subject building is located on Oahu, which is classified as Region 2 (Figure 2).
- The maximum post height is h = 19 inches, which is less than 4 feet.
- The minimum post height is 12 inches.
- The ratio between maximum and minimum post heights is r = 19/12 = 1.58, which lies between 1.5 and 2.0.
- The spacing between the posts is 6 feet in both directions, which is less than 8 feet.

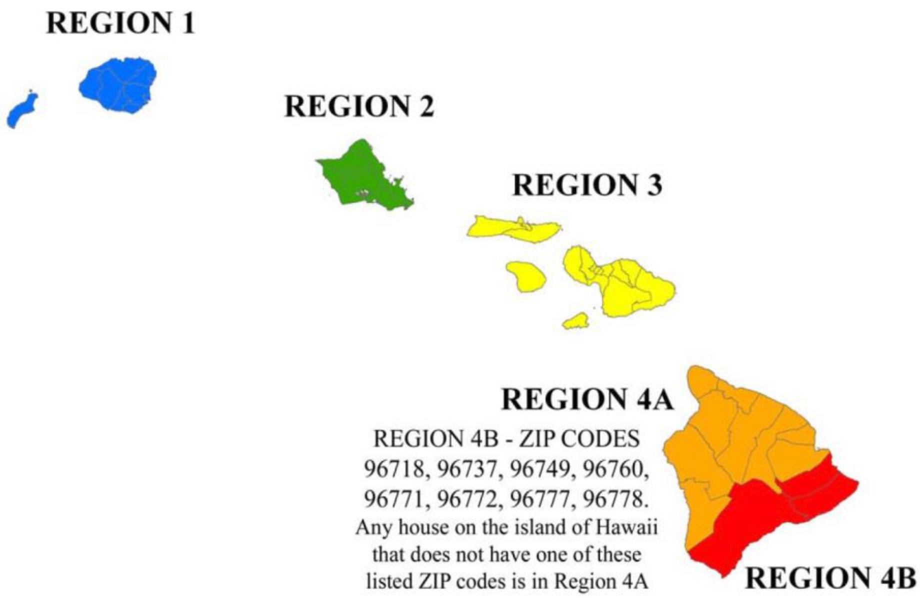


Figure 2: Earthquake Vulnerability Regions from Retrofit Report Figure 4-1.

As shown by the highlighted terms in Table 5-1, contained in Figure 3, this would require a "B,B" retrofit. Table 5-2, also shown in Figure 3, explains that the first B in a "B,B" retrofit includes reinforcement of exterior posts at the corners of the building and every other exterior post along all sides of the building. The second B in a "B,B" retrofit adds reinforcement of every other interior post. This level of retrofit is illustrated schematically in Figure 4.

