Calculation Cover Sheet (Cont.)

Calc. No.: 91-E-0094-01 Unit: 1

Rev. No: 3 Verification Method: Design Review: X
Alternate Calculation: ____ Qualification Testing: ____

Pages Revised and/or Added: REVISED 2,3,4, 7, 7a & THRU 17 & 19
ADDED 4a, 5a, 6a, 6b, 7b, 7c, 8a, 8b, 9a, 9b, 10a, 10b, 10c
12a, 14a, 15a & 16a

Purpose of Revision: TO ADDRESS THE IMPACT ON 27' SLAB SPAN DUE TO 17 TON CASK DROP

Initiating Documents	Resulting Document(s)	Reference Calcs.

Amends Calc(s): CIVIL CALC. 11406-130

Supercedes Calc(s): —

Computer Software(Ver.): —

By: Tony Dib / TD / 10/11/91 Rvw'd: NA / /
Chk'd: Ken Baird / KB / 10/14/91 Apv'd: DOYLE G. ADAMS / DGA / 10.15.91
(Print Name) (Initials) (Date) (Print Name) (Initials) (Date)

Rev. No: ____ Verification Method: Design Review: ____
Alternate Calculation: ____ Qualification Testing: ____

Pages Revised and/or Added: ____

Purpose of Revision: ____

Initiating Documents	Resulting Document(s)	Reference Calcs.

Amends Calc(s): ____

Supercedes Calc(s): ____

Computer Software(Ver.): ____

By: / / Rvw'd: / /
Chk'd: / / Apv'd: / /
(Print Name) (Initials) (Date) (Print Name) (Initials) (Date)

Check if Additional Revisions ____

ARKANSAS NUCLEAR ONE

REV 4-25-8

Calculation Cover Sheet (Cont.)

Calc. No.: 91-E-0094-01 Unit: 1

Rev. No: 1 Verification Method: Design Review: X
Alternate Calculation: ____ Qualification Testing: ____

Pages Revised and/or Added: REVISED PG 3, 4, 7 & 18, ADDED PG. 7a
ADDED ATTACHMENT 1 (15 PGS)

Purpose of Revision: TO QUALIFY UNIT-1 CONTROL RM. SLAB FOR 17 TON CASK DROP W/ 27' SPAN.

Initiating Documents	Resulting Document(s)	Reference Calcs.
—	—	11406-130 (CIVIL)

Amends Calc(s): CIVIL CALC. 11406-130

Supercedes Calc(s):

Computer Software(Ver.):

	(Print Name)	(Initials)	(Date)		(Print Name)	(Initials)	(Date)
By:	TONY DIB	TD	9/19/91	Rvw'd:			
Chk'd:	KEITH BAIRD	KWB	9/19/91	Apv'd:	DOYLE G. ADAMS	DGA	9.24.91

Rev. No: 2 Verification Method: Design Review: X
Alternate Calculation: ____ Qualification Testing: ____

Pages Revised and/or Added: REVISED PG. 19

Purpose of Revision: TO ADDRESS SPALLING DUE TO 17 TON CASK DROP.

Initiating Documents	Resulting Document(s)	Reference Calcs.
—	—	11406-130 (CIVIL)

Amends Calc(s): CIVIL CALC. 11406-130

Supercedes Calc(s):

Computer Software(Ver.):

	(Print Name)	(Initials)	(Date)		(Print Name)	(Initials)	(Date)
By:	TONY DIB	TD	9-20-91	Rvw'd:			
Chk'd:	KEITH BAIRD	KWB	10-1-91	Apv'd:	DOYLE G. ADAMS	DGA	10.1.91

Check if Additional Revisions ____

REV 4-26-89

Calculation Cover Sheet

Calc. No.: 91-E0094-01 Unit: 1 Category: Q

Calc. Title: 17 TON CASK DROP ANALYSIS FOR CONCRETE FLOOR ABOVE ANO-1 CONTROL ROOM

System(s): —

Topic(s): STRU.

