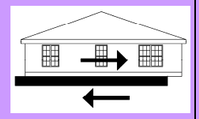
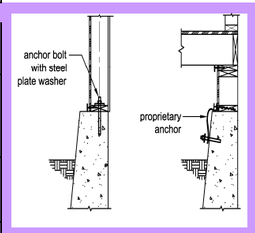
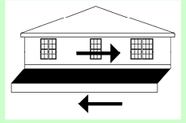
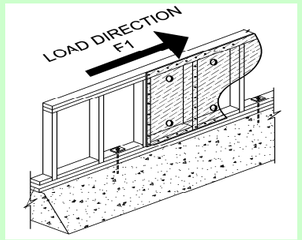
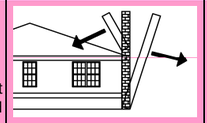
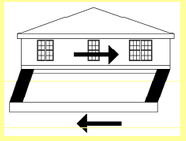
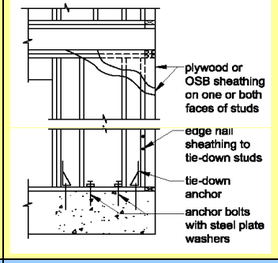
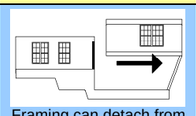
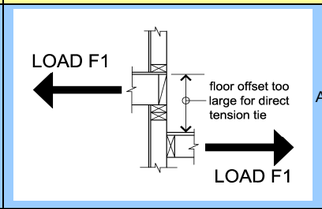
Seismic Vulnerabilities - One- and Two-Family Wood-Frame Dwellings - Voluntary Seismic Rehabilitation

