ENGINEERING STUDY OF
BLAST-RESISTANT DOORS
Submitted to
U. S. CORPS OF ENGINEERS
Protective Construction Branch
Contract No. DA-49-129-ENG-434

by
Charles D. Price
Mosler Safe Co.
30 November 1960
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<td>Derivation of $R_{el}$ and $X_{el}$ for Solid Steel Plate</td>
</tr>
</tbody>
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NOMENCLATURE

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>DLF</td>
<td>Dynamic Load Factor (to convert a given dynamic load to an equivalent static load)</td>
</tr>
<tr>
<td>E</td>
<td>Modulus of elasticity (psi)</td>
</tr>
<tr>
<td>f_{dy}</td>
<td>Dynamic yield strength of steel (psi)</td>
</tr>
<tr>
<td>I</td>
<td>Moment of inertia (inches^4)</td>
</tr>
<tr>
<td>K_L</td>
<td>Load factor</td>
</tr>
<tr>
<td>K_M</td>
<td>Mass factor</td>
</tr>
<tr>
<td>K_{LM}</td>
<td>Load mass factor</td>
</tr>
<tr>
<td>k</td>
<td>Spring factor (kips/foot)</td>
</tr>
<tr>
<td>M</td>
<td>Bending moment (inch-pounds)</td>
</tr>
<tr>
<td>P_r</td>
<td>Reflected shock wave overpressure (psig)</td>
</tr>
<tr>
<td>P_{so}</td>
<td>Overpressure (psig)</td>
</tr>
<tr>
<td>S</td>
<td>Section modulus (inches^3)</td>
</tr>
<tr>
<td>T</td>
<td>Time of idealized triangular load (seconds)</td>
</tr>
<tr>
<td>T_n</td>
<td>Natural period of oscillation (seconds)</td>
</tr>
<tr>
<td>t</td>
<td>Time in seconds</td>
</tr>
<tr>
<td>t_+</td>
<td>Positive phase duration (seconds)</td>
</tr>
<tr>
<td>U_o</td>
<td>Shock front velocity (feet per second)</td>
</tr>
</tbody>
</table>
SYNOPSIS

This final report is the nuclear-blast-resistant door section of a study, which also includes blast valve closures, under Contract DA-49-129-ENG-434 with the Protective Construction Branch, U. S. Corps of Engineers, Washington, D. C. Blast valve closures were covered in a separate report. (1)

The purpose of this report is to evaluate various existing blast-resistant door designs and then to select the optimum door designs for the door sizes, types, and blast pressure ratings specified in the contract, taking into consideration economy, ease of manufacture from standard available materials, reliability of operation, and a minimum amount of maintenance.

From the optimum door designs complete drawings and specifications were prepared suitable for competitive bidding and manufacture.

This report summarizes the results of the Interim Blast Door Study (2) which included detailed preliminary design calculations, sketches, and comparisons.
SECTION I - SCOPE OF WORK

The criteria specifies 25, 50, and 100 psi overpressures (see Figures I-1, I-2, and I-3, which are compiled from item 3 in the Bibliography), with full reflected pressures to be withstood elasto-plastically by the doors, which are to be operable after three blasts under conditions of moisture and extremes of temperature with a minimum of maintenance.

The door sizes and types to be considered are as follows (see Figure I-4):

A. Pedestrian door 3'-6" wide x 7'-0" high, single-leaf, side-hinged
B. Pedestrian door 6'-0" wide x 7'-0" high, double-leaf, side-hinged
C. Vehicular door 8'-0" x 8'-0", double-leaf, side-hinged
D. Vehicular door 12'-0" x 12'-0", single- and double-leaf, sliding
E. Rail and truck door 14'-0" wide x 18'-0" high, single-leaf, sliding
F. Hatch door 3'-0" x 3'-0", single-leaf, side-hinged, suitable for horizontal or vertical mounting
G. Service tunnel door 2'-6" wide x 4'-0" high, single-leaf, side-hinged

Door sizes mentioned above are clear opening sizes. The 12'-0" x 12'-0", 25 psi rating, double-leaf, sliding door is powered by a manually operated hand chain geared trolley. The 12'-0" x 12'-0", 50 and 100 psi rating, single-leaf sliding doors, and the 14'-0" x 18'-0", 25, 50, and 100 psi rating, single-leaf sliding doors are powered by electric motor drives with an emergency manual handwheel drive.
The remainder of the doors are manually opened and shut, either single or double-leaf. By using bank-vault-door type three-way adjustable hinges, the door leaves are easily opened and shut by one person with just a few pounds pull on the door handle, even though the door leaf may weigh 5 tons or more.

The doors were designed complete with frame and hardware. Doors and frames (except for sliding doors) were designed as integral units. The frames are of a one-piece box construction. The doors are designed to be mounted in the door frames, adjusted and operated at the factory, and shipped together as one unit, thus insuring proper fit and operation on the job.

Doors are also designed to resist a 25% maximum rebound force, except where calculations indicate a greater percentage, in which case the calculated figure is used. The rebound force is taken care of by a bank-vault-door type locking bolt mechanism.
Figure I-1
DISTANCE NECESSARY FROM
LONG TO WALL TO OBTAIN
FULL CLEAR SPACE WHEN
DOOR IS OPEN

SIZE | PRESSURE | ABC | DEF | GHI | J
------|-----------|-----|------|------|------
30" x 30" | 25 PSI | 61 | 13 | 5 | 2 | 114 | 65 | 3 | 880
30" x 30" | 50 PSI | 61 | 13 | 5 | 2 | 114 | 65 | 3 | 3000
30" x 30" | 100 PSI | 61 | 13 | 5 | 2 | 114 | 65 | 3 | 3100
2.5" x 4.5" | 25 PSI | 59 | 12 | 5 | 2 | 111 | 62 | 3 | 1400
2.5" x 4.5" | 50 PSI | 60 | 13 | 5 | 2 | 115 | 65 | 3 | 3000
2.5" x 4.5" | 100 PSI | 61 | 13 | 5 | 2 | 114 | 65 | 3 | 4400
6" x 4.25" | 25 PSI | 60 | 12 | 5 | 2 | 112 | 63 | 3 | 1200
6" x 4.25" | 50 PSI | 60 | 12 | 5 | 2 | 112 | 63 | 3 | 2500
6" x 4.25" | 100 PSI | 70 | 17 | 5 | 2 | 125 | 70 | 3 | 4000
8" x 4.75" | 25 PSI | 61 | 13 | 5 | 2 | 114 | 65 | 3 | 1000
8" x 4.75" | 50 PSI | 61 | 13 | 5 | 2 | 114 | 65 | 3 | 2250
8" x 4.75" | 100 PSI | 70 | 17 | 5 | 2 | 125 | 70 | 3 | 4250

GENERAL NOTES
PRESSURE SHOWN ARE
INCIDENT BLAST OVER PRESSURE
DOORS DESIGNED TO RESIST
FULL REFLECTED PRESSURE
## SECTION II - REVIEW OF EXISTING ELAST DOORS STUDIED

Rather than a detailed list of all door drawings available for study (which would be unduly voluminous), a representative cross-section of various doors is presented.

<table>
<thead>
<tr>
<th>Drawing</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammann &amp; Whitney</td>
<td>Constructed of 8&quot; channel and beams running short way of door with 3/8&quot; outer plate and 1/4&quot; back plate.</td>
</tr>
<tr>
<td>60-02-058, Sheet #18</td>
<td>5'-4&quot; x 7'-2&quot; opening side-hinged</td>
</tr>
<tr>
<td></td>
<td>3/8&quot; outer plate, 1/4&quot; back plate, 3 side hinges, 3 separate manual latches, and rubber gasket.</td>
</tr>
<tr>
<td>Ammann &amp; Whitney</td>
<td>Constructed of 14&quot; @ 43 WF beams running long way of door with 3/8&quot; outer plate and 1/4&quot; back plate.</td>
</tr>
<tr>
<td>60-02-58, Sheet #17</td>
<td>10'-0&quot; x 14'-0&quot; sliding door</td>
</tr>
<tr>
<td></td>
<td>2-ton trolleys, Sealing gasket and turnbuckle anchor dogs.</td>
</tr>
<tr>
<td>Ammann &amp; Whitney</td>
<td>Constructed of 8&quot; thick solid steel plate. Moved on double flanged wheels on bottom of door. Sliding door.</td>
</tr>
<tr>
<td>Sheet #1 &amp; Sheet #2</td>
<td></td>
</tr>
<tr>
<td>6'-0&quot; x 8'-0&quot;</td>
<td></td>
</tr>
<tr>
<td>Black &amp; Veatch</td>
<td>Constructed of 12&quot; &quot;I&quot; beams running long way. 9/16&quot; thick steel plates front and back. Runs on trolleys.</td>
</tr>
<tr>
<td>33-15-58, Sheet #9</td>
<td>12'-0&quot; x 12'-0&quot; Double sliding door</td>
</tr>
<tr>
<td></td>
<td>3/16&quot; x 1-1/2&quot; rubber-impregnated canvas belting for seals.</td>
</tr>
<tr>
<td>33-03-15, Sheet #8</td>
<td>3'-0&quot; x 6'-8&quot;</td>
</tr>
<tr>
<td>33-03-15, Sheet #7</td>
<td>8'-0&quot; x 8'-0&quot;</td>
</tr>
<tr>
<td>Drawing Description</td>
<td>Drawing</td>
</tr>
<tr>
<td>---------------------</td>
<td>--------</td>
</tr>
<tr>
<td>Lorenzo S. Winslow</td>
<td></td>
</tr>
<tr>
<td>49-100-9 3'-0&quot; x 6'-6&quot; Side-hinged</td>
<td></td>
</tr>
<tr>
<td>Constructed of structural tees, ST 5 I's running short way and ST 5 B's running long way, with 7/16&quot; thick steel outer plate and 1/4&quot; thick steel back plate.</td>
<td></td>
</tr>
<tr>
<td>Lorenzo S. Winslow</td>
<td></td>
</tr>
<tr>
<td>49-100-9 4'-8&quot; x 6'-6&quot; Side-hinged</td>
<td></td>
</tr>
<tr>
<td>Double door, constructed of structural tees, ST 5 I's running long way and 5&quot; x 1-1/8&quot; bars running short way, with 1/2&quot; thick steel outer plate and 1/4&quot; thick steel back plate.</td>
<td></td>
</tr>
<tr>
<td>Leo A. Daly</td>
<td></td>
</tr>
<tr>
<td>A-11 7'-9&quot; high Single- and Double-leaf, side-hinged</td>
<td></td>
</tr>
<tr>
<td>Constructed of 1/4&quot; thick steel plate with 3&quot; x 2&quot; x 1/4&quot; angle frame, with canvas-covered rubber gasket and refrigerator type handle and latch.</td>
<td></td>
</tr>
<tr>
<td>General Services Administration</td>
<td></td>
</tr>
<tr>
<td>49-100-9 3'-8-1/2&quot; x 6'-7-1/8&quot; Side-hinged</td>
<td></td>
</tr>
<tr>
<td>6-11/16&quot; thick door consists of structural tees, ST 6 I's running short way and ST 6 B's running long way, with 6&quot; channel outer frame, with 7/16&quot; thick steel outer plate and 1/4&quot; thick steel back plate.</td>
<td></td>
</tr>
<tr>
<td>General Services Administration</td>
<td></td>
</tr>
<tr>
<td>49-100-9 2'-8&quot; x 6'-7&quot; Side-hinged</td>
<td></td>
</tr>
<tr>
<td>5-11/16&quot; thick door consists of structural tees, ST 5 I's running short way and ST 5 B's running long way, with 5&quot; channel outer frame, with 7/16&quot; thick steel outer plate and 1/4&quot; thick steel back plate.</td>
<td></td>
</tr>
<tr>
<td>Faulkner, Kingsbury, &amp; Stenhouse</td>
<td></td>
</tr>
<tr>
<td>13 various size doors consisting of 5/8&quot; or 7/8&quot; thick solid steel plate on outer or hinge side and an outside frame of 3-1/2&quot; x 1&quot; steel bar with a 1/8&quot; steel back cover plate.</td>
<td></td>
</tr>
<tr>
<td>Daniel, Mann, Johnson &amp; Mendenhall &amp; Associates</td>
<td></td>
</tr>
<tr>
<td>AP-1511/16 5'-0&quot; x 7'-0&quot;</td>
<td></td>
</tr>
<tr>
<td>2&quot; thick curved steel plate, side-hinged door.</td>
<td></td>
</tr>
</tbody>
</table>
From the preceding summary of existing door designs, the following generalities are obtained:

1. Large doors are of built-up construction with a heavy front and back steel plate, with structural steel beams between the plates.