Table 5-1. Retrofit Option 1 retrofit levels and applicability for all houses

Max Post		h ≤ 4 ft					4 < h ≤ 6 ft						6 < h ≤ 9 ft						9 < h ≤ 12 ft						
Max /Min Post Height Ratio		r =1	1< r ≤1.5	1.5< r ≤2	2< r ≤3	3< r ≤4	r =1	1< r ≤1.5	1.5< r ≤2	2< r ≤3	3< r ≤4	4< r ≤6	r =1	1< r ≤1.5	1.5< r ≤2	2< r ≤3	3< r ≤4	4< r ≤6	r =1	1< r ≤1.5	1.5< r ≤2	2< r ≤3	3< r ≤4	4< r ≤6	6< r ≤9
Post Spacing ≤ 8 ft																									
Region	1	C,B	C,B	B,B	B,B	A,B	C,B	B,B	B,B	A,B	A,B	A,B	C,B	B,B	B,B	A,B	A,B	N/A	C,B	B,B	B,B	A,B	A,B	N/A	N/A
	2	C,B	B,B	B,B	A,B	A,B	C,B	B,B	B,B	A,B	A,B	A,A	C,B	B,B	B,B	A,B	A,B	N/A	C,B	B,B	B,B	A,B	A,B	N/A	N/A
	3	C,B	B,B	A,B	A,A	A,A	C,B	B,B	A,B	A,A	N/A	N/A	C,B	B,B	A,B	N/A	N/A	N/A	C,B	B,B	A,B	N/A	N/A	N/A	N/A
	4a	B,B	A,A	A,A	N/A	N/A	B,B	A,A	N/A	N/A	N/A	N/A	B,B	A,A	N/A	N/A	N/A	N/A	B,B	A,A	N/A	N/A	N/A	N/A	N/A
	4b	A,A	A,A	N/A	N/A	N/A	A,A	A,A	N/A	N/A	N/A	N/A	A,A	N/A	N/A	N/A	N/A	N/A	A,A	N/A	N/A	N/A	N/A	N/A	N/A
8 ft < Post Spacing ≤ 10 ft																									
Region	1	C,B	B,B	B,B	A,B	A,A	C,B	B,B	B,B	A,B	A,A	N/A	C,B	B,B	B,B	A,B	A,A	N/A	C,B	B,B	A,B	A,B	N/A	N/A	N/A
	2	C,B	B,B	A,A	A,A	A,A	C,B	B,B	A,A	A,A	N/A	N/A	C,B	A,B	A,A	N/A	N/A	N/A	C,B	A,B	A,A	N/A	N/A	N/A	N/A
	3	B,B	A,A	A,A	N/A	N/A	B,B	A,A	A,A	N/A	N/A	N/A	B,B	A,A	A,A	N/A	N/A	N/A	B,B	A,A	N/A	N/A	N/A	N/A	N/A
	4a	A,A	A,A	N/A	N/A	N/A	A,A	N/A	N/A	N/A	N/A	N/A	A,A	N/A	N/A	N/A	N/A	N/A	A,A	N/A	N/A	N/A	N/A	N/A	N/A
	4b	A,A	N/A	N/A	N/A	N/A	A,A	N/A	N/A	N/A	N/A	N/A	A,A	N/A	N/A	N/A	N/A	N/A	A,A	N/A	N/A	N/A	N/A	N/A	N/A
10 ft < Post Spacing ≤ 12 ft																									
Region	1	C,B	B,B	B,B	A,A	A,A	C,B	B,B	A,B	A,A	A,A	N/A	C,B	B,B	A,B	A,A	N/A	N/A	C,B	B,B	A,B	A,A	N/A	N/A	N/A
	2	B,B	A,A	A,A	N/A	N/A	B,B	A,A	A,A	N/A	N/A	N/A	B,B	A,A	A,A	N/A	N/A	N/A	B,B	A,A	A,A	N/A	N/A	N/A	N/A
	3	B,A	A,A	N/A	N/A	N/A	A,A	A,A	N/A	N/A	N/A	N/A	A,A	A,A	N/A	N/A	N/A	N/A	A,A	A,A	N/A	N/A	N/A	N/A	N/A
	4a	A,A	N/A	N/A	N/A	N/A	A,A	N/A	N/A	N/A	N/A	N/A	A,A	N/A	N/A	N/A	N/A	N/A	A,A	N/A	N/A	N/A	N/A	N/A	N/A
	4b	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 5-2. Retrofit Option 1 post installation schedule for different retrofit levels

Retrofit Level	Exterior Post Installation	Interior Post Installation
A	At Every Post	At Every Post
B	At Corners and Every Other Post	At Every Other Post
C	At Corner Posts Only	None Required

Figure 3: Tables 5-1 and 5-2 from the Retrofit Report showing reinforcement recommended for the subject building.

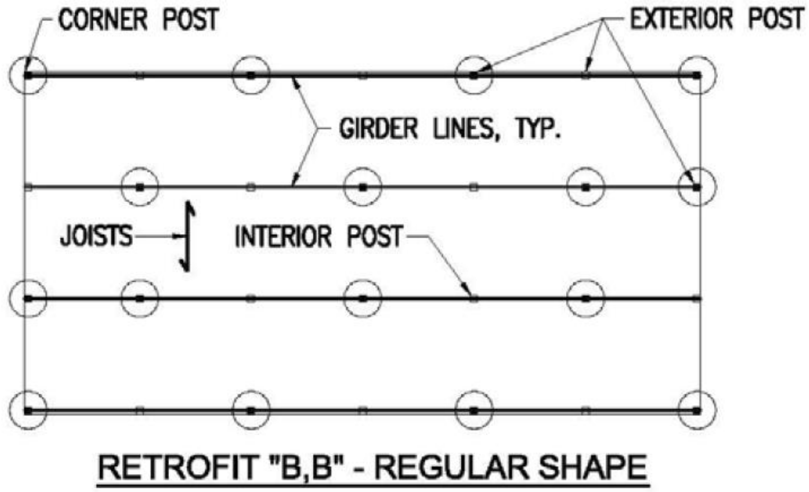


Figure 4: Retrofit "B,B" for a regular shape building as illustrated in Figure 5-1 of the Retrofit Report.

