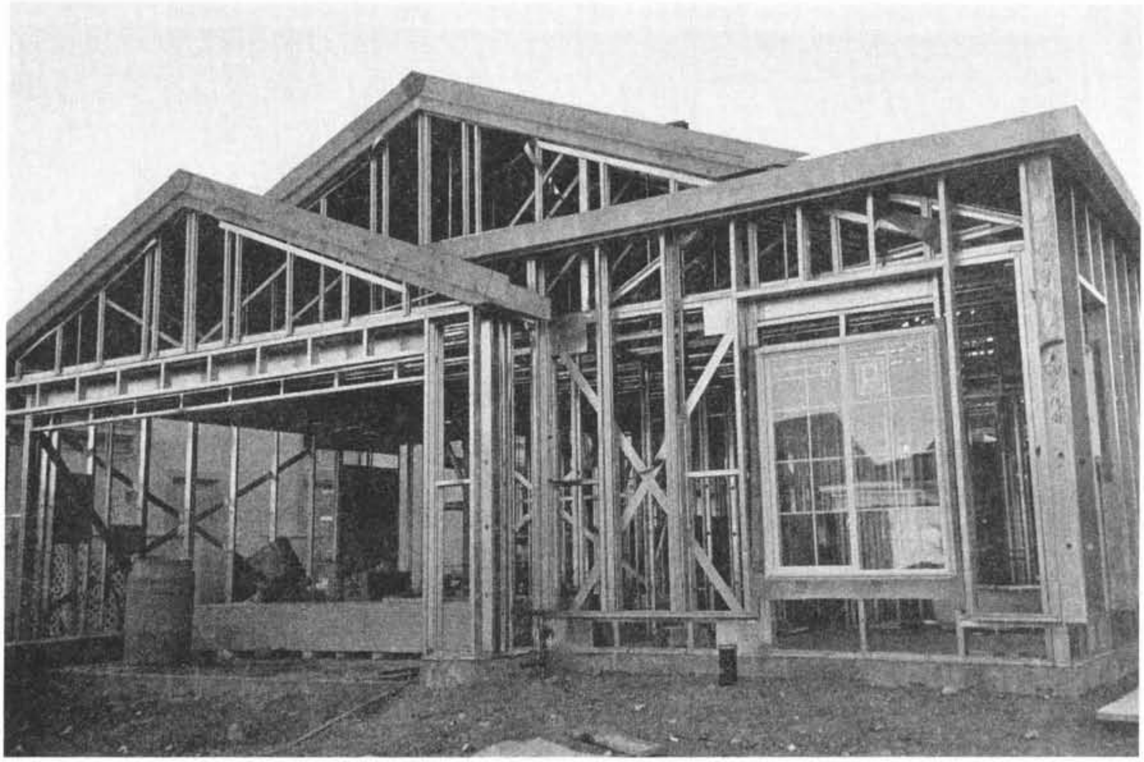


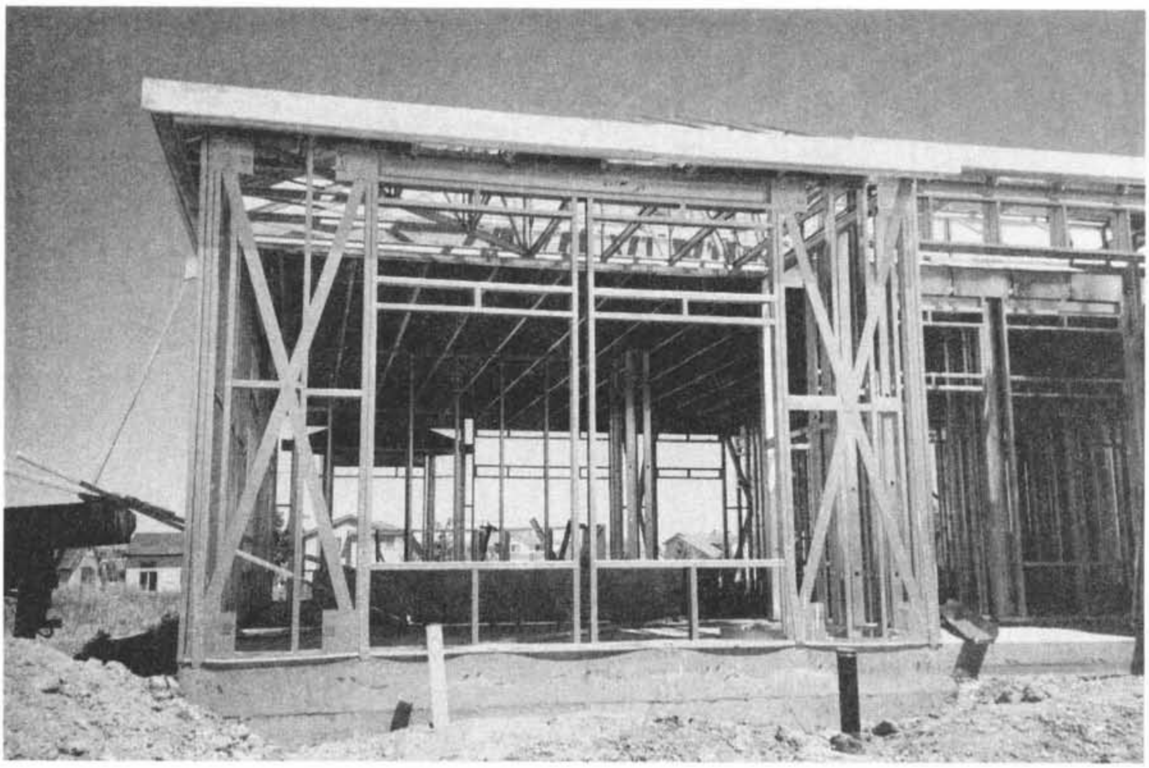


Figure 78

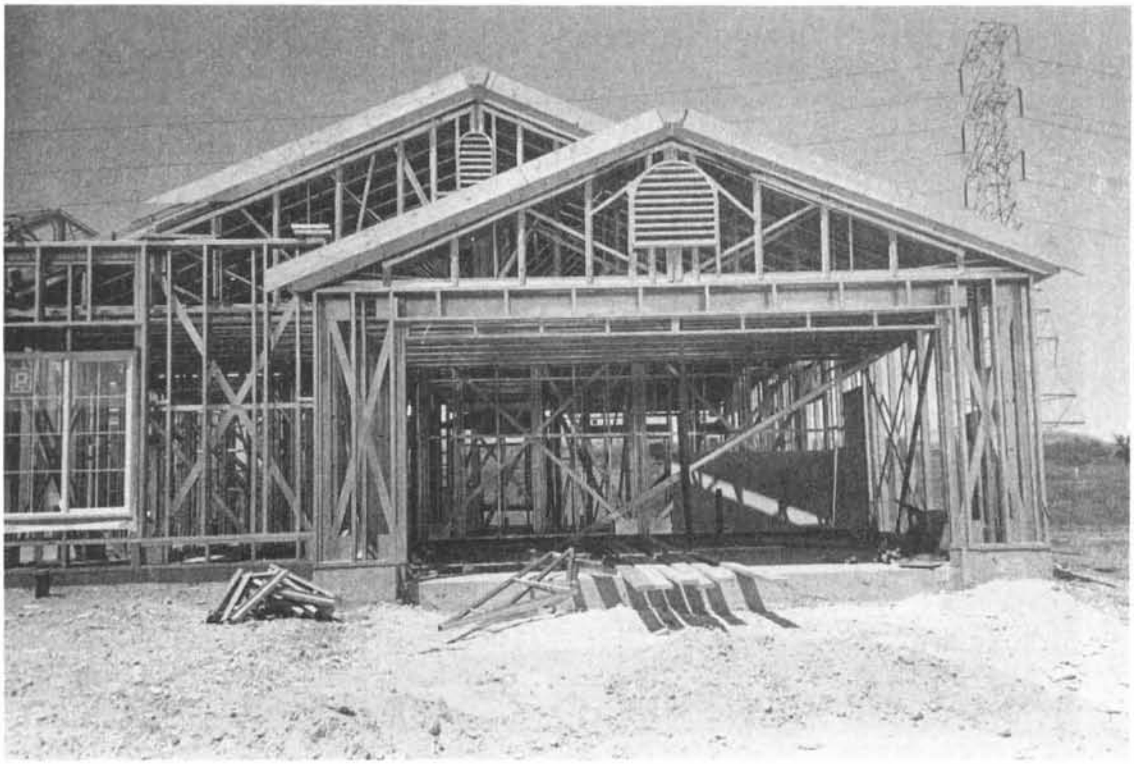


Figure 79

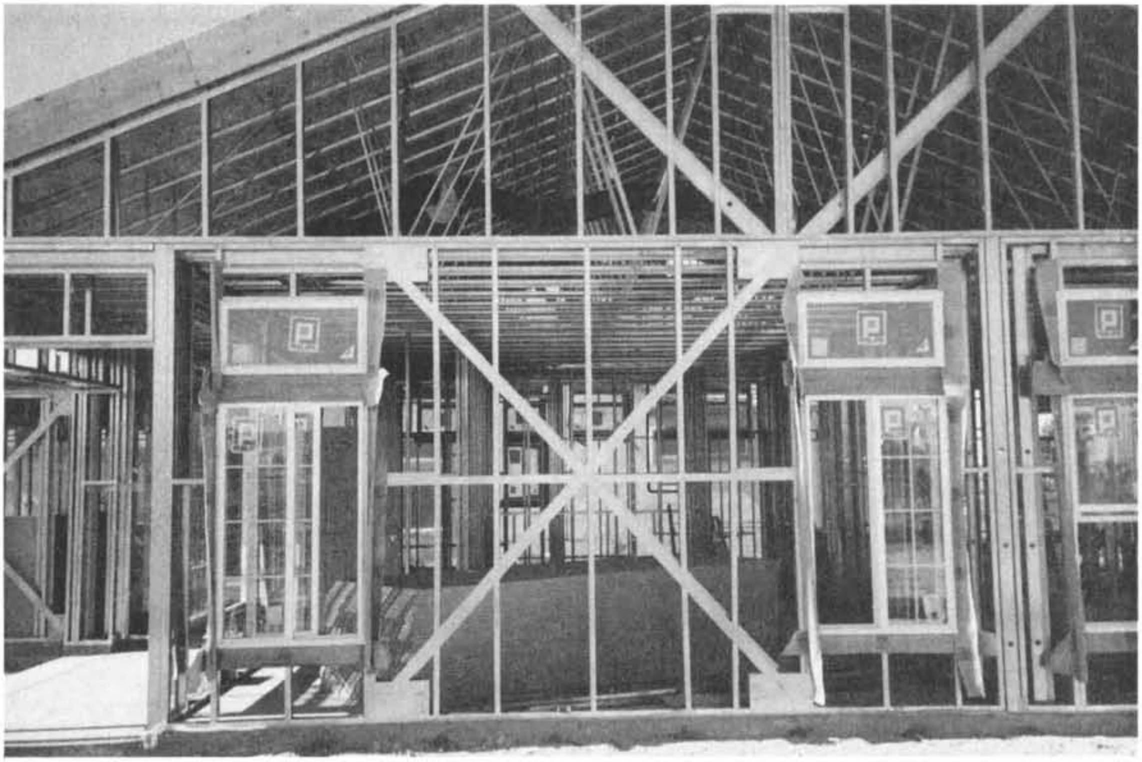
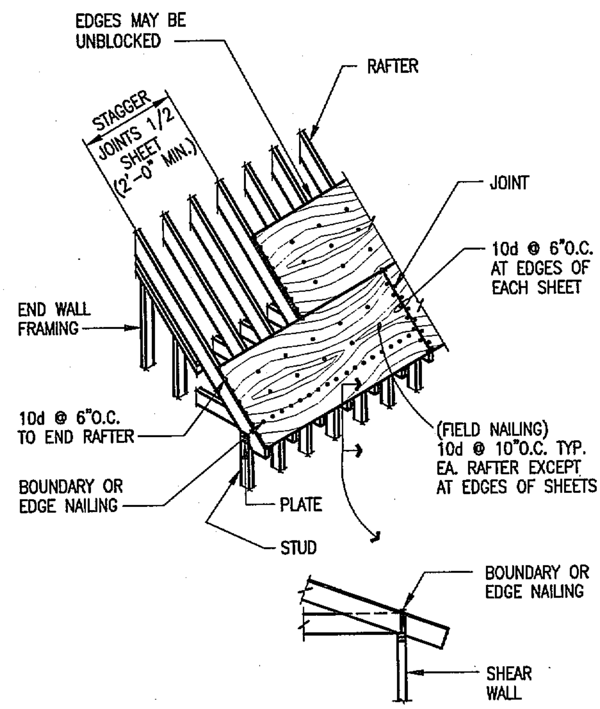


Figure 80

9. ROOFS

Roofs act as horizontal diaphragms and are essential elements in transmitting earthquake induced horizontal forces to the shear walls. Although gypsum board finish materials on the underside of the ceiling joists will assist the roof sheathing in transferring horizontal forces, it is best to assume (except in areas of low seismic risk) that the roof sheathing acts alone in resisting the earthquake. Roofs must conform to certain diaphragm ratios or plan dimensions and shapes. Variations in form are permissible provided the perimeters are supported by shear walls and continuity is maintained at openings in the diaphragm. The perimeter or boundary edges of roof diaphragms should be nailed to blocking or rim joists that are toe nailed to wall top plates or collectors so that the earthquake forces from the diaphragms can be resisted by the shear walls. See Figure 81. Openings in diaphragms are permitted, but should be limited in size and location.



ROOF DIAPHRAGM SHEATHING

Figure 81

Simple, regular shapes symmetrical about each axis with unbroken planes provide good diaphragm performance. A flat or slightly pitched roof with square or nearly square configuration is best for good behavior as long as the roof plane is not interrupted by large openings or rendered discontinuous at the boundaries by cut-outs or notches that destroy continuity or symmetry of the diaphragm.

