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Title
MUON SHIELDING: DOOR HARDWARE STRUCTURAL CALCULATIONS

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THE "DOORS" ARE RESTRAINED AT THE BOTTOM
BY THE FLOOR CHANNELS & SEISMIC STOPS AND AT
THE TOP BY THE DOOR HANGERS WHICH ATTACH TO
THE FIXED FRAME OR SUPERSTRUCTURE

CALCULATIONS SHOW THAT, FOR A .7g EARTHQUAKE,
THE STRESSES IN THE ATTACHMENT HARDWARE
ARE WITHIN THE ALLOWABLE VALUES SPECIFIED
BY AISC.
LARGE DOOR

DOOR WEIGHT = 78.5 k

MUON CHAMBERS = 11.1 k @ 10 lb/ft²

HARDWARE = 2.0 k

\[
91.6 \geq 92 \text{ k} = W
\]
**Small Door**

Door Weight = \( 54.5\, \text{kN} \)

Muon Chambers = \( 7.0\, \text{kN} \) @ 1012/ft²

Hardware = \( 2.0\, \text{kN} \)

\[
\frac{63.5}{64} = W
\]
LOAD ACTING ON LARGE DOOR C.S ALONG BEAM LINE IS DUE TO EARTHQUAKE AND PEP-Q MAGNET

\[ F_2 = EARTHQUAKE \]
\[ = 0.7(9.8) \quad = 64.4 \text{kN} \]

FORCES AT TOP \( F_t \) AND BOTTOM \( F_b \) OF DOOR

\[ F_t = \frac{148.3}{311.5} \quad P = 0.48P \quad 0.48(64.4) = 31\text{kN} \]

\[ F_b = 0.52P \quad 33.5\text{kN} \]

FORCE ACTING ON WEST ROLLER \( F_{bw} \) 

\[ F_b \]
\[ F_{bw} = \frac{625}{111.5} \quad F_b \quad 0.56F_b \quad 0.56(33.5) = 18.8\text{kN} \]

\[ F_{be} = 0.44F_b \quad 14.7\text{kN} \]

FORCE ACTING ON WEST HANGER \( F_{tw} \)

\[ F_t \]
\[ F_{tw} = 50F_t \quad 80.5 \quad 0.62F_t \quad 0.62(31) = 19.2\text{kN} \]

\[ F_{te} = 0.38F_t \quad 11.8\text{kN} \]
LOAD ACTING ON SMALL DOOR C.G. ALONG BEAM LINE IS DUE TO EARTHQUAKE AND PEP-9 MAGNET.

\[ P_2 = \text{EARTHQUAKE} = 0.7 \times 64 \text{k} = 45 \text{k} \]

**Forces at Top Ft and Bottom Fb of Door**

\[ F_t = \frac{1569 \text{(P)}}{311.5} = 50 \text{P} \]

**Earthquake**

\[ F_t = 22.5 \text{k} \]

\[ F_b = 50 \text{P} \]

**Earthquake**

\[ F_b = 22.5 \text{k} \]

**Force acting on West Roller Fbw and East Roller FeE**

\[ F_{bw} = 26.4 \frac{F_b}{58.25} \]

**Earthquake**

\[ F_{bw} = 14.5 \frac{F_b}{58.25} \]

\[ F_{bw} = 10.1 \text{k} \]

\[ F_{bw} = 55 \frac{F_b}{58.25} \]

\[ F_{bw} = 12.4 \text{k} \]

**Force acting on West Hanger Ftw and East Hanger Fte**

\[ F_{tw} = 34.6 \frac{F_t}{71.5} \]

**Earthquake**

\[ F_{tw} = 48 \frac{F_t}{71.5} \]

\[ F_{tw} = 10.3 \text{k} \]

\[ F_{tw} = 52 \frac{F_t}{71.5} \]

\[ F_{tw} = 11.7 \text{k} \]
FORCES IN X DIRECTION (PERPENDICULAR TO BEAM)

LARGE DOOR

\[ P_x = \text{EARTHQUAKE} = 0.7(92k) = 64.4 \, k \]

Find force at top \( F_{Tx} \) for \( R_2 = 0 \) (to keep door from lifting \( R_2 \))

\[ \sum F_x = F_{Tx} + F_{Bx} = P_x \]
\[ F_{Bx} = P_x - F_{Tx} = 64.4 - 16.2 = 48.2 \, k \]

Or \[ \frac{R_1}{W} = \frac{24.1 \, k}{192 \, k} \]

\[ R_1 = W = 92k \]

Rollen has so\'t capacity

SMALL DOOR

\[ P_x = \text{EARTHQUAKE} = 0.7(64k) = 45k \]

Find \( F_{Tx} \) so \( R_1 = 0 \)

\[ \sum F_x = P_x - R_2 - F_{Tx} = 0 \]
\[ F_{Tx} = \frac{P_x (156.9) - 26.4(W) - (311.5 \, k)}{311.5} \]
\[ = 17.2 \, k \]

\[ \sum F_x = F_{Bx} = P_x - F_{Tx} = 45 - 17.2 = 27.8 \, k \]

