# SMUD CALCULATION COVER SHEET

SACRAMENTO MUNICIPAL UTILITY DISTRICT ☐ 6201 S Street, P.O. Box 15830, Sacramento CA 95852-1830 (916) 452-3211

ISFSI CONCRETE SLAB DESIGN

(M41.02-12)

CALC. NO. Z-DRY -C1024

FILE NO.

QUALITY CLASS 33

SEISMIC CATEGORY

SHEET 1 OF

| RECORD OF ORIGINAL ISSUE AND REVISIONS | | | SMUD ORIGINATED CALCS | | | NUCLEAR ENGRG ACCEPTANCE | |
|---|---|---|---|---|---|---|---|
| REV. NO. | REVISION DESCRIPTION | DATE | ORIG. | CKR. | SUPVY. REVIEW | DE | DGS |
| 0 | ISSUE FOR CONSTRUCTION | 9-28/93 | | | | WHH 9/20/93 | [illegible] |
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## RESULTS OF CHECKER REVIEW

| ITEM DESCRIPTION | | ORIG. ISSUE | REVISION NO. | | | | | |
|---|---|---|---|---|---|---|---|---|
| MUST INITIAL ONE: FINAL RESULT NUMERICAL DIFFERENCES ARE NOT SIGNIFICANT; NO CORRECTIONS NECESSARY. | INITIAL | WHH 9/20/93 | | | | | | |
| MUST INITIAL ONE: FINAL RESULT NUMERICAL DIFFERENCES ARE SIGNIFICANT, NECESSARY CORRECTIONS ARE MADE. | INITIAL | WHH 9/20/93 | | | | | | |
| CHECK MADE BY ATTACHED ALTERNATE CALCULATIONS. _____ SHEETS | INITIAL | N/A | | | | | | |
| | DATE | N/A | | | | | | |
| REVIEWED FOR IMPACT | OPS. PROC. | N/A | | | | | | |
| | MAINT. PROC. | N/A | | | | | | |

| | PRINTED NAME | SIGNATURE | INITIAL | DISCIPLINE | DATE |
|---|---|---|---|---|---|
| ORIGINATOR | | | | | |
| CHECKER | | | | | |
| SUPVY. REVIEW | | | | | |
| DESIGN ENG. | W.H. HAWLEY | W.H. Hawley | WHH | TS/C | 9/20/93 |
| DISC. GRP. SUP. | J J FIELD | J J Field | JJF | TS/M | 9/28/93 |

ENG-053 REV. 2

# DOCUMENT APPROVAL COVER SHEET

ABB
ASEA BROWN BOVERI
ABB IMPELL CORPORATION

DOCUMENT NUMBER: 0079-00541-2

DOCUMENT TITLE: ISFSI Concrete Slab Design

DOCUMENT TYPE:
X CALCULATION
___ SPECIFICATION
___ REPORT
___ DOCUMENT PER QP-3.11

CLIENT: SMUD

PROJECT: Independent Spent Fuel Storage Installation

PROJECT NUMBER: 0079-00541

SUMMARY DESCRIPTION:

Design of ISFSI Reinforced Concrete Slab.

| REVISION | DESCRIPTION: | |
|---|---|---|
| A | Issued for Comment | TOTAL NO. OF PAGES 182 |
| ORIGINATOR: | Mike David MD | DATE: 4-30-93 |
| VERIFIER: | BRAD SENN BS / TOS Terry Stelter | DATE: 4/30/93 |
| APPROVER: | N/A | DATE: |

| REVISION | DESCRIPTION: | |
|---|---|---|
| B | Re-Issued for Comment | TOTAL NO. OF PAGES 671 |
| ORIGINATOR: | Mike David MD | DATE: 5-18-93 |
| VERIFIER: | BRAD SENN BS | DATE: 5-27-93 |
| APPROVER: | BRAD SENN BS | DATE: 5-27-93 |

| REVISION | DESCRIPTION: REVISED ~~SHTS~~ 1, 2, 3, 4, | |
|---|---|---|
| 0 | Issued for USE | TOTAL NO. OF PAGES 688 |
| ORIGINATOR: | Mike David MD | DATE: 6-8-93 |
| VERIFIER: | B. SENN BS | DATE: 6-10-93 |
| APPROVER: | B. SENN BS | DATE: 6-10-93 |

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Effective 4/92

M41.02-12 sub 2

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Purpose :

The purpose of this calculation is to design the Independent Spent Fuel Storage Installation @ Rancho Seco Nuclear Generating Station.

Methodology :

The reinforced concrete design of the ISFSI slab on grade will be based on a finite element analysis performed by SAP90 version PS.40. The slab(s) will be modeled with quadrilateral plate elements with a thickness to length/width ratio of approximatelly 1:5. The supporting soil will be modeled by springs at each joint with a stiffness based on a modulas of subgrade reaction K = 300 ksf/ft per reference 11. Various loading conditions will consider dead load, live load, and seismic. The following load combinations and associated load factors will be considered in accordance with reference 3 §2609(c):

(9-1) $U = 1.4D + 1.7L \longrightarrow$ Envelope & use $U = 1.7(D+L)$

(9-2) $U = 0.75[1.4D + 1.7(1.1E)] = 1.05D + 1.40E \rightarrow$ Envelope & Use $U = 1.4(D+E)$

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| A | MD | 4-30-93 | BJB | 4/30/93 |

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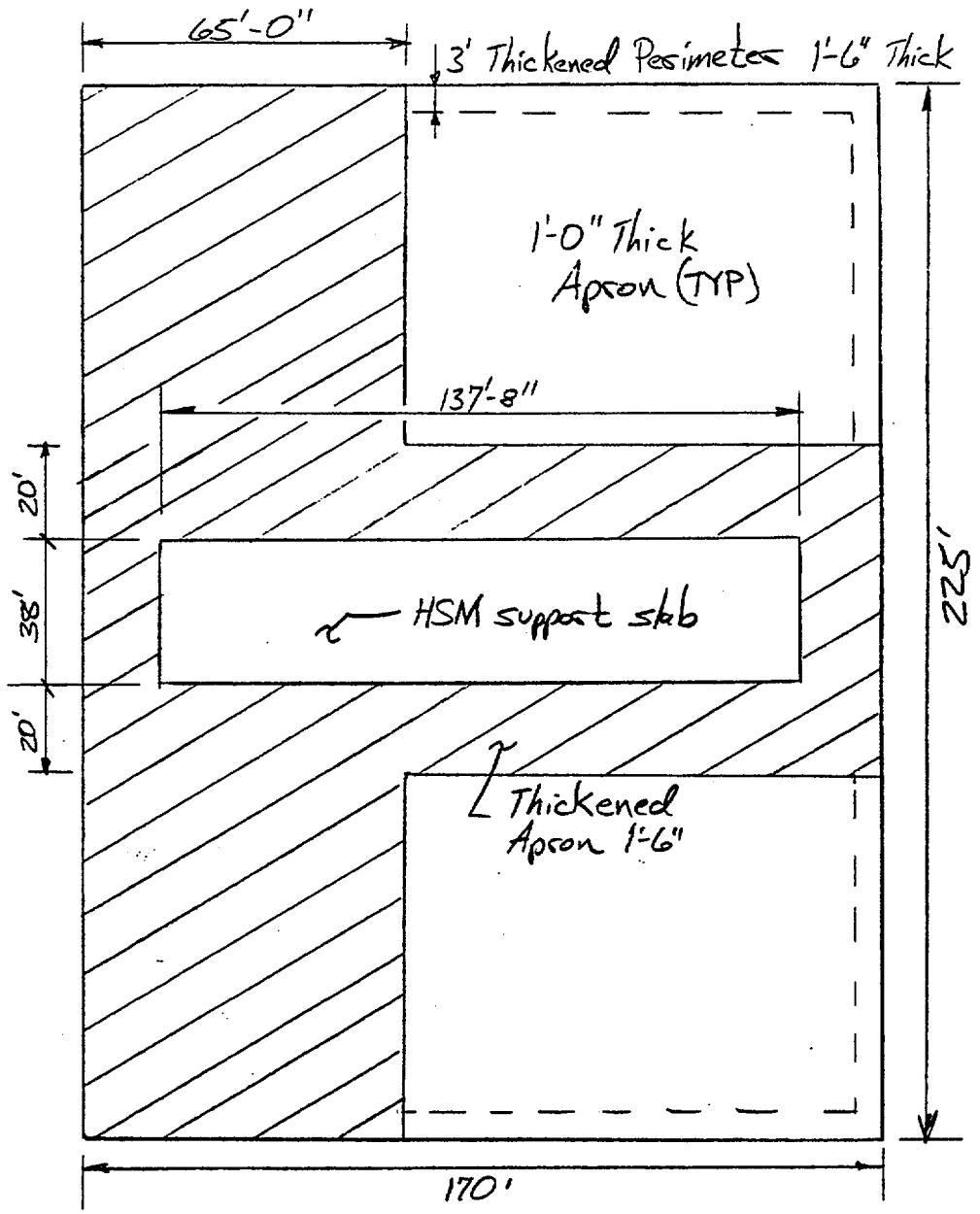
JOB NO 0079-00541
CALC NO 0079-00541-2

## References


1. Rancho Seco ISFSI Design Criteria Rev A, March 10, 1993
2. ABB Impell Letter # 79-541-L1, April 12, 1993
3. Uniform Building Code 1991
4. FAX Transmissions from Dave Middleton & Keith Trommler / Bragg Crane & Rigging Dated 4/12/93, 4/14/93, 5/7/93, & 5/11/93, regarding Link-Belt 200ton wire rope truck crane HC-258. General Specifications and rigging study for 120ton lift.
5. ACI 360 R-91 (Draft)
6. ABB Impell Letter No. 79-541-L3, April 23, 1993
7. Geotechnical Engineering Investigation by GEOCON Inc. dated 8/16/91, File No. 30004-05-01
8. Handbook of Concrete Engineering, 2nd Edition, Mark Fintel
9. SAP90, Version PS.40
10. Manual of Steel Construction, ASD 9th Edition
11. Geotechnical Study for Proposed ISFSI, Rancho Seco Nuclear Generating Station, Job No. ES-519/E306-01, 6-1-93

ISFSI Layout =

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| B | MD | 5-18-93 | BB | 5/27/93 | ABB ASEA BROWN BOVERI ABB Impell Corporation | JOB NO 0079-00541 | PAGE 5 |
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## Design Loads: [per Ref 1 & 2]

### Transporter:

Max loaded wt = 145 ton = 290K / Unloaded wt = 25t = 50K

Ave Jack load = 74K

Rear Jack max load = 142K  Front Jack min Load = 22K

Max wheel load = 20K

Max tire press = 150psi

Four axles w/ 32 tires total

20' long, 12' wide

### Horizontal Storage Module (HSM):

Max loaded wt = 250 ton = 500k  cg ht = 93" from bottom

Min wt = 130 ton = 260K  cg ht = 120" from bottom

Ht = 15'-0"  Width = 9'-8"  Length = 19'-0"

### Dual Purpose Cask:

Max loaded wt = 120 ton = 240K

ht = 17'  dia = 8'

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Determine min slab thickness based on punching shear requirements

Transporter

Rear jacks down on apron near HSM's :

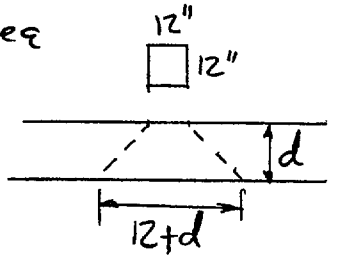
loaded area = 12" square [Ref 2]

max load = 142$^K$

[Ref 3] § 2611(m) $V_c = \left(2+\frac{4}{\beta_c}\right)\sqrt{f'_c}\, b_o d \le 4\sqrt{f'_c}\, b_o d$ (11-36)

where $\beta_c = 1$ for square loaded area

critical section $b_o = 4(12+d)$




$\phi V_n = \phi V_c = 0.85(4)\sqrt{4000}(4)(12+d)d$

$\phi V_n = 860d^2 + 10{,}322d$

live load factor

want $\phi V_n \ge V_u = 1.7(142{,}000)$

$\therefore\ 860d^2 + 10{,}322d \ge 1.7(142{,}000)$

$d^2 + 12d - 280.65 = 0$

$d = 11.8$ in

Slab thickness $= 11.8 + 3$ (cover) $=$ 14.8" try 18" in this area

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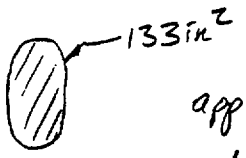
Punching Shear Cont'd:

Transporter tires:

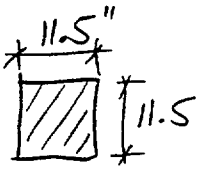
find loaded area [Per Ref 5] → $\frac{\text{Tire load}}{\text{tire press}} = \frac{20{,}000\ lb}{150\ psi} = 133.3\ in^2$

single tire:




approximate as square

side = $\sqrt{133} = 11.5''$




as before $b_o = 4(11.5+d)$

$$\phi V_n \geq V_u$$

$$0.85(4)\sqrt{4000}(4)(11.5+d)\,d \geq 1.7(20{,}000)$$

$$860d^2 + 9891.6d \geq 1.7(20{,}000)$$

$$d^2 + 11.5d - 39.5 = 0 \Rightarrow d = 2.8''$$

look at possibly 2 tires side by side:

equivalent square side = $[2(133.3)]^{1/2} = 16.3''$ on a side

$\therefore\ b_o = 4(16.3+d)$

$$\phi V_n \geq V_u$$

$$0.85(4)\sqrt{4000}(4)(16.3+d)\,d \geq 1.7(2)(20{,}000)$$

$$860d^2 + 14020d - 1.7(2)(40{,}000) = 0$$

$$d^2 + 16.3d - 79.06 = 0$$

$$d = 3.9\ in$$

$\therefore$ min slab thickness = $3.9 + \underset{\text{cover}}{3} = \underline{\underline{7''}}$

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Punching Shear (Cont'd)

Dual Purpose Cask: Max wt = 240$^k$

find equivalent square bearing area for 8' dia circular area

Area = $\pi(4)^2 = 50.26\ ft^2$ equiv. sq. side = $\sqrt{50}$ = 7' approx

as before $b_o = 4(7 \times 12 + d) = 4(84 + d)$

Use 25% impact to account for setting of cask on slap ⇒ "wt" = 1.25(240) = 300$^k$

$$\phi V_n \geq V_u$$

$$0.85(4)\sqrt{4000}(4)(84+d)d \geq 1.7(300{,}000)$$

$$860d^2 + 72{,}252d \geq 1.7(300{,}000)$$

$$d^2 + 84d - 593.0 = 0$$

$$d = 6.6''$$

∴ min slab thickness = 6.6 + 3 (cover) = <u>9.6" min</u>

Summary:

Min slab thickness required for the thinner part of the apron is 9.6". Try <u>12" slab</u>

Min slab thickness required for thicker part of the apron is 14.8". Try <u>18" slab</u>

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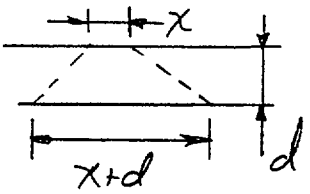
Punching Shear (cont'd)

Check crane outrigger crib pad min dimension reqmts

Crane outrigger max load = 292,310 lb  Ref [4]

Determine required crib pad dimensions for 12" & 24" slab:

as before, loaded area is square $\Rightarrow \beta_c = 1$




12" slab : $d = 12 - 3 - 1.5(.5) = 8.25''$

cover  Bar ϕ

18" slab : $d = 18 - 3 - 1.5(.75) = 13.8''$

$\phi V_n = .85(4)\sqrt{f'_c}\, b_o d$

$\phi V_n = .85(4)\sqrt{4000}\,(4)(x+8.25)(8.25)$  12" slab

$\phi V_n = 7096.2(x+8.25)$

want $\phi V_n \geq V_u$

$7096.2(x+8.25) \geq 1.7(292,210)$

$x \geq 61.8\text{ in} =$ 5'-2" square  12" slab

$\phi V_n = 0.85(4)\sqrt{4000}\,(4)(x+13.8)(13.8)$  18" slab

$\phi V_n = 11,870(x+13.8)$

$\phi V_n \geq V_u$

$11,870(x+13.8) \geq 1.7(292,210)$

$x \geq 28.1 \simeq 2'-4''$ sq

Use 4'x4' cribbing per Ref 4 on 18" slab OK ✓

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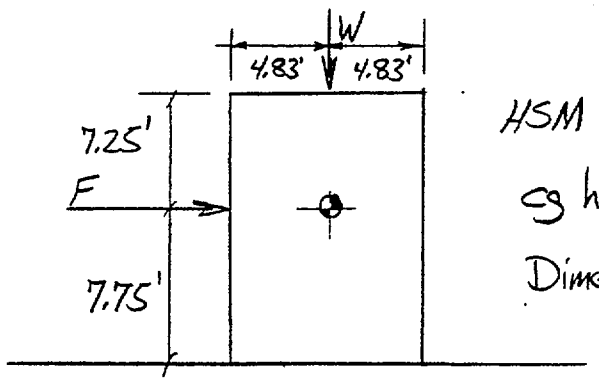
Develop application of loads onto slab:

Fully Loaded HSM:




HSM max wt $W = 500^K$

cg ht = 93" from bottom

Dimensions: 15' x 9.66' x 19'
ht width length
[per Ref 1]

Seismic Base Shear $F = 1.5(ZPA)W$, where $ZPA = 0.25g$
[Per Ref 1]
$= 1.5(0.25)W = 0.375W$ [Per Ref 6]
$= 0.375(500) = 187.5^K$

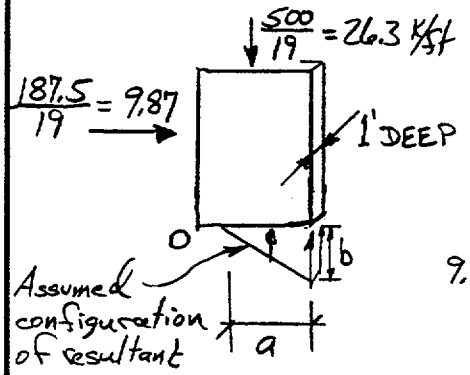
Check OT:

OT moment $= 7.75F = 7.75(187.5) = 1453.1$ K·ft

Rtg moment $= 4.83W = 4.83(500) = 2415$ K·ft

factor of safety $= \frac{2415}{1453} = 1.66$ GOOD

find distribution of reaction along length of HSM (19' long)




$\Sigma F_{vert} = 0$

$26.3 - \frac{1}{2}ab = 0 \Rightarrow ab = 52.6$

$\Sigma M_O = 0$

$9.87(7.75) + 26.3(4.83) = \frac{1}{2}ab(9.67 - \frac{1}{3}a)$

$203.52 = \frac{1}{2}(52.6)(9.67 - \frac{1}{3}a)$

$a = 5.8\text{ ft} \Rightarrow b = \frac{52.6}{5.8} = 9.08$ K/ft/ft

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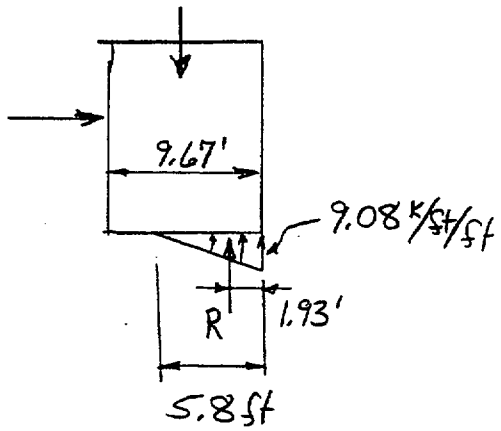
## HSM reaction (cont'd)




$R = \frac{1}{2}(5.8)(9.08)$

$R = 26.3$ K/ft along length of HSM

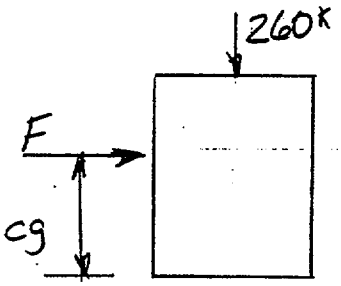
HSM @ max wt.

Empty HSM: wt = 260K cg ht = 120" from bottom

per [ref 2] cg ht is approx.

∴ Look @ 2 cases — if cg is taken @ ht of that for a fully loaded HSM, the OT moment is reduced and therefore the differential between loaded & empty HSM's is greater. This will be compared to the OT affects due to an HSM with a cg @ 120" from the bott.

Case ① = cg = 120" Case ② cg = 93"




$F = 0.375(260) = 97.5^K$

OT moment ① $= 97.5\left(\frac{120}{12}\right) = 975$ k·ft

OT moment ② $= 97.5\left(\frac{93}{12}\right) = 755.6$ k·ft

Rtg moment $= 260(4.83) = 1255.8$ k·ft

$F.S._{①} = \frac{1255.8}{975} = 1.3$ ok $\quad F.S._{②} = \frac{1255.8}{755.6} = 1.66$ ok

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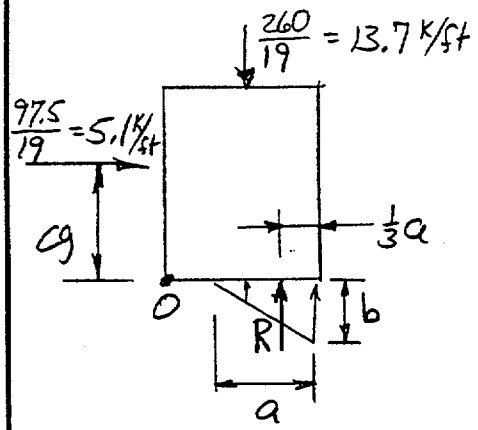
## HSM reaction (cont'd)

Distribution of reaction along HSM 19' length:




cg ① = 10'  cg ② = 7'-9"

Case ①: $\Sigma F_{vert} = 0$

$13.7 - \frac{1}{2}ab = 0 \Rightarrow ab = 27.4$

$\Sigma M_o = 0$

$5.1(10) + 13.7(4.83) = \frac{1}{2}ab(9.67 - \frac{1}{3}a)$

$117.2 = \frac{1}{2}(27.4)(9.67 - \frac{1}{3}a)$

$a = 3.4$ ft

$b = \frac{27.4}{3.4} = 8.17$ K/ft/ft

$R_① = \frac{1}{2}ab = \frac{1}{2}(3.4)(8.17) = 13.9$ K/ft

Case ②: $\Sigma F_{vert} = 0$

$ab = 27.4$

$\Sigma M_o = 0$

$5.1(7.75) + 13.7(4.83) = \frac{1}{2}(27.4)(9.67 - \frac{1}{3}a)$

$a = 5.86$ ft

$b = \frac{27.4}{5.86} = 4.67$ K/ft/ft

$R_② = \frac{1}{2}(5.86)(4.67) = 13.7$ K/ft

Two cases very close → use ave value of 13.8 K/ft for analysis

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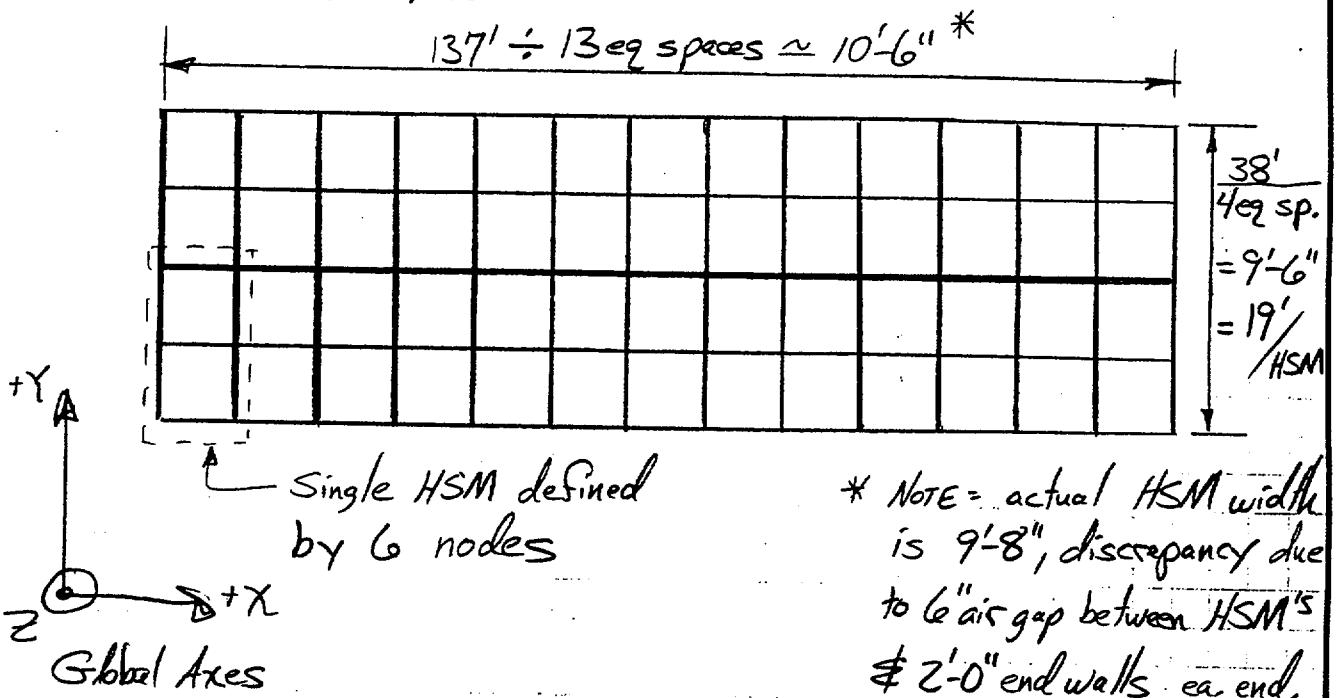
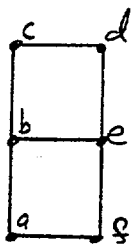
## HSM reaction (cont'd)

FEM node location = 26 HSM's Total




* NOTE = actual HSM width is 9'-8", discrepancy due to 6" air gap between HSM's & 2'-0" end walls ea. end.