It is possible to provide some variety in form when using square, rectangular or other symmetrical shapes. This is especially true of flat roofs that can be sectionalized and tilted at different angles or by having one section dropped into a different plane. Consider that diaphragms in different planes become separate diaphragms and each diaphragm must meet all requirements independently. See Figure 82.

Roofs at different levels are similar to floors with split level configurations and require special connection details at common walls. See discussion of split level floors on page 30 and roof details Figures 60 and 61 on page 31.

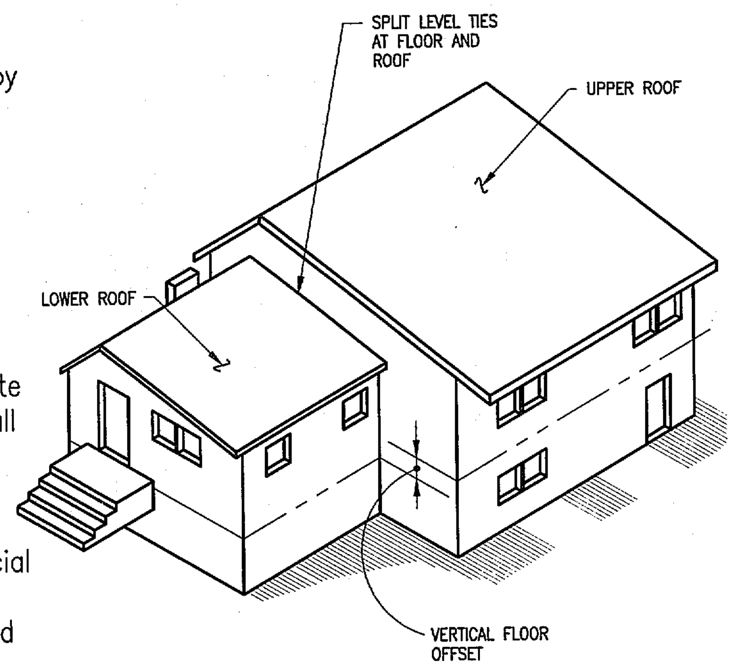


Figure 82

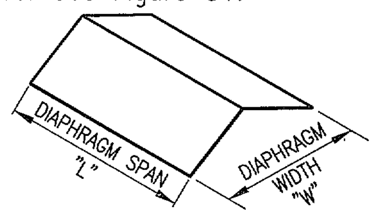
Other roof shapes are acceptable if precautions are observed to retain the characteristics of single plane surfaces and symmetry and to maintain continuity at breaks in the plane of the diaphragm. This includes such roof shapes or styles as pitched roofs, shed roofs, gables with both moderate and steep slopes, hips and valleys, and mansards as long as roof surfaces in the same plane remain unbroken and vertical offsets and discontinuities at wall boundary lines are avoided. See Table No. 4, page 48.

To function properly, diaphragms must conform to specific shape limitations that are controlled by the diaphragm ratios. See Figures 83 and 84. If the exterior wall locations are such as to make the span–width ratio unacceptable, interior shear walls must be used in conjunction with the outside walls so that acceptable span–width ratios are maintained. Each edge of the diaphragm should be supported by a shear wall. However, it is permissible to use shear walls which are not under the edge of a diaphragm by using collectors or drag struts connected to the shear walls. The most commonly used collectors are wall top plates or rim or header joists secured to the top plates. If rim joists act as collectors, they must be spliced for continuity.

Openings in roofs should be limited in number and moderate in size. In general, they should be restricted to one principal opening for a fireplace chimney and several smaller penetrations for plumbing vents, conduits and pipes. Large openings, as for skylights and atria, should have special nailing of the diaphragm sheathing to framing placed around the opening. Openings should be avoided at the corners of diaphragms.

At ridges or changes in slope it is necessary to tie the sections of the diaphragm together by nailing to blocking common to both planes and overlapping and nailing the framing members perpendicular to the ridge at the change in slope. See Figure 11.

Several common sheathing materials are available for roof diaphragms. Structural grade plywood or oriented strand board is recommended in high seismic risk areas. Where used, sheets should be oriented with the face grain perpendicular to the joists or rafters. See Figure 81.



HORIZONTAL DIAPHRAGM

Figure 83

MAXIMUM DIAPHRAGM RATIO
(See also Table No. 3, Page 39)

	SEISMIC RISK	
	High	Moderate & Low
Material	Max. Span–Width Ratio	
1. Plywood * ** sheathing with edges blocked and unblocked	4 : 1	4 : 1
2. Diagonal sheathing	2 : 1	3 : 1
3. Straight sheathing	Not Recom–mended	2 : 1 Low Seismic Risk Area Only

* Wood Structural Panel
** Oriented Strand Board can be substituted for plywood

Figure 84

Blocking can be omitted along the long edges of the sheets; but, if it is omitted, metal ply clips along the unblocked edges should be used to prevent differential movement of the edges which could tear the roofing. To limit this type of damage or to create a stiffer diaphragm, blocking under all edges of Wood Structural Panel sheets with edge nailing of the sheathing to the blocking may be used. The short edges of abutting sheets must be supported by the same framing member with edge nailing along the common member for each sheet.