Or \[ \frac{R_2}{W} = \frac{13.9 \, k}{64 \, k} \]

\[ R_2 = W = 64 \, k \]
SEE PREVIOUS PAGE P 1965984 FOR CHANNEL LAYOUT

CHECK CHANNEL ATTACHMENT TO FLOOR

CHECK WORST CASE

DOORS CLOSED

SMALL DOOR WEST ROLLER AND LARGE DOOR EAST ROLLER

\[ F_{sw} = 10.1 \quad F_{sw} = 14.7 \]

\[ F_1 = \frac{F_{sw} (1.5) + F_{sw} (4.75)}{48} \]

\[ = \frac{1}{3} (14.7) + 1 (10.1) = 15.0 \text{ k} \]

\[ F_2 = F_{sw} + F_{sw} - F_1 \]

\[ = 14.7 + 10.1 - 15 = 9.8 \text{ k} \]

ALLOWABLE = 21 k

FROM PREVIOUS PAGE

CHECK CHANNEL BENDING

\[ M = \frac{F_{sw} (0.5) (4.75) + F_{sw} (1.0)(3)}{48} = \frac{10.1 (1.5)(4.75) + 14.7 (1.0)(3)}{48} \]

\[ = 161 \text{ k-ft} \]

\[ \theta = \frac{M s}{2 a.7} = \frac{161 \text{ k-ft}}{20.7} = 7.8 \text{ ksi} \]

ALLOWABLE = 21.6 ksi

FROM PREVIOUS PAGE

0 k
CHECK ROLLER ATTACHMENT TO DOOR

MAX FORCE = EARTHQUAKE IN X DIRECTION FOR LARGE DOOR (PAGE 6)

\[ \text{Max Force} = 24.1 \text{k} \]

2 in. Dia Pin 1018 Cold Rolled

\[ F_u = 65 \text{kpsi}, \quad \tau_u = 0.65F_u = 42.2 \text{kpsi} \]

\[ F_y = 55 \text{kpsi} \]

TOTAL WELD LENGTH

\[ 10 + 10 + 7 + 7 = 34 \text{ in} \]

20C1836 ROLLER DAMPER (RUBBER)

1-6" UNC 4 PL

20C1836 SOUTH LARGE DOOR ASSY

10X30 CHANNEL

20C1856

100 T HILLMAN ROLLER

CHECK SHEAR ON 2 IN. DIAM PIN

\[ A = 3.14 \text{ in}^2 \]

\[ \tau_u = \frac{24.1 \text{k}}{3.14 \text{ in}^2} = 7.6 \text{kpsi} \]

\[ F_s = 5 \]

2 IN. PIN FITS INTO NEMA G-10 INSULATING BUSHING BEARING ON BUSHING

\[ \text{Bearing} = \frac{24.1 \text{k}}{2 \text{in} \times 0.75 \text{in}} = 16 \text{kpsi} \]

\[ F_s = 3.8 \]

COMPRESSIVE STRENGTH

NEMA G-10

\[ 60 \text{kpsi} \]
Weld shear stress roller mounting bracket
to "door"

\[
\text{Shear} = \frac{24.1k}{5in \times 34in} = 1.4 \text{ksi}
\]

Allowable =

\[
= 0.4 \times F_y = 0.4(16 \text{ksi}) = 10.4 \text{ksi}
\]

Roller to channel seismic stop - parallel to channel

20C2114 door lower seismic Assy

F = Earthquake = 24.1 k

3-8 UNC bolts, 4 per side

A-307 allow = 1.33 x 7.8 k = 10.3 k

10x30 channel

1.0x3 slot 1/4 fillet all around

Weld allowable = 2.5 k/in x 6 slots x 7 in/slot = 105 k

Bolt allowable

8 bolts x 10.3 k/bolt = 82.4 k

Shear lip area = 1in x 3in /side

A = 3C \quad F_y = 36 ksi

Allowable = 0.4 \times F_y \times A = 0.4(36 \text{ksi}) \times (2)(3 \text{ in})

= 86.4 k

Max. Load = 24.1 k -> 0 k
**Roller and Channel Seismic Stop - Perpendicular to Channel**

Worst Side Force: \( F_{BW} = 18.8 \, k \)

(Large Door)

\[
F_{BOLT} = \frac{5.8}{6.06} \cdot \frac{F_{BW}}{2} = \frac{96}{2}(F_{BW})
\]

Earthquake

\[
F_{BOLT} = 18.8 \, k(0.48) = 9.0 \, k
\]

Allowable

A 307 Bolt: \( 1.33 \, (12.1k) = 16k \)
Door Hangers

1 in Dia Pin

4140

Fu = 90 ksi

Fy = 65 ksi

A36 Plate

Fu = 58 ksi

Fy = 36 ksi

See Dust 20C.2026 Door Hanger Assy

1/2

6 x 6 x 3/8 Tube I = 40.5

A-A

Plate I = I0 + Ad2

= 2 (.083) + 2 (.5)(3)(3)2

= 72

I_{tot} = 40.5 + 72 = 112.5 in^4

S = \frac{I}{c} = \frac{112.5}{3} = 37.5 in^3

Check Bending & Shear at A-A

F = Earthquake

= 19.2 k
BENDING
\[ \frac{C}{E} = \frac{M}{E} = \frac{19.2k(14in)}{37.5in^3} \]
\[ = 7.2ksi \]
ALLOWABLE = 0.6F_y = 0.6(21.6ksi) = 12.96ksi

CHECK WELD STRENGTH.