2. Built-up-construction doors feature more one-way construction than two-way construction. On double-leaf doors the one-way construction runs the long way of the door due to the one edge of the door being unsupported.

3. Built-up-construction doors with two-way reinforcement feature a "tee" beam reinforcement which allows the leg of the tee to be welded to one plate and the other plate to be slotted and welded to the flange of the tee from the outside, overcoming what would otherwise be a fabrication problem. Two-way reinforcement is very much in the minority, however.

4. Small or medium strength and size doors might be made of a solid steel plate as well as of a built-up fabrication.

5. There is a wide variety of hinges and latching devices, practically none of which appear adequate and capable of withstanding significant rebound forces.

6. Little progress has been made in the design of doors departing from conventional designs, such as curved doors or prestressed concrete doors.

Of considerable interest, in addition to the above-mentioned doors, is a particular door design which was successfully tested in 1957 in "Operation Plumbbob" at the Nevada Test Site under very high pressures. This was a standard bank vault door, a Mosler Safe Co. C-10 door. The damage to the door was only superficial, peeling off ornamental trim, etc., the door being reopened without any difficulty. The interior of the above-ground vault was entirely protected by the door. Although the concrete covering of the vault was badly damaged, the steel lining of the vault kept it air tight. This door is shown in Figures II-1, II-2, II-3, II-4, and II-5.
NOT REPRODUCIBLE
NOT REPRODUCIBLE

Figure II-3
SECTION III - COMPARISON OF DOOR DESIGNS AND FINAL DOOR DESIGN SELECTIONS

There are several possibilities of door designs and materials. Possible designs included:

A. Solid flat plate door leaves
B. One-way reinforced built-up welded door leaves
C. Two-way reinforced built-up welded door leaves
D. Curved door leaves

Possible materials for door leaves included:

A. Aluminum
B. Concrete
C. Plastic
D. Steel

Referring to Interim Blast-Resistant Door Study (2), for reasons of economy and ease of fabrication, steel was selected as the best material.

Likewise, for the various possible door designs, the one-way reinforced built-up welded door leaf design was selected for all but the lighter section doors. For these doors it was found more economical to use the solid steel flat plate design.

For easy swinging of the hinged type doors, only two hinges should be used for best performance and ease of operation. The bottom hinge contains radial-thrust bearings to take all the downward weight of the door and half of the radial (horizontal) thrust which is due to the rotational effect of the overhang of the door.

The upper hinge takes only the other half of the radial (horizontal) thrust (which is actually a couple). This construction, by relieving the upper hinge bearing of any thrust loads, allows adjustment of the hinge in a vertical direction without danger of overloading the bearings by the adjusting screws. In
some designs studied the weight of the door was evenly divided by thrust bearings in the upper and lower hinges, which could result in overloaded hinge bearings if there is a slight misalignment or if one of the vertical adjusting screws is turned too far so that the screw is trying to "jack" against the two bearings and force them apart. In other door designs studied there were three hinges per door leaf, which made this problem even worse. In the final hinged door design the upper hinge bearing "floats" vertically on the hinge pin and is therefore unaffected by vertical adjustment or misalignment.

The top and bottom hinges by being adjustable in the other two directions also, become three-way adjustable. This permits very accurate alignment of the doors so that they swing easily, do not go "up hill" or "down hill", and have no "run" in any position.

Since the door leaf, when closed, seats evenly against a finished section of the door frame all around the door periphery, and is firmly clamped from "rebouncing" open by means of the tapered end locking bolt system, the blast forces on the door are isolated from the hinge bearings.

The tapered wedge locking bolt system used in the final design is a duplicate of the same system which has been used for the last 50 years on bank vault doors and was successfully tested under an actual nuclear blast in "Operation Plumbbob."

A completed 6'-0" x 7'-0" double-leaf blast door, 100 psi rating, is shown in Figures III-1 and III-2.

If it is desired to have these blast doors power-operated (say for remote control or interlocking in pairs), this is easily accomplished. Figures III-3 and III-4 show the 3'6" x 7'-0" single-leaf blast door, 100 psi rating, with the additional blast-proof operator.
NOT REPRODUCIBLE
NOT REPRODUCIBLE

Figure III-3

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A composite list of the door sizes, drawing numbers, and specification numbers of the final door designs is as follows:

<table>
<thead>
<tr>
<th>Door Size</th>
<th>Drawing Number 25 PSI</th>
<th>Drawing Number 50 PSI</th>
<th>Drawing Number 100 PSI</th>
<th>Specification Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>3'6&quot; x 7'-0&quot;</td>
<td>60-12-06</td>
<td>60-12-07</td>
<td>60-12-08</td>
<td>60-12-06-60</td>
</tr>
<tr>
<td>6'0&quot; x 7'-0&quot;</td>
<td>60-12-09</td>
<td>60-12-10</td>
<td>60-12-11</td>
<td>60-12-09-60</td>
</tr>
<tr>
<td>8'-0&quot; x 8'-0&quot;</td>
<td>60-12-12</td>
<td>60-12-13</td>
<td>60-12-14</td>
<td>60-12-12-60</td>
</tr>
<tr>
<td>12'-0&quot; x 12'-0&quot;</td>
<td>60-12-15</td>
<td>60-12-16</td>
<td>60-12-17</td>
<td>60-12-15-60</td>
</tr>
<tr>
<td>14'-0&quot; x 18'-0&quot;</td>
<td>60-12-18</td>
<td>60-12-19</td>
<td>60-12-20</td>
<td>60-12-18-60</td>
</tr>
<tr>
<td>3'-0&quot; x 3'-0&quot;</td>
<td>60-12-21</td>
<td>60-12-22</td>
<td>60-12-23</td>
<td>60-12-21-60</td>
</tr>
<tr>
<td>2'-6&quot; x 4'-0&quot;</td>
<td>60-12-24</td>
<td>60-12-25</td>
<td>60-12-26</td>
<td>60-12-24-60</td>
</tr>
</tbody>
</table>
SECTION IV - DESIGN CALCULATIONS

In calculating the strengths of the door leafs, there are three basic types of calculations, as follows:

1. Curved door, 3'-6" x 7'-0", 25 psi rating (Figure IV-1)
2. Solid steel plate doors simply supported all four sides, all 3'-0" x 3'-0" and 2'-6" x 4'-0" doors (Figure IV-2)
3. Structural Beam doors welded flange to flange (Figure IV-3)

In the case of the welded structural beam doors, calculations were made on a per beam basis, considering the beam as simply supported each end.

In the case of the solid steel plate doors, the calculations were made on the basis of a plate simply supported on all four sides. Basic plate formulae used were from "Theory of Plates and Shells" by Prof. S. Timoshenko (13).

For the convex curved plate door a completely elastic design was used, as the curved plate would otherwise fail by buckling as soon as the elastic limit was exceeded.

In all cases calculations were made in accordance with the Corps of Engineers Design Manuals (4 through 12). The Design Manuals show two basic approaches, the Energy Method and the Deflection Method. The Deflection Method was chosen as the most suitable. A numerical method of analysis was used in conjunction with an Acceleration Impulse Extrapolation Table.

Recurring constants in the various door calculations were lumped together to form one constant. Derivations of the various constants are shown in Figures IV-5 through IV-

Calculations are broken down into repetitive step-by-step procedures. A certain door section is assumed and then by a series of trials the optimum section is determined.
Typical calculations are shown for the 3'-6" x 7'-0", 25 psi curved door (Figure IV-1), the 3'-6" x 7'-0", 50 psi built-up door (Figure IV-2), the 14'-0" x 18'-0", 50 psi built-up door (Figure IV-3), and the 2'-6" x 4'-0", 100 psi, solid steel plate door (Figure IV-4).
DOOR NO. 60-12-06
TRIAL NO. 1
CURVED DOOR

CALCULATIONS BY T.A.
CHECKED BY H.S.

Door opening = 3'-6" x 7'-0"
Door vertical
Assume 6" bearing width and $\alpha = 60^\circ$, arch fixed at supports
$f_s = 41.6$ ksi
Incident pressure = 25 psi = $P_{so}$
Peak reflected pressure = 80 psi

$L = 4'-0"

R - h = R \cos \frac{\alpha}{2} = 4 \times (0.867) = 3.468$

$h = 0.532$
DOOR 60-12-06
Trial No. 1

Design for Direct Loading - Elastic

Assume a D.L.F. = 2.00  \( P_r = 0.08 \text{ ksi} \)

\[ T = P_R = 0.08 \times (2) 12 (4) = 7.68 \text{ k/in.} \]

\[ V = P_R \sin \alpha/2 = 0.08 \times (2) 12 (4) \times 0.5 = 3.84 \text{ k/in.} \]

\[ H = P_R \cos \alpha/2 = 0.08 \times (2) 12 (4) \times 0.867 = 6.66 \text{ k/in.} \]

Required Thickness

| Arch Plate | \( t = \frac{7.68}{41.6} = 0.185 \) | Try 3/16" plate |
| Tie Plate  | \( t = \frac{6.66}{41.6} = 0.160 \) | Try 11/64" plate |

Shock Velocity

\[ U_0 = 1117 \left[ 1 + \frac{6 \times P_{so}}{7 \times (14.7)} \right]^{1/2} \]

\[ U_0 = 1117 \left[ 1 + \frac{6 \times (25)}{102.9} \right]^{1/2} = 1750 \text{ ft/sec} \]

Time of Pressure Rise

\[ t_o = \frac{h}{U_0} = \frac{0.532}{1750} = 0.000304 \text{ sec.} \]

Period of Vibration of Arch Plate

\[ T_N = 2\pi \frac{L^2}{C_2} \sqrt{\frac{m}{EI}} \]

\[ C_2 = 4 \sin^2 \alpha/2 \left[ \frac{2}{3} \left( \frac{R}{k} \right)^2 + \left( \frac{\pi^2}{\alpha^2} - 1 \right) \right]^{1/2} \]

\[ k = \sqrt{\frac{1}{A}} = \sqrt{\frac{12}{12 \times (3/16)^3}} = \sqrt{\frac{(3/16)^2}{12}} = 0.0541 \text{ in.} \]

\[ \frac{R}{k} = \frac{48}{0.0541} = 887.2 \]
Dynamic Response of Arch Plate

The loading curve is assumed to have a triangular shape as shown below.

\[
\frac{t_o}{T_n} = \frac{0.00304}{0.001828} = 0.16 \quad \text{D.L.F.} = 1.95 \approx 2 \quad \text{Section O.K.}
\]

(The David W. Taylor Model Basin, USN, "Effects of Impact on Simple Elastic Structures". Report 481, April 1942, Fig. 18)
Buckling

\[ P_c R = \frac{EI}{R^3} \left( k^2 - 1 \right) \]

\[ k = 8.5 \text{ for } \alpha = 60^\circ \]

\[ P_c R = \frac{30 \left( 10^6 \right) .000549}{(48)^3} \left[ (8.5)^2 - 1 \right] \]

\[ = .1489 \left[ 71.25 \right] = 10.6 \text{ psi} \quad 80 (2) = 160 \text{ psi} \quad \text{No Good} \]

3/16" plate O.K. for elastic direct loading, but not good for buckling. Try 1/2" plate for buckling.

\[ I = \frac{bd^3}{12} = \frac{1 (1/2)^3}{12} = .0104 \]

\[ P_c R = \frac{30 \left( 10^6 \right) .0104}{(48)^3} \left[ (8.5)^2 - 1 \right] \]

\[ = 2.82 \left[ 71.25 \right] = 201 \text{ psi} \quad 80 (2) = 160 \text{ psi} \quad \text{O.K.} \]

Use 1/2" arch plate

Use 11/64" tie plate
CALCULATIONS

1-WAY SPAN DOOR  TRIAL NO. 2  ELASTO-PLASTIC
BUILT-UP DESIGN  DOOR NO. 60-12-07
SIMPLY SUPPORTED 4 SIDES  CALCULATIONS BY T.A.
3'-6" x 7'-0", 50 PSI  CHECKED BY H.S.