06.25.09

Item	Behavior If Adequate	Behavior if Inadequate or Missing	Where to Look	Why to Look	What to Look For	What might be found	Priority for Rehabilitation	How to Proceed	Design Approaches[1] IEBC	IRC	Eng	Concept for Seismic Rehabilitation	Discussion
A **ANCHORAGE** Inadequate or missing anchorage of dwelling framing to foundation	Anchorage between wood sill and concrete or masonry foundation resists sliding of wood framing across the top of the foundation	 Wood framing can slide relative to foundation	For dwellings with wood-frame floors with crawlspace, look from inside crawlspace at dwelling perimeter	-Dwellings built prior to approximately 1950 are not likely to have anchorage (date may vary) -Dwellings with cripple wall bracing being added may need additional anchor bolts at cripple wall sheathing locations	Anchor bolts connecting wood sill to foundation	No anchorage	**HIGH**	Add new anchor bolts or retrofit anchors attaching wood framing to foundation	X	X	X	 Install anchor bolts (where access permits) or install proprietary retrofit anchor to carry load direction F1	Top priority for seismic rehabilition if HIGH or MEDIUM. This is one of the most commonly seen failure types, occuring in most moderate to major earthquakes since the late 1800's. Benefits of seismic rehabilitation are much greater than cost. A condition survey is required for decayed wood framing, rusted anchor bolts, deteriorated foundation, no continuous foundation **Resources:** IEBC Appendix Chapter A3, local building department guidance, FEMA G225, ATC 50-1 Chapter 5, FEMA 547 Chapter 5, Standard Plan A Residential Seismic Strngthening Plan and Home Earthquake Retrofit Series.
						Anchor bolts spaced further apart than 6 feet[2]	**MEDIUM**						
						Anchor bolts spaced 6 ft on center or less[2]	**LOW**	Add new anchor bolts if recommended as part of Item B Cripple Wall Bracing or engineered design	X	X	X		
						Anchorage connectors other than anchor bolts	**Varies based on adequacy of installation**	Contact architect or engineer[3]			X		
					Continuous foundations	Isolated pier foundations at post and pier floor system Intermittent foundations	**HIGH**	Add continuous or intermittent foundation and anchor bolts			X		
			For dwellings with concrete slabs on grade, anchorage can often only be observed if the wall finishes are opened up. For this reason, priority is low and anchorage is usually only checked if wall sheathing is being modified. Contact architect or engineer[3]								X		
B **CRIPPLE WALL BRACING** Inadequate or missing sheathing of cripple walls, OR post and pier foundation without cripple walls	Cripple wall sheathing resists in-plane earthquake loads	 Wood cripple wall can fail due to in-plane loading. Dwelling can fall off of foundation	Look from inside crawl space at building perimeter	-Until recent building codes, cripple walls were not required to have plywood or OSB sheathing	Plywood or OSB sheathing extending from cripple wall top plates to foundation sill plates	No plywood or OSB sheathing	**HIGH**	Add cripple wall sheathing. Improve connections at top and bottom of cripple wall	X	X	X	 Install sheathing on cripple wall to resist load direction F1 (usually installed on inside face of cripple wall, but exterior also OK)	Top priority for seismic rehabilitation. This is one of the most commonly seen failure types, occuring in most moderate to major earthquakes since the late 1800's. A condition survey is required for decayed wood framing, rusted anchor bolts, deteriorated foundation, no continuous foundation **Resources:** IEBC Appendix Chapter A3, local building department guidance, FEMA G225, ATC 50-1 Chapter 5, FEMA 547 Chapter 5, Standard Plan A Residential Seismic Strengthening Plan and Home Earthquake Retrofit Series.
C **CHIMNEY BRACING** Unreinforced masonry chimneys are very vulnerable to damage and collapse	Reinforcing steel, short chimney height above roof and anchorage at roof, ceiling and floors may reduce chimney falling hazard but not eliminate damage.	 Partial or full collapse of chimney, etither onto or away from the house	-Is height of unreinforced masonry chimney above roof significant?	An unreinforced masonry chimney with significant height above the roof line may break at the roof line	Compare height above roof at middle of chimney to smaller plan dimension	Chimney higher than least plan dimension is a possible concern for breaking at the roof	**Varies based on risk posed if chimney falls**	Contact architect or engineer[3]			X	Professional opinions vary widely; alternatives suggested include: -Do nothing until after the earthquake -Put plywood in the attic to slow chimney if it falls through -Add anchor ties to chimney to hold against dwelling -Remove chimney above roof line and replace with light-frame box and metal flue -Remove chimney and firebox in their entirety and replace with wood-frame box and metal flue	This is one of the most commonly seen failure types, occuring in most moderate to major earthquakes. Bracing struts from the chimney top to the roof are discouraged. See ATC 50-1, Chapter 6. After earthquakes, masonry chimneys should be inspected for cracks prior to use. **Resources:** FEMA 232 Chapter 9, ATC 50-1 Chapter 6, FEMA 547 Chapter 5, City of Los Angeles Building Code, www.abag.ca.gov/bayarea/eqmaps/fixit/chimneys.html.
			-Can chimney anchor straps be seen in attic at celing and roof framing?	Anchorage of the chimney to the framing will help resist full chimney collapse	Steel straps from the face of the chimney masonry with substantial bolting or nailing to wood framing	No straps, straps poorly connected to framing, framing not adequately anchored to roof or ceiling							
D **OPEN FRONT DWELLINGS OR PORTIONS OF DWELLINGS** Front of dwelling or wing of dwelling has bracing walls narrower than 4 FT	Adequately detailed narrow walls resist in-plane earthquake loads	 Narrow walls can fail or move excessively due to wall in-plane loading	Look at inside face of narrow wall piers, often in garage. This may be visible or may involve opening observation holes in interior wall finish	Many homes have narrow walls without adequate detailing	-Narrow walls without tie-downs and plywood or OSB -Narrow walls with tie-downs and ply wood or OSB -Manufactured Narrow walls	Narrow walls with no plywood/OSB and no tie-downs	**HIGH**	-Add narrow wall detailing, OR -Tie building wing with narrow walls to main dwelling if walls are close to aligning, OR -Add steel moment frame		X[4]	X	 Well detailed narrow shear wall including: -OSB or plywood -anchor bolts -tie-downs	Shear walls may be too narrow to meet requirements of code. Where this occurs, design by an architect or engineer is needed. Tie-downs need to go into continuous footing that is of adequate size and strength; this sometimes means adding a footing. Design by an architect or engineer is needed. Post-tensioned slabs require architect or engineer guidance when adding anchorage **Resources:** ATC 50-1 Section 8.5, FEMA 232 Chapter 9, FEMA 547 Chapter 5
						Narrow walls with plywood/OSB shear walls, but no tie-downs							
						Narrow walls with plywood/OSB shear walls and [illegible]	**LOW**	Verify wall system is adequately installed					
						Narrow walls with manufactured shear wall devices							
						Narrow walls with continuous header and steel straps at top							
E **SPLIT LEVEL DWELLINGS** Floor or roof framing at different levels is supported on a common wall	If adequately attached, framing will not separate from common wall	 Framing can detach from common wall, permitting a portions of the floor or roof to fall	Look at direction and attachment of framing that is supported on stud face with ledger	Where split levels occur, framing on each side can move differently during an earthquake causing seperation and loss of vertical support.	Framing perpendi-cular to common wall and attached with a ledger board with nails that would act in withdrawal	Framing that is supported on the face of a stud wall does not have a clip angle or strap that can carry tension	**HIGH for combined split level and open front** **MEDIUM for split level floor framing** **LOW for split level roof framing**	-Adequately tie 2 portions of dwelling together OR -Make sure each portion has an independent gravity and seismic load resisting system			X	 Anchor framing at common wall for load direction F1	Damage of this type was seen in the 1971 San Fernando Earthquake. Often one portion of the building at the split level is an open-front garage (Item D). **Resources:** ATC 50-1 Section 8.6, FEMA 232 Chapter 9

[1]IEBC=International Existing Building Code Appendix Chapter A3, IRC= International Residential Code, IBC=International Building Code, Section 2308, Eng=Design by an archiect or engineer using engineering methods.

