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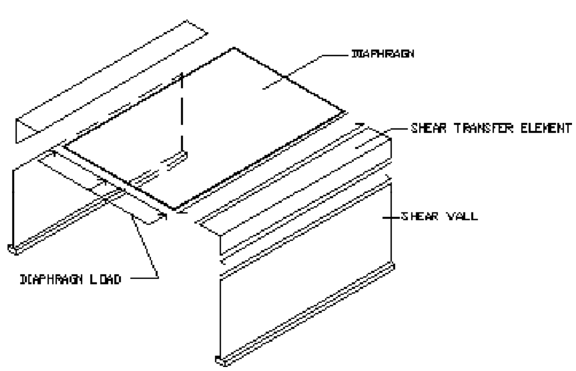
SHEAR TRANSFER AT TOP PLATE: DRAG STRUT DESIGN

Summary: This Tech Note discusses the design for shear transfer between diaphragms and the supporting vertical lateral force resisting system. Design requirements for drag struts at openings (interior and exterior) and at offset walls, and diaphragm chord and strut splices are covered. The design procedure presented is based on the requirement for a direct and positive load path to transfer forces.

Introduction

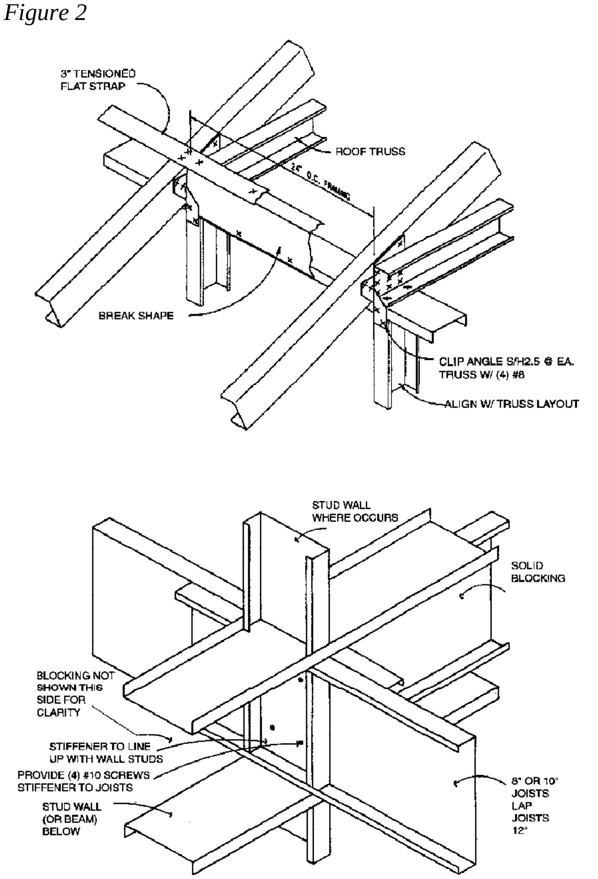
Design of horizontal diaphragms for lateral forces produced by wind or seismic activity depends on the connection between the diaphragm and the vertical lateral force resisting system (VLFRS). Figure 1 illustrates the distribution of forces for a simple diaphragm-shear wall system. The diaphragm is assumed to act as a thin, deep beam in flexure which is supported by the VLRFS. The skin (sheathing) of the diaphragm functions at the web of the beam (resisting shear, V) and the boundary elements of the diaphragm, perpendicular to the load, function as the beam's flanges (resisting the internal moment, M).

Distribution of loads in a diaphragm.
Figure 1

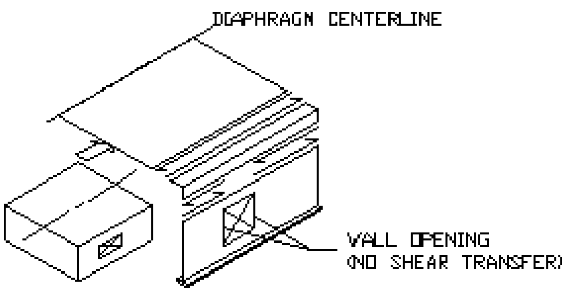


Different framing techniques may be used to transfer the shear, V, from the diaphragm to the wall. Figure 2 (*LGSEA Details Manual, 1996*) shows two possible framing mechanisms of load transfer. Note that in both of the cases shown in Figure 2, the blocking serves two purposes: (1) shear load transfer to the wall and (2) prevention of torsional instability of the joist or roof truss at the wall.