Find load per node =




DL only = fully loaded = 500K
empty = 260K

| HSM | Loaded | Empty |
|---|---|---|
| a, f<br>c, d | 62.5K | 32.5K |
| b, e | 125K | 65K |

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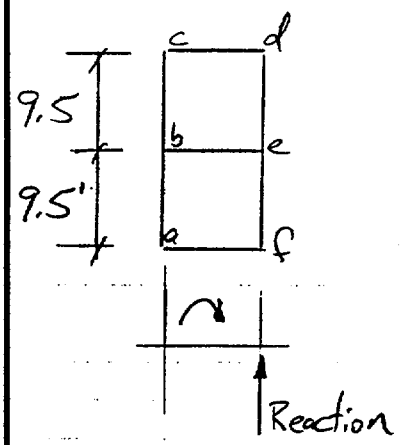
## HSM reaction (cont'd)

DL + Seismic Loads: Conservativelly apply reaction per tributary length of node to one side only of HSM:

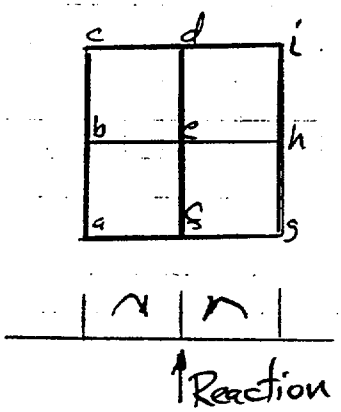
fully loaded = 26.3 K/f

empty = 13.8 K/ft




| HSM | Loaded | Empty |
|---|---|---|
| d, f | 125$^K$ | 65.6$^K$ |
| e | 250$^K$ | 131.1$^K$ |

Two HSM'S rocking toward one-another:




| HSM | Both Loaded | Both Empty | One Loaded One Empty |
|---|---|---|---|
| d, f | 250$^K$ | 131.1$^K$ | 190.6$^K$ |
| e | 500$^K$ | 262.2$^K$ | 381.1$^K$ |

| REV | BY | DATE | CHECKED | DATE |
|---|---|---|---|---|
| B | MD | 5-18-93 | [illegible] | 5/27/93 |
| A | MD | 4-30-93 | [illegible] | 4/30/93 |

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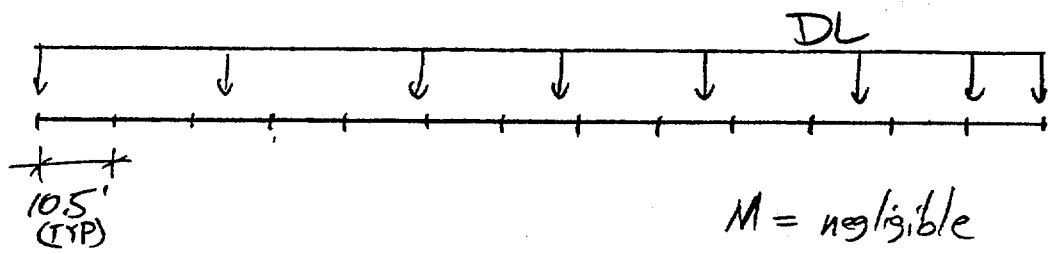
# Load Cases – HSM Longitudinal Direction

Values per .FEF files in Appendices

Moments indicated are absolute maximums enveloping pos & neg. Node locations may be representative of several nodes with identical stresses.

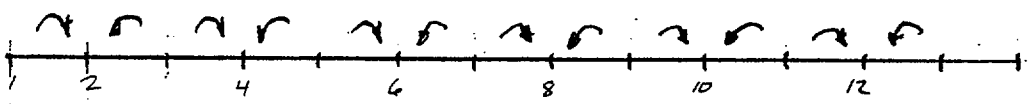
## Load Case 1




M = negligible

## Load Case 2

HSM'S Fully loaded & racking as shown

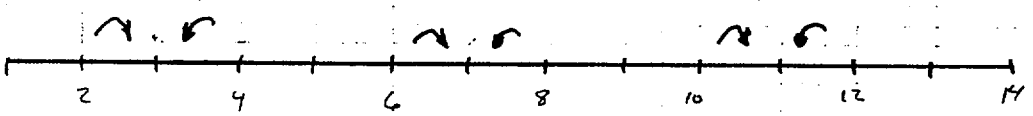



Node 68 $M_y = \frac{321.2 \text{ k·ft}}{4.75'}$

$= 67.6 \text{ k·ft/ft}$

## Load Case 3

HSM's Loaded & racking as shown




Node 46 $M_y = \frac{380.8 \text{ k·ft}}{4.75}$

Some Springs in tension $\Rightarrow M_y = 80.2 \text{ k·ft/ft}$

Tension Springs Cut $\Rightarrow M_y = \frac{381.0}{4.75} = 80.2 \text{ k·ft/ft}$ (approx. no. change)
Per Appendix D node #3

| REV | BY | DATE | CHECKED | DATE |
|---|---|---|---|---|
| 0 | MD | 6-8-93 | [illegible] | 6/10/93 |
| B | MD | 5-18-93 | [illegible] | 5/27/93 |
| A | MD | 4-30-93 | [illegible] | 4/30/93 |

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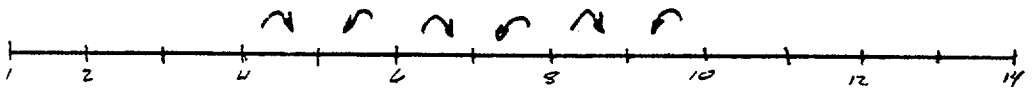
## Load Cases - HSM

### Load Case 4

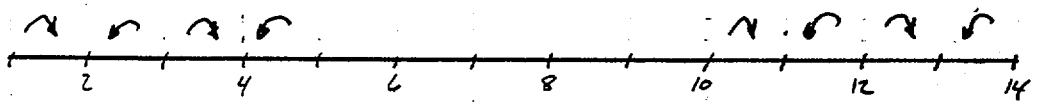
HSM'S Fully Loaded & Rocking as Shown




Node 65 $M_y = \frac{322.7}{4.75} = 67.9$ k·ft/ft

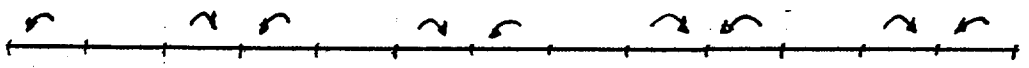
### Load Case 5

HSM'S Fully Loaded & Rocking as Shown



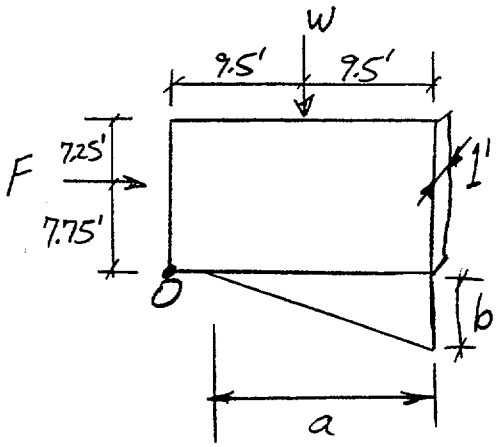

Node 67 $M_y = \frac{316.2}{4.75} = 66.6$ k·ft/ft

### Load Case 6



Node 60 $M_y = \frac{384.5}{4.75} = 80.9$ k·ft/ft

HSM load transverse direction:




$W = 500^k \quad F = 187.5^k$

Find reaction distribution along HSM width of 9'-8"

For 1' width: $W = \frac{500}{9.67} = 51.7\ ^k/ft$

$F = \frac{187.5}{9.67} = 19.4\ ^k/ft$

$\Sigma F_{vert} = 0$

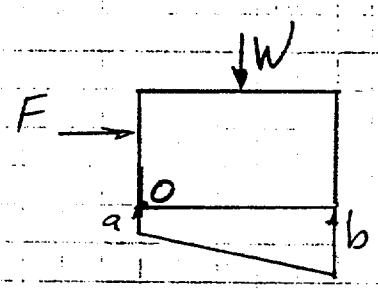
$51.7 - \frac{1}{2}ab = 0 \Rightarrow ab = 103.4\ ^k/ft$

$\Sigma M_o = 0$

$51.7(9.5) + 19.4(7.75) = \frac{1}{2}ab(19 - \frac{1}{3}a)$

$641.5 = \frac{1}{2}(103.4)(19 - \frac{1}{3}a)$

$a = 19.77\ ft$ ∴ reaction along entire bottom




$\Sigma M_o = 0$

$641.5 = \frac{1}{2}a(19)^2 + \frac{1}{2}(b-a)\frac{2}{3}19^2$

$3.554 = a + \frac{2}{3}(b-a) = \frac{2}{3}b + \frac{1}{3}a$

$10.66 = 2b + a$

$\Sigma F_{vert} = 0$

$51.7 - \frac{1}{2}(a+b)19 = 0$

$a = 5.442 - b$

$10.66 = 2b + 5.442 - b$

$b = 5.22\ ^k/ft^2$

$a = 5.442 - 5.22 = 0.22\ ^k/ft^2$

| REV | BY | DATE | CHECKED | DATE |
|---|---|---|---|---|
| B | MG | 5-18-93 | [illegible] | 5/27/93 |
| A | MG | 4-30-93 | [illegible] | 4/30/93 |

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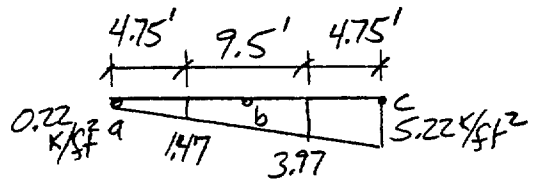
## HSM Load transverse direction (cont'd)



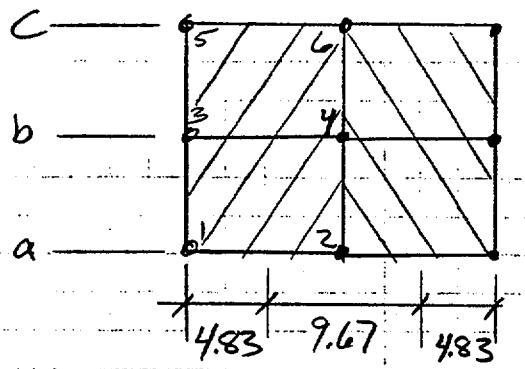

node load for trib distribution

$a = \frac{1}{2}(.22+1.47)4.75 = 4.0\ K/ft$

$b = \frac{1}{2}(1.47+3.97)9.5 = 25.8\ K/ft$

$c = \frac{1}{2}(3.97+5.22)4.75 = 21.8\ K/ft$

HSM FEM mesh :




$1 = 4.83(4\ K/ft) = 19.3\ K$

$2 = 9.67(4) = 38.7\ K$

$3 = 4.83(25.8) = 124.6\ K$

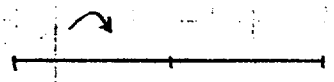
$4 = 9.67(25.8) = 249.5\ K$

$5 = 4.83(21.8) = 105.3\ K$

$6 = 9.67(21.8) = 210.8\ K$

Load Case:
Values per FEF files in Appendices

\# 7

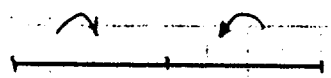


Node 29: $M_x = \frac{123.2\ K\cdot ft}{5.25'} = 23.5\ K\cdot ft/ft$

\#8

Node 40: $M_x = \frac{178.0\ K\cdot ft}{5.25'} = 33.9\ K\cdot ft/ft$

\#9



Node 40 $M_x = \frac{177.8\ K\cdot ft}{5.25'} = 33.9\ K\cdot ft/ft$

| REV | BY | DATE | CHECKED | DATE |
|---|---|---|---|---|
| B | MO | 5-18-93 | [illegible] | 5/18/93 |
| A | MO | 4-30-93 | [illegible] | 4/30/93 |

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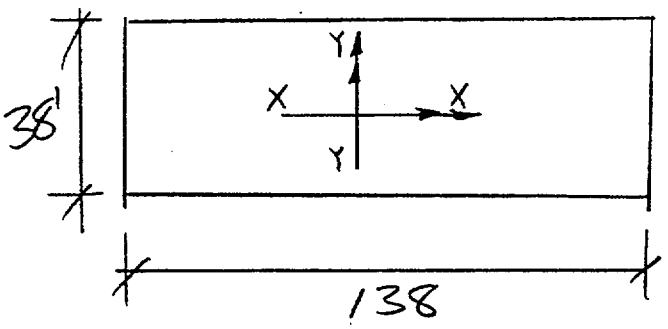
CALC NO 0079-00541-2

# HSM Slab Design




Max moment $M_y$ for all load cases:

Load Case 6 $M_y^+ = M_y^- = 80.9$ k·ft/ft

Load due to DL+Seismic ✓ ∴ concrete load factor = 1.4 (As defined in the Methodology section)

$\therefore M_u^{+-} = 1.4(80.9) = 113.3$ k·ft/ft

Slab thickness = 24" ⇒ $d = 24 - 3 - \frac{1}{2}(.75) = 20.6$ in (3 = covers, .75 = ½ bar ϕ)

Try #6 @ 4" ⇒ $\rho = \frac{0.44}{20.4 \times 4} = 0.00534$

$$\phi M_n = \phi A_s f_y d\left(1 - \frac{0.59 \rho f_y}{f'_c}\right)$$

$$\phi M_n = 0.9\left(\frac{12}{4}\right)(.44)(60)(20.6)\left[1 - \frac{.59(.00534)60}{4}\right] = 1400 \text{ k·in/ft} = 116.6 \text{ k·ft/ft}$$

$M_u < \phi M_n$ ✓ OK

| REV | BY | DATE | CHECKED | DATE |
|---|---|---|---|---|
| B | MB | 5-18-93 | [illegible] | 5/27/93 |
| A | MB | 4-30-93 | JA | 4/30/93 |

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## HSM Slab Design (Cont'd)

Min shrink & temp steel

gross $A_s = 0.0018(24 \times 12) = 0.52$

Try #5 @ 12" oc T&B

$\therefore$ gross $A_s = 2(.31) = 0.62$ ✓ ok

Flexure $d = 24 - 3 - .75 - \frac{1}{2}(.6) \simeq 20''$

covers #6 ½ #5

$$\phi M_n = 0.9(.31)60(20)\left[1 - \frac{.59\left(\frac{.31}{12 \times 20}\right)60}{4}\right] = 331 \text{ k}\cdot\text{in} = \underline{\underline{27.6 \text{ k}\cdot\text{ft}}}$$

Max moment $M_x = 33.9$ k·ft/ft Load Case #8/9

$M_u = 1.4(33.9) = 47.5$ k·ft/ft

Try #6 @ 9" $\Rightarrow \rho = \frac{0.44}{19.8 \times 9} = 0.00247$

$d = 24 - 3 - 1.5(.75) = 19.8''$

$$\phi M_n = 0.9\left(\tfrac{12}{9} \times .44\right)60(19.8)\left[1 - \frac{.59(.00247)60}{4}\right]$$

$\phi M_n = 674$ k·in/ft $= 51.1$ k·ft/ft $> M_u$ ✓ ok

| REV | BY | DATE | CHECKED | DATE |
|---|---|---|---|---|
| B | MD | 5-18-93 | BB | 5/27/93 |
| A | MD | 4-30-93 | TOJ | 4/30/93 |

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CALC NO 0079-00541-2

## HSM soil Pressure

Check soil pressure under HSM slab for following load combinations :

① D+L
② D+E

① D+L : As prev stated, max wt of fully loaded HSM = 500$^k$ No. HSM's = 26

Slab dimensions 137'x38'x2' (Approx)

$$\therefore \text{Uniform Soil Pressure} = \frac{26(500)}{\underset{HSM's}{137 \times 38}} + \underset{\text{slab DL}}{0.15(2)}$$

$$= 2.8 \text{ ksf}$$

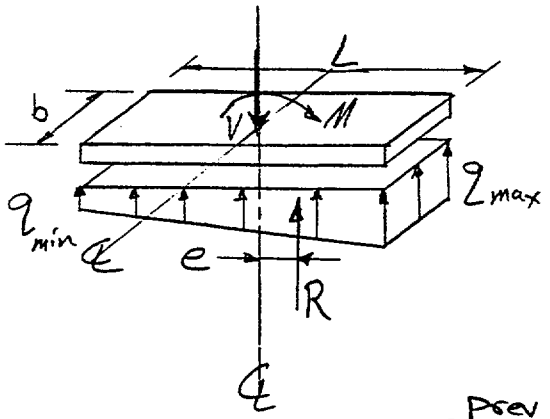
Per Ref 11, allow soil press for D+L = 4ksf ✓ OK

| REV | BY | DATE | CHECKED | DATE | | JOB NO | PAGE |
|---|---|---|---|---|---|---|---|
| 0 | [illegible] | 6-8-93 | [illegible] | 6/10/93 | ABB ASEA BROWN BOVERI ABB Impell Corporation | 0079-00541 | 22 |
| | | | | | | CALC NO 0079-0054/-2 | CONT ON 23 |

HSM Soil Press. (cont'd)

② D+E :

Overturning in Longitudinal Direction :




b = 38'
L = 137'
R = resultant = V
e = eccentricity

prev determined

M = total overturning moment = 1453.1 K·ft/HSM × 26 HSM's = 37,781 K·ft

V = total Vertical load = 26(500) HSM's + 137 × 38 × 2 × 0.15 slab = 14,562 K

$$e = \frac{M}{V} = \frac{37,781}{14562} = 2.59 \text{ ft}$$

$$\frac{L}{6} = \frac{137}{6} = 22.8 \text{ ft} \quad \therefore \text{ e within kern (middle third)}$$

$$\therefore q = \frac{V}{bL}\left(1 \pm \frac{6e}{L}\right) = \frac{14562}{38 \times 137}\left[1 + \frac{6(2.59)}{137}\right]$$

$$q_{max} = 3.11 \text{ ksf}$$

Per Ref 11, allow soil press for D+E = 4/3 (4) = 5.3 ksf ✓ Ok

| REV | BY | DATE | CHECKED | DATE |
|---|---|---|---|---|
| 0 | MAF | 6-8-93 | PB | 6/10/93 |

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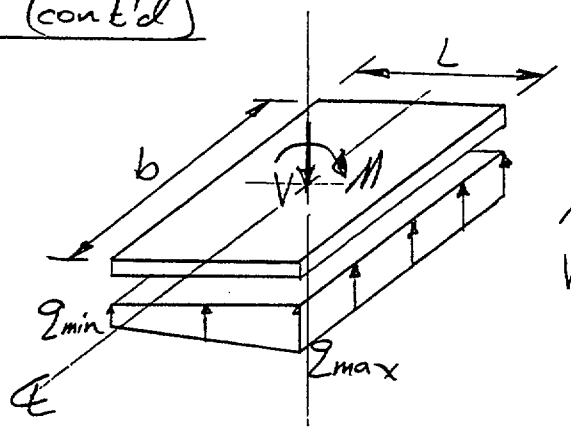
CALC NO 0079-00541-2

HSM Soil Press (cont'd)

② D+E

Overturning in Transverse Direction:




$b = 137'$

$L = 38'$

$M = 37{,}781$ k·ft

$V = 14{,}562$ k

as prev determined $e = 2.59$ ft

$\frac{L}{6} = \frac{38}{6} = 6.3$ ft $\therefore$ e within kern

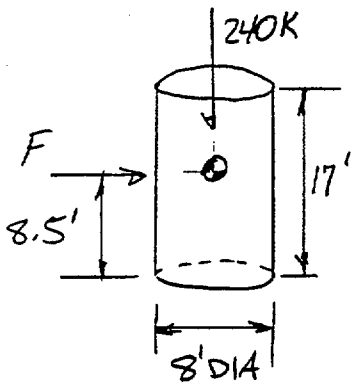
$$\therefore q = \frac{V}{bL}\left(1 \pm \frac{6e}{L}\right) = \frac{14562}{137 \times 38}\left[1 + \frac{6(2.59)}{38}\right]$$

$q_{max} = 3.94$ ksf $< q_{Allow} = 5.3$ ksf ✓OK

| REV | BY | DATE | CHECKED | DATE | | JOB NO | PAGE |
|---|---|---|---|---|---|---|---|
| 0 | [illegible] | 6-8-93 | [illegible] | 10/10/93 | ABB ASEA BROWN BOVERI ABB Impell Corporation | 0079-0054/ | 24 |
| | | | | | | CALC NO 0079-0054/-2 | CONT ON 25 |

# APRON DESIGN:

## Dual Purpose Cask Reaction:




Max wt = 240 K  Assume cg @ mid ht

F = 0.375 W (as before)

F = 0.375(240) = 90 K

Check OT:

OT Moment = 90(8.5) = 765 K·ft

Rtg Moment = 240(4) = 960 K·ft

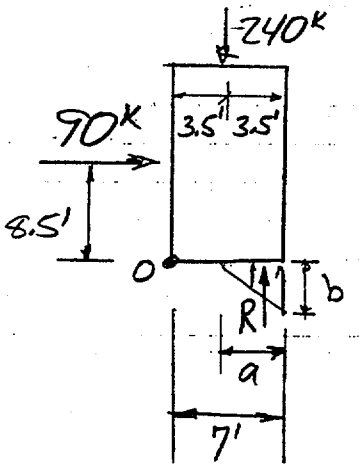
$$F.S. = \frac{960}{765} = 1.25 \quad OK$$

Simplify circular area with a square of equivalent area

Contact area = $\pi 4^2 = 50.3\ ft^2$

Use $7' \times 7' = 49\ ft^2$

Find distribution of reaction




$\Sigma F_{vert} = 0$

$240 - \frac{1}{2}ab = 0 \Rightarrow ab = 480$

$\Sigma M_o = 0$

$90(8.5) + 240(3.5) = \frac{1}{2}ab(7 - \frac{1}{3}a)$

$1605 = \frac{1}{2}(480)(7 - \frac{1}{3}a)$

$a = 0.94\ ft$

$$b = \frac{480}{0.94} = 512\ K/ft$$

$R = 240^K$

| REV | BY | DATE | CHECKED | DATE |
|---|---|---|---|---|
| B | MO | 5-18-93 | BRS | 5/27/93 |
| A | MO | 4-30-93 | BRS | 4/30/93 |

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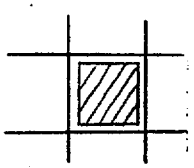
CALC NO 0079-00541-2

# Dual Purpose Cask Reaction (cont'd)

Determine pattern of nodes to be loaded by dual purpose cask for DL & seismic conditions:

## DL only:

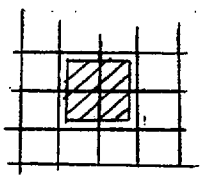
10x10:



Let 4 nodes carry $240^k$ load

$$\text{load/node} = \frac{240}{4} = 60^k \text{ ea}$$

5x5:



Let 9 nodes carry $240^k$ load

$$\text{load/node} = \frac{240}{9} = 26.67^k$$

| REV | BY | DATE | CHECKED | DATE |
|---|---|---|---|---|
| B | MD | 5-18-93 | BB | 5/27/93 |
| A | MD | 4-30-93 | BB | 4/30/93 |

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Dual Purpose Cask Reaction (cont'd) :

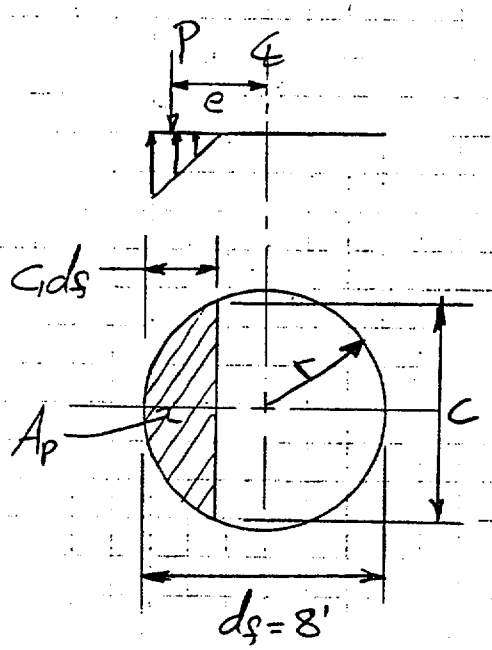
Check punching shear for cask overturning :

Use Reference 8, pg 145 analogy to a circular footing with associated soil bearing pressure to find loaded area under cask with overturning moment. As previously determined, cask is stable and does not overturn.

as prev determined OT moment = 765 k·ft

Cask wt = 240 K , dia = 8 ft

eccentricity $e = \frac{M}{P} = \frac{765}{240} = 3.19\,ft$




$\frac{e}{d_f} = \frac{3.19}{8} = 0.3984$

Tables:

| $e/d_f$ | $C_1$ |
|---|---|
| .375 | .295 |
| .398 | .240 ← interpolate |
| .400 | .235 |

$C_1 d_f = .24(8) = 1.92\,ft$

Per Ref 10, pg 6-16

$C = 2\sqrt{2br - b^2}$ where $b = C_1 d_f$

$= 2\sqrt{2(1.92)(4) - 1.92^2}$

$C = 6.83'$

| REV | BY | DATE | CHECKED | DATE |
|---|---|---|---|---|
| B | MO | 5-18-93 | [illegible] | 4/30/09 |