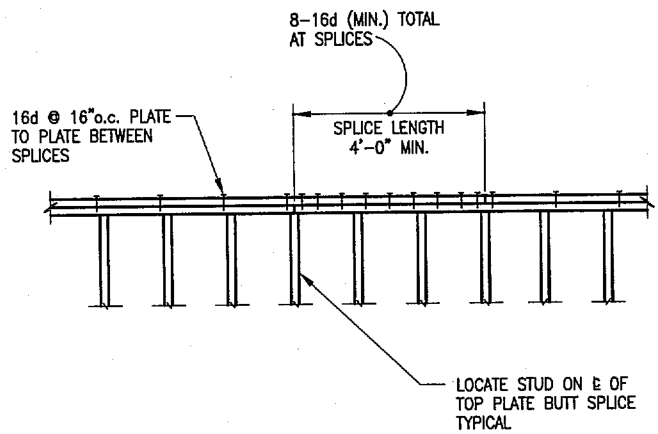
Diagonal sheathing, no longer commonly used, is an option for earthquake resistance for any seismic risk area and can be used as a substitute for plywood provided the nailing is as required by code. See Section 7 FLOORS for a discussion of this material. Straight sheathing should only be used as a diaphragm in low seismic risk areas.

In exposed beam ceilings, framing 1x or 2x tongue and groove straight sheathing over the tops of the beams may be used. A Wood Structural Panel overlay should be placed over the sheathing in high and moderate seismic risk areas. Edge nailing should be provided at the boundary of each Wood Structural Panel sheet. Field nailing should be located to avoid penetrating straight sheathing boards.

Skip-spaced boards used for attaching shingles form a very weak diaphragm and are not recommended. Spaced boards should only be used in low seismic risk areas that also have a low wind exposure. Skip spaced boards may not be used where prohibited by Code.

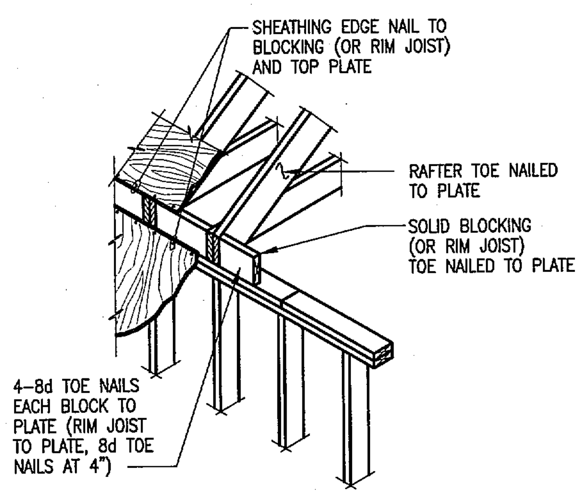
In order to form complete diaphragms, top plates of walls supporting roof diaphragms usually act as chords and/or collectors and should be continuous. The plates must be internailed and receive additional nailing in the lap length at splices. See Figure 85.

Top plates must provide continuity along the full widths and lengths of diaphragms. Roof sheathing must be nailed to rim joists parallel to framing or blocking inserted at the ends of the joists perpendicular to the walls, see Figure 86. Rim joists or blocking must be attached to the top plates. Prefabricated sheet metal framing clips can be used to secure rim joists or blocking to the plates.



TYPICAL TOP PLATE SPLICE

Figure 85



ROOF DIAPHRAGM CONNECTION TO SHEAR WALL

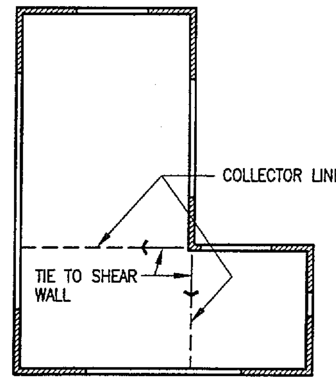
Figure 86

Earthquake forces in roof diaphragms can be delivered to shear walls that are outside the diaphragm limits by collectors that are connected to diaphragms. Collectors should run in straight continuous lines and be attached to the tops of shear walls. See Figure 87.

Collectors can be used to transfer earthquake loads developed in areas of roofs that project out from main roof diaphragms such as roofs or canopy projections over an open porch. Collectors or ties must be nailed to the projecting roofs and extend into and be nailed to the sheathing within the limits of the main roof diaphragms. See Figure 88.

