I-1 SUSPENDED CEILING BRACING

a. Introduction.

(1) Purpose. The purpose of this example problem is to illustrate the design of suspended ceiling bracing using Chapter 10 of this manual, and Chapter 6 of FEMA 302 (Components). Suspended ceiling systems without adequate lateral bracing have collapsed in a number of earthquakes causing injury to building occupants and disruption of safe egress and building function.

(2) Scope. The problem follows the steps in Tables 4.5 and 4.6 to analyze the ceiling bracing and anchors. Typical ceiling bracing details found in Figure 10-4 are inadequate for immediate occupancy in high seismic zones.

b. Component description.

The ceiling used in this example problem is suspended from a roof framing system consisting of steel joists and metal decking. The ceiling and equipment laterally supported by the ceiling, such as light fixtures and HVAC registers, are required to function after an earthquake.

c. Component design.

A.1 *Determine appropriate Seismic Use Group*

Due to the requirement that the ceiling and associated equipment must be functional after an earthquake, the ceiling and attachments are given a performance level of immediate occupancy (IO). The Seismic Use Group and other performance parameters are determined from Table 4-4, as follows;

Performance Level:	IO	(per problem statement)
Seismic Use Group:	IIIE	(Table 4-4)
Ground Motion:	3/4 MCE (B)	(Table 4-4)
Performance Objective:	3B	(Table 4-4)

A.2 *Determine site seismicity.*

The following value is assumed for this example:

$S_S = 1.50g$ (MCE Maps)

A.3 *Determine site characteristics.*

Soil type D is assumed for this problem

Soil type: D (Table 3-1)

A.4 *Determine site coefficients.*

$F_a = 1.0$ (Table 3-2a)

A.5 *Determine adjusted MCE spectral response accelerations.*

$S_{MS} = F_a S_S = 1.0(1.50)g = 1.50g$ (EQ. 3-1)

A.6 *Determine design spectral response accelerations.*

$S_{DS} = 3/4\ S_{MS} = 3/4(1.50) = 1.125g$ (EQ. 3-3)

A.7 *Bracing system.*

Assume that the suspension system consists of 5 wires; one vertical and four inclined at 45 degrees. Inclined wires are oriented parallel and perpendicular to the direction of the steel deck flutes as shown in Figure I1-2.

A.8 *Select R_p, a_p, and I_p factors.*

$a_p = 1.0$ (Table 10-1)
$R_p = 2.5$ (Table 10-1)
$I_p = 1.5$ (per Paragraph 10-1d)

A.10 *Determine member sizes for gravity load effects.*

Vertical hanger wire design;
Assume suspension system is placed at 12-ft. (3.66m) on center each way. Assume actual load is 3.5-lbs. per square foot (0.17KN/m), but must use the minimum value of 4-lbs. per square foot (0.19KN/m) per Paragraph 10-2d(4).

$W_p = 4psf(12')12' = 576\text{-lb}$ (2.56KN)

Use #8 galvanized soft steel wire (ASTM A651)

$f_u = 70ksi$ (482.7MPa)
$f_y = 50ksi$ (344.8MPa) (assumed) use $f_{allow} = f_y = 50ksi$ (344.8MPa)
$A_s = 0.0206\text{-in}^2$ (13.3mm^2)

Determine factored loads for gravity load effects;

$P_u = 1.4D$ (ANSI/ASCE 7-95)
$P_u = 1.4(576\text{-lb}) = 806\text{-lb-tension}$ (3.59KN)

Therefore,
$f_s = P_u/A_s = 806\text{-lb}/0.0206\text{-in}^2 = 39.1ksi < 50ksi = f_{allow}$ (269.6MPa < 344.8MPa) **O.K.**

Note: Table 4-6 was created as an aid for building design and is not entirely applicable in the design of nonstructural systems and components. The following steps are based on the intent of this document, and do not have a one to one correspondence to steps as listed in Table 4-6.

F.1 *Determine seismic force effects.*

Seismic forces (F_p) shall be determined in accordance with Chapter 10 as follows:

$$F_p = \frac{0.4a_p S_{DS} W_p}{R_p / I_p}\left(1 + 2\frac{z}{h}\right) \quad \text{(EQ. 10-1)}$$

where; $z/h = 1.0$ (assumed at the top story)

F_p is not required to be greater than:

$$F_p = 1.6 S_{DS} I_p W_p \quad \text{(EQ. 10-2)}$$

nor less than:

$$F_p = 0.3 S_{DS} I_p W_p \quad \text{(EQ. 10-3)}$$

$$F_p = \frac{0.4(1.0)1.125(576-\text{lb})}{2.5/1.5}(1+2(1)) = 0.81(576-\text{lb}) = 467-\text{lb} \quad (2.07KN)$$

$$(F_p)_{max} = 1.6(1.125)1.5(576-\text{lb}) = 1{,}555-\text{lb} > 467-\text{lb} = F_p \quad (6.92KN > 2.07KN)$$ **O.K.**

$(F_p)_{min} = 0.3(1.125)1.5(576 - lb) = 292 - lb < 467 - lb = F_p \quad (1.30KN < 2.04KN)$ **O.K.**