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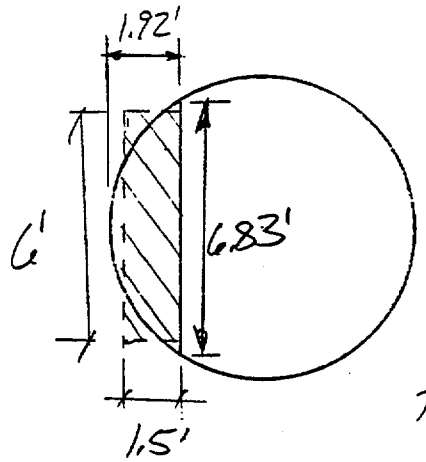
## Dual Purpose Cask Reaction – Punching Shear (cont'd)

For simplicity, approximate loaded area with a rectangle =




DL+E load factor

$V_u = 1.4(240{,}000) = 336^K$

$\phi V_n = \phi\left(2+\frac{4}{\beta_c}\right)\sqrt{f'_c}\, b_o d$

with $\beta_c = \frac{\text{long side}}{\text{short side}} = \frac{6}{1.5} = 4$

$\therefore\ \phi V_n = \phi 3\sqrt{f'_c}\, b_o d$

Try $d = 14.6''$ for $18''$ thick slab

$b_o = (6\times12 + 14.6)2 + (1.5\times12 + 14.6)2$

$b_o = 238.5\text{ in}$

$\phi V_n = 0.85(3)\sqrt{4000}(238.5)(14.6)$

$\phi V_n = 562K > V_u$ by factor of ~2½

✓ OK which should make up for any non-conservatisms due to approximation of loaded area.

| REV | BY | DATE | CHECKED | DATE | | JOB NO | PAGE |
|---|---|---|---|---|---|---|---|
| B | MD | 5-18-93 | [illegible] | 4/30/03 | ABB ASEA BROWN BOVERI ABB Impell Corporation | 0079-00541 | 28 |
| | | | | | | CALC NO 0079-00541 | CONT ON 29 |

Transporter Reaction:

Loaded wt = 290$^k$

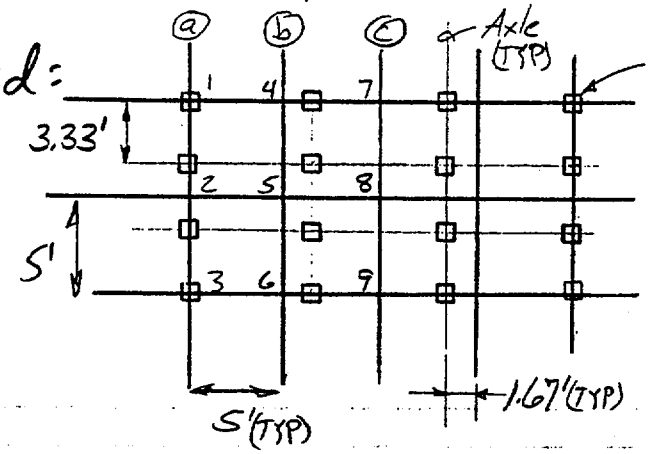
Unloaded wt = 50$^k$

Wheel Loads:

Length = 20', 4 axles equal space approx, 12' wide

32 tires total, 8 tires/axle

5'x5' Grid:




Possible tire arrangement

Distribute wt as a line load on each axle and apply to nodes per their tributary area

$$load/_{axle} = \frac{290}{4} = 72.5\ ^k/_{axle}$$

load per node line per unit length

| | |
|---|---|
| a | $72.5^k/10' = 7.25^k/ft$ |
| b | $\frac{3.33}{5}(72.5)/10' = 4.83\ ^k/ft$ |
| c | $2\left[\frac{1.67}{5}(72.5)\right]/10' = 4.83\ ^k/ft$ |

| | Loaded Transp. | Unloaded Trans. @ 50/290 factor |
|---|---|---|
| 1 | 2.5(7.25) = 18.1 K | 3.125 |
| 2 | 5(7.25) = 36.2 | 6.250 |
| 3 | = 18.1 | 3.125 |
| 4 | 2.5(4.83) = 12.1 | 2.083 |
| 5 | 5(4.83) = 24.2 | 4.167 |
| 6 | = 12.1 | 2.083 |
| 7 | = 12.1 | 2.083 |
| 8 | = 24.2 | 4.167 |
| 9 | = 12.1 | 2.083 |

Symetrical

| REV | BY | DATE | CHECKED | DATE |
|---|---|---|---|---|
| B | MO | 5-18-93 | [illegible] | 5/27/93 |
| A | MO | 4-30-93 | [illegible] | 4/30/93 |

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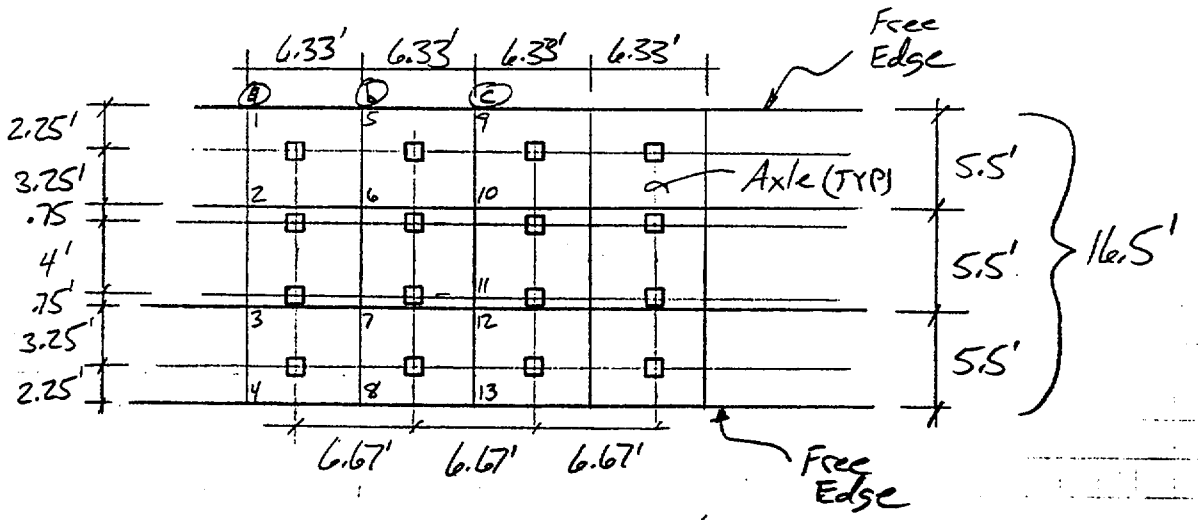
CALC NO 0079-00541-2

# Transporter Reaction (cont'd)

5'-6" x 6'-4" Grid:




load per axle = 72.5 K/axle

load per node line: $a = \frac{1}{2}\left(\frac{72.5}{16.5}\right) = 2.2$ K/ft

$b = 2(2.2) = 4.4$ K/ft

$c = 4.4$ K/ft

| | Load per node |
|---|---|
| 1 | $\frac{1}{2}(5.5)(2.2) = 6.05^K$ |
| 2 | $5.5(2.2) = 12.1^K$ |
| 3 | $12.1^K$ |
| 4 | $6.05^K$ |
| 5 | $\frac{1}{2}(5.5)(4.4) = 12.1^K$ |
| 6 | $(5.5)(4.4) = 24.2^K$ |
| 7 | $24.2^K$ |
| 8 | $12.1^K$ |

Symetrical

| REV | BY | DATE | CHECKED | DATE |
|---|---|---|---|---|
| B | MA | 5-18-93 | [illegible] | 5/27/93 |
| A | MA | 4-30-93 | [illegible] | 4/30/93 |

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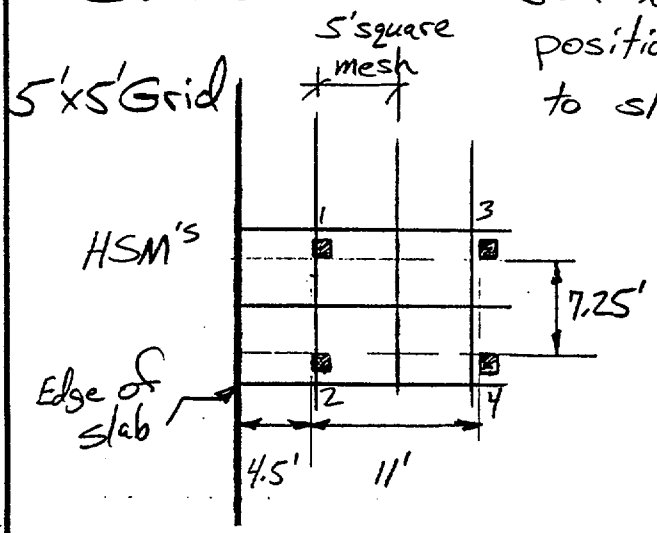
## Transporter Reaction (cont'd)

Jack Loads =




Jack locations per [Ref 2]. Jack positions placed as close as possible to slab edge and/or to one-another deemed to be most critical.

Directly apply jack loads to nodes 1-4

Rear Jack = $142^k$ max

Front Jack = $22^k$ min

∴

| NODE |
|---|
| 1 & 2 = $142^k$ |
| 3 & 4 = $22^k$ |

Empty Transporter wt = 25 tons = $50^k$

equally distributed among 4 jacks = $50/4 = 12.5^k$/ea

| REV | BY | DATE | CHECKED | DATE |
|---|---|---|---|---|
| B | MD | 5-18-93 | [illegible] | 5/27/93 |
| A | MD | 4-30-93 | [illegible] | 4/30/93 |

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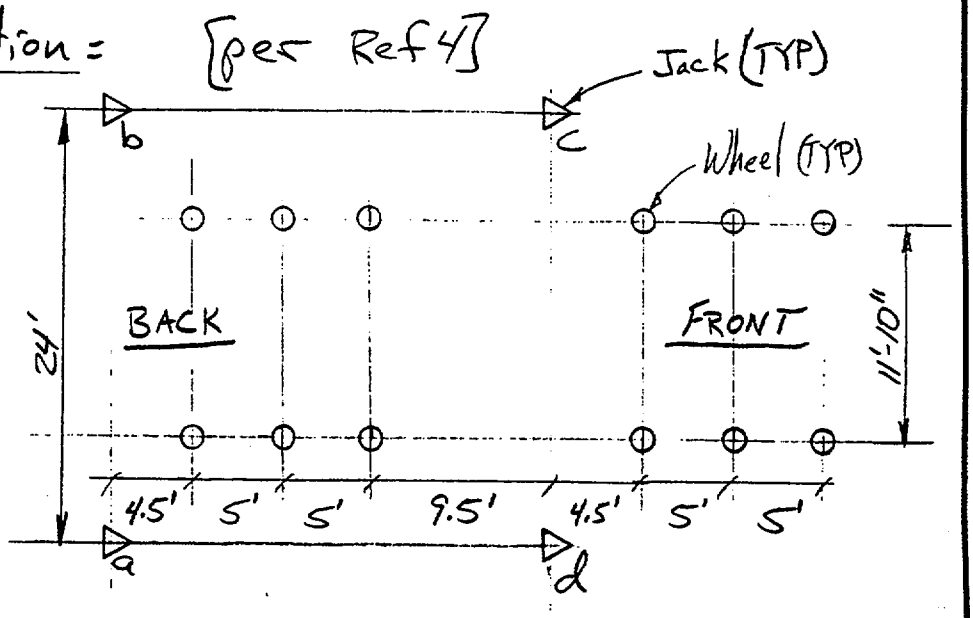
Crane Reaction: [per Ref 4]

Configuration =

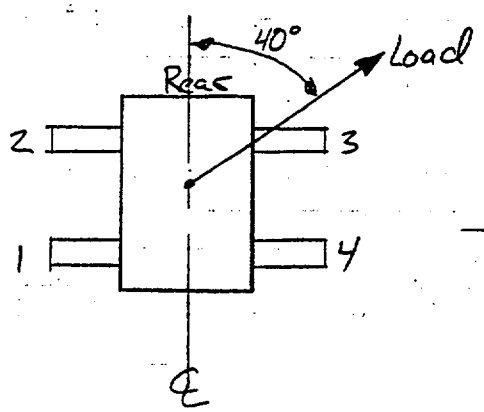



Gross Vehicle Wt = 220.4 K

$$\text{load/tire} = \frac{220.4}{12} = 18.37^K$$

Unloaded crane sitting on 4 outriggers → $\frac{\text{load}}{\text{outrigger}} = \frac{220.4}{4} = 55.1^K/\text{outrigger}$

Loaded Crane with boom directly over rear outrigger:




Per Reference 4:

| Outrigger | LOAD | LOAD/node |
|---|---|---|
| 1 | $90^K$ | $\div 4 = 22.5^K$ |
| 2 | $115^K$ | $\div 4 = 28.8^K$ |
| 3 | $210^K$ | $\div 4 = 52.5^K$ |
| 4 | $165^K$ | $\div 4 = 41.3^K$ |
| | $580^K$ Total | |

| REV | BY | DATE | CHECKED | DATE |
|---|---|---|---|---|
| B | MD | 5/18/93 | [illegible] | 5/18/93 |
| A | MD | 4/30/93 | [illegible] | 4/30/93 |