The reinforcement indicated for each post is illustrated in Figure 5. Holddowns must be installed between the post and the foundation block. A post-to-beam connector must be installed at the top of the post, and connector straps must be installed at both ends of the diagonal braces. The Retrofit Report lists the necessary connectors for each of these locations.

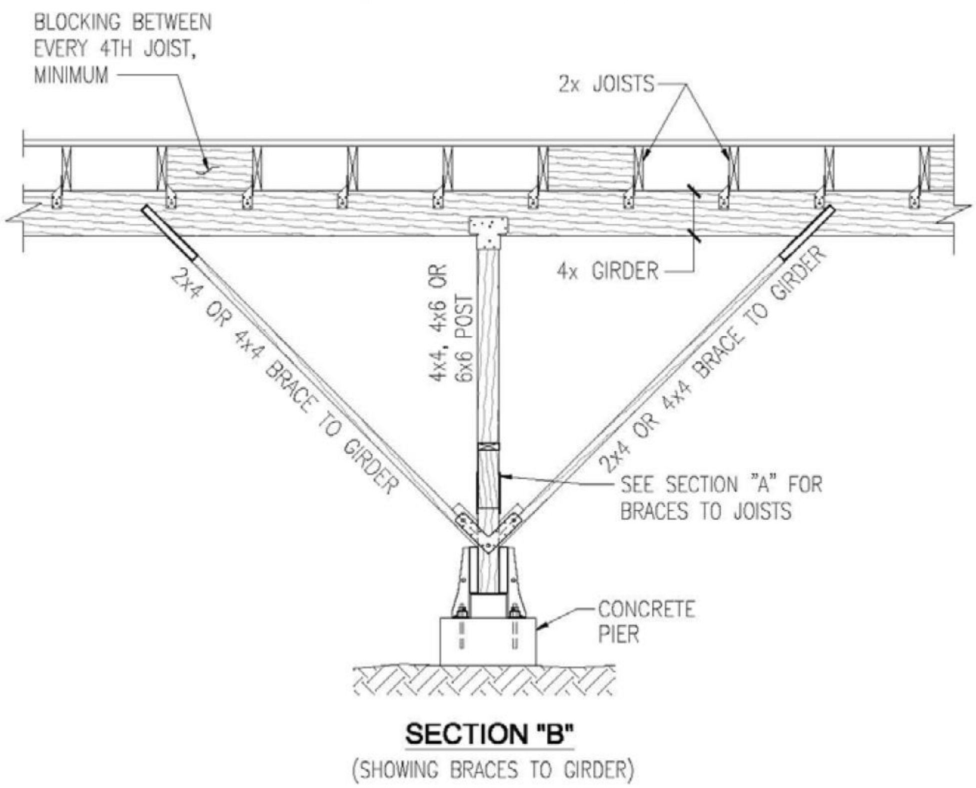


Figure 5-2. Post retrofit 1 general overview

Figure 5: Typical post and pier reinforcement recommended for Retrofit Option 1 (from Retrofit Report Fig. 5-2)

Retrofit Application to Subject Building

Application of Retrofit Option 1 to the subject property presented a number of challenges. These challengers are presented in this section along with recommended alternative reinforcement options.

Low crawl space clearance

Because of the low clearance between the elevated floor and grade at the subject building (which is not in compliance with building current code clearances from grade to the lowest structural member), it was not possible to access the interior posts and piers to perform the recommended retrofit to every other interior post. The alternative solution is to increase the number of exterior posts receiving reinforcement. Instead of only reinforcing corner posts and every other exterior post, it is recommended that the reinforcement be applied to every exterior post. This would be equivalent to a retrofit "A,C" as illustrated in Figure 6.

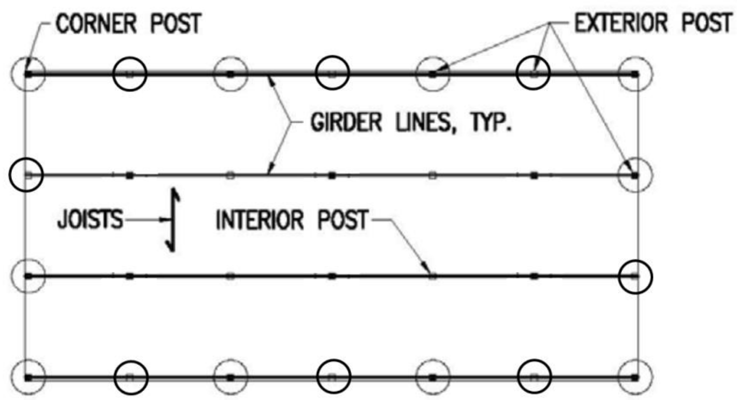


Figure 6: Proposed retrofit "A,C" for buildings with sub-standard crawl space height.