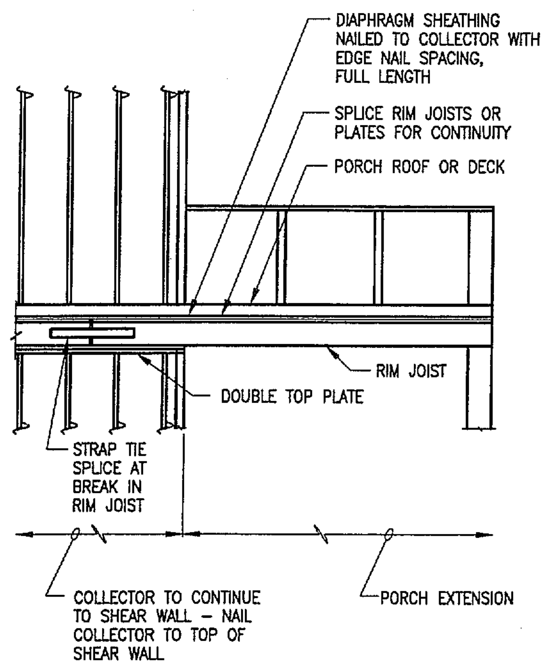
In high seismic risk areas, minimum nailing of roof sheathing should be in accordance with code requirements. Roof sheathing should be fastened with nails with a diameter equivalent to common or box nails. When using a nailing gun to fasten plywood or oriented strand board, care must be exercised to avoid overdriving the nails. The gun operator should also confirm that the nails penetrate the framing members below. A new nail should be driven for each nail not properly installed. Adhesive applied to rafters under roof sheathing is not conventionally used. However, as for floors, adhesives will stiffen roof diaphragms and improve their ability to withstand earthquake shaking.

Where architectural expression requires roof configurations not specifically covered in the Guide, the builder should consult a design professional.



PLAN

Figure 87



ELEVATION

TYPICAL COLLECTOR TIE AT PORCH EXTENSION

Figure 88

Some roof forms are not considered to be covered by the details included in this Guide. This does not imply that such forms cannot be made to be earthquake resistant. However, application of standard details shown in this Guide may not be appropriate and professional guidance is required. The following descriptions and illustrations show two forms not covered by the Guide.

1) Monitor or pop–up elevated portions of a roof that interrupt an otherwise complete diaphragm. See Figure 89. Monitor roofs are often supported on mullions with an all glass exterior and with no solid shear wall panels between roof levels.

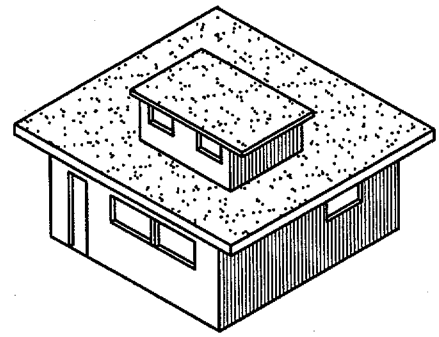
2) Shed dormers that extend over nearly the full length or width of a roof plane especially on the sloping faces of gable roofs or hip framing. See Figure 90.

Other roof configurations excluded from the Guide are roofs with the following characteristics:

1) Large square or rectangular openings in roof planes for skylights or light shafts especially at corners.

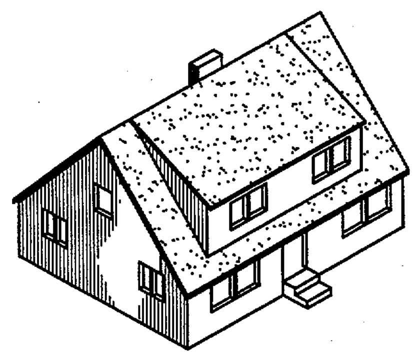
2) Large openings in roofs over central atria or interior patios where the courtyard walls have all glass exposure, or where there are only column supports for the framing above.

3) Discontinuities at ridges where the roof sheathing does not extend to the break in the roof planes.



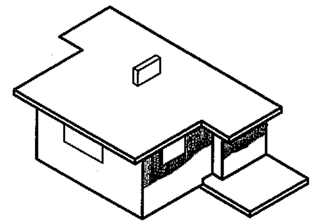
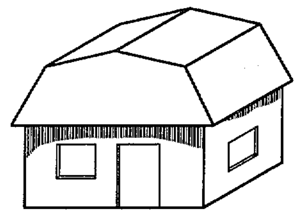
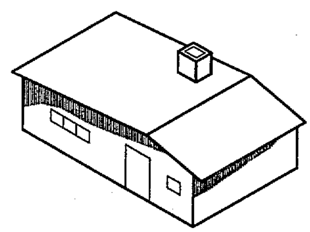
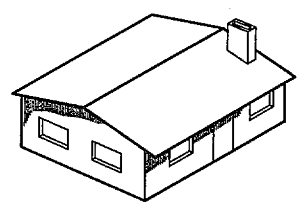
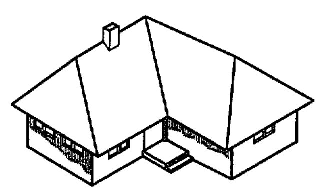
MONITOR ROOF