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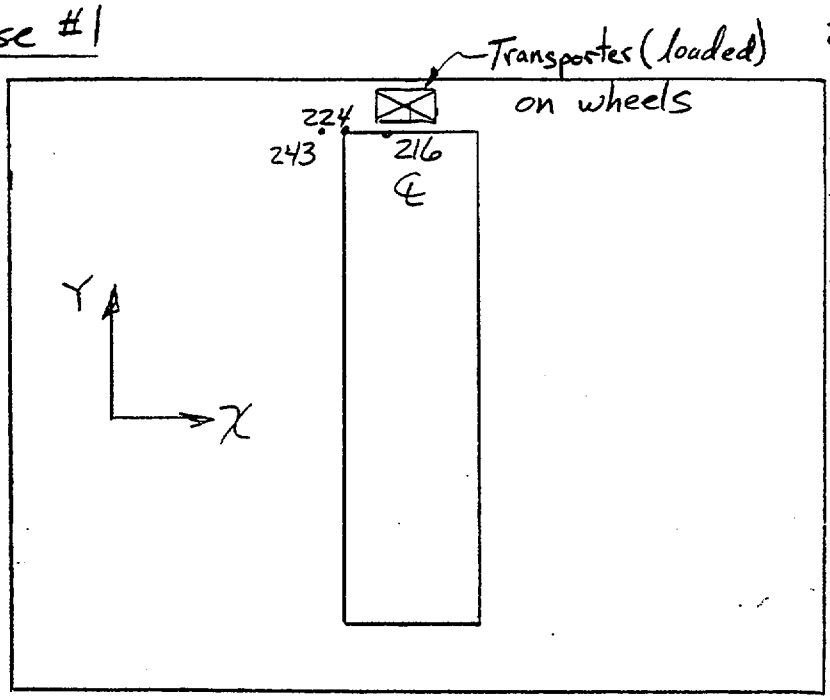
CALC NO 0079-00541-2

# Load Cases - ISFSI

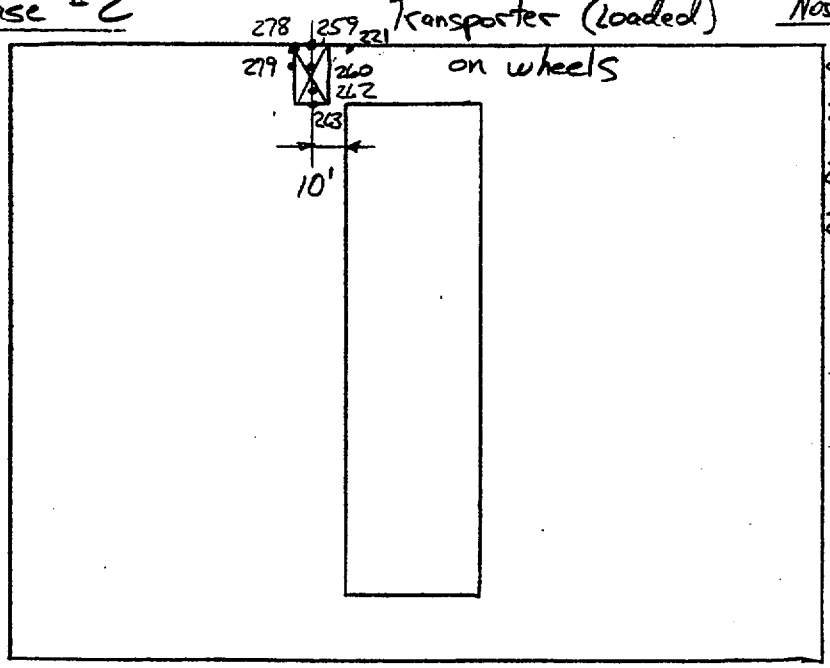
## Load Case #1




| Node | Max Moments |
|---|---|
| 216 | $M_y = +2.7$ k·ft/ft |
| 224 | $M_y = -4.2$ k·ft/ft |
| 243 | $M_x = -0.3$ k·ft/ft |
| 215 | $M_x = +0.4$ k·ft/ft |

SEE Appendix for determination of values and locations

## Load Case #2




| Node | Max Moments |
|---|---|
| 259 | $M_y = +15.5$ k·ft/ft |
| 221 | $M_y = -6.5$ k·ft/ft |
| 263 | $M_x = +6.6$ k·ft/ft |
| 260 | $M_x = -3.6$ k·ft/ft |

| REV | BY | DATE | CHECKED | DATE |
|---|---|---|---|---|
| B | MD | 5-18-93 | [illegible] | 5/27/93 |
| A | MD | 4-30-93 | [illegible] | 4/30/93 |

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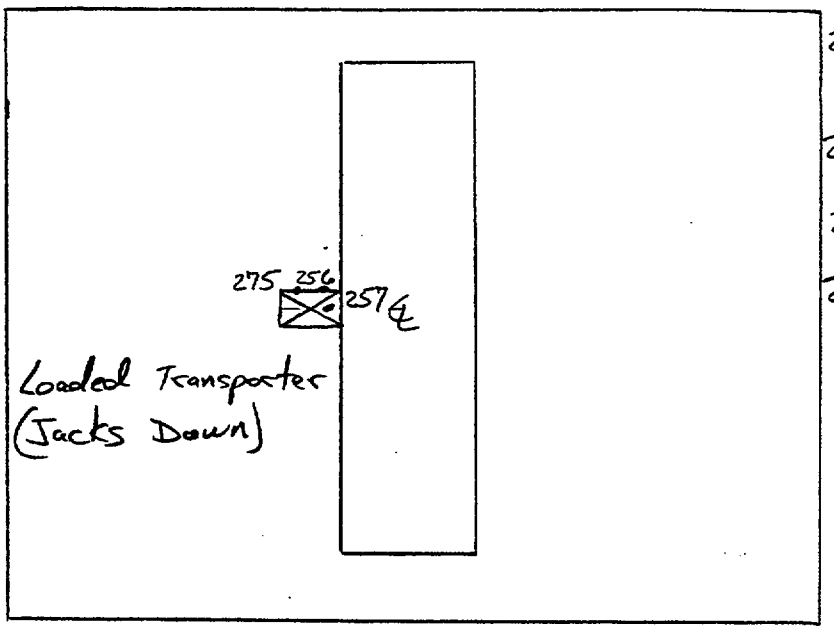
CALC NO 0079-00541-2

# Load Cases – ISFSI (contd)

## Load Case #3



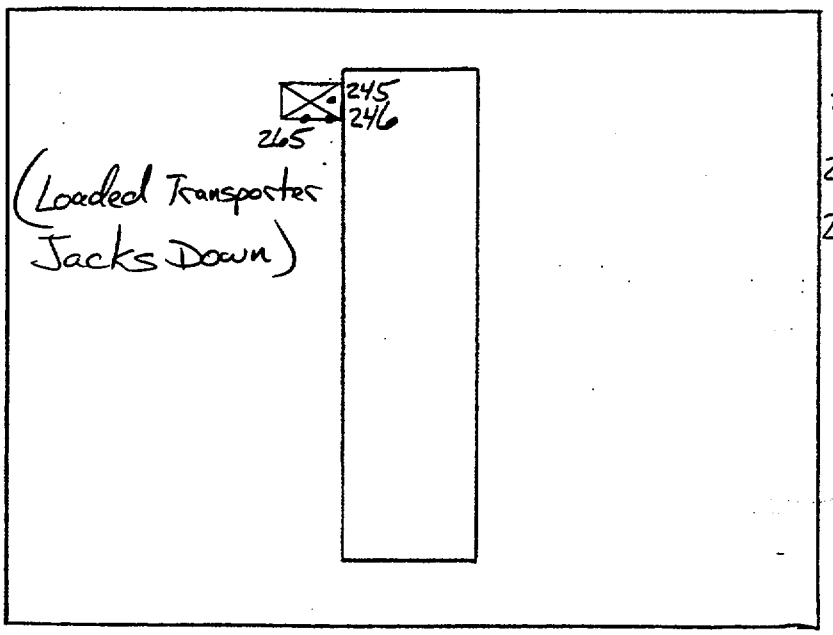

256 $M_x = +26.6$ K·ft/ft

257 $M_x = -8.4$ K·ft/ft

256 $M_y = +25.4$ K·ft/ft

275 $M_y = -7.3$ K·ft/ft

## Load Case #4




244 $M_y = +27.2$ K·ft/ft

265 $M_y = -7.2$ K·ft/ft

246 $M_x = +26.9$ K·ft/ft

245 $M_x = -7.9$ K·ft/ft

| REV | BY | DATE | CHECKED | DATE |
|---|---|---|---|---|
| B | MO | 5-18-93 | [illegible] | 5/27/93 |
| A | MO | 4-30-93 | [illegible] | 4/30/93 |

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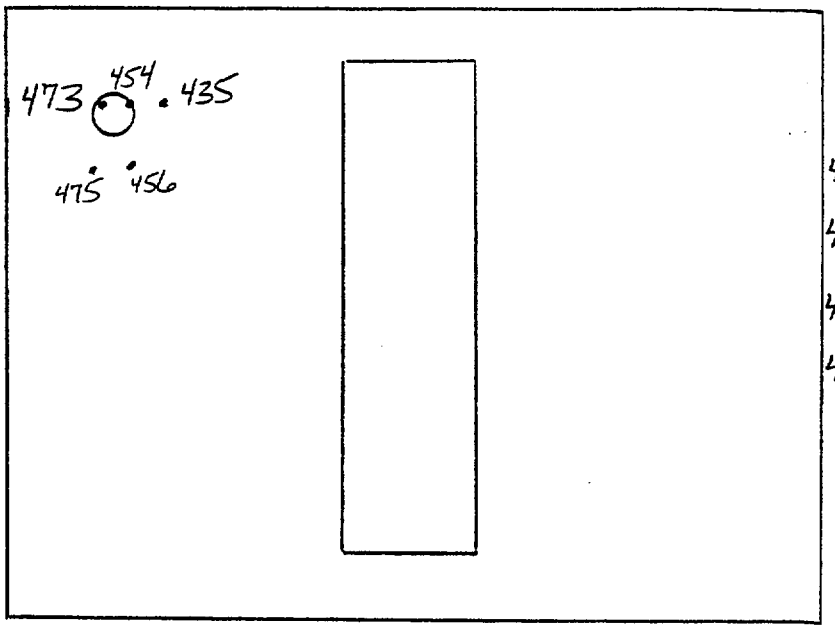
JOB NO 0079-00541
CALC NO 0079-00541-2

## Load Cases – ISFSI (cont'd)

### Load Case 5

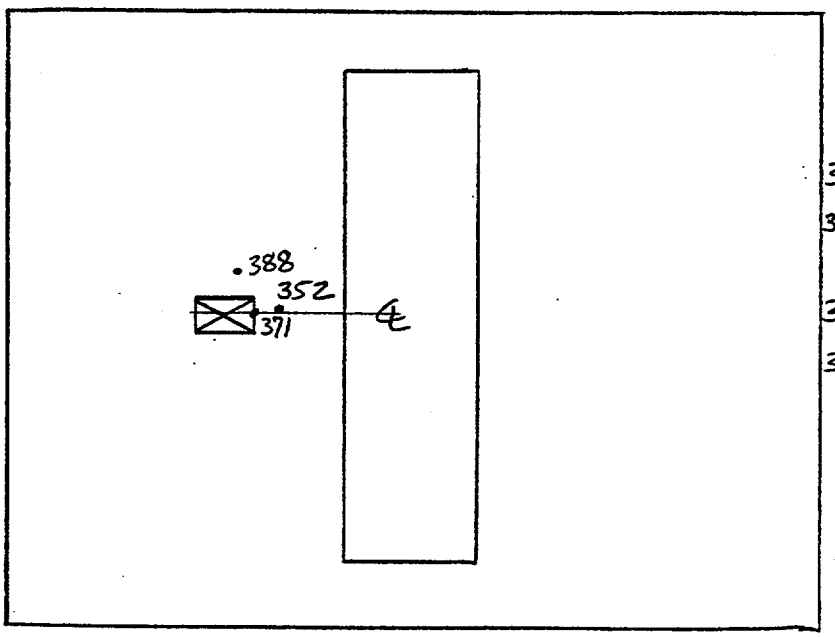



Dual Purpose Cask w/ Seismic

473 $^{+}M_x = 29.6$ k·ft/ft
456 $^{-}M_x = 4.9$ k·ft/ft

473 $^{+}M_y = 20.7$ k·ft/ft
435 $^{-}M_y = 6.6$ k·ft/ft

### Load Case 6




Transporter (loaded) on wheels

371 $^{+}M_y = 4.7$ k·ft/ft
352 $^{-}M_y = 2.5$ k·ft/ft

371 $^{+}M_x = 4.7$ k·ft/ft
388 $^{-}M_x = 1.9$ k·ft/ft

| REV | BY | DATE | CHECKED | DATE |
|---|---|---|---|---|
| B | MD | 5-18-93 | [illegible] | 5/27/93 |
| A | MD | 4-30-93 | [illegible] | 4/30/93 |