Holddown Connectors on Short Posts

When the crawl space height is less than the 24" required by the current Honolulu Building Code, it can be difficult or impossible to install the holddown anchors in the manner specified in the original Retrofit Report (Figure 7).

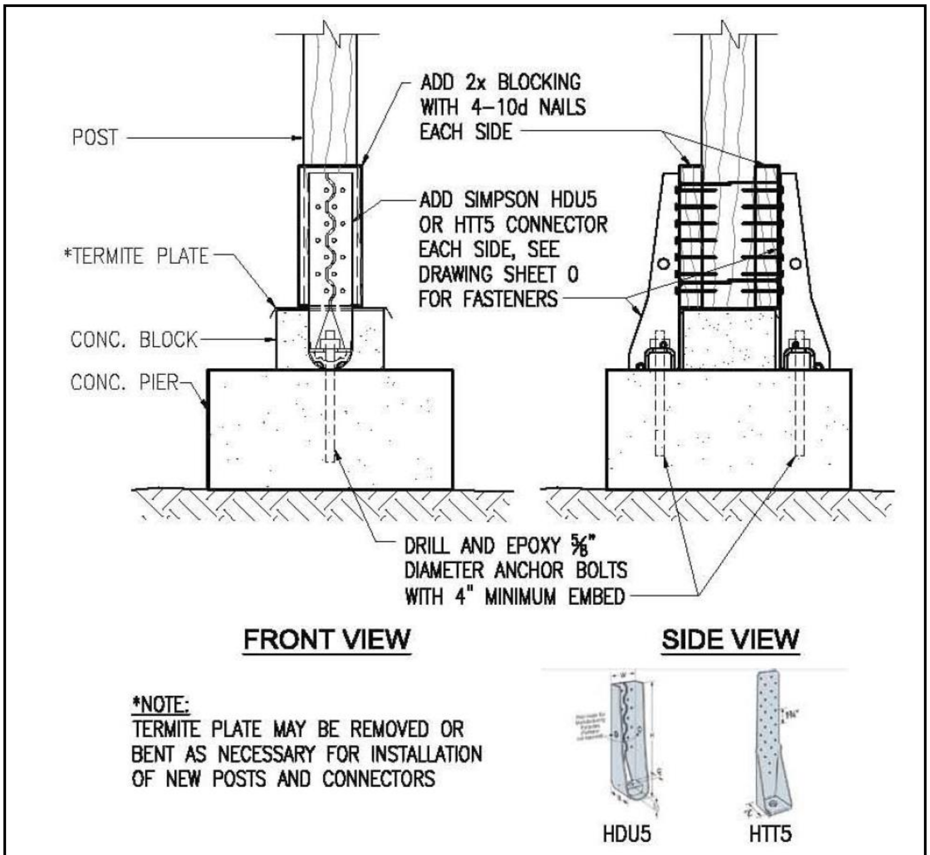
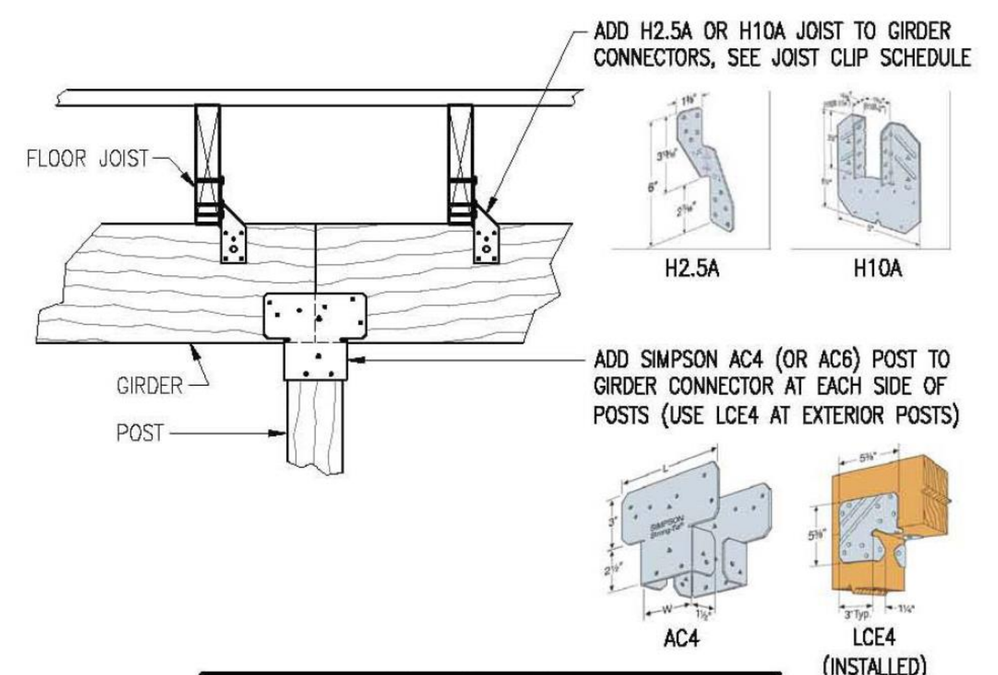