Figure 89



SHED ROOF

Figure 90

Table No. 4 Roof Shapes	
Flat Roof	
Mansard	
Shed Roof – Opposing Pitch	
Gable Roof	
Hip and Valley Roof	

10. MASONRY CHIMNEYS

Observations from the Northridge Earthquake as well as other earthquakes indicate that masonry chimneys, for reasons noted below, are not appropriate when used with light frame construction in high seismic risk areas unless properly reinforced, anchored and constructed. See Figure 91.

Masonry chimneys are usually heavy, rigid, brittle and may be highly susceptible to damage from earthquakes. Because of their weight and rigidity, they can become falling hazards and require special care when used with buildings such as wood framed structures in high and moderate seismic risk areas. See Figure 95a. When built monolithically with masonry buildings, chimneys will generally perform satisfactorily.

In high seismic risk areas, wood frame or steel stud framing for flue or chimney enclosures is recommended in lieu of masonry. See Figure 95b. Heavy finishes such as stone or masonry veneer should be avoided for chimneys where possible.

Where used, the dead load of the masonry should be supported independently on a substantial reinforced concrete spread footing or pad. A masonry chimney flue enclosure must have at least a minimum amount of horizontal and vertical reinforcing. The vertical reinforcing should run the full height without splices and each bar should be doweled to the footing. To prevent separation of the chimney from the building, anchor ties secured to the framing must be installed. These ties must be provided at every diaphragm level. See Figure 92. The ties must engage the diaphragm sheathing, be embedded in the masonry enclosure, and extend to and be bent around the vertical reinforcing on the far side of the chimney.

Minimum vertical reinforcing should consist of at least one vertical bar in each corner for chimneys of usual size. Chimneys that are large in plan may require more vertical reinforcing. Horizontal ties (at least #4 @ 18") should be placed around the vertical reinforcing. Sufficient grout space around the flue must be provided to fully embed the reinforcing. See Figures 92 and 93.

Vertical bars and ties must continue to the tops of the projection of chimneys above roofs. Grouting must also continue to the top and be continuous without interruption or voids.