GIVEN:

Assumed Beam = 5 x 5 WF 16#

T = Load Duration = .050 Sec.
P = Peak Reflected Pressure = 197 PSI
W = Total Weight of Beam = 58.6 Lbs.
A = Area of Beam (Width x Span) = 220.5 Sq. In.
L = Span Length of Beam = 3-1/2 Feet
S = Section Modulus of Beam = 8.53 Inch³
I = Moment of Inertia of Beam = 21.3 Inch⁴
Kₑ₀ = Elastic Mass Constant = .780
Kₚ₀ = Plastic Mass Constant = .667

FIND:

1. MAXIMUM ELASTIC DEFLECTION (FEET)

\[ X_{el} = \frac{0.0017333 \times L^2 \times S}{I} = \frac{0.0017333 \times 3.5^2 \times 8.53}{21.3} \]

= \[0.0017333 \times 4.91 = 0.008511\]

2. NATURAL PERIOD (SECONDS)

\[ T_n = 6.2832 \times \sqrt{\frac{M_e}{K_1}} \]

= \[6.2832 \times \sqrt{\frac{0.01420}{7949}} \]

= \[6.2832 \times 0.0042265 = 0.0266\]
3. **EQUIVALENT MASS (ELASTIC) (KIP-SEC²/FT.)**

   \[ M_e = \frac{W \times KLM_e}{32,200} = \frac{58.6 \times .78}{32,200} = .001420 \]

4. **EQUIVALENT MASS (PLASTIC) (KIP-SEC²/FT.)**

   \[ M_p = W \times 20.704 \times 10^{-6} = .001213 \]

5. **STIFFNESS FACTOR (KIP/FOOT)**

   \[ K_1 = 16,000 \times \frac{1}{L^3} = 16,000 \times \frac{21.3}{42.875} = 7.949 \]

6. **MAX. ELASTIC RESISTANCE (KIP LB)**

   \[ R_{el} = 27.7333 \times \frac{8}{3.5} = 68 \]
7. **CONSTANTS FOR EXTRAPOLATION TABLE**

**ELASTIC RANGE**

a. \( \frac{T_n}{10} = \frac{0.00266}{10} = 0.000266 \)

b. \( \Delta t = 0.0002 \)

c. \( (\Delta t)^2 = 4 \times 10^{-8} \)

d. \( P_o = \frac{P \times A}{1,000} = \frac{197 \times 220.5}{1,000} \text{ KIP } 43.4 \)

e. \( P_1 = P_o \left( 1 - \frac{\Delta t}{0.05} \right) = 43.4 \left( 1 - \frac{0.0002}{0.05} \right) = 43.2 \)

f. \( P_o - P_1 = 43.4 - 43.2 = 0.2 \)

g. \( a_o = \frac{1}{M_e} \left( \frac{P_o}{2} + \frac{P_1 - P_o}{6} \right) = \frac{1}{0.001420} \left( \frac{43.4}{2} - \frac{0.2}{6} \right) = 15,253 \)

h. \( X_1 = a_o x (\Delta t)^2 = 15,253 \times (4 \times 10^{-8}) = 0.00610 \)

i. \( \frac{(\Delta t)^2}{M_e} = \frac{4 \times 10^{-8}}{0.001420} = 2817 \times 10^{-8} \)

**PLASTIC RANGE**

a. \( \Delta t = 0.0002 \)

b. \( (\Delta t)^2 = 4 \times 10^{-8} \)

c. \( \frac{(\Delta t)^2}{M_p} = \frac{4 \times 10^{-8}}{0.001213} = 3298 \times 10^{-8} \)
### ACCELERATION IMPULSE EXTRAPOLATION TABLE

\[ X_{el} = 0.00511 \quad R_{el} = 68 \quad K_1 = 7949 \]

<table>
<thead>
<tr>
<th>( N ) (Sec.)</th>
<th>( P_n ) (Kips)</th>
<th>( R_n ) (Kips)</th>
<th>( P_n - R_n ) (Kips)</th>
<th>( (\Delta t)^2 ) (in ft.)</th>
<th>( A_n (\Delta t)^2 ) (in ft.)</th>
<th>( 2 X_n ) (in ft.)</th>
<th>( X_{n-1} ) (in ft.)</th>
<th>( X_{n+1} ) (in ft.)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>43.4</td>
<td>4.8</td>
<td>38.4</td>
<td>(-10^{-8} \times 2817)</td>
<td>(0.000610)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>43.2</td>
<td>4.8</td>
<td>38.4</td>
<td>&quot;</td>
<td>(0.001082)</td>
<td>(0.001220)</td>
<td>0</td>
<td>0.000610</td>
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<tr>
<td>2</td>
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<td>24.7</td>
<td>&quot;</td>
<td>(0.000418)</td>
<td>(0.014666)</td>
<td>0.004690</td>
<td>0.007233</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>42.8</td>
<td>37.3</td>
<td>5.5</td>
<td>&quot;</td>
<td>(0.000315)</td>
<td>(0.009380)</td>
<td>0.002302</td>
<td>0.004690</td>
<td></td>
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<tr>
<td>4</td>
<td>42.6</td>
<td>57.5</td>
<td>-14.9</td>
<td>&quot;</td>
<td>(0.000315)</td>
<td>(0.009380)</td>
<td>0.002302</td>
<td>0.004690</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>42.4</td>
<td>68.0</td>
<td>-25.6</td>
<td>(-10^{-8} \times 3298)</td>
<td>(-0.000844)</td>
<td>(0.018716)</td>
<td>0.007233</td>
<td>0.009358</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>42.2</td>
<td>68.0</td>
<td>-25.8</td>
<td>&quot;</td>
<td>(-0.000857)</td>
<td>(0.022140)</td>
<td>0.010639</td>
<td>0.011070</td>
<td>&quot;MAX.&quot;</td>
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<tr>
<td>7</td>
<td>42.0</td>
<td>68.0</td>
<td>-26.0</td>
<td>&quot;</td>
<td>(-0.000752)</td>
<td>(0.021288)</td>
<td>0.011070</td>
<td>0.010644</td>
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<tr>
<td>8</td>
<td>41.8</td>
<td>64.6</td>
<td>-22.8</td>
<td>&quot;</td>
<td>(-0.000449)</td>
<td>(0.018932)</td>
<td>0.010644</td>
<td>0.009466</td>
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<tr>
<td>9</td>
<td>41.6</td>
<td>55.2</td>
<td>-13.6</td>
<td>&quot;</td>
<td>(-0.000030)</td>
<td>(0.013678)</td>
<td>0.009466</td>
<td>0.007839</td>
<td></td>
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<td>10</td>
<td>41.4</td>
<td>42.3</td>
<td>-0.9</td>
<td>&quot;</td>
<td>(-0.000030)</td>
<td>(0.013678)</td>
<td>0.009466</td>
<td>0.007839</td>
<td></td>
</tr>
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<td>11</td>
<td>41.2</td>
<td>29.1</td>
<td>12.1</td>
<td>&quot;</td>
<td>(0.000399)</td>
<td>(0.012364)</td>
<td>0.007839</td>
<td>0.006182</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>41.0</td>
<td>19.1</td>
<td>21.9</td>
<td>&quot;</td>
<td>(0.000722)</td>
<td>(0.009848)</td>
<td>0.006182</td>
<td>0.004924</td>
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<td>13</td>
<td>40.8</td>
<td>14.9</td>
<td>25.9</td>
<td>&quot;</td>
<td>(0.000854)</td>
<td>(0.008776)</td>
<td>0.004924</td>
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<td>(\ldots)</td>
<td>(\ldots)</td>
<td>(\ldots)</td>
<td>(\ldots)</td>
<td>(\ldots)</td>
</tr>
</tbody>
</table>

**RESULTS**

- Maximum Deflection = 0.011070
- Elastic Deflection = 0.008511
- Permanent Deflection = 0.002559

At .5" allowable total deflection - will take 16.3 max. blasts.
**R_x TABLE**

Maximum $R_x$ to Minus $R_{el}$

<table>
<thead>
<tr>
<th>$R_{\text{Max.}}$</th>
<th>$(X_{\text{Max.}})$</th>
<th>$X_x$</th>
<th>$K_1$</th>
<th>$R_x$</th>
</tr>
</thead>
<tbody>
<tr>
<td>68</td>
<td>.011070</td>
<td>.010694</td>
<td>.000426</td>
<td>7,949</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>.009466</td>
<td>.001604</td>
<td>&quot;</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>.007839</td>
<td>.003231</td>
<td>&quot;</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>.006182</td>
<td>.004888</td>
<td>&quot;</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>.004924</td>
<td>.006146</td>
<td>&quot;</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>.004388</td>
<td>.006682</td>
<td>&quot;</td>
</tr>
</tbody>
</table>

26d
+ RESISTANCE (KIPS)

MAX. ELASTIC RESISTANCE

PERMANENT DEFLECTION

+ Deflection (Feet)

Max. Rebound

K₁

Scale: Approved by:

DOOR NO. 60-12-07 - T2
1-WAY SPAN, BUILT-UP

LOAD DURATION - .050 Sec.
7. CONSTANTS FOR EXTRAPOLATION TABLE

ELASTIC RANGE

a. \( \frac{T_n}{10} = \frac{.00266}{10} = .000266 \)

b. \( \Delta t = .0002 \)

c. \((\Delta t)^2 = 4 \times 10^{-8}\)

d. \( P_o = \frac{P_x X A}{1,000} = \frac{197 \times 220.5}{1,000} \text{ KIP} = 43.4 \)

e. \( P_1 = P_o (1 - \frac{t}{.009}) = 43.4 (1 - \frac{.0002}{.009}) = 42.4 \)

f. \( P_o - P_1 = 43.4 - 42.4 = 1 \)

g. \( a_o = \frac{1}{Me} (\frac{P_o}{2} + \frac{P_1 - P_o}{6}) = \frac{1}{.001420} (\frac{43.4}{2} - \frac{1}{6}) \) 
\[ = 15,162 \]

h. \( X_1 = a_o X (\Delta t)^2 = 15,162 \times (4 \times 10^{-8}) = .000606 \)

i. \( \frac{(\Delta t)^2}{Me} = \frac{4 \times 10^{-8}}{.001420} = 2,817 \times 10^{-8} \)

PLASTIC RANGE

a. \( \Delta t = .0002 \)

b. \((\Delta t)^2 = 4 \times 10^{-8}\)

c. \( \frac{(\Delta t)^2}{M_p} = \frac{4 \times 10^{-8}}{.001213} = 3,298 \times 10^{-8} \)
ACCELERATION IMPULSE EXTRAPOLATION TABLE

\[ X_{el} = 0.008511 \quad K_1 = 7949 \]

<table>
<thead>
<tr>
<th>( N )</th>
<th>( t ) (Sec.)</th>
<th>( P_n ) (Kips)</th>
<th>( R_n ) (Kips)</th>
<th>( P_n - R_n ) (Kips)</th>
<th>( (\Delta t)^2 ) ( M )</th>
<th>( A_n (\Delta t)^2 ) (Feet)</th>
<th>( 2X_n ) (Feet)</th>
<th>( X_n - 1 ) (Feet)</th>
<th>( X_n + 1 ) (Feet)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>43.4</td>
<td>--</td>
<td>--</td>
<td>( 10^{-8} \times 2817 )</td>
<td>0.000606</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
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<td>0.0002</td>
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<td>4.8</td>
<td>37.6</td>
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<td>0.001212</td>
<td>0</td>
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</tr>
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<td>23.3</td>
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<td>0.004542</td>
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</tr>
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<td>0.006</td>
<td>40.4</td>
<td>36.5</td>
<td>3.9</td>
<td>&quot;</td>
<td>0.00106</td>
<td>0.009184</td>
<td>0.002271</td>
<td>0.004592</td>
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</tr>
<tr>
<td>4</td>
<td>0.008</td>
<td>39.4</td>
<td>55.8</td>
<td>-16.4</td>
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<td>-0.000462</td>
<td>0.14038</td>
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<tr>
<td>5</td>
<td>0.01</td>
<td>38.4</td>
<td>68.0</td>
<td>-29.6</td>
<td>( 10^{-8} \times 3298 )</td>
<td>-0.000976</td>
<td>0.17968</td>
<td>0.007019</td>
<td>0.008984</td>
<td>MAX.</td>
</tr>
<tr>
<td>6</td>
<td>0.012</td>
<td>37.4</td>
<td>68.0</td>
<td>-30.6</td>
<td>&quot;</td>
<td>-0.01009</td>
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<td>0.008984</td>
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<td>0.19906</td>
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<td>0.17794</td>
<td>0.009953</td>
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<td>44.8</td>
<td>-10.4</td>
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<td>-0.00343</td>
<td>0.14098</td>
<td>0.008897</td>
<td>0.007049</td>
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<tr>
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<td>27.3</td>
<td>6.1</td>
<td>&quot;</td>
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<td>0.007049</td>
<td>0.004858</td>
<td></td>
</tr>
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<td>11.5</td>
<td>20.9</td>
<td>&quot;</td>
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<td>0.05736</td>
<td>0.004858</td>
<td>0.002868</td>
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<td>30.2</td>
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<td>0.026</td>
<td>30.4</td>
<td>1.2</td>
<td>31.6</td>
<td>&quot;</td>
<td>0.01042</td>
<td>0.02524</td>
<td>0.001567</td>
<td>0.001262</td>
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<tr>
<td>14</td>
<td>0.028</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.01262</td>
<td>0.001999</td>
<td></td>
<td></td>
<td></td>
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</table>