Figure 5-3. Post to foundation holdown detail

Figure 7: Post to foundation holddown detail from Retrofit Report

Figure 7 shows the post to foundation holddown detail specified in the Retrofit Report. It requires either an HDU5 or HTT5 connector on each side of the existing post. An HDU5 connector is 13.25” tall while an HTT5 connector is 16” tall. At the top of the post, the Retrofit Report requires an AC4 (or AC6 for 6x6 post) on either side to connect the post to the beam as shown in Figure 8. The AC4 extends 2.5” below the beam to connect to the post. As shown in Figure 9 where the post is only 19” tall, there is barely enough space to install the HTT5 (16”) and AC4 (2.5”) without overlap. Using an HDU5 holddown and the AC4 connector would allow installation on a post as short as 16”. However, as shown in Figure 10, some of the posts on this house were as short as 12”. The only available solution was to install HDU2 holddowns with the AC4 connector. With a height of 8.75”, the HDU2 could fit below the AC4. On even shorter posts, it was necessary to overlap the HDU2 and the AC4 as shown in Figure 11.

The HDU2 has an uplift capacity that is approximately 70% of that for the HTT5, and 55% of the HDU5. Nevertheless, it is still adequate to secure the post to the foundation block and prevent the post from moving off the foundation, as has been observed during earthquakes when no connectors are provided.



JOIST CLIP SCHEDULE		
EXTERIOR POST RETROFIT	CLIP	SPACING
A	H10A	EACH JOIST
B	H10A	EVERY OTHER JOIST
C	H2.5A	EACH JOIST

Figure 5-6. Post to girder and joist to girder connection details

Figure 8: Post to girder connection details from Retrofit Report

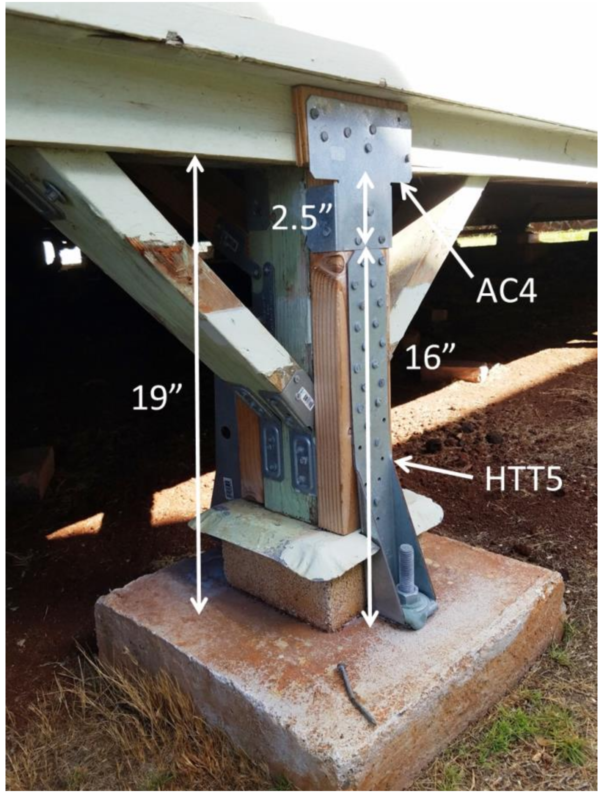


Figure 9: A 19” tall post provides just enough height to install the specified holddown and post-to-beam connectors.