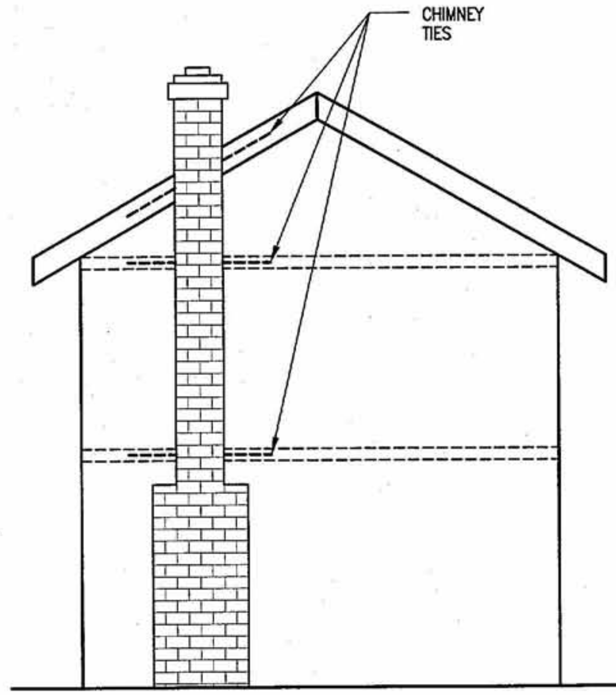


Figure 91

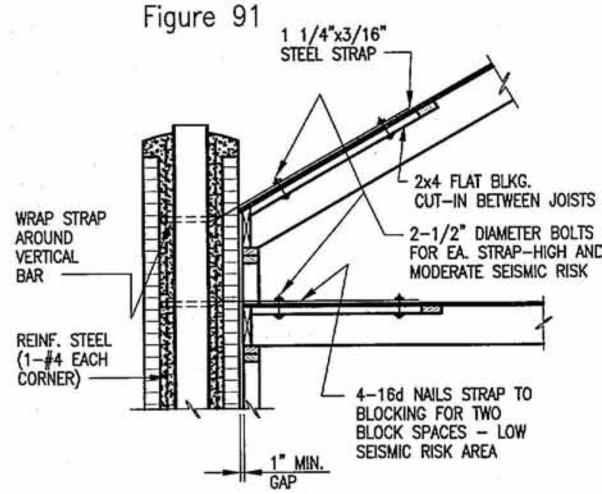


Figure 92

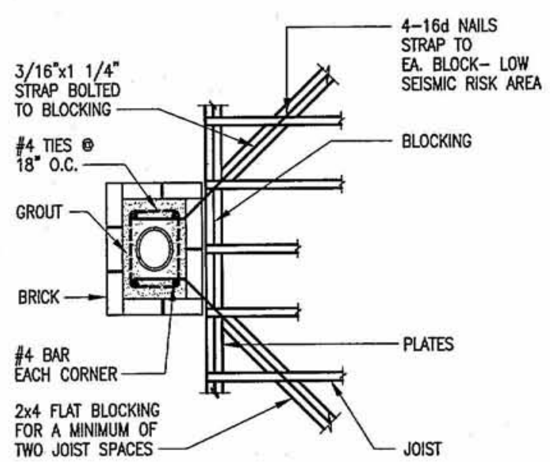


Figure 93

Strap anchors holding the chimneys transfer earthquake loads into the diaphragms. See Figures 92 and 93. Therefore, the straps should extend diagonally into the diaphragms and be bolted to the framing with 2–1/2" diameter bolts in high and moderate seismic risk areas. One strap should be located on each side of the chimney. Intermediate straps may be needed for large chimneys. The diaphragm sheathing should be nailed with 8–10d nails to the same member to which the strap is bolted. For low seismic risk areas, the straps may be nailed to the framing with 4–10d nails.

In the case of floor ties where the joists run at right angles to the straps, the straps should extend a minimum length into the diaphragm as follows:

High Seismic Risk – 4 joist spaces
Moderate Seismic Risk – 4 joist spaces
Low Seismic Risk – 2 joist spaces

When floor joists run parallel to the straps, the straps can be installed in the same manner as above or the straps may project from the face of the wall into the diaphragm and be bolted to the face of a joist or rafter.

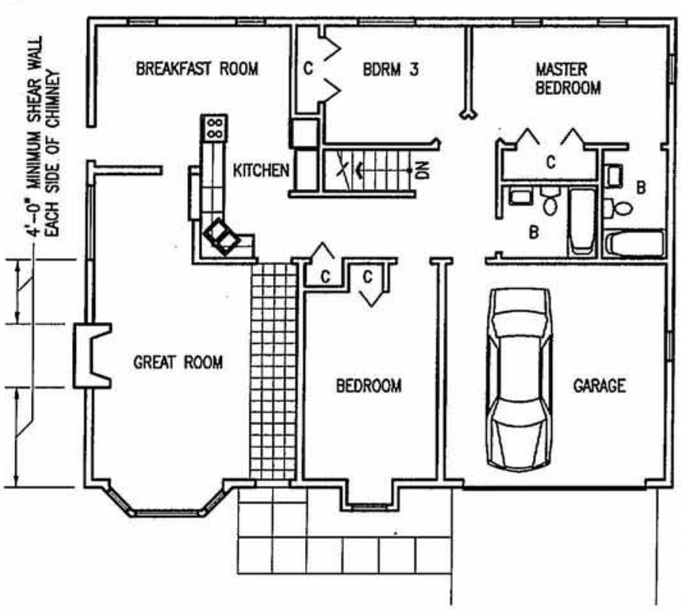


Figure 94

As noted before, anchor straps should be attached to each block as follows:

High seismic risk – 2–1/2" ø bolts
Moderate seismic risk – 2–1/2" ø bolts
Low seismic risk – 4–10d nails

Anchor straps prescribed by building codes have, at times, proven to be inadequate in earthquakes. For this reason it is important in high seismic risk areas to use only bolted straps or, better yet, to avoid masonry chimneys in favor of lighter weight chimney framing.

Because of the concentrated loads introduced into floor or roof diaphragms by earthquake loading from chimneys it is necessary to avoid openings in diaphragms near or adjacent to chimneys except as required for the flue or chimney structures. Openings should not occur adjacent to the anchor straps. Chimney openings in roof diaphragms should receive perimeter framing with edge nailing of the surrounding sheathing.

A minimum length of 4'–0" of shear wall should be located on each side of and immediately adjacent to a masonry chimney. See Figure 94. These walls should be solid sheathed without openings. Heavy veneers should not be attached to these shear walls. Chimneys that are reinforced and anchored in low seismic risk areas may not need adjacent shear walls, but better protection can be achieved if wall bracing is available in the walls adjacent to chimneys and windows or doors are avoided in the vicinity of chimneys.

Chimney loads will likely increase the forces in the adjacent shear walls. In narrow end walls, penetrations for windows or doors should be avoided or be kept to a minimum to provide as much solidly sheathed shear wall as is architecturally acceptable.

The UBC requires that every masonry chimney in high and moderate seismic risk areas be reinforced and anchored at each floor or ceiling line more than 6 feet above grade.