[2]6 ft. on center is a common spacing for dwellings constructed using conventional construction provisions. An existing anchor bolt spacing somewhat greater than 6 ft. may be classified as low priority for rehabilitation if the anchor bolts are provided at all exterior continuous footings, and are in no case spaced more than 9 ft. apart.

[3]A licensed architect or registered engineer experienced in seismic rehabilitation design

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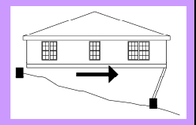
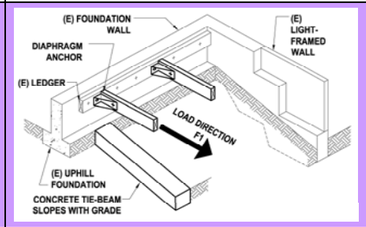
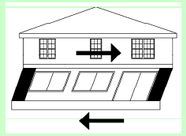
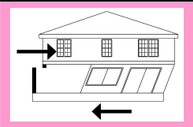
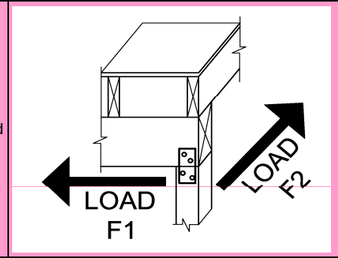
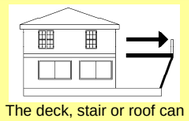
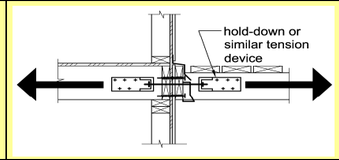
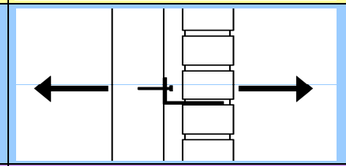
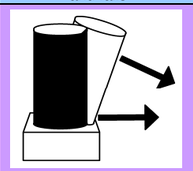
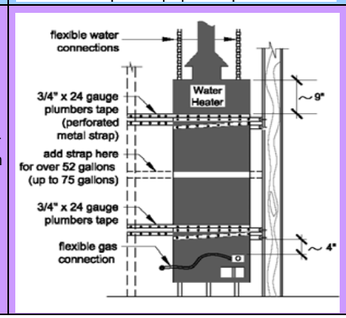
F **HILLSIDE DWELLINGS** Inadequate anchorage of dwelling to uphill foundation	An adequately anchored dwelling will not separate from uphill foundation	 Dwelling can pull away from the uphill foundation, permitting collapse	Between lowest occupied floor (or portions of floors) and grade	Concentration of seismic load in uphill foundation has not always been adequately considered in design	Anchor to resist dwelling pulling away from uphill foundation	No bracing system	**HIGH**	Provide anchorage to uphill foundation			X		Provide adequate capacity at uphill foundation/ stiffest load path	Should be top priority for seismic rehabilitation. Damage of this type was seen in the 1994 Northridge Earthquake. **Resources:** City of Los Angeles Building Code, ATC 50-1 Section 8.6, FEMA 547 Chapter 5
						Cripple walls with inadequate connection installed as skirt walls	**HIGH**	Provide anchorage to uphill foundation or provide cripple wall anchorage to foundation if sufficiently stiff						
						Cripple walls with greatly varying hieght and therefore stiffness	**MEDIUM**							
						Steel diagonal rod bracing	**MEDIUM**	Evaluate adequacy of strength, stiffness and detailing for bracing system						
G **WALL LINES WITH INADEQUATE SHEAR WALL LENGTH** Front of dwelling or wing of dwelling has inadequate bracing walls	Shear wall bracing is long enough to provide adequate strength and stiffness	 Shear wall can fail or move excessively due to in-plane load	Look for exterior walls with a very high portion of door and window openings	Bracing wall adequacy has not always been considered in dwelling design. Building code requirements for wall bracing have increased over the years	For prescriptively designed dwelling only: shear wall length less than would be required by IRC or IBC prescriptive bracing provisions	Less than 50% of IRC or IBC required shear wall length at lowest story	**HIGH**	Add additional bracing wall length (frame out and sheath over existing openings) or Add detailing to existing bracing walls to increase capacity as per Item D or Add steel moment frame or steel cantilevered columns		X[4]	X	See Item D		See Item D
						Less than 75% of IRC or IBC required shear wall length at lowest story	**MEDIUM**							
						Less than 50% of IRC or IBC required shear wall length at upper story	**MEDIUM**							
						Less than 75% of IRC or IBC required shear wall length at upper story	**LOW**							
H **POST ATTACHMENT AT TOP AND BOTTOM** Posts not anchored adequately to move with house	An anchored post will move with the framing that it supports	 Beam can pull away from top of post, allowing beam and supported floor to fall	Look for exposed post to beam connections. Connections that are encased in finishes are much less vulnerable	Even when dwellings have an adequate seismic bracing system, they can sometimes move horizontally several inches over the height of a story during an earthquake. If posts have a nominal attachment top and bottom, they are likely to move with the structure above and below	Post top or bottom with little or no connection -Look under dwelling -Look at dwelling exterior	No connection or small number of toenails	**MEDIUM for other posts ≤ 4 ft and supporting ≤ 50 sq ft** **LOW for post and pier foundation posts**	Install nailed connector plate or adequate toe-nails	No design required				Fasten post to framing above and below to resist forces F1 and F2	Corrosion resistant hardware and fasteners should be used where exposed to weather or to pressure treated framing members. Connection should not be so stiff that it resists post rocking. **Resources:** ATC 50-1 Section 6.6.