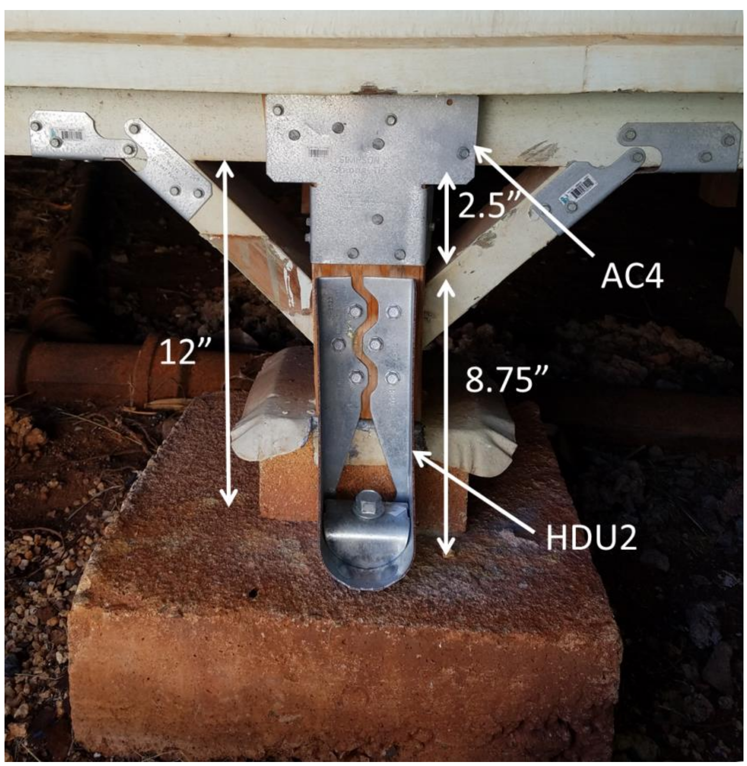


Figure 10: A 12” tall post with HDU2 and AC4 connectors.

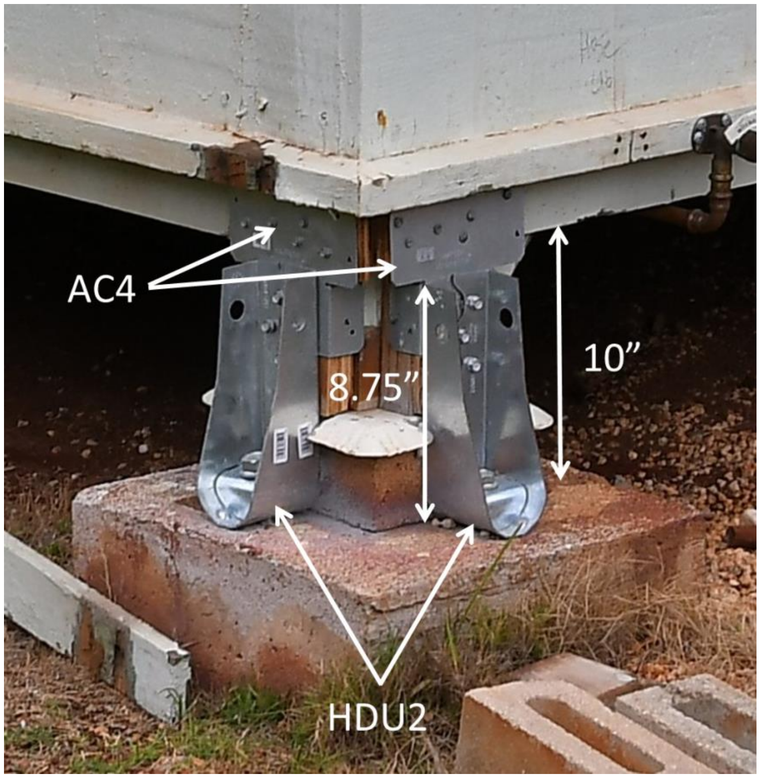


Figure 11: Installation of HDU2 holddown overlapping AC4 connector on two sides of very short corner post.

Anchor bolts

Epoxied threaded rod anchor bolts (utilized in Figure 9) can be substituted by heavy duty screw anchors (shown in Figures 10, 11 and 12). The heavy duty screw anchors should be stainless steel and embedded at least 4 inches into the concrete footing. These should require less labor to install. Note that both require predrilling of the hole for the anchor bolt.