Ratio \[ \frac{1.2}{68} = \]

Max. Rebound =
### R<sub>x</sub> TABLE

Maximum R<sub>x</sub> to Minus R<sub>el</sub>

<table>
<thead>
<tr>
<th>R&lt;sub&gt;Max.&lt;/sub&gt;</th>
<th>(X&lt;sub&gt;Max.&lt;/sub&gt; - X&lt;sub&gt;x&lt;/sub&gt;)</th>
<th>X</th>
<th>K&lt;sub&gt;1&lt;/sub&gt;</th>
<th>R&lt;sub&gt;x&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>68</td>
<td>0.009973</td>
<td>0.009953</td>
<td>0.00020</td>
<td>7.949</td>
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<td>&quot;</td>
<td>0.008897</td>
<td>0.001076</td>
<td>&quot;</td>
<td>8.6</td>
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<td>0.001262</td>
<td>0.008711</td>
<td>&quot;</td>
<td>69.2</td>
</tr>
</tbody>
</table>
CALCULATION FOR LOCAL CONDITION

1. $M_e = M_s = \frac{1}{4} \times 41.6 \times t^2 = \frac{1}{4} \times 41.6 \times 0.141$
   $= 1.4 \text{ K in/in}$

2. $\sum M = \frac{2M}{12} = \frac{1}{6} \times \frac{1.4}{6} = 0.233 \text{ K-ft/in}$

3. $R = \frac{8M}{L} = \frac{8 \times 0.233}{0.432} = 4.3 \text{ K/in}$

4. $F = \frac{12 \times F_x \times L \times 1 \text{ (per inch)}}{1,000} = \frac{(12)(197)(432)}{1,000} = 1 \text{ K/in}$

5. $D.L.F. = \frac{R}{F} = \frac{4.3}{1} = 4.3 > 2$ (Member remains elastic)
CHECK FOR LOCAL BUCKLING OF ONE-WAY BEAMS

Beam = 5 x 5 WF @ 16#

\[ a = 4-1/4 \]
\[ b = 5-3/16 \]
\[ d = 5 \]
\[ t_f = 3/8 \]
\[ t_w = 1/4 \]

Web Ratio = \( \frac{a}{t_w} = \frac{4.25}{.25} = 17 \)

WEB REINFORCEMENT (WHEN REQUIRED)

Length of Stiffeners
Locate symmetrical with mid-point of door

26k
CHECK FOR LATERAL-TORSIONAL BUCKLING

GIVEN:

\[ k^1 = 0.51 \]
\[ L = \text{Span} = 42 \]
\[ d = \text{Depth of Beam} = 5.000 \]
\[ b = \text{Width of Flange} = 5.184 \]
\[ T_f = \text{Thickness of Flange} = 0.360 \]

1. \[ \frac{k^1 L d}{b T_f} = \frac{0.51 \times 42 \times 5.000}{5.184 \times 0.360} \]
   \[ = \frac{107.100}{1.866} \]
   \[ = 57.4 < 100 \quad \text{O.K.} \]
BEARING AREA STRESS

\[ R_m = \text{Maximum Resistance of Door} \]
\[ = R_{el} \times \frac{\text{Area of Leaf}}{\text{Area of Beam}} = R_{el} \times \frac{L_2 \times h}{L_2 \times W_b} = R_{el} \times \frac{h}{W_b} \]

\[ R_{el} = 68,000 \text{#} \]
\[ R_m = 68,000 \times \frac{85}{5.000} = 1,156,000 \]

\[ S_b = \text{Bearing Stress} = \frac{R_m}{A_B} = \frac{R_m}{2T \times h} \]
\[ A_B = 2 \times 1/2 \times 85 = 85 \text{ in}^2 \]
\[ S_b = \frac{1,156,000}{85} = 13,600 < 30,000 \text{ PSI OK} \]
STRIKER THICKNESS CALCULATIONS

Take a 1" wide typical strip.

Force per Lineal Inch = \( F = \frac{Rm}{2 \times L_1} \) (see p. 26m)

\[ = S_B \times T = 13,600 \times .500 = 6,800 \]

Bending Moment = \( M = F \times D = 6,800 \times .372 = 2,550 \)

Thickness = \( d = \frac{\sqrt{6M}}{S_B} = \sqrt{.367788} = .60696 \) USE 1"

\*\( S_B \) = Allowable Bending Stress #A-7 Steel = 41,600
REBOUND LOAD CALCULATION FOR LOCK BOLTS

Consider rebound resisted equally by "dead latch" and lock bolts.

Then:

\[ \text{Rebound force per bolt} = P = \frac{0.25 P_m}{\frac{\text{Max. Rebound Force}}{2 \times \text{no. of lock bolts}}} \]

\[ = \frac{289,000}{12} = 24,083 \]

Maximum total rebound force is obtained from rebound calculations.
LOCK BOLT CALCULATIONS - REBOUND - BLAST DOOR

MAX. L = .909

\[ P = 24,083 \]

\[ D = 1.750 \]

\[ L \]

\[ A \]

P = Equiv. Static Force per Bolt in Pounds

L = Length in inches

D = Diameter in inches

A = Bearing area in sq. in.

MIN. A = .803

1. Vertical Shear

\[ \frac{4 \times P}{\pi \times D^2} = \frac{4 \times 24,083}{3.1416 \times 3.0625} = \frac{96,332}{9.62} = 10,014 \]

2. Horiz. Shear

\[ \frac{16 \times P}{3\pi \times D^2} = \frac{16 \times 24,083}{3 \times 3.1416 \times 3.0625} = \frac{385,328}{28.86} = 13,352 \]

3. Bending Stress

\[ \frac{32 \times P \times L}{\pi \times D^3} = \frac{32 \times 24,083 \times .875}{3.1416 \times 5.359} = \frac{674,324}{16.84} = 40,043 \]

4. Bearing Stress

\[ \frac{P}{A} = \frac{24,083}{1.898} = 12,689 \]

Allowable Stresses - #A-7 Steel:

1. 21,000 PSI
2. 21,000 PSI
3. 41,600 PSI
4. 30,000 PSI
CALCULATIONS FOR RADIAL-THRUST BEARINGS
IN LOWER HINGE*

\[
\text{RPM} \leq 50 \quad \frac{F_a}{F_r} \quad .65
\]

Rotating Inner Ring

<table>
<thead>
<tr>
<th>Load Type</th>
<th>Expression</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thrust Load</td>
<td>( F_a )</td>
<td>2,076</td>
</tr>
<tr>
<td>Radial Load</td>
<td>( F_r )</td>
<td>746</td>
</tr>
<tr>
<td>Rotation Factor</td>
<td>( V )</td>
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</tr>
<tr>
<td>Thrust Factor</td>
<td>( Y )</td>
<td>1.45</td>
</tr>
<tr>
<td>Radial Factor</td>
<td>( X )</td>
<td>.67</td>
</tr>
</tbody>
</table>

\[
P \quad \text{Equivalent Load}
\]

\[
P = X V F_r + Y F_a
\]

\[
= .67 F_r + 1.45 F_a
\]

\[
= (0.67 \times 746) + (1.45 \times 2,076)
\]

\[
= 500 + 3,010
\]

\[
= 3,510
\]

\[
\frac{C}{P} \geq 1.0
\]

* Minimum bearing is SKF #5303 or equivalent.

Use SKF bearing #5304 or equivalent.

* Formula shown is for Series 5200 and 5300 double row, deep groove SKF bearings. Series #5300 preferred. For other design bearings, check formula.
STRESS ANALYSIS DIAGRAM - HINGE BEARINGS

\[ A = 24.5/8 \]

\[ W = 2,076 \]

\[ B = 68.5 \]

\[ \text{COUPLE} \]

\[ F_x = F \times \cos \theta \]

\[ F_y = F \times \sin \theta \]

\[ W \times A = F \times B \]

\[ F = \frac{W \times A}{p} = \frac{2,076 \times 24.625}{68.5} = \frac{51,121.5}{68.5} = 746 \]
STRESS ANALYSIS DIAGRAM - HINGE BOLTS (NO SAFETY FACTOR)

W = Weight = 2,076
(Lower 4 bolts)
Min. Resistance to Twisting Moment per Bolt:
\[ R_M = \frac{W \times C}{4 \times D} = \frac{2,076 \times 8}{4 \times 4.033} = \frac{16,608}{16.132} = 1,029 \]

(Upper 4 Bolts only)
Min. Resistance to Tension per Bolt:
\[ R_T = \frac{W \times B}{4 \times E} = \frac{2076 \times 2.5}{4 \times 61} = \frac{5190}{244} = 21.27 \]

(Lower 4 Bolts only)
Min. Resistance to Shear per Bolt:
\[ R_S = \frac{W}{4} = \frac{2076}{4} = 519 \]
CALCULATIONS - DOOR SWING AND DOOR TAPER

\[ A = 43 \quad B = 2-1/8 \]

\[ C = 5 \quad D = 2.5 \]

\[ E = \frac{C^2 + (C \times D)}{(A + B)} = \frac{24 + 12.5}{45.125} = \frac{36.5}{45.125} = 0.81 \]

Swing = \[ S = \sqrt{(A + B)^2 + (C + D)^2} = \sqrt{(45.125)^2 + (7.5)^2} \]
\[ = \sqrt{2036.27 + 56.25} = \sqrt{2092.52} = 45.74 \]

Use 13/16
CALCULATIONS

1-WAY SPAN DOOR TRIAL NO. 2
BUILT-UP DESIGN
SIMPLY SUPPORTED 2 SIDES
PARTIALLY LOADED OVER FULL SPAN
14'-0" x 18'-0", 50 PSI

GIVEN:

Assumed Beam = 24 WF @ 145
T = Load Duration = .050 Sec.
\( p_r \) = Peak Reflected Pressure = 197 PSI
W = Total Weight of Beam = 2465 Lbs.
A = Area of Beam (Width x Span) = 2268 Sq. In.
L = Span Length of Beam = 17 Feet
S = Section Modulus of Beam = 3725 Inch\(^3\)
I = Moment of Inertia of Beam = 4561 Inch\(^4\)
\( K_{LM_e} \) = Elastic Mass Constant = .67
\( K_{LM_p} \) = Plastic Mass Constant = .57
\( L_1 \) = Loaded Portion of Beam = 14 Feet

FIND:

1. MAXIMUM ELASTIC DEFLECTION (FEET)

\[ X_{el} = \frac{.000346666 \times S}{I} \left( \frac{8 \frac{L_2^3}{L_1} - 4 \frac{L_1^2 L_2}{L_1} + \frac{L_1^3}{L_1}}{2 \frac{L_2}{L_1}} \right) = \frac{(.000346666) (.081671) (39304 - 13328 + 2744)}{20} \]

\[ = .000346666 \times 94.869034 = .032888 \]

2. NATURAL PERIOD (SECONDS)

\[ T_n = 6.2832 \times \sqrt{\frac{M_e}{K_1}} \]

\[ = 6.2832 \times \sqrt{.051290 \over 15706} \]

\[ = 6.2832 \times \sqrt{.0000326563} \]

\[ = 6.2832 \times .001807 = .011354 \]
3. **EQUIVALENT MASS (ELASTIC) (KIP-SEC²/FT.)**

\[ M_e = \frac{W \times K_{LM}}{32,200} = \frac{2465 \times .67}{32,200} = .051290 \]

4. **EQUIVALENT MASS (PLASTIC) (KIP-SEC²/FT.)**

\[ M_p = W \times 20.704 \times 10^{-6} = 2465 \times 20.704 \times 10^{-6} = .051035 \]

5. **STIFFNESS FACTOR (KIP/FOOT)**

\[ K_1 = \frac{80,000 \times \frac{I}{8 L_2^3 - 4 L_1^2 L_2 + L_1^3}}{4561} = \frac{80,000}{39304 - 13328 + 2744} \]

\[ = 80,000 \times \frac{4561}{23,232} = 15,706 \]

