

# DESIGN OF SINGLE DEEP LEG TRACK TO ACCOMMODATE VERTICAL DEFLECTION

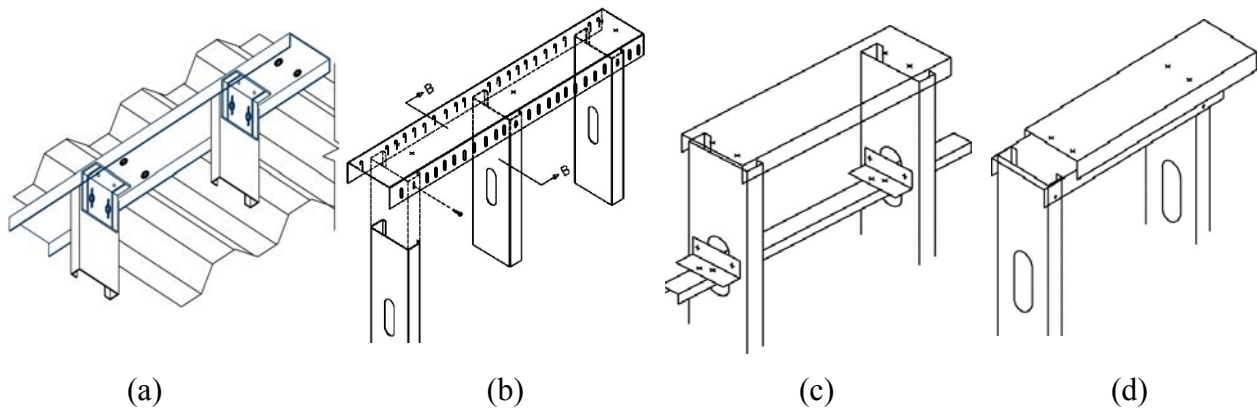
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## INTRODUCTION

Allowing vertical deflection of the floor system at the head of wall due to live loads is required in light steel framing interior and exterior non-load bearing walls. This allowance ensures the isolation of the wall from the primary structure, without transfer of axial live load to the studs. Such a connection can be achieved in several ways:

- Slotted clip angle connected to the stud and the head-of-wall track (Figure 1-a).
- Slotted track connected to the stud (Figure 1-b).
- Single deep leg track with no attachment to the stud (Figure 1-c).
- Double track assembly with no attachment of the inside track to the outside one (Figure 1-d).

This technical note gives emphasis on design of the single deep leg track for strength and deformation requirements. The note shows that the method of matching the track thickness to the corresponding stud thickness may not be valid in many cases. The note also clarifies the design checks needed when using the deep leg track.



**Figure 1:** Vertical deflection connections at head-of-wall

## DESIGN OF SINGLE DEEP LEG TRACK

### Design for Strength

*Procedure 1:* The Army Corps of Engineers adopted a procedure (TI 809-07 superceding ETL 1110-3-439) which provides a methodology to calculate the thickness on the track based on an effective width  $b_{eff}$  of the track leg. This procedure, using the Allowable Stress Design (ASD) Method, can be summarized as follows:

- Design deflection gap  $e$  = distance between stud web at end of stud and track web
- Minimum engagement between stud and track = 1.25 in. (preferably 1.5 in.)
- Minimum track leg size =  $e + 1.5''$ .

Based on the stress distribution assumption in the leg plate of the track shown in Figure 2, the effective width of the track leg in plate bending  $b_{eff}$  is given by:

$$b_{eff} = w_{stud} + 2 \left[ \frac{e + 1.5''}{\tan(30^\circ)} \right] \leq S \quad (1)$$

where:

- $w_{stud}$  = flange width of the stud (in.).
- $S$  = spacing between studs (in.).