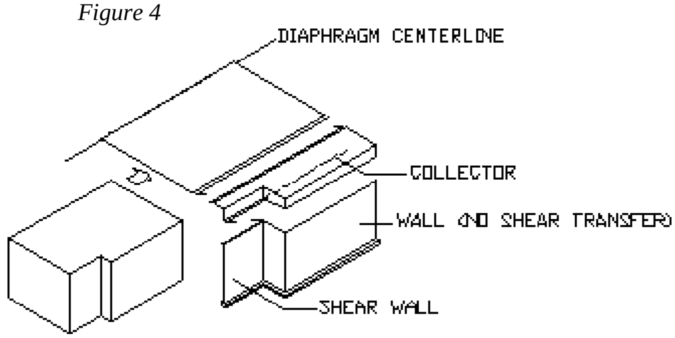
Typical blocking details for shear transfer
Figure 2



Load transfer in shear wall with opening
Figure 3



Load transfer in offset shear wall
Figure 4



Openings in walls (see Figure 3) may prohibit adequate transfer of diaphragm shear along the length of the wall above the opening (if not specifically accounted for in design). Thus, unless explicitly designed to transfer shear, the portion of the wall above the opening is typically assumed to provide no load transfer. In this case, to ensure the diaphragm shear is transferred to the wall, a drag strut (collector) is needed across the opening. A similar condition exists in diaphragms with plan irregularities where shear walls may be located in offset walls (see Figure 4).

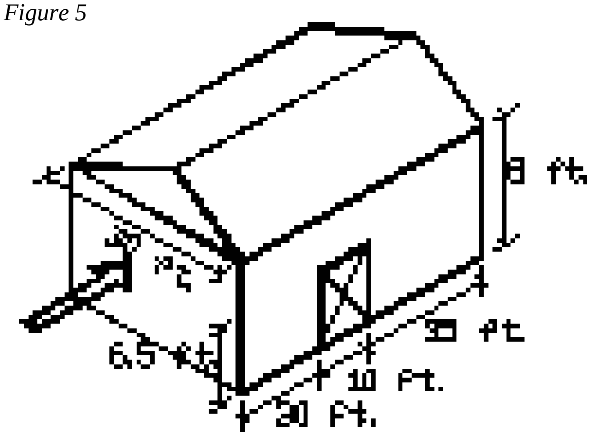
DESIGN EXAMPLES

In the following section, a design example is presented which illustrates some of the design considerations discussed above.

Design for shear transfer

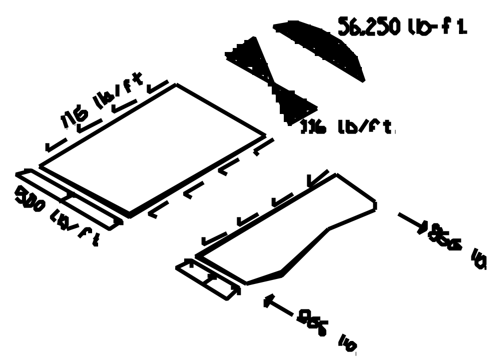
For the pitched roof structure shown in Figure 5, assume the design lateral load is 500 lb/ft. in the roof diaphragm (in the direction indicated). As discussed above, the sheathing is designed to transfer load to the struts and the chords resist the induced moment. The distribution of shear and the chord forces may be computed using principles of mechanics, as described below and illustrated in Figure 6.

Building system
Figure 5



Shear in the diaphragm varies from a maximum, v_{max}, at the longitudinal edge to zero at the center of the transverse length.