Figure 12 A Holdown with a heavy duty concrete screw anchor

Brace Connectors

The Retrofit Report shows that each end of the diagonal 2x4 braces is connected to the post by means of L straps or HRS12 straps as shown in Figure 13. The top ends of the braces are to be connected to the girder or floor joist by means of HRS12 straps as shown in Figure 14.

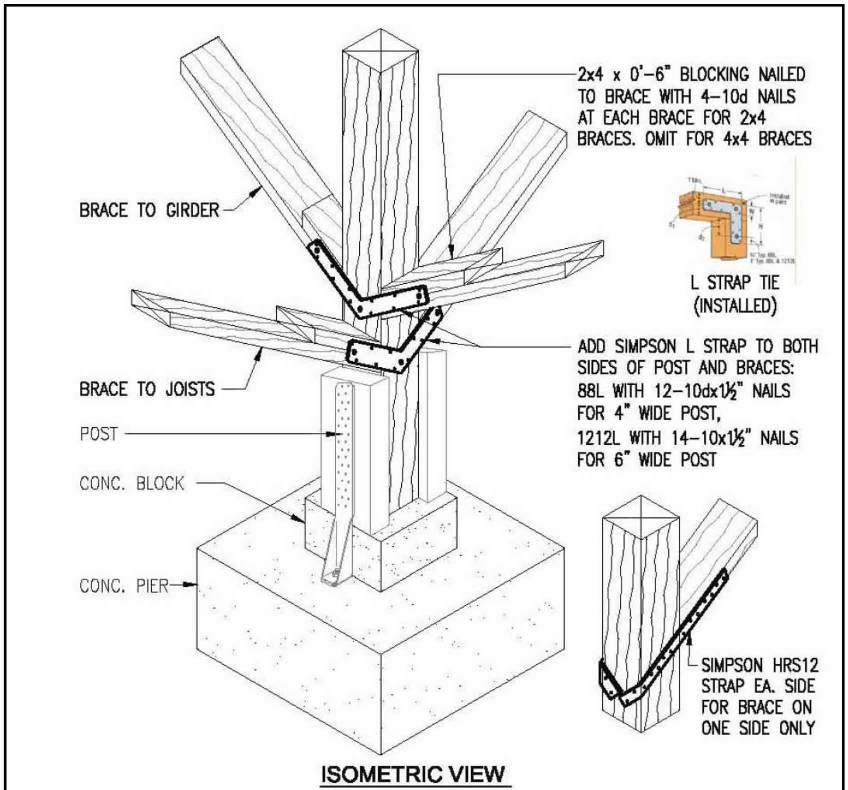


Figure 5-7. Brace to post connection detail

Figure 13: Diagonal brace to post connection detail from Retrofit Report.

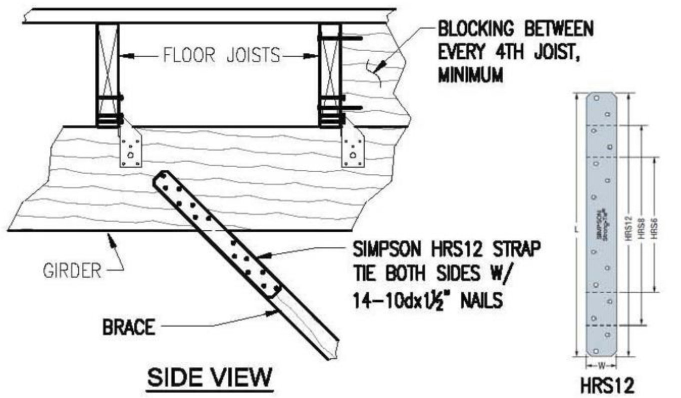


Figure 5-8. Typical brace to girder connection

Figure 14: Diagonal brace to girder connection from Retrofit Report.

Given the congestion caused by the holddown connectors, particularly when the post is short, it is often difficult to install the HRS12 or L straps. Note that in Figure 5-7 from the Retrofit Report (Figure 13), the brace connectors are installed above the holddowns. This would clearly not be possible for a short post as shown in Figure 10. However, the recently introduced Knee-Brace Stabilizer, KBS1Z, can provide a more convenient connection at both ends of the braces (Figure 15). Figure 9 and Figure 10 show how these connectors have been installed on both sides of the diagonal braces at the short posts. Although the capacity of the KBS1Z connectors is only about 50% of the specified HRS12 or L-straps, the demand on these shorter braces is likely to be less than would be required for the taller posts considered in the Retrofit Report. This is therefore considered a suitable substitute for the end connections of the diagonal braces at short posts.