By equating the required moment capacity  $M_{req}$  and the allowable moment capacity  $M_{all}$  of the track leg, the track thickness  $t$  can be calculated as follows:

$$M_{all} \geq M_{req}$$

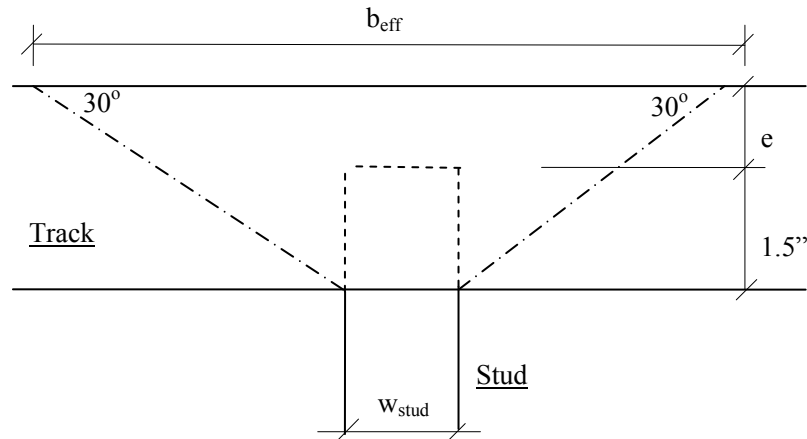
$$\frac{1}{6} b_{eff} t^2 (0.6 F_y) \geq \omega P \cdot e$$

$$t \geq \sqrt{\frac{10 \omega P e}{b_{eff} F_y}} \quad (2)$$

where:

- $P$  = maximum reaction at the top of the stud (kips).
- $F_y$  = minimum yield strength of the track material (ksi).
- $\omega$  = wind/seismic load reduction factor. Load standards (e.g. IBC 2003, Sec. 1605.3.1, and UBC 97, Sec. 1612.3.1) require  $\omega = 1.0$  for a dead plus wind load combination without any increase in allowable stresses.

The same design-for-strength procedure can be followed when designing the outer track of a double track assembly (Figure 1-d), except that the effective width  $b_{eff}$  is allowed to be taken equal to the stud spacing  $S$ .



**Figure 2:** Stress distribution in track leg plate

Procedure 2: In 2004, the American Iron and Steel Institute (AISI) published a new Standard for Wall Stud Design that includes another design methodology, based on ultimate strength design, to estimate the strength of the track when subjected to a transverse load. The method proposes the following equation to calculate the nominal strength of the track  $P_{ndt}$ :

$$P_{ndt} = \frac{b_{eff} t^2 F_y}{4e} \quad (3)$$

The expression for the effective width of the track leg  $b_{eff}$  is derived through correlation of the test results with the above equation, and is given as:

$$b_{eff} = 0.11 \left( \frac{e^{0.5}}{t^{1.5}} \right) + 5.5 \leq S \quad (4)$$

By applying the proper safety factor, Equation 3 can be used to estimate the track thickness  $t$  for ASD Method in a similar manner to Equation 2 as follows:

$$t \geq \sqrt{\frac{2.8\omega P(4e)}{b_{eff} F_y}} = \sqrt{\frac{11.2\omega P e}{b_{eff} F_y}} \quad (5)$$

Notice that the effective width of the track leg  $b_{eff}$  in Equation 4 is a function of the track thickness  $t$  and the design gap  $e$ , while in Equation 1 it is a function of the stud flange width  $w_{stud}$  and the design gap  $e$ .

### Design for Deformation

Both Procedures 1 and 2 for strength design don't give a complementary method to check track deflection. In this section, it is presented that deformation of the track leg due to the reaction at the top of the stud can be calculated in a simple form.

If the fasteners are spaced uniformly between studs, with spacing equal to stud spacing  $S$ , the total deformation of the track leg consists of 3 parts as follows (model illustrated in Figure 3):

- Deformation of the track  $\Delta_1$  between fasteners to the structure (typically insignificant and can be ignored).
- Deformation of the track leg  $\Delta_2$  due to rotation  $\theta$  of track web.
- Deformation of the track leg  $\Delta_3$  by bending.