Distribution of loads in the diaphragm.
Figure 6



Thus, treating the diaphragm as a simply supported member, the maximum longitudinal shear, v_{max}, will be:

$$v_{max,roof} = \frac{500 \cdot 30}{2 \cdot 65} \cdot 1000 = 116\ lb/ft$$

The tension and compression chord forces (T_c and C_c, respectively), at the midspan of the transverse length may be computed as follows:

$$C_c = T_c = \frac{M_{max}}{65}$$

$$M_{max} = \frac{500 \cdot 30^2}{8} \cdot 1000 = 56{,}250\ lb-ft.$$

$$C_c = T_c = \frac{56{,}250}{65} = 866\ lb$$

Based on the above calculations, the attachment of the roof sheathing to the trusses and blocking at the longitudinal boundaries must be sufficient to transfer 116 lb/ft. This can be accomplished with 3/8-in. plywood sheathing attached with No. 8 x 1-1/4 in. screws at 6 in. on center—at supported panel edges and intermediate supports. In cases where the computed design shear is higher, the screw schedule and use of blocking must be modified in accordance with the computed shear force.

The top chords of the trusses or the rafters (including splices in these members) at the transverse ends of the diaphragm, must be designed to resist the induced tension and compression equal to 866 lb. (ASD).

Interior and exterior drag struts (collectors)

Shear transfer from the roof sheathing to the wall is achieved by attachment of the roof sheathing to the trusses and blocking along the wall, then from the trusses and blocking to the top of the wall. In the wall, if the sheathing above the opening is assumed to transfer no shear, the design load across the top plate will be: v_{roof} = 116 lb/ft. and v_{wall} = 137 lb/ft. (see calculation below).

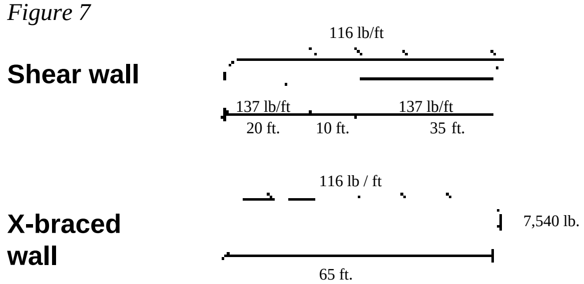
$$v_{wall} = \frac{v_{roof} \bullet 65}{55} = 137 \text{ lb/ft.}$$

If flat strap X-bracing is used instead of a shear wall, resistance at the top plate provided by the X-bracing will be at a discrete point or at discrete points (if multiple braces are used). In this example, assuming a single X-brace, at the point where the strap is attached, the top plate must be designed for a concentrated load of 7,540 lb.

$\left(v_{roof} \bullet 65 \text{ ft.} \right)$, as illustrated in Figure 7.

Distribution of load across the top plate

Figure 7



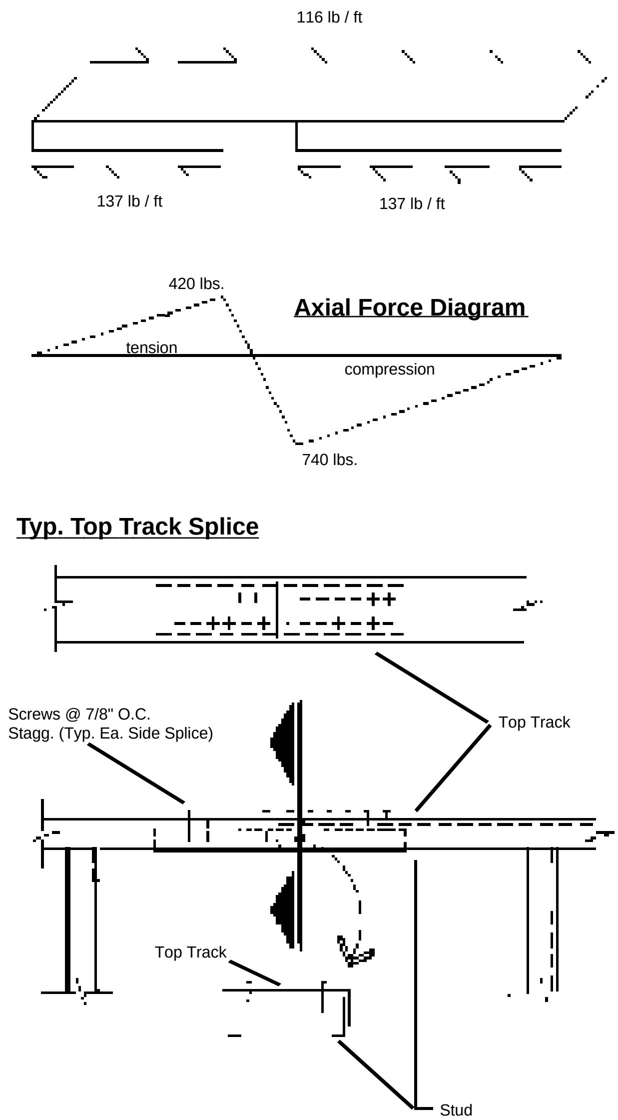
For the shear wall load distribution shown in Figure 7, the top plate between the shear wall resisting elements must be designed for a strut force of 740 lb.