WELD IS FULL PENETRATION ALL AROUND
FOR LARGE DOOR WEST HANGER

\[ \begin{align*}
\text{TOP BENDING} & : Sw = \frac{b \cdot d^4}{4} = \frac{8(6)}{4} = 144 in^2 \\
\text{TORSION} & : Sw = \frac{b}{2} (b^2 + 3d^2) = 229 in^3 \\
\text{SIDE BENDING} & : Sw = 360 in^2 \\
\text{TORSION} & : Sw = 1693 in^2 \\
\end{align*} \]

SEE BLODGETT "DESIGN OF WELDMENTS"
F = F_1w = 19.2 k

\[
\begin{align*}
\text{TOP} \\
M & = 14 \text{in} \times 19.2 \text{k} = 269 \text{k-in} \\
T & = 7 \text{in} \times 19.2 \text{k} = 134 \text{k-in} \\
\Rightarrow f & = \frac{M}{5w} = \frac{269}{144} = 1.87 \text{k/in} \\
\Rightarrow f & = \frac{T_c}{4w} = \frac{134}{214} = 0.63 \text{k/in} \\
\text{SIDE} \\
M & = 3 \text{in} \times 19.2 \text{k} = 57.6 \text{k-in} \\
T & = 24 \text{in} \times 19.2 \text{k} = 461 \text{k-in} \\
\Rightarrow f & = \frac{M}{5w} = \frac{57.6}{360} = 0.16 \text{k/in} \\
\Rightarrow f & = \frac{461}{1693} = 0.28 \text{k/in} \\
\end{align*}
\]

Total weld length = 2(10) + 2(3) = 56 in

Shear = \frac{19.2 \text{k}}{56 \text{in}} = 0.34 \text{k/in}

\[
\begin{align*}
\text{TOP} \\
\frac{(2.93 \times 34)}{3.27} & \Rightarrow f_r = \sqrt{\frac{3.17^2 - 1.97^2}{3.77}} \\
& = 3.77 \text{k/in}
\end{align*}
\]

Allowable \frac{1}{2} \text{ weld} \equiv 5.0 \text{k/in}

So top weld alone is O.K.

And all other hangers are O.K. since they have more weld length.
CHECK ATTACHMENT TO FIXED FRAME / SUPER STRUCTURE

SHEAR AREA = 0.75x1x2
= 1.5 in² for both sides

1.5 R BEARING AREA = 0.75x1
= 0.75 in²

SUPER STRUCTURE 20G 2086 OR
FIXED FRAME 19C 7706

DOOR HANGER 20G 1796

Fₚₚₙ = LARGE DOOR
WEST HANGER = 19.2 k

F = 3/4

CHECK PIN - IN DOUBLE SHEAR
A = \( \frac{\pi}{4} (1)^2 = 0.785 \) in²

\[
\tau = \frac{F}{A} = \frac{19.2k}{2(0.785)} = \frac{12.3 kips}{F_s = 4.8}
\]

ULT SHEAR =
0.65 F_v = 0.65 x 90 = 58.5 kips
CHECK TEAROUT

\[ T = \frac{F}{A} = \frac{19.2k}{1.5in^2} = 12.8 \text{ksi} \]

ULT. SHEAR = \( G_T(F_V) \) = \( 37.7 \text{ksi} \)

FS = 2.9

CHECK BEARING STRESS

\[ G_B = \frac{F}{A} = \frac{19.2k}{1.5in^2} = 12.8 \text{ksi} \]

ALLOWABLE = \( 0.9 F_Y = 0.9(26) = 23.4 \text{ksi} \)

CHECK BOLT STRESS

\[ P = \frac{F (6.2)}{5.7} = F(1.1) \]

\[ = 19.2(1.1) = 21.1 \]

\[ G = \frac{P}{A} = \frac{21.1k}{2.05in^2} = 17.4 \text{ksi} \]

FS = 1.9

PROOF STRESS

\[ A = 0.7 \text{ in} \times \text{bolt} \]

\[ = 33 \text{ksi} \]

THREAD ENGAGEMENT

FROM MACHINERY'S HANDBOOK 26TH ED. PAPER 1168)

SHEAR AREA, INTERNAL THREADS TO \( 1 \)" UNC = 2.34 in\(^2\)/in

\[ A = 2.34 \text{in}^2/\text{in} \times 0.875N = 2.05 \text{in}^2 \]

ULT. STRENGTH = \( 25(58 \text{ksi}) \times 2.05 \text{in}^2 = 77.3 \text{ksi/bolt} \)
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