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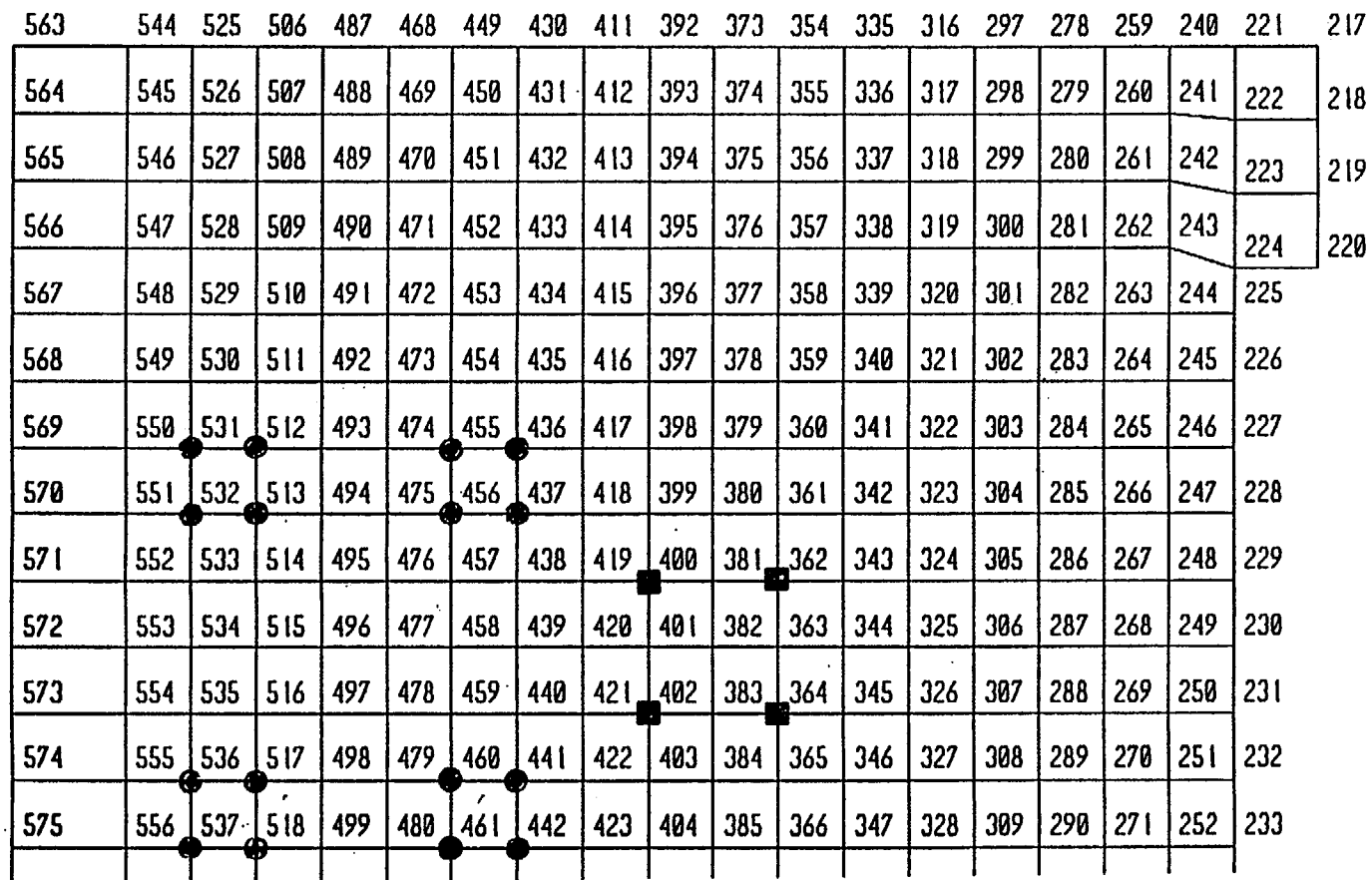
JOB NO 0079-00541
CALC NO 0079-00541-2

# Loaded Crane, Max Outrigger Load




LOAD CASE #7

■ Transporter Jack ● Crane Outrigger

436 $+M_y$ = 11.4 k·ft/ft 475 $-M_y$ = 5.4 k·ft/ft

455 $+M_x$ = 11.7 k·ft/ft 458 $-M_x$ = 6.3 k·ft/ft

442 $+M_y$ = 11.4 k·ft/ft 480 $-M_y$ = 6.7 k·ft/ft

441 $+M_x$ = 7.9 k·ft/ft 462 $-M_x$ = 2.3 k·ft/ft

Y X

APRON

UNDEFORMED SHAPE

OPTIONS

JOINT IDS WIRE FRAME

SAP90

| REV | BY | DATE | CHECKED | DATE |
|---|---|---|---|---|
| B | MC | 5/8/93 | [illegible] | 5/27/93 |

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JOB NO 0078-0054 1-

CALC NO 0078-0054 1-2

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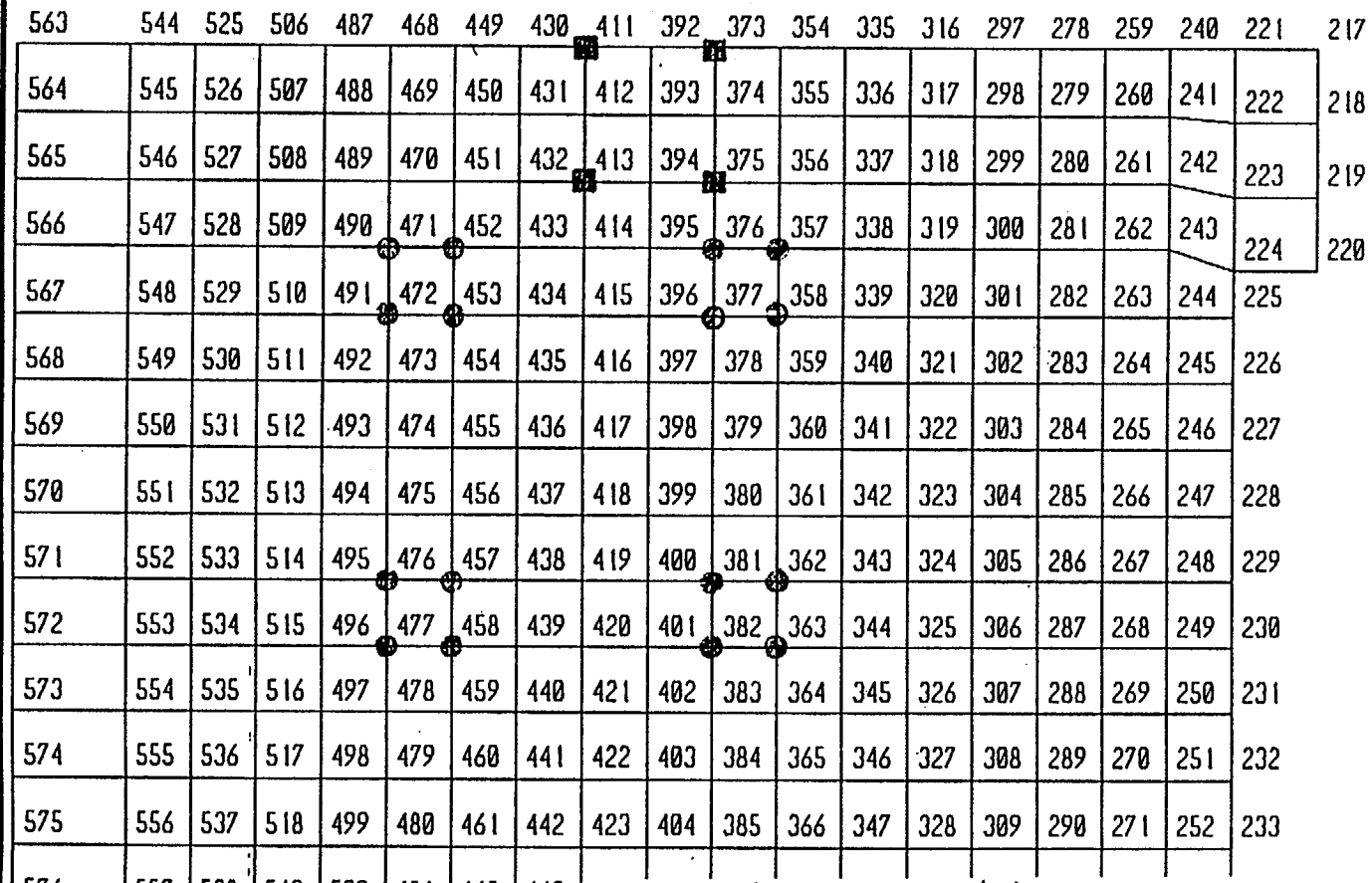
# Loaded Transporter, Max Outrigger Load




LOAD CASE #8

■ TRANSPORTER JACK ● CRANE OUTRIGGER

412 $-M_X = 22.4$ k·ft/ft 413 $+M_X = 19.7$ k·ft/ft

411 $+M_Y = 60.5$ k·ft/ft 449 $-M_Y = 11.8$ k·ft/ft

Y X

APRON

UNDEFORMED SHAPE

OPTIONS

JOINT IDS

WIRE FRAME

SAP90

| REV | BY | DATE | CHECKED | DATE |
|---|---|---|---|---|
| B | MMC | 5/18/93 | [illegible] | 5/27/93 |

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JOB NO 0079-00541

CALC NO 0079-00541-2

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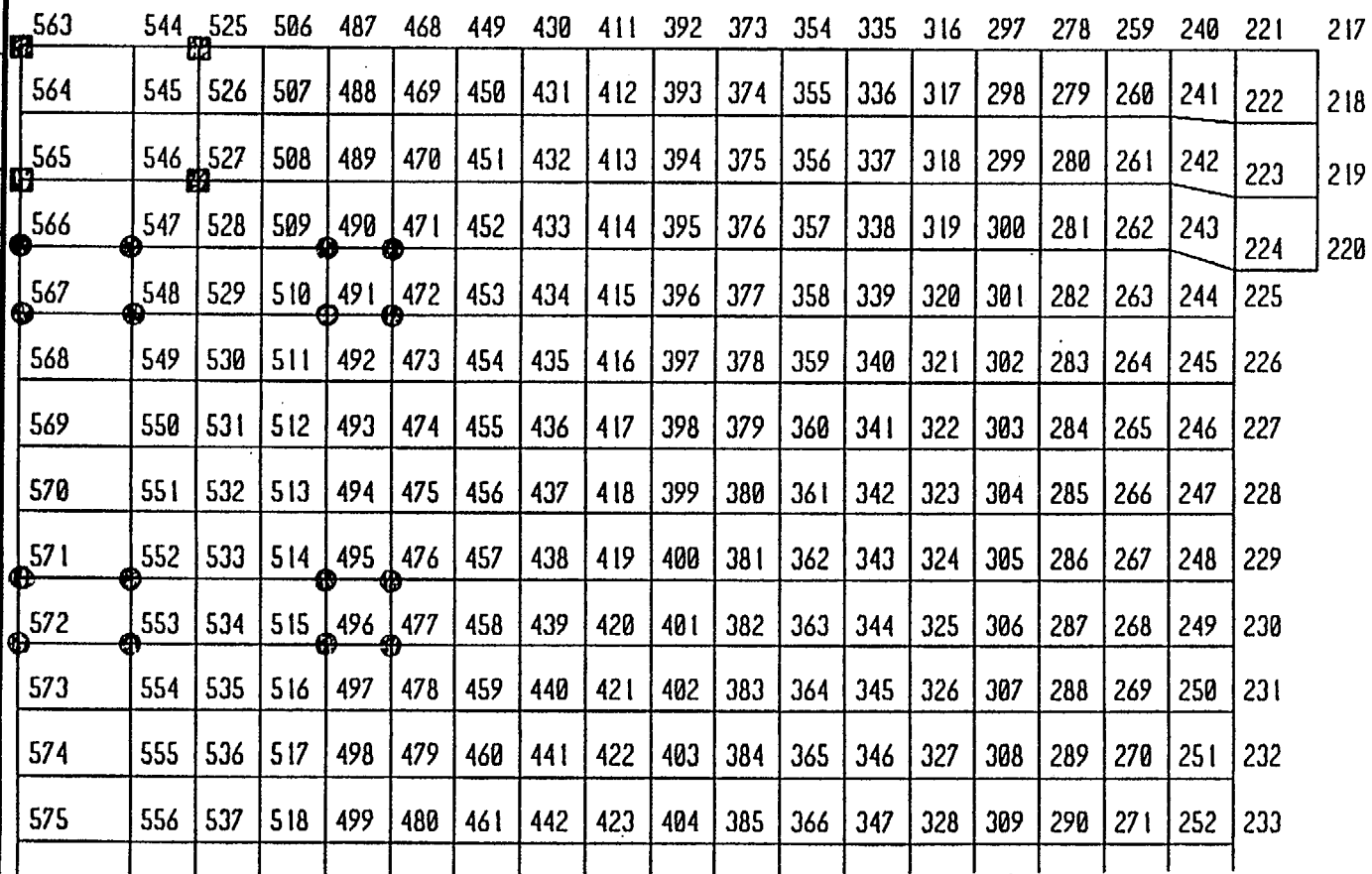
Z-DRY-C1024