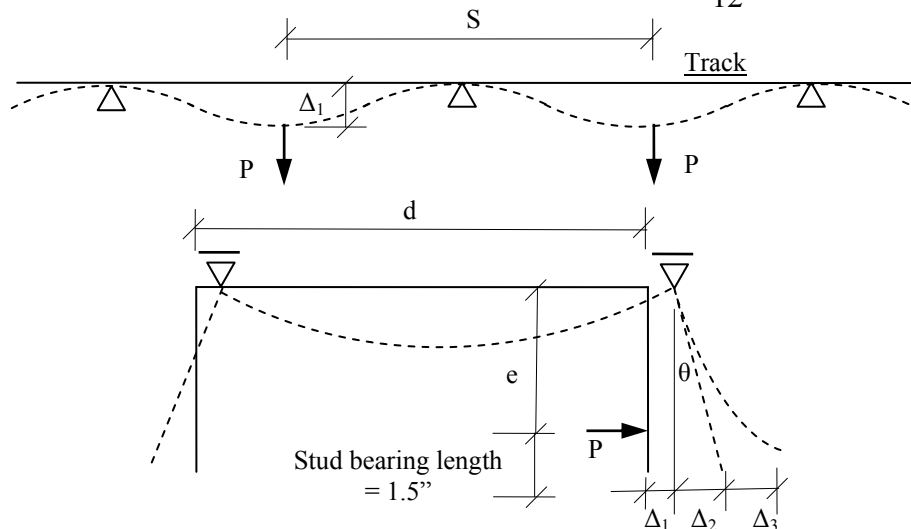
Based on the model in Figure 3, an expression for the total deformation  $\Delta_{Total}$  can be given as:

$$\Delta_{Total} = \Delta_2 + \Delta_3 = \theta(e + 1.5'') + \left[ \frac{Pe^3}{3EI_p} + \frac{1.5''Pe^2}{2EI_p} \right]$$

$$\Delta_{Total} = \frac{Ped}{3EI_p}(e + 1.5'') + \frac{Pe^2}{3EI_p}(e + 2.25'') \quad (6)$$

where:

- $E$  = modulus of elasticity of material (equals to 29,500 ksi).
- $I_p$  = moment of inertia of the track leg plate only (in.<sup>4</sup>), (equals to  $\frac{1}{12} b_{eff} t^3$ ).



**Figure 3:** Deformation model for the track

The total deformation of the track leg  $\Delta_{Total}$  should not exceed a serviceability limit value. This limit is normally set as 1/8 in. at edge of track for walls with wood or gypsum board sheathing. A lesser value may be considered for brick veneer walls to limit possible cracking of the wall.

### Sample Design Table

Table 1 shows a generated sample design chart for a deep leg track to accommodate floor deflection. The table uses the AISI Wall Stud Design Standard strength procedure and the proposed deformation method. The input data for the table are; design wind pressure, wall height, stud spacing, and design deflection gap. The output data are; the minimum thickness and the minimum leg size of the track. The table is generated using the following assumptions:

- Yield strength of track material = 33 ksi.
- Wind/seismic load reduction factor  $\omega = 1.0$ .
- Stud and track depth = 6.0 in.
- Stud flange width = 1.625 in.
- Deformation limit for leg of track = 1/8 in.

### **CLOSING REMARKS**

Table 1 shows that the resulting thickness of a single deep leg track when used to allow for floor vertical deflection is practical (33 to 54 mils) in case of low wind pressure and relatively short walls. However, the table shows the need for thicker tracks (68 mils and up) for curtain wall conditions (wind pressure 20 psf and up) and/or taller walls. Some limitations exist on the use of the single deep leg track when design gap reaches 1.0 in. and wall height exceeds 15 ft. Moreover, the following design issues need to be considered by the design professional:

- **End rotation restraint of stud:** AISI Specification, Sec. D4, requires that studs need to be restrained from rotation about its longitudinal axis at their ends. This can be achieved by using a row of bridging within 12-18 in. of the stud end.
- **Web crippling of stud:** Crippling of stud web needs to be checked as reaction is transferred to the track by bearing against track leg.
- **End of track condition:** Caution is needed when a stud is at or near the end of the deep leg track since the effective width resisting load and deformation is reduced. This condition occurs frequently as tracks are typically supplied in 12 ft. length segments. It can also occur when full height windows are used by the architect so that a top track is stopped at the edge of each window.
- **Movement in-plane of wall:** In seismic-active areas, standards require a minimum of 1/2 in. in-plane movement of the stud at the head of exterior walls (e.g. IBC 2003, Sec. 1621.1). As temporary screwing is usually used at this connection during construction, care must be given to ensure removal of the screws after completion of construction to allow for the in-plane movement.