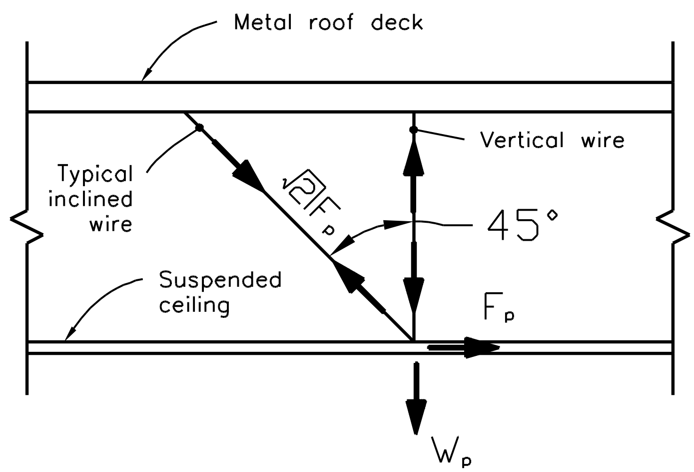


Figure I1-1. Force diagram for bracing wires

F.2 *Design members.*

Inclined wires;
Tension in inclined wire $= \sqrt{2}F_p = 660 - lb \quad (2.94KN)$ (see Figure I1-1)
Since only lateral loads are acting in the inclined wires all load combinations reduce to;

$Q_u = 1.0E = 1.0F_p = 660\text{-lb}$ (2.94KN)
(ANSI/ASCE 7-95)

Use #10 galvanized soft steel wire (ASTM A651)

$f_u = 70ksi$ (482.7MPa)
$f_y = 50ksi$ (344.8MPa) (assumed) use $f_{allow} = f_y = 50ksi$ (344.8MPa)
$A_s = 0.0143\text{-in}^2$ ($9.23mm^2$)

$f_s = Q_u/A_s = 660\text{-lb}/0.0143\text{-in}^2 = 46.2ksi < 50ksi = f_{allow}$ (318.5MPa < 344.8MPa) **O.K.**

Vertical wires;
Dead load on the wire was previously calculated as $W_p = 576\text{-lb}$ (2.56KN). The ability of the dead load to keep the wire taught is to be checked.

$Q_u = 0.9D + 1.0Q_E = 0.9(-576\text{-lb}) + 467\text{-lb} = -51\text{-lb-tension}$ (0.23KN) **O.K.**

Connections;
A L2X2X3/16X1’-3” (L50.8mmX50.8mmX4.8mmX0.38m) angle is used to transfer load to the steel deck. Angle is to be welded to at least two flutes of the deck as shown in Figure I1-2. The worst case loading is due to gravity load effects acting alone and was calculated as $P_u = 806\text{-lb}$ (3.59MN). It is decided to weld to each flute using 2-in. by 1/8-in. (50.8mmX3.2mm) fillet welds as shown (total weld length is 8-in. (203.2mm)).

Check capacity of welds;

$$A_{eff} = \frac{0.125-in}{\sqrt{2}} = 0.088-\frac{in^2}{in}$$

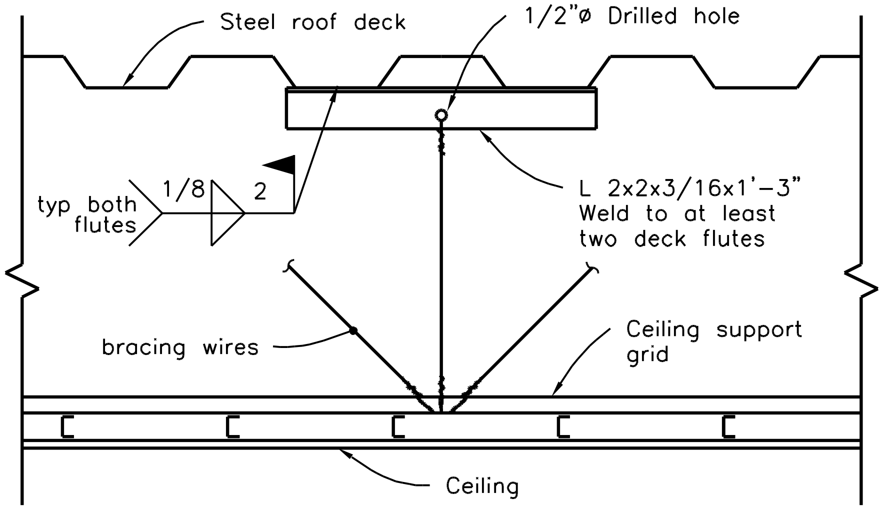
Use E70 electrodes: f_{exx} = 70ksi (482.7MPa)

Therefore,

$Q_E = \phi(0.6)f_{exx}(A_{eff})$ x (the total length of welds)

$Q_E = 0.75(0.6)70ksi(0.088\text{-}in^2)8" = 22.3^k > 0.806^k$ (99.2KN > 3.59KN) **O.K.**

Note: Connections are overdesigned, but required to distribute forces to the steel deck.



Note: For metric equivalents; 1-in = 25.4mm, 1-ft = 0.30m

Figure I1-2. Wire support and bracing system