$\left(\left(116 \; lb/ft \bullet 30 \; ft \right) - \left(137 \; lb/ft \bullet 20 \; ft \right) \right)$,

as illustrated in the axial force diagram in Figure 8, for the case where the diaphragm load is in the longitudinal direction.

Distribution of load in top plate across the opening

Figure 8

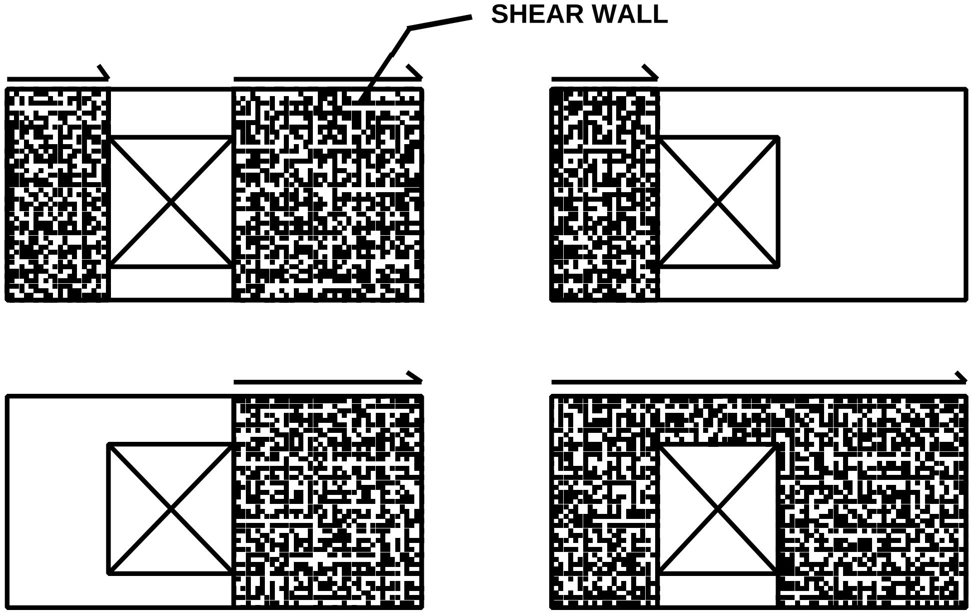


Where blocking is used to transfer the diaphragm shear, the blocking also provides flexural and torsional stability to the track. Thus, the track capacity may be calculated based on the effective section properties at the yield strength of the material. Assuming 33 ksi steel is used, a 3-1/2 in., 20 gauge flanges will be adequate for this application.

The designer must ensure that any splices or holes in the web of the top plate are accounted for in design. Holes cut in the top plate for utilities may cause premature tensile or compressive failure of the diaphragm struts and must be check by the designer.

Alternative shear wall configurations and distribution of load at top plate

Figure 8.



References

1. LGSEA (1996). "One- and Two-Story Light Gauge Steel Framing Details", Nashville, TN, July.
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