I **ANCHORAGE OF STAIRS, DECKS, ROOFS** Lack of positive connection of appendages to main dwelling	Adequately anchored decks, stairs and roofs will not separate from the dwelling	 The deck, stair or roof can pull away from the dwelling and fall	Look at deck, stair and roof framing connection to dwelling	Very often appendages do not have proper anchorage to the main dwelling. Nails in withdrawal do not provide reliable seismic force resistance	Deck, roof, stair framing fastening to dwelling	Ledger nailed to rim joist only, with no positive connection	**HIGH at exit locations** **MEDIUM at other locations**	Install tension connector directly from interior to exterior framing member. Interior ceiling may need to be removed for access			X		Anchor deck, stair or roof directly to framing member.	Lag bolting deck framing to a floor rim joist is not adequate; entire rim joists have been pulled out due to their minimal connection to interior framing. Connect to framing member and make sure member is attached to floor or roof sheathing. Attention to detail is needed to avoid permitting water intrusion at connection locations **Resources:** ATC 50-1 Section 6.6. FEMA 232 Chapter 7
J **VENEER ANCHORAGE** Anchorage of stone or masonry veneer to wood-frame wall system behind	Adequately anchored veneer will create a low to moderate falling hazard	 Unanchored veneer separates from the house and falls	Requires selective opening of veneer or opening of wall cavity and building paper	Unless constructed very recently, veneer is unlikely to have code required anchors	Look for sheet metal anchors attaching veneer to wall framing	No veneer anchors	**Varies based on risk posed if veneer falls**	Contact design professional[2]			X		Professional opinions vary on approach.	Where a low safety hazard is posed by falling veneer, it may be left and replaced after the earthquake. Other alternatives include removal and replacement with anchors, and pinning to substructure (ATC 50-1); both of these are expensive and invasive procedures. Veneer at a height of 30 feet and above (38 ft at gable end walls) should be supported on a non-combustible lintel. **Resources:** ATC 50-1 Chapter 6
K **WATER HEATER ANCHORAGE** Anchorage of water heater to avoid sliding and tipping	Adequately anchored water heater reduces risk of movement and damage	 Unbraced water heaters shift or roll over, causing damage, possibly resulting in water leakage and fire hazard	Look at water heater installation	Many water heaters in older homes have been installed without earthquake bracing	Straps around tank near top and bottom, tightly anchored to wall framing (to avoid tipping), anchorage of water heater base or pedestal to supporting floor (to avoid sliding)	No water heater bracing	**HIGH**	Install bracing, anchorage at base, flexible gas and water lines	See discussion for prescriptive design approaches				Strap or brace water heater	Should be top priority for seismic rehabilitation. Water heater failure occurs very commonly in moderate to large earthquakes. Significant fires have sometimes occured due to gas line rupture. Strap or brace water heater to wall, secure base or pedestal to floor, provide flexible gas and water lines to water heater to avoid rupture. **Resources:** ATC 50-1 Chapter 6, FEMA 232 Chapter 8, California Division of the State Architect Waterheater Guidelines

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[3]A licensed architect or registered engineer experienced in seismic rehabilitation design.

[4]Prescriptive construction per the IRC may be used provided tie-downs to an existing footing are not required. Where tie-downs are required by the IRC, design by an architect or engineer is needed.