# Loaded Transporter, Max Outrigger Load

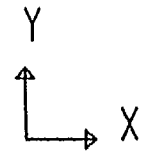



LOAD CASE #9

■ TRANSPORTER JACK ● CRANE OUTRIGGER

564 $-M_x = 50$ k·ft/ft 565 $+M_x = 24.1$ k·ft/ft

544 $-M_y = 39.1$ k·ft/ft 565 $+M_y = 26.4$ k·ft/ft




APRON

UNDEFORMED SHAPE

OPTIONS

JOINT IDS

WIRE FRAME

SAP90

| REV | BY | DATE | CHECKED | DATE |
|---|---|---|---|---|
| B | MJC | 5/18/93 | [illegible] | 5/27/93 |

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JOB NO 0079-00541

CALC NO 0079-00541-2

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4°

Z-DRY-C1024

## Apron Slab Design

Establish slab capacity with shrink & temp steel only:

**1' slab:** min steel $= 0.0018(12 \times 12) = 0.259\ in^2/ft$

#4 @ 16" T&B $\Rightarrow A_{s_{gross}} = \frac{2(.2)(12)}{16} = 0.3\ in^2/ft$

#3 @ 10" T&B

#5 @ 28" T&B NG min space @ 18"

Try #4 @ 16" T&B $\quad {}^{+}d = 12 - 3 - 1.5(.5) = 8.25"$

$-d = 12 - 2 - 1.5(.5) = 9.25"$

flexure: $\rho^{+} = \frac{0.2}{8.25 \times 16} = 0.00152 \quad \rho^{-} = \frac{0.2}{9.25 \times 16} = 0.00135$

$$\phi M_n = \phi A_s f_y d \left(1 - \frac{0.59 \rho f_y}{f'_c}\right)$$

$${}^{+}\phi M_n = 0.9\left(\tfrac{12}{16} \times 0.2\right) 60 (8.25)\left(1 - \frac{0.59(.00152)60}{4}\right)$$

$${}^{+}\phi M_n = 65.9\ k \cdot in = 5.5\ k \cdot ft$$

$$M_u \le \phi M_n$$

$$1.7 M_{max} \le \phi M_n \Rightarrow \underline{M_{max}^{(+)} \le \frac{5.5}{1.7} = 3.23\ k \cdot ft}$$

$$-\phi M_n = 0.9\left(\tfrac{12}{16} \times 0.2\right) 60 (9.25)\left[1 - \frac{0.59(.00135)60}{4}\right]$$

$$-\phi M_n = 74\ k \cdot in = 6.2\ k \cdot ft$$

$$\underline{M_{max}^{(-)} = \frac{6.2}{1.7} = 3.6\ k \cdot ft}$$

| REV | BY | DATE | CHECKED | DATE |
|---|---|---|---|---|
| B | MW | 5-18-93 | BZG | 5/27/93 |
| A | MW | 4-30-93 | TJ | 4/30/93 |

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CALC NO 0079-00541-2

Apron Slab Design (Contd)

Establish capacity with shrink & temp steel only

1'-6" slab:

min steel = 0.0018(12x18) = 0.389 in²/ft

#3 @ 6½" T&B

#4 @ 12" T&B ⇒ $A_s$ = 2(.2) = 0.4 in²/ft

#5 @ 18" T&B

Try #4 @ 12"

Flexure: $d^+ = 18-3-1.5(.5) = 13.5''$ $d^- = 18-2-1.5(.5) = 15.25''$

$$\rho^+ = \frac{0.2}{12\times13.5} = 0.00123 \qquad \rho^- = \frac{0.2}{12\times15.25} = 0.0011$$

$$(+)\ \phi M_n = 0.9(.2)(60)(13.5)\left[1-\frac{0.59(.00123)60}{4}\right] = 144.2\ k\cdot in = 12\ k\cdot ft$$

$$(+)\ M_{max} = \frac{12}{1.7} = 7.1\ k\cdot ft$$

$$(-)\ \phi M_n = 0.9(.2)(60)(15.25)\left[1-\frac{0.59(.0011)60}{4}\right] = 163\ k\cdot in = 13.6\ k\cdot ft$$

$$(-)\ M_{max} = \frac{13.6}{1.7} = 8.0\ k\cdot ft$$

| REV | BY | DATE | CHECKED | DATE |
|---|---|---|---|---|
| B | MO | 5-18-93 | [illegible] | 5/27/93 |
| A | MO | 4-30-93 | TOJ | 4/30/93 |

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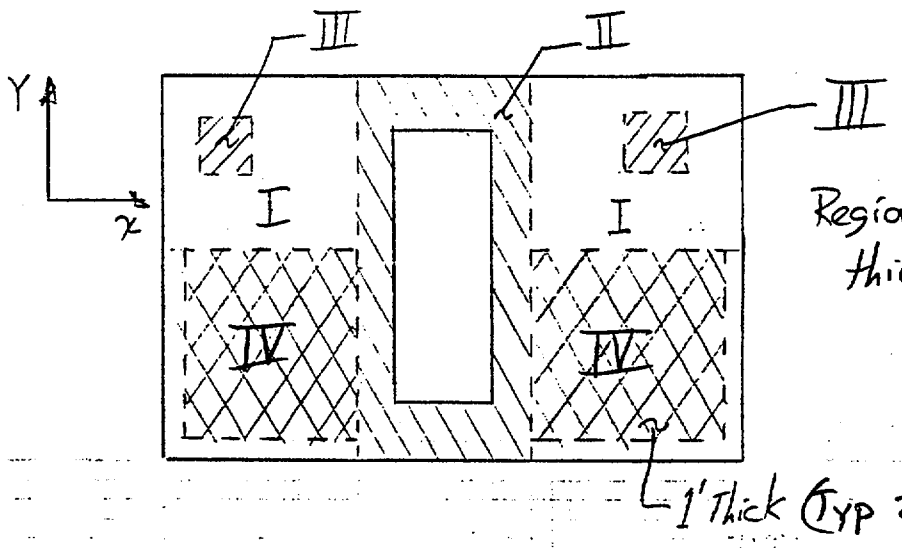
JOB NO 0079-00541
CALC NO 0079-00541-2

## Apron Slab design (cont'd)

Overview of Design Moments:




Regions I, II, III slab thickness 1'-6"

For each load case envelope positive & negative moments between X & Y directions so that slab design will have same steel T&B, EW. Look @ providing different steel for the 4 different regions marked on the Apron

| Load Case | Max Moment | Region |
|---|---|---|
| 1 D+L | 4.2 K·ft/ft | II |
| 2 D+L | 15.5 K·ft/ft | II |
| 3 D+L | 26.6 K·ft/ft | II |
| 4 D+L | 27.2 K·ft/ft | II |
| 5 D+Seismic | 29.6 K·ft/ft | III |
| 6 D+L | 4.7 K·ft/ft | IV |
| 7 D+L | 11.7 K·ft/ft | I |
| 8 D+L | 60.5 K·ft/ft | I |
| 9 D+L | 50 K·ft/ft | I |

Load Cases not used since outriggers will not be allowed w/in 10' of slab perimeter

| REV | BY | DATE | CHECKED | DATE |
|---|---|---|---|---|
| B | MD | 5-18-93 | BB | 9/30/93 |

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Z.DRY.C1024

Apron Slab Design 1'-6" thick portion:

Region I $\Rightarrow$ $M = 11.7$ k·ft/ft

$M_u = 1.7(11.7) = 19.9$ k·ft/ft

$d = 18 - 3 - 1.5(.75) = 13.8''$

cover $1\frac{1}{2} \times \#6\,\phi$

Try #6 @ 14 oc $\Rightarrow \rho_{flex} = \frac{0.44}{13.8 \times 14} = 0.00228$

$\phi M_n = \phi A_s f_y d \left[1 - \frac{0.59 \rho f_y}{f'_c}\right]$

$\phi M_n = 0.9\left(\frac{12}{14} \times .44\right) 60 (13.8) \left[1 - \frac{0.59(.00228)60}{4}\right]$

$\phi M_n = 275$ k·in/ft $= 23$ k·ft/ft $> M_u$ ✓ ok

Use #6 @ 14" T&B EW

| REV | BY | DATE | CHECKED | DATE | | | |
|---|---|---|---|---|---|---|---|
| B | [illegible] | 5-18-93 | [illegible] | 5/27/93 | ABB Impell Corporation | JOB NO 0079-00541 / CALC NO 0079-00541-2 | PAGE 42 / CONT ON 43 |

Apron Slab Design (Cont'd) 1'-6" portion:

Region II:

Critical Design Moment = 27.2 k·ft/ft

$$M_u = 1.7(27.2) = 46.2 \text{ k·ft/ft}$$

live load factor

$$d = 18 - 3 - 1.5(.75) = 13.8''$$

cover 1½ x #6 bar ϕ

Try #6 @ 6" oc $\Rightarrow \rho_{flex} = \frac{0.44}{6 \times 13.8} = 0.00531$

$$\phi M_n = \phi A_s f_y d \left[1 - \frac{0.59 \rho f_y}{f'_c}\right]$$

$$= 0.9(2 \times .44)\,60(13.8)\left[1 - \frac{0.59(.00531)60}{4}\right]$$

$$\phi M_n = 625 \text{ k·in/ft} = 52 \text{ k·ft/ft} > M_u \checkmark \text{OK}$$

use #6@6" top & bottom each way

| REV | BY | DATE | CHECKED | DATE |
|---|---|---|---|---|
| B | MT | 5-18-93 | [illegible] | 5/27/93 |

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CALC NO 0079-00541-2

Apron Slab Design (cont'd) 1'-6" portion:

Region III = max moment = 29.6 k·ft/ft pos bending

for DL + Seismic $M_u = 1.4(29.6) = 41.4$ k·ft/ft

Since this is pos bending only & region III is within region I, look @ providing same top steel as for region I & just increasing No. of bars on lower mat under dual purpose casks to handle larger pos moment.

Region I bars are #6 @ 14" oc – Try #6 @ 7" for lower mat in Region III: $\rho = \frac{0.44}{13.8 \times 7} = 0.00455$

$$\phi M_n = 0.9\left(\tfrac{12}{7} \times 0.44\right) 60 (13.8) \left[1 - \frac{0.59(0.00455)60}{4}\right]$$

$\phi M_n = 539$ k·in/ft $= 45.0$ k·ft/ft $> M_u$ ✓ ok

use #6 @ 7", lower mat under dual purpose casks

| REV | BY | DATE | CHECKED | DATE | | | |
|---|---|---|---|---|---|---|---|
| B | [illegible] | 5-18-93 | [illegible] | 5/27/93 | ABB ASEA BROWN BOVERI ABB Impell Corporation | JOB NO 0079-00541 CALC NO 0079-00541-2 | PAGE 44 CONT ON 45 |

## Apron Slab design (cont'd)

Design 1' thick portion

Load Case 6 : envelope top & bottom, both directions

Design moment = 4.7 k·ft/ft (DL+LL)

$M_u = 1.7(4.7) = 8.0$ k·ft/ft

$d = 12 - 3 - 1.5(.5) = 8.25''$

Try #4@10" $\Rightarrow$ $\rho = \frac{0.2}{8.25 \times 10} = 0.00242$

$\phi M_n = 0.9(\frac{12}{10} \times .2)60(8.25)\left[1 - \frac{.59(.00242)60}{4}\right]$

$\phi M_n = 105$ k·in/ft $= 8.7$ k·ft/ft $> M_u$ ✓ OK

Use #4@10" over 1' thick portion

@ 1'-6" thick perimeter, min steel req'd for shrink & temp was prev determined as #4@12"

∴ If continuing #4@10" @ perimeter were ok

| REV | BY | DATE | CHECKED | DATE |
|---|---|---|---|---|
| B | [illegible] | 5-18-93 | [illegible] | 5/27/93 |

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CALC NO 0079-00541-2

## Apron Slab Design (cont'd)

Determine lap splice for #6 bar

UBC § 2612 development length $l_d = 0.04 A_b f_y / \sqrt{f'_c}$
with following factors =

Top reinforcement = 1.3 (No Hooks)
1'-6" section only

Use Class B lap splice = $1.3 l_d$

$$\therefore \text{lap splice} = 1.3 l_d = \frac{1.3(1.3)(0.04)(.44)\,60{,}000}{\sqrt{4000}}$$

lap splice = 28.2"

Use 2'-6" = 30"

## Soil Pressure =

By comparison to soil pressure analysis for HSM slab and considering the size of the HSM slab and total applied vertical load, the soil pressure for the apron slab is judged to be non critical and well within the allowable values set forth in Ref 11.

| REV | BY | DATE | CHECKED | DATE |
|---|---|---|---|---|
| 0 | MO | 6-8-93 | [illegible] | 6/10/93 |
| B | MO | 5-18-93 | [illegible] | 5/27/93 |

ABB
ASEA BROWN BOVERI
ABB Impell Corporation

JOB NO 0079-00541
CALC NO 0079-00541-2