6. **MAX. ELASTIC RESISTANCE (KIP LB)**

\[ R_{el1} = \frac{27.7333 \times S}{2 L_2 - L_1} = 517 \]
7. **CONSTANTS FOR EXTRAPOLATION TABLE**

**ELASTIC RANGE**

a. \( \frac{T_n}{10} = \frac{.01}{10} = .001 \)

b. \( \Delta t = .001 \)

c. \((\Delta t)^2 = 1 \times 10^{-6}\)

d. \(P_0 = \frac{P_f X A}{1000} = 447\text{ KIP}\)

e. \(P_1 = P_0(1 - \frac{t}{.05}) = 447(1 - \frac{.001}{.05}) = 438\)

f. \(P_0 - P_1 = 447 - 438 = 9\)

g. \(a_o = \frac{1}{M_e} (\frac{P_o}{2} + \frac{P_1 - P_0}{6}) = 4.328\)

h. \(X_1 = a_o X (\Delta t)^2 = 4328 \times 10^{-6} \times 1 = .004328\)

i. \(\frac{(\Delta t)^2}{M_e} = \frac{1 \times 10^{-6}}{.051290} = 19.496 \times 10^{-6}\)

**PLASTIC RANGE**

a. \(\Delta t = .001\)

b. \((\Delta t)^2 = 1 \times 10^{-6}\)

c. \(\frac{(\Delta t)^2}{M_p} = \frac{10^{-6}}{.051035} = 19.594 \times 10^{-6}\)
ACCELERATION IMPULSE EXTRAPOLATION TABLE

\[ X_{el} = 0.032888 \quad R_{el} = 517 \quad K_1 = 15,706 \]

<table>
<thead>
<tr>
<th>( N )</th>
<th>( t ) (Sec.)</th>
<th>( P_n ) (Kips)</th>
<th>( R_n ) (Kips)</th>
<th>( P_n - R_n ) (Kips)</th>
<th>( (\Delta t)^2 ) ( m )</th>
<th>( A_n (\Delta t)^2 ) Feet</th>
<th>( 2X_n ) (Feet)</th>
<th>( X_n - 1 ) (Feet)</th>
<th>( X_n + 1 ) (Feet)</th>
<th>Remarks</th>
</tr>
</thead>
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<tr>
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<td>0</td>
<td>447</td>
<td>( 19496 \times 10^{-6} )</td>
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<td>0</td>
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<td>0</td>
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<td>0</td>
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</tr>
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<tr>
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<td>0.057719</td>
<td>0.056102</td>
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</tbody>
</table>

RESULTS
- Maximum Deflection = 0.078824
- Elastic Deflection = 0.032888
- Permanent Deflection = 0.045936
- Ratio = \( \frac{517}{447} = 1.16 \)
- Max. Rebound =

At 3" allowable total deflection - will take 5.4 max. blasts
### $R_x$ Table

Maximum $R_x$ to Minus $R_{el}$

<table>
<thead>
<tr>
<th>$R_{Max.}$</th>
<th>$\left( \frac{X_{Max.}}{X_x} \right)$</th>
<th>$X_x$</th>
<th>$K_1$</th>
<th>$R_x$</th>
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<tbody>
<tr>
<td>517</td>
<td>0.7382</td>
<td>0.01343</td>
<td>15,706</td>
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<td>0.073423</td>
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<td>0.057719</td>
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<tr>
<td>&quot;</td>
<td>0.056102</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
</tbody>
</table>

"-27 d
7. CONSTANTS FOR EXTRAPOLATION TABLE

ELASTIC RANGE

a. \( \frac{T_n}{10} = 0.001 \)

b. \( \Delta t = 0.001 \)

c. \( (\Delta t)^2 = 1 \times 10^{-6} \)

d. \( P_o = \frac{\pi}{1,000} = 447 \) KIP

e. \( P_1 = P_o (1 - \frac{\Delta t}{0.024}) = 428 \) KIP

f. \( P_o - P_1 = 447 - 428 = 19 \) KIP

g. \( a_o = \frac{1}{M_e} \left( \frac{P_o}{2} + \frac{P_1 - P_o}{6} \right) = 4296 \)

h. \( X_1 = a_o \Delta t (\Delta t)^2 = 4296 \times 1 \times 10^{-6} = 0.004296 \)

i. \( \frac{(\Delta t)^2}{M_e} = 1 \times 10^{-6} \times 0.051290 = 19.496 \times 10^{-6} \)

PLASTIC RANGE

a. \( \Delta t = 0.001 \)

b. \( (\Delta t)^2 = 1 \times 10^{-6} \)

c. \( \frac{(\Delta t)^2}{M_p} = 19.594 \times 10^{-6} \)
### ACCELERATION IMPULS Extrapolation Table

<table>
<thead>
<tr>
<th>N</th>
<th>t (Sec.)</th>
<th>P_n (Kips)</th>
<th>R_n (Kips)</th>
<th>P_n - R_n (Kips)</th>
<th>((\Delta t))^2</th>
<th>A_n ((\Delta t))^2 (Feet)</th>
<th>2 X_n (Feet)</th>
<th>X_n - 1 (Feet)</th>
<th>X_n + 1 (Feet)</th>
<th>Remarks</th>
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<td>447</td>
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#### RESULTS

- **Maximum Deflection** = .063079
- **Ratio** = \(\frac{517}{447}=1.16\)
- **Elastic Deflection** = .032888
- **Permanen Deflection** = .030191
- **Max. Rebound** = -14 Kips

At 3" allowable total deflection - will take max. blasts
### $R_x$ Table

Maximum $R_x$ to Minus $R_{el}$

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<thead>
<tr>
<th>$R_{\text{Max.}}$</th>
<th>$\left( X_{\text{Max.}} - X_x \right)$</th>
<th>$\times K_1$</th>
<th>$= R_x$</th>
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27h
Scale: [Table]

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<td>DOOR NO. 60-12-19 - T1</td>
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<td>24-1/2&quot; thick - 50 PSI Incident Pressure</td>
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<tr>
<td>LOAD DURATION - .024 Sec.</td>
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CALCULATION FOR LOCAL CONDITION

1. \( M_L = M_s = \frac{1}{4} \times 41.6 \times t^2 = \frac{1}{4} \times 41.6 \times 1 \)
   \( = 10.4 \text{ K in/in} \)

2. \( \sum M = \frac{2 M}{12} = \frac{1}{6} \times 10.4 = 1.73 \text{ K-ft/in} \)

3. \( R = \frac{8 M}{L} = \frac{1.73 \times 8}{1.125} = 12.3 \text{ K/in} \)

4. \( F = \frac{12 P \times L \times 1 \text{ (per inch)}}{1,000} = \frac{12 \times 197 \times 1.125}{1,000} = 2.66 \text{ K/in} \)

5. \( \text{D.L.F.} = \frac{R}{F} = \frac{12.3}{2.66} = 4.6 > 2 \) (Member remains elastic)
CHECK FOR LOCAL BUCKLING OF ONE-WAY BEAMS

Beam = 24 WF @ 145

\[ a = 22-1/2 \]
\[ b = 13-1/2 \]
\[ d = 24-1/2 \]
\[ t_f = 1 \]
\[ t_w = 0.625 \]

1. Compression Flange Ratio \( \frac{b}{t_f} = 13.5 \)

2. Web Ratio \( \frac{a}{t_w} = \frac{22.5}{0.625} = 36 \)

WEB REINFORCEMENT (When required)

\[ t_s \geq \frac{t_w}{5/8} \]

3. \( b_s \leq 6 t_s \) - Web Stiffener
   \( \leq 7 t_s \) - Load Bearing or Compression Stiffener

Length of Stiffeners
Locate symmetrical with mid-point of door

27 k
CHECK FOR LATERAL-TORSIONAL BUCKLING

GIVEN:

\[ \begin{align*}
K^L &= .51 \\
L &= \text{Span} = 204 \\
d &= \text{Depth of Beam} = 24-1/2 \\
b &= \text{Width of Flange} = 13-1/2 \\
T_f &= \text{Thickness of Flange} = 1
\end{align*} \]

1. \[ \frac{K^L d}{b T_f} = \frac{.51 \times 204 \times 24-1/2}{13.5 \times 1} = 188.8 \]
BLAST COLUMN DESIGN

PLAN SECTION OF COLUMN

\[ P_T = \text{Total Blast Load} \]
\[ P_c = \text{Column Load} = \frac{P_T}{2} \]

\[ P_T = H \times W \times P_R \times \frac{R_{EL}}{P_{Max}} \times 144 = 18 \times 14 \times 197 \times 1.2 \times 144 \]

\[ = 8,578 \text{ KIPS} \]

\[ P_c = \frac{P_T}{2} = \frac{8,578}{2} = 4,289 \text{ KIPS} \]
BLAST COLUMN DESIGN

A. COLUMN LOADING - NO ALLOWANCE FOR CONCRETE

\[ S = \frac{M}{Z} \quad M = \text{Maximum Bending Moment} \]
\[ Z = \text{Section Modulus} \]

\[ M = \frac{wL^2}{8} = \frac{WL}{8}, \text{ since } W = wL \]

\[ M = \frac{4.289 \times 216}{8} = 115,803 \text{ in. Kips} \]

\[ S = \frac{M}{Z} = \frac{115,803,000 \text{ in}^2}{5,503 \text{ in}^3} = 21,044 \text{ #/in}^2 < 41,600 \text{#/in}^2 \]

\[ \therefore \text{ Column section is satisfactory for bending stresses. Concrete filling of column will prevent buckling or twisting of column.} \]

\[ I_{na} = \frac{36 \times 60^3}{12} - \frac{32 \times 56^3}{12} = (3 \times 60^3) - (2.75 \times 56^3) = 165,078 \text{ in}^4 \]

\[ Z - \text{Section Modulus} = \frac{I_{na}}{c} = \frac{165,078 \text{ in}^4}{30 \text{ in.}} = 5,503 \text{ in}^3 \]

\[ W = P_c = 4289 \text{ KIPS} \]
\[ w = \frac{W}{L} = 43.6 \text{ KIPS/IN} \]
B. COLUMN FRONT PLATE LOADING

Assume 1" wide strip and 45° stress distribution to concrete.

1. \( W = \text{Column load per inch} = \frac{4,289 \text{ KIPS}}{216 \text{ in}} = 19,856 \# \)

2. \( R_c = \text{Resistance of concrete} = S_c \times A \)
   \( S_c = 3,900 \text{ PSI} \)
   \( R_c = 3,900 \times 1 \times 9 = 42,900 \# \)

3. Thus steel must resist a load of \( (W - R_c) \) and \( (in - R_c) \) can be used as the applied load.
   \( W - R_c = 19,856 - 35,100 \)
   \( W_A = \text{Since concrete resistance is enough, any steel plate is O.K.} \)

4. \( S_s = \frac{M}{Z} = \frac{bh^2}{6} = \frac{1 \times 3^2}{6} = 1.5 \)
   \( M_{\text{max}} = \left[ (18 \frac{W_a}{2}) + \frac{4 W_a}{2 \times 2} \right] \)
   \( M = 9 W_a + W_a = 10 W_a = 10 \times 660 = 6,600 \text{ in}\# \)
   \( S_s = \frac{6600 \text{ in}\#}{1.5 \text{ in}^3} = 4,400 \#/\text{in}^2 < 41,600 \#/\text{in}^2 \)
   \( \therefore \) 2" plate is O.K.
C. **CONCRETE BEARING STRESS**

Assume column set 24" in concrete

\[ S_c = \frac{P}{A} \quad P = \text{Bearing Load} = \frac{P_c}{2} \]

\[ A = \text{Bearing Area} = \text{W} \times \text{h} \quad \text{where W = column width} \]

\[ h = \text{depth of column in concrete} \]

\[ S_c = \frac{P_c}{2A} = \frac{4.289 \text{ KIPS}}{2 \times 36 \times 24} = 2,482 \text{ KIPS/in}^2 < 3,900\#/\text{in}^2 \]

\[ \therefore \text{Column set 24" in concrete in O.K.} \]
REBOUND COLUMN DESIGN

PLAN SECTION OF COLUMN

\[ P_c = \text{Column Load (applied blast)} \]
\[ P_{cr} = \text{Column Rebound Load} \]

Assume 25\% rebound

Then \( P_{cr} = \frac{P_c}{4} = \frac{4,289}{4} \text{ KIPS} = 1,072 \text{ KIPS} \)
REBOUND COLUMN DESIGN

A. COLUMN LOADING - NO ALLOWANCE FOR CONCRETE

\[ M = \frac{wL^2}{8} \quad \text{since } W = wL \]

\[ M = \frac{1,072 \times 216}{8} = 28,944 \text{ in. Kips} \]

\[ S = \frac{M}{Z} = \frac{28,944,000 \text{ in}^2}{2,178} = 13,289\text{#/in}^2 < 41,600\text{#/in}^2 \]

Column section is satisfactory for bending stresses. Concrete filling will prevent buckling or twisting of column.

\[ I_{na} = \frac{36 \times 30^3}{12} - \frac{33 \times 26^3}{12} = (3 \times 30^3) - (2.75 \times 26^3) = 32,660 \text{ in}^4 \]

\[ Z = \text{Section Modulus} = \frac{I_{na}}{c} = \frac{32,660 \text{ in}^4}{15 \text{ in}} = 2,178 \text{ in}^3 \]

\[ W = P_{CR} = 1072 \text{ KIPS} \]

\[ w = 4962\text{#/IN} \]
REBOUND COLUMN DESIGN

B. CHECK REBOUND COLUMN LOADED BY DIRECT BLAST ON COLUMN FACE - NO ALLOWANCE FOR CONCRETE

1. \( W_L = h \times W \times 144 \times 2P_x = 18 \times 3 \times 144 \times 394 = 3,064 \text{ KIPS} \)

2. \( M = \frac{W_L}{8} = \frac{3,064 \times 216}{8} = 82,728 \text{ in-kips} \)

3. \( S = \frac{M}{Z} = \frac{82,728}{2,178} \text{ in}^2 = 37,983 \text{#/in}^2 = 41,600 \text{#/in}^2 \)

Since no allowance was made for concrete, the concrete fill will make this column strong enough to withstand a direct blast.