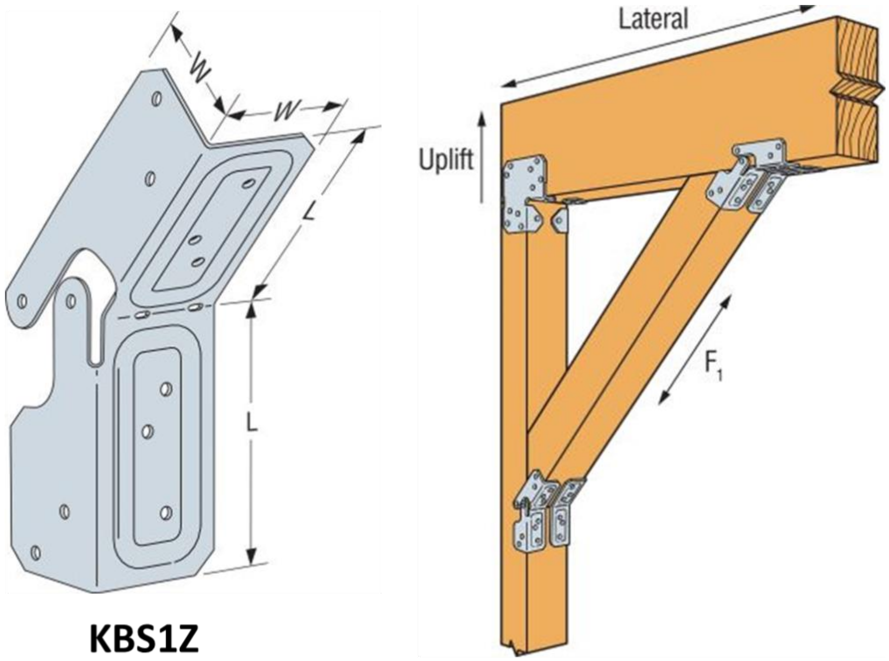


Figure 15: Knee-Brace Stabilizer, KBS1Z connector for diagonal brace end connections.

Figure 16: Two Knee-Brace Stabilizers, KBS1Z, connecting an interior brace to a floor joist.

An alternative for the end connections of the diagonal braces is the use of Strong-Drive SDWH timber screws as shown in Figure 17. These screws are available in various diameters and lengths, and are either hot-dipped galvanized (HDG) or Type 316 stainless steel (SS) for increased corrosion resistance. Four SDWH screws provide the same tensile capacity as two KBS1Z connectors. For brace ends that conflict with the post holddowns, or where installation of the KBS1Z connectors is not practical, SDWH screws could be used to secure the ends of the diagonal braces. This solution was used at the base of the diagonal braces in Figure 10.

Figure 17: Simpson Strong-Drive SDWH Timber-Hex screws

Corrosion Protection

For most locations, standard galvanized connector plates and fasteners (nails and screws) are adequate to provide protection against corrosion. However, for any locations close to the shoreline, it would be wise to consider using stainless steel connectors and fasteners. These are more expensive and may need to be special-ordered, but they will provide considerably longer life in coastal environments than the galvanized components. An intermediate alternative to extend the life of galvanized components is to first apply a coat of zinc-rich cold-galvanizing compound to the connectors and fasteners after installation as shown in Figure 18. Then, the connectors can now be painted with a three-coat system consisting of a 1) Zinc-Rich Epoxy Primer 3 to 5 mils thick, 2) an Epoxy Polyamide intermediate coat 3 to 5 mils thick, and 3) a Polyurethane Topcoat 2 to 3 mils thick. This coating system is considered appropriate for the coating of galvanized steel surfaces.

Figure 18: Galvanized connectors sprayed with zinc-rich cold-galvanizing paint to increase corrosion resistance. (To be followed by the second and third coats in the three-coat painting system)

References

FEMA, 2009. "Structural Seismic Retrofits for Hawaii Single Family Residences with Post and Pier Foundations, Volume I", Final Report prepared by Ian Robertson and Gary Chock for FEMA Hazard Mitigation Grant Program DR-1664-HI, May 15, 2009. Available for download at: https://hilo.hawaii.edu/~nathazexpert/expertsystem/Report_forPost_andPierRetrofits-Volume1.pdf