**Table 1:** Generated sample design chart for a 6.0 in. deep leg track to accommodate floor deflection

Wind Pressure		5 psf		20 psf				30 psf				40 psf				50 psf			
Stud Spacing		24" o.c.		16" o.c.		24" o.c.		16" o.c.		24" o.c.		12" o.c.		16" o.c.		12" o.c.		16" o.c.	
Design Gap		0.5"	1"	0.5"	1"	0.5"	1"	0.5"	1"	0.5"	1"	0.5"	1"	0.5"	1"	0.5"	1"	0.5"	1"
Wall Height (ft.)	9	33m/2"	33m/2½"	43m/2"	54m/2½"	54m/2"	97m/2½"	54m/2"	97m/2½"	68m/2"	97m/2½"	54m/2"	97m/2½"	68m/2"	97m/2½"	68m/2"	97m/2½"	97m/2"	118m/2½"
	12	33m/2"	<u>43m/2½"</u>	43m/2"	68m/2½"	68m/2"	97m/2½"	68m/2"	97m/2½"	97m/2"	118m/2½"	68m/2"	97m/2½"	97m/2"	118m/2½"	97m/2"	118m/2½"	118m/2"	N/A
	15	33m/2"	<u>43m/2½"</u>	54m/2"	97m/2½"	97m/2"	118m/2½"	97m/2"	118m/2½"	97m/2"	N/A	97m/2"	118m/2½"	97m/2"	N/A	97m/2"	N/A	N/A	N/A
	18	33m/2"	<u>54m/2½"</u>	68m/2"	97m/2½"	97m/2"	118m/2½"	97m/2"	118m/2½"	118m/2"	N/A	97m/2"	118m/2½"	97m/2"	N/A	97m/2"	N/A	N/A	N/A
	21	<u>43m/2"</u>	54m/2½"	68m/2"	118m/2½"	97m/2"	N/A	97m/2"	N/A	118m/2"	N/A	97m/2"	N/A	118m/2"	N/A	118m/2"	N/A	N/A	N/A
	24	<u>43m/2"</u>	54m/2½"	97m/2"	118m/2½"	97m/2"	N/A	97m/2"	N/A	N/A	N/A	97m/2"	N/A	118m/2"	N/A	118m/2"	N/A	N/A	N/A

**Notes:**

- Table is based on the AISI Wall Stud Design Standard strength procedure and the proposed deformation method.
- Underlined cells indicate that design is controlled by deflection.
- Yield strength of track material = 33 ksi
- Wind/seismic load reduction factor  $\omega = 1.0$
- Deformation limit for leg of track = 1/8 in.
- Stud and track depth = 6.0 in.
- Stud flange width = 1.625 in.

**REFERENCES**

- American Iron and Steel Institute (2004), "Standard for Cold-Formed Steel Framing- Wall Stud Design", AISI/COFS/WSD-2004, Washington, DC.
- American Iron and Steel Institute (2002), "Cold-Formed Steel Framing Design Guide", AISI Design Guide CF02-1, Washington, DC.
- American Iron and Steel Institute (2001), "North American Specification for the Design of Cold-Formed Steel Structural Members", AISI Standard, 2001 Edition, Washington, DC.
- American Society for Civil Engineers (2002), "Accommodating Building Deflections", ASCE-SEI Committee on Cold-Formed Steel.
- International Code Council (2003), "International Building Code", ICC Standard, 2003 Edition, Virginia.
- International Conference of Building Officials, "Uniform Building Code", ICBO Standard, 1997 Edition, California.
- US Army Corps of Engineers (1998), "Design of Cold-Formed Load-Bearing Steel Systems and Masonry Veneer/Steel Stud Walls", Technical Instructions TI 809-07, Washington, DC.
- Steel Stud Manufacturers Association (2000), "Single Deflection Track Selection", SSMA Technical Note.