4. Concrete Bearing Stress
   Column set 36" into concrete
   \( S_c = \frac{P}{A} = \frac{W_L}{2} \quad A \approx (48)(36) \)
   \( S_c = \frac{3064}{(2)(36)(15)} = 3 \text{ KIPS/IN}^2 \)
   \( S_c = 2837 \text{#/IN}^2 = 3900 \text{#/IN}^2 \)

" Column set 24" in concrete is O.K.

\[ W_L = 10,368 \text{ KIPS} \]
\[ w = 48,000 \text{"/IN} \]

216" (18')
CALCULATIONS

2-WAY SPAN DOOR TRIAL NO. 1
SOLID DESIGN
SIMPLY SUPPORTED 4 SIDES 2'-6" x 4'-0", 100 PSI

ELASTO-PLASTIC DOOR NO. 60-12-26
CALCULATIONS BY T.A.
CHECKED BY H.S.

GIVEN:

\[ t = \text{Assumed Thickness} = 2.50 \text{ Inches} \]
\[ T = \text{Load Duration} = 0.050 \text{ Sec.} \]
\[ P_I = \text{Peak Reflected Pressure} = 500 \text{ PSI} \]
\[ W = \text{Total Weight of Door} = 1021 \text{ Lbs.} \]
\[ a = \text{Short Span of Door} = 30 \text{ Inches} \]
\[ b = \text{Long Span of Door} = 48 \text{ Inches} \]
\[ \beta = \text{Timoshenko Moment Constant} = 0.0862 \]
\[ \alpha = \text{Timoshenko Deflection Constant} = 0.0906 \]
\[ K_{LM} = \text{Mass-Load Constant} = \frac{.74}{\text{ELASTIC}} \frac{.58}{\text{PLASTIC}} \]

FIND:

1. ELASTIC RESISTANCE (KIP)

\[ R_{el} = \frac{6.933 \times t^2 \times b}{\beta \times a} = \frac{6.933 \times 2.50^2 \times 48}{0.0862 \times 30} \]
\[ = \frac{2079.90}{2.586} = 804 \]

2. ELASTIC DEFLECTION (FEET)

\[ X_{el} = \frac{6.933 \times \alpha \times a^2}{360 \times 10^3 \times t \times \beta} = \frac{0.0906 \times 30^2 \times 6.933}{360 \times 10^3 \times 2.5 \times 0.0862} \]
\[ = \frac{565.31682}{77,580} = 0.007287 \]
3. **PLASTIC MOMENT** (KIP-Inch/Inch)

\[ M_p = 10.4 \times t^2 = 10.4 \times 2.5^2 = 65 \]

4. **ASSUMED TRAPEZOID FOR CRACK-LINE SECTION**

(All dimensions in feet)

![Diagram of assumed trapezoid for crack-line section]

- **Loaded Area Cross-Hatched**
- **Total Moment Arm**

5. **AREA OF TRAPEZOID LOADED (SQUARE FEET)**

\[ A = (f + e) \times g = (1.5 + .9833) \times 1.24998 = 3.10408 \]

6. **MOMENT ARM "c" (FEET)**

\[ "c" = \frac{\frac{f \times g^2}{3} + \frac{e \times g^2}{2}}{A} \]

\[ = \frac{1.5 \times 1.24998^2}{3} + \frac{.9833 \times 1.24998^2}{2} \]

\[ = \frac{3.10408}{3.10408} = .49915 \]
7. **TOTAL MOMENT ARM (FEET)**

\[
\text{TMA} = "c" + h = 0.4991511 + 0.04167 = 0.54082
\]

8. **UNIT RESISTANCE (Kip/Foot^2)**

\[
R_{\text{unit}} = \frac{M_p \times L}{\text{TMA} \times A} = \frac{65 \times 4.0833}{0.54082 \times 3.10408} = 158
\]

9. **ASSUMED TRIANGLE FOR CRACK-LINE SECTION**

*(All dimensions in feet)*
10. **AREA OF TRIANGLE LOADED (SQUARE FEET)**

\[ A = \frac{1}{2} \times k \times j = \frac{1}{2} \times 1.50833 \times 2.514 = 1.8960 \]

11. **MOMENT ARM "c" (FEET)**

\[ "c" = \frac{k}{3} = \frac{1.50833}{3} = 0.50278 \]

12. **TOTAL MOMENT ARM (FEET)**

\[ TMA = "c" + h = 0.50278 + 0.04167 = 0.54445 \]

13. **UNIT RESISTANCE (Kip/Foot²)**

\[
R_{unit} = \frac{M \times L}{\frac{TMA \times A}{1.032277}} = \frac{65 \times 2.5833}{0.54445 \times 1.8960} = 167.9145 \times \frac{1}{1.032277} = 163
\]

14. **TOTAL EFFECTIVE RESISTANCE (KIP)**

\[
R_1 = 2 \times (R_{unit} \times A + R_{unit} \times A) \times 0.80
\]

\[ = 2 \times (158 \times 3.10408) + (163 \times 1.8960) \times 0.80\]

\[ = 1.60 \times 799.49 = 1279 \]

15. **PEAK LOAD (KIP)**

\[ P_o = \frac{P \times a \times b}{1,000} = \frac{500 \times 30 \times 48}{1,000} = 720 \]

16. **ELASTIC SPRING CONSTANT (Kip/Foot)**

\[ K_1 = \frac{R_{el}}{X_{el}} = \frac{804}{0.007287} = 110333 \times 10^6 \]

28 c
17. **PLASTIC SPRING CONSTANT (Kip/Foot)**

(Assume $X_1 = 3X_e$)

$$X_2 = \frac{R_1 - R_{el}}{X_1 - X_{el}} = \frac{1272 - 804}{.005757} = \frac{475}{.005757}$$

$$= .082508 \times 10^6$$

18. **EFFECTIVE MASS (Kip - Sec²/Foot)**

$$M_e = \frac{W \times K_{LM}}{32,200} = \frac{1021 \times .74}{32,200} = .023464$$

$$M_p = \frac{W \times K_{LM}}{32,200} = \frac{1021 \times .58}{32,200} = .018391$$

19. **NATURAL PERIOD (SECONDS)**

$$T_n = 2\pi \times \sqrt{\frac{M_e}{K_1}}$$

$$= 6.2832 \times \sqrt{\frac{.023464}{.110333 \times 10^6}}$$

$$= 6.2832 \times \sqrt{.000000212665295}$$

$$= 6.2832 \times .0004612 = .002898$$

28 d
20. **CONSTANTS FOR EXTRAPOLATION TABLE**

**ELASTIC**

a. \( \frac{T_n}{10} = \frac{0.0029}{10} = 0.00029 \text{ Sec.} \)

b. \( \triangle t = 0.0002 \text{ Sec.} \)

c. \( (\triangle t)^2 = 4 \times 10^{-8} \text{ Sec.}^2 \)

d. \( P_o = 720\text{Kip} \)

e. \( P_1 = P_o \left( 1 - \frac{\triangle t}{0.050} \right) = 720 \left( 1 - \frac{0.0002}{0.050} \right) = 717 \text{ KIP} \)

f. \( P_o - P_1 = 720 - 717 = 3 \text{ Kip} \)

g. \( a_o = \frac{1}{m_e} \times \left( \frac{P_o}{2} + \frac{P_1 - P_o}{6} \right) \)

\[
= \frac{1}{0.023464} \left( \frac{720}{2} - \frac{3}{6} \right) = 15,321
\]

h. \( X_1 = a_o \times (\triangle t)^2 = 15,321 \times 4 \times 10^{-8} = 0.000613 \text{ ft.} \)

i. \( \frac{(\triangle t)^2}{m_e} = \frac{4 \times 10^{-8}}{0.023464} = 170 \times 10^{-8} \)
ELASTO-PLASTIC \[ M_e \sim M_{ep} \]

* PLASTIC (For \(X_1\) only)

a. \[ \left( \frac{\Delta t}{m_p} \right)^2 = \]

b. \(K_2\) =

c. \(R_{el}\) =

d. \(R_x\) = \(R_{el} + K_2 (X_x - X_{el})\)

* Not used this calculation

28 f
### ACCELERATION IMPULSE EXTRAPOLATION TABLE

\[ X_{el} = 0.007287 \quad R_{el} = 804 \quad K_1 = 110,333 \quad K_2 = 82,508 \]

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<th>( t ) (Sec.)</th>
<th>( P_n ) (Kips)</th>
<th>( R_n ) (Kips)</th>
<th>( P_n - R_n ) (Kips)</th>
<th>( \left( \frac{\Delta t}{m} \right)^2 )</th>
<th>( A_n \left( \frac{\Delta t}{m} \right)^2 )</th>
<th>( 2 \times X_n ) (Feet)</th>
<th>( X_n - 1 ) (Feet)</th>
<th>( X_n + 1 ) (Feet)</th>
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**RESULTS**

- Maximum Deflection = 0.013479
- Elastic Deflection = 0.007287
- Permanent Deflection = 0.006192

**Ratio** = \( \frac{1315}{720} = 1.83 \)

At 0.5" allowable total deflection - will take 6.7 max. blasts
**R\_x TABLE (T = .05)**

Plastic Range to Maximum R\_x

<table>
<thead>
<tr>
<th>X_x</th>
<th>X_el</th>
<th>X</th>
<th>K_2</th>
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<th>R_x</th>
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.28 h
<table>
<thead>
<tr>
<th>$R_{\text{Max.}}$</th>
<th>$\left( \bar{x}_{\text{Max.}} - \bar{x}_x \right)$</th>
<th>$\times$</th>
<th>$k_1$</th>
<th>$\equiv$</th>
<th>$R_x$</th>
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</table>
20. **CONSTANTS FOR EXTRAPOLATION TABLE (T = .0041)**

**ELASTIC**

a. \[
\frac{T_n}{10} = \frac{0.0029}{10} = 0.00029
\]

b. \[\Delta t = 0.0002\]

c. \[(\Delta t)^2 = 4 \times 10^{-8}\]

d. \[P_o = \frac{P_k \times A}{1,000} = 720 \text{ KIP}\]

e. \[P_1 = P_o (1 - \frac{\Delta t}{0.0041}) = 720 \left(1 - \frac{0.0002}{0.0041}\right) = 685 \text{ KIP}\]

f. \[P_o - P_1 = 720 - 685 = 35 \text{ KIP}\]

g. \[a_o = \frac{1}{m_e} \times \left(\frac{P_o}{2} + \frac{P_1 - P_o}{6}\right)\]

\[= \frac{1}{0.023464} \left(\frac{720}{2} - \frac{35}{6}\right) = 15,094\]

h. \[X_1 = a_o \times (\Delta t)^2 = 15,094 \times 4 \times 10^{-8} = 0.00604\]

i. \[\frac{(\Delta t)^2}{m_e} = \frac{4 \times 10^{-8}}{0.023464} = 170 \times 10^{-8}\]

**ELASTO-PLASTIC** \[M_e \simeq M_{ep}\]

* **PLASTIC**

* Not used this calculation

28 k
# Acceleration Impulse Extrapolation Table

\[ X_{el} = 0.007287 \quad R_{el} = 804 \quad K_1 = 110,333 \quad K_2 = 82,508 \]

<table>
<thead>
<tr>
<th>N (Sec.)</th>
<th>( P_n ) (Kips)</th>
<th>( R_n ) (Kips)</th>
<th>( P_n - R_n ) (Kips)</th>
<th>((\Delta t)^2) (\frac{m}{\text{Kips}})</th>
<th>( A_n ) ((\Delta t)^2) (Feet)</th>
<th>( 2X_n ) (Feet)</th>
<th>( X_n - 1 ) (Feet)</th>
<th>( X_n + 1 ) (Feet)</th>
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Ratio \[\frac{432}{1315} = 32.9\%\]

Max. Rebound = 432 Kips
Plastic Range to Maximum $R_x$

<table>
<thead>
<tr>
<th>$X_x$</th>
<th>$X_{el}$</th>
<th>$X$</th>
<th>$K_2$</th>
<th>$\times$</th>
<th>$R_{el}$</th>
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</table>

28 m
### $R_x$ TABLE

Maximum $R_x$ to Minus $R_{e1}$

<table>
<thead>
<tr>
<th>$R_{Max.}$</th>
<th>$\left( \frac{X_{Max.} - X_x}{K_1} \right)$</th>
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<th>$K_1$</th>
<th>$R_x$</th>
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<td>0.014118</td>
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</table>

28n
The diagram shows a graph with the following key points:

- **X-axis**: Permanent Deflection (in Ft.)
- **Y-axis**: Resistance (in Kips)

The graph includes two main lines:
- **Max. Elastic Resistance**
- **Max. Rebound**

**Scale:**
- 28.0
- 1200 1000 800 600 400 200 -200 -400
- -0.004 -0.002 0.002 0.004 0.006 0.008 0.010 0.012

**Approved by:**

- Door No. 60-12-26 - T1
- 2-1/2" Thick Solid Steel - 100 PSI Incident
- Load Duration - 0.0041 Sec.
BEARING STRESS

A =
B = 32
C = 50
D = 48
E = 18
F = 7.6
T = 1

R_M = Maximum Door Resistance = 1,315,000

Bearing Stress (along long edge is a maximum) =

\[
\frac{R_M \times \frac{(C + E)}{2} \times F}{B \times C \times D \times T} = \frac{1,315,000 \times 34 \times 16}{32 \times 50 \times 48 \times 1} = \frac{44,710,000}{4,800}
\]

S_B = 9,315 for T = 1"

Use T = 1/2" (S_B = 18,730#/D")
VERTICAL STRIKER THICKNESS CALCULATION

Take a typical 1" long vertical strip.

Average Force per Lineal Inch = \( F = S_B \times T = 9,315 \)

Bending Moment = \( M_b = F \times D = 9,315 \times .625 = 5,822 \)

Minimum Required Thickness = \( d = \sqrt{\frac{6 \ M_b}{41,600}} = \sqrt{\frac{34,932}{41,600}} \)

= \( \sqrt{.839712} = .916 \) (for \( T = 1" \))

Use \( d = 3/4" \) (.7117 Min.) (for \( T = 1/2" \))

\( F_c \) = Total force on vertical striker

41,600 = allowable bending stress
REBOUND LOAD CALCULATION FOR LOCK BOLTS

Consider rebound resisted equally by "dead latch" and lock bolts.

Then:

Rebound force per bolt = \( P = \frac{\text{Max. Rebound Force}}{2 \times \text{no, of lock bolts}} \)

\[
= \frac{432,000}{8} = 54,000
\]

Maximum total rebound force is obtained from rebound calculations.
LOCK BOLT CALCULATIONS - REBOUND - BLAST DOOR

\[ P = 54,000 \]

\[ .8125 = L \]

\[ \text{LOCKING BOLT} \]

\[ D = 2.250 \]

P = Equivalent Static Force per Bolt in Pounds
L = Length in Inches
D = Diameter in Inches
A = Bearing Area in Sq. In.

Min. "A" = 1.800

1. Vertical Shear = \[ \frac{4P}{\pi D^2} = \frac{4 \times 54,000}{\pi \times 5.0625} = \frac{216,000}{15.904} = 13,582 \]

2. Horiz. Shear = \[ \frac{16P}{3 \times \pi \times D^2} = \frac{16 \times 54,000}{3 \times \pi \times 5.0625} = \frac{864,000}{47.712} = 18,109 \]

3. Bending Stress = \[ \frac{32P \times L}{\pi D^3} = \frac{32 \times 54,000 \times .8125}{3.1416 \times 11.3906} = \frac{1,404,000}{35.785} = 39,234 \]

4. Bearing Stress = \[ \frac{P}{A} = \frac{54,000}{2.336} = 23,116 \]

ALLOWABLE STRESSES - #A-7 STEEL:
1. 21,000 PSI
2. 21,000 PSI
3. 41,600 PSI
4. 30,000 PSI
CALCULATIONS - DOOR SWING AND DOOR TAPER

Swing = S = \sqrt{(A + B)^2 + (C + D)^2} = \sqrt{(31.0625)^2 + (3.75)^2} = \sqrt{978.94140625} = 31.2880

Taper = E = \frac{C^2 + CD}{(A + B)} = \frac{6.25 + 3.125}{31.0625} = \frac{9.375}{31.0625} = .30181

Use 5/16"
KLM FACTOR FOR VARIOUS BEAM BLAST LOADING CONDITIONS

**Uniform Blast Loading Over Entire Span**

<table>
<thead>
<tr>
<th>Strain Range</th>
<th>Load-Mass Factor KLM</th>
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</thead>
<tbody>
<tr>
<td>Elastic</td>
<td>.78</td>
</tr>
<tr>
<td>Plastic</td>
<td>.66</td>
</tr>
</tbody>
</table>

**Symmetrical Uniform Blast Loading Over Part of Span**

<table>
<thead>
<tr>
<th>Strain Range</th>
<th>Load-Mass Factor KLM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elastic</td>
<td>( \frac{384 \times L^3}{\pi^4 (8L^3 + L_1^3 - 4LL_1^2)} )</td>
</tr>
<tr>
<td>Plastic</td>
<td>( \frac{2L}{3(2L - L_1)} )</td>
</tr>
<tr>
<td>Elasto-Plastic</td>
<td>( \frac{.5(K_{LM} + K_{LM_P})}{2} )</td>
</tr>
</tbody>
</table>

**Concentrated Blast Load at Mid-Point**

<table>
<thead>
<tr>
<th>Strain Range</th>
<th>Load-Mass Factor KLM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elastic</td>
<td>A</td>
</tr>
<tr>
<td>Plastic</td>
<td>B</td>
</tr>
</tbody>
</table>

A = Concentrated Mass  
B = Uniform Mass

* Expressed in terms of L and L₁

Figure IV-5
DERIVATION OF $K_{LM}$ FOR BEAM

PARTIALLY LOADED SPAN

Simply Supported One-way Beam of Constant Cross-Section

Shear Distortion Negligible

\[ \text{Simply Supported One-way Beam of Constant Cross-Sec-} \]
\[ \text{tion} \]

\[ \text{Left Reaction} \quad \text{Span} \quad \text{Right Reaction} \]

GIVEN:
Simply supported one-way beam of constant cross-section

FIND:
$K_{LM}$ - Elastic and Plastic

Total Load = $w \times L_1 = W$

Spring Constant = $k = \frac{384 \times E \times I}{(8L^3 + L_1^3 - 4LL_1^2)}$

ELASTIC

\[ 2\pi \times \sqrt{\frac{m_e}{k}} = \frac{2}{\pi \times n^2} \times \sqrt{\frac{m \times L^3}{E \times I}} \]  (Consider fundamental node only $n = 1$)

\[ \frac{\pi^2 \times m_e}{k} = \frac{m \times L^3}{\pi^2 \times E \times I} \]
\[ K_{LM_e} = \frac{m_e}{m} = \frac{k \times L^3}{\pi^4 \times E \times I} = \frac{384 \times E \times I \times L^3}{\pi^4 \times E \times I \times (8L^3 + L_1^3 - 4L_1^2)} \]

\[ = \frac{384 \times L^3}{\pi^4 \times (8L^3 + L_1^3 - 4L_1^2)} \]

**PLASTIC**

\[ \frac{W}{2} \times L_o - M_e = \frac{I_{AB} \times X'}{L_2} \]

(Where \( L_o = \frac{L}{2} - \frac{L_1}{4} = \frac{2L - L_1}{4} \))

\[ W - 2 M_o = \frac{4 I_{AB} \times X' \times CL}{L \times L_o} = m_e \times X' \]

\[ m_e = \frac{4 I_{AB}}{L \times L_o} = \frac{4}{L \times L_o} \times \frac{m L^2}{246} \]

\[ K_{LM_p} = \frac{m_e}{m} = \frac{m \times L}{m \times 6 \times L_o} = \frac{L}{6L_o} = \frac{4 \times L}{6(2L - L_1)} = \frac{2 \times L}{3(2L - L_1)} \]

**ELASTO-PLASTIC**

\[ K_{LM_{ep}} \approx 0.05 (K_{LM_e} + K_{LM_p}) \]
DERIVATION OF $K_{LM}$ FOR BEAM - PARTLY LOADED SPAN

Elasto-plastic - Solid Steel

Plastic Range Solid Steel

Plastic Range Flanged Members and Concrete

Deflection

Elastic Range

IDEALIZED RESISTANCE-DEFLECTION DIAGRAM

MAXIMUM POSSIBLE ERRORS USING FIRST MODE ONLY - ELASTIC RANGE

<table>
<thead>
<tr>
<th>UNIFORM LOAD ($\frac{T}{T_n} &gt; 2$)</th>
<th>CONCENTRATED LOAD ($\frac{1}{T_n} &gt; 2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absolute*</td>
<td>Absolute*</td>
</tr>
<tr>
<td>Average**</td>
<td>Average**</td>
</tr>
<tr>
<td>$&lt; 14%$</td>
<td>$&lt; 14%$</td>
</tr>
<tr>
<td>$&lt; 2%$</td>
<td>$&lt; 70%$</td>
</tr>
<tr>
<td>$&lt; 5%$</td>
<td>$\sim 0$</td>
</tr>
<tr>
<td>$&lt; 1%$</td>
<td>$\sim 0$</td>
</tr>
<tr>
<td>Support Shear</td>
<td>$&lt; -10%$</td>
</tr>
<tr>
<td>Mid-Span Moment</td>
<td></td>
</tr>
<tr>
<td>Mid-Span Deflection</td>
<td></td>
</tr>
</tbody>
</table>

* Assuming Maximums of all Modes Occur Simultaneously and Neglecting Damping

** Using Average of all Modes and Neglecting Damping
DERIVATION OF $R_{el}$, $X_{el}$, and $K_1$ FOR PARTIALLY LOADED SPAN

**GIVEN:**

\[ a = \frac{L_2 - L_1}{2} \]

$P_e$ = Elastic Pressure (Unit) = PSI

$w$ = Pressure per Unit of Length - $W \times P_e$ #/inch

**FIND:**

$R_{el}$

Elastic Load = $w \times L_1$

Beam

\[ \frac{R_{el}}{2} = \frac{w \times L_1}{2} \]

$R_{el} = w \times L_1 = \frac{w \times 8M}{w(2L_2 - L_1)} = \frac{8M}{(2L_2 - L_1)} = \frac{8 \times 41.6 \times S}{(2L_2 - L_1)} = \frac{332.8 \times S}{K - #}$

or, if $L_1$ and $L_2$ are in feet:

$R_{el} = \frac{332.8 \times S}{12(2L_2 - L_1)} = \frac{27.79333 \times S}{K - #}$

$M_{elastic} = M_{max. \ @ \ center} = \left[ \frac{w \times L_1}{2} \times \frac{L_2}{2} - \frac{w \times L_1}{2} \times \frac{L_1}{4} \right] = \frac{w \times L_1 \times L_2}{4} - \frac{w \times L_1^2}{8} = \frac{w \times w \times L_1 \times L_2}{8} - \frac{w \times L_1^2}{8} = \frac{wL_1(2L_2 - L_1)}{8}$ or $L_1 = \frac{8M}{w(2L_2 - L_1)}$

Figure IV-6
Given: \( w = \) Elastic load per lineal inch

Find: \( X_{el} \)  
\[ X_{el} = \frac{L_2}{2} \]

\[ X_{el} = 2 \int_{a}^{2} \frac{wx}{48\ E\ I} (3L_2^2 - 4x^2) \]  
\[ \left( \text{Timoshenko "Strength of Materials" 2nd Edition, Part I, Page 158} \right) \]

\[ = \frac{2w}{48\ E\ I} \left\{ 3L_2^2 \int_{a}^{2} x\ dx - 4 \int_{a}^{2} x^3\ dx \right\} \]
\[ = \frac{2w}{48\ E\ I} \left\{ 3L_2^2 \left[ \frac{L_2^2}{8} - \frac{a_2^2}{2} \right] - 4 \left[ \frac{L_2^4}{64} - \frac{a_4}{4} \right] \right\} \]
\[ = \frac{w}{24\ E\ I} \left( \frac{3}{8} L_2^4 - \frac{3}{2} a_2^2 L_2^2 - 4 \frac{L_2^4}{64} + 4 \frac{a_4}{4} \right) \]
\[ = \frac{w}{24\ E\ I} \left( \frac{5}{16} L_2^4 - \frac{3}{2} a_2^2 L_2^2 + a_4 \right) \]

But: \( a = \frac{L_2 - L_1}{2} \)

\[ \therefore \]  
\[ X_{el} = \frac{w}{24\ E\ I} \left[ \frac{5}{16} L_2^4 - \frac{3}{2} L_2^2 \left( \frac{L_2 - L_1}{2} \right)^2 + \left( \frac{L_2 - L_1}{2} \right)^4 \right] \]
\[ \begin{align*}
x_{e1} &= \frac{w}{24EI} \left[ \frac{5}{16} L_2^4 - \frac{3L_2^2}{2} \left( \frac{L_2^2 - 2L_1 L_2 + L_1^2}{4} \right) \right. \\
& \quad \quad + \left. \frac{L_2^4 - 4L_1^3 + 6L_1^2 L_2 - 4L_1^3 L_2 + L_1^4}{16} \right] \\
&= \frac{w}{24EI} \left[ \frac{5}{16} L_2^4 - \frac{3L_2^2}{8} \left( \frac{L_2^4 - 2L_1^3 + L_1^2}{L_2^2} \right) \right. \\
& \quad \quad + \left. \frac{L_2^4}{16} - \frac{1}{4L_1^3} + \frac{3L_2^2}{8L_1 L_2} - \frac{1}{4L_1 L_2} + \frac{L_1^4}{16} \right] \\
&= \frac{w}{24EI} \left( \frac{5}{16} L_2^4 - \frac{3L_2^2}{8L_2^2} + \frac{3L_1 L_2^3}{4L_2^2} - \frac{3L_2^2}{8L_2 L_2} + \frac{L_2}{16} \right. \\
& \quad \quad - \left. \frac{1}{4L_1^2} + L_2^2 \right) \left( \frac{3L_2^3}{4L_1 L_2} - \frac{L_1^3}{4L_1 L_2} + \frac{L_1^4}{16} \right) \\
&= \frac{w}{24EI} \left( \frac{1}{2L_1^2} - \frac{3L_2^2}{4L_1 L_2} + \frac{L_2^4}{16} \right)
\end{align*} \]

But:
\[ w = \frac{332.8 \times S}{L_1(2L_2 - L_1)} \] - K #/Lineal Inch (per page 30 c)

\[ \begin{align*}
x_{e1} &= \frac{332.8 \times S}{L_1(2L_2 - L_1)} \times \frac{L_1^3}{24EI} \left( \frac{L_2^3}{2} - \frac{L_2^2 L_2}{4} + \frac{L_1^3}{16} \right) \text{ Kip Inches} \\
&= \frac{0.46222 \times 10^{-6}}{(2L_2 - L_1)} \times \frac{S}{1} \left( \frac{8L_2^3 - 4L_1 L_2^3 + L_2^3}{16} \right) \\
&= 28.8888 \times 10^{-6} \times \frac{S}{1} \left( \frac{8L_2^3 - 4L_1 L_2^3 + L_2^3}{2L_2 - L_1} \right) = 0.00002888 \times \frac{S}{1} \left( \frac{8L_2^3 - 4L_1 L_2^3 + L_2^3}{2L_2 - L_1} \right)
\end{align*} \]

or, if \( L_1 \) and \( L_2 \) are in feet:
\[ x_{e1} = 0.00034666 \times \frac{S}{1} \left( \frac{8L_2^3 - 4L_1 L_2^3 + L_1^3}{2L_2 - L_1} \right) \]

Check this formula for case where \( L_2 = L_1 = L \):
\[ x_{e1} = \frac{w}{24EI} \left( \frac{L_2^4}{2} - \frac{L_2^4}{4} + \frac{L_2^4}{16} \right) = \frac{w L^4}{384 EI} \] - Formula checks
Elastic Moment = \( 41,600 \times S \quad "\# = M_{el} \)  

(1)

Also, Elastic Moment = \( \frac{w L_1}{8} (2L_2 - L_1) = M_{el} \)  

(2)

or \( w = W \times P_e = \frac{8 M_{el}}{L_1 (2L_2 - L_1)} \)  

(2a)

\( \frac{8 \times 41,600 \times S}{L_1 (2L_2 - L_1)} \quad \text{#/lineal inch} \)  

(2b)

\( \frac{332.8 \times S}{L_1 (2L_2 - L_1)} \quad \text{K#/lineal inch} \)  

(3)
FIND: \( K_1 \)

\[
K_1 = \frac{R_{el}}{X_{el}} = \frac{27.3333 \times S}{(2L_2 - L_1)} \times \frac{I (2L_1 - L_1)}{0.00034666 \times S \times (8L_2^3 - 4L_1^2L_2 + L_1^3)}
\]

\[
= \frac{27.3333 \times I}{0.00034666 \times (8L_2^3 - 4L_1^2L_2 + L_1^3)}
\]

\[
= 80,000 \times \frac{I}{8L_2^3 - 4L_1^2L_2 + L_1^3}
\]

Check this formula for case where \( L_2 = L_1 = L \) (in feet)

\[
K_1 = 80,000 \times \frac{I}{8L^3 - 4L^3 + L^3}
\]

\[
= 80,000 \times \frac{I}{5L^3} = 16,000 \times \frac{I}{L^3}
\]

Formula checks.
DERIVATION OF CONSTANTS $X_{el}$, $R_{el}$, and $K_1$

$w = \text{Pressure}$

$\text{Stress} = \frac{M}{S}$ \hspace{1cm} $b$ \text{ is in inches}

$L$ \text{ is in feet}

$b = 12 \times L$

or Moment = Stress $\times$ Section Modulus = 41,600 $S$ Inch-lbs.

Also, Moment $= \frac{w \times b^2}{8} = \frac{R \times b}{8}$ \hspace{1cm} $(R - w \times b = \text{Resistance})$

or $R = w \times b = \frac{8 \times M}{b} = \frac{8 \times 41,600 \times S}{b}$

$\therefore \quad X_{el} = \frac{5 \times w \times b^4}{384 \cdot E \cdot I} = \left(\frac{w \cdot b}{384 \cdot E \cdot I}\right) \left(\frac{5 \cdot b^3}{5 \cdot L^3}\right) = \frac{w \cdot b \cdot 384 \cdot E \cdot I}{5 \cdot L^3} = \frac{R}{K_1} \quad \text{(lbs/in)}$

$\therefore \quad X_{el} = \frac{8 \times 41,600 \times S \times 5 \times b^3}{b \times 384 \times E \times I} = \frac{8 \times 41,600 \times 5 \times b^2 \times S}{384 \times 30 \times 10^6 \times I}$

$= \frac{1,664,000 \times b^2 \times S}{11,520,000 \times I} = \frac{0.0001444 \cdot b^2 \times S}{I} \quad \text{Inches}$

Or $X_{el} = \frac{0.0001444 \cdot (12L)^2 \times S}{12 \times I} = 0.0001444 \times 12 \times \frac{L^2 \times S}{I}$

$\therefore \quad X_{el} = \frac{0.0017333 \times L^2 \times S}{I} \quad \text{Feet}$
\[ t_y = \text{Stress} = \frac{M}{S} \quad R_{el} = w_{el} \times L \quad w_{el} L^2 = R_{el} \times L \quad (L \text{ is in feet}) \]

\[ M = f_{dy} \times S = 41.6 \times S \quad \text{K-Ft.} \]

\[ w_{b}^2 = 8M \]

\[ R_{el} = \frac{8 \times M}{L} = \frac{8 \times 41.6 \times S}{L \times 12} = \frac{8 \times 41.6}{12} \left( \frac{S}{L} \right) = 27.7333 \times \frac{1}{3} \left( \frac{S}{L} \right) \quad \text{K - \#} \]

\[ K_1 = \frac{384 \times E \times I}{5 \times L^3} = \frac{384 \times 30 \times 10^6 \times I}{5 \times (12 \times L)^3} = \frac{384 \times 30 \times 10^6 \times I}{5 \times 12^3 \times L^3} = 1,333,333\frac{1}{3} \left( \frac{I}{L^3} \right) \quad \text{#/In.} \]

\[ = 1,333\frac{1}{3} \times \left( \frac{I}{L^3} \right) \quad \text{K/In.} \quad \text{(Divided by 1,000)} \]

\[ = 16,000 \left( \frac{I}{L^3} \right) \quad \text{K/Ft.} \quad \text{(Divided by 12)} \]

Also, \[ K_1 = \frac{R_{el}}{X_{el}} = \frac{27.7333 \times S}{L} \times \frac{I}{.0017333 \times L^2 \times S} \]

\[ = \frac{27.7333}{.0017333} \times \frac{I}{L^3} = 16,000 \left( \frac{I}{L^3} \right) \quad \text{(Checks with above derivation)} \]
DERIVATION OF CONSTANTS $R_{el}$ and $X_{el}$

**SOLID STEEL PLATE DOOR**

Bending Moment - Section Modulus $\times$ Unit Stress

$f_{dy}$ = Dynamic Yield Stress - 41.6 K for A-7 Steel

$a$ = Short span in inches $\quad b$ = long span in inches

$\varphi$ = Elastic unit pressure

$\beta$ = Timoshenko constant

1. Elastic Moment (for 1” width) = $M_{el} = \frac{1}{6} \times t^2 \times f_{dy} = \frac{41.6}{6} t^2 = 6.933 t^2$ - K in/lb.

Also, $M_{el} = \beta \times a^2 \ast$ or $\frac{M_{el}}{\beta \times a^2} = \frac{6.933 \times t^2}{\beta \times a^2} = \frac{6.933 \times t^2 \times b}{\beta \times a} = \frac{6.933 \times t^2 \times b}{\beta \times a}$ - K lb./sq. in.

\[.\] Total Elastic Resistance = $R_{el} = \varphi \times \text{Area}$

$= \frac{6.933 \times t^2 \times b \times a}{\beta \times a^2} = \frac{6.933 \times t^2 \times b}{\beta \times a}$ - Kip

* Timoshenko "Plates & Shells" p. 133
2. Elastic Deflection: \[ X_{el} = \frac{\alpha \times a^4 \times \varphi}{E \times t^3} \]

\[ \varphi = \frac{6.933 \times t^2}{\beta \times a^2} \] - Kip Lb/sq. in.

\[ \alpha = \text{Timoshenko Constant} \]

\[ \beta = \text{Timoshenko Constant} \]

\[ t = \text{thickness in inches} \]

\[ a = \text{Short span of door in inches} \]

\[ b = \text{Long span of door in inches} \]

\[ X_{el} = \frac{\alpha \times a^4 \times 6.933 \times t^2}{30 \times 10^6 \times t^3 \times \beta \times a^2} = \frac{\alpha \times a^2 \times 6.933}{30 \times 10^6 \times t \times \beta} \text{ Kip-Inches} \]

\[ = \frac{6.933 \times \alpha \times a^2 \times 10^3}{30 \times 10^6 \times t \times \beta \times 12} \text{ Feet} \]

\[ = \frac{6.933 \times \alpha \times a^2}{360 \times 10^3 \times t \times \beta} \text{ Feet} \]

* Timoshenko "Plates and Shells" p. 133
SECTION V - BIBLIOGRAPHY


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