Calc. Type: CG.

Component No(s).: —

Plt Area: Bldg. 1AB Elev. 404

Room ____ Wall ____

Coordinates: ____

Abstract (Include Purpose/Results):

PURPOSE: TO EVALUATE / PERFORM 17 TON (712 mm) CASK DROP ANALYSIS, LIMITED TO 9" DROP, FOR THE FLOOR ABOVE THE UNIT-1 CONTROL ROOM.

RESULTS: 1) THE FLOOR IS QUALIFIED FOR MAX. OF 3" DROP WITHOUT HEXAGONAL HONEYCOMB ENERGY ABSOB. MAT'L.
2) THE FLOOR IS QUALIFIED FOR 9" DROP WITH 3" OF HEXAGONAL HONEYCOMB ENERGY ABSOB. MAT'L. (260 PSI)

Rev. No: 0 Verification Method: Design Review: X

Alternate Calculation: ____ Qualification Testing: ____

Pages Revised and/or Added: ALL NEW PG 1 THRU 19

Purpose of Revision: SAME AS ABSTRACT.

Initiating Documents	Resulting Document(s)	Reference Calcs.
—	—	11406-130 (CIVIL)

Amends Calc(s): CIVIL CALC. 11406-130

Supercedes Calc(s): —

Computer Software(Ver.): —

	(Print Name)	(Initials)	(Date)		(Print Name)	(Initials)	(Date)
By:	Tony Dih	TD	8/8/91	Rvw'd:	KEJ BAND	KB	8-12-91
Chk'd:	Kirby Bushong	KOB	8/9/91	Apv'd:	H. NUGENT / David J. [illegible]	HDN	8-9-91 / 8/12/91

Check If Additional Revisions: ____

APL

ARKANSAS NUCLEAR ONE

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PURPOSE:

To evaluate and perform shipping cask drop analysis for the concrete floor area above the ANO-1 Control Room, with and/or without hexagonal honeycomb, using the following data:

- Shipping cask diameter = 712 mm = 28"
- hipping cask weight = 17 Ton, use 35 kips
- maximum drop = 9"

DESIGN APPROACH:

Using Bechtel Topical Report BC-TOP-9A, Rev. 2, an analysis will be performed utilizing Kinetic Energy Formulas to determine the true Kinetic Energy the slab may absorb. Steps in this analysis are:

1) Establish four different loading cases taken for this analysis, page 3 to page 4a.
2) Determine the combined moment of inertia for the structure, page 5 to page 6.
3) Calculate the maximum moment Mu capacity of the slab for all four (4) cases, page 6a to page 6b.
4) Calculate the ultimate load (Pu) based on Mu for each of the four cases, page 7 to page 8.
5) Calculate the deflection (Δu) based on Pu for each of the four cases, page 7 to page 8.
6) Calculate the ultimate shear capacity of the slab, Vmax. based on concrete/reinforcement strength, page 8a to page 9a.
7) Calculate the maximum load Ps to cause Vmax. for each of the four (4) cases, page 8a to page 9a
8) Calculate the deflection due Ps and compare with deflections due to Pu and dead weight of slab, for each of the four (4) cases. page 9a to page 9a.
9) Check bond stress at the face of concrete wall, page 9b to page 9b.
10) Plot the deflection VR load curve to calculate the kinetic energy for each of the four (4) cases, page 10 to page 10C.
11) Calculation of maximum drop height of cask that the slab can take based on equivalency of strain energy to kinetic energy, page 11 to page 12a.

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DESIGN APPROACH: (cont.)

12) Calculation of the required energy absorption material required for 9" cask drop, page 13 to page 13,

13) Calculation of the safety factors using the max. allowed height drop without any energy absorption material for all four cases, page 14 to page 16.

14) Calculation of the safety factors using 3" energy absorption material with 9" cask drop, page 17 to page 18.

REFFRENCES:

1) ACI 318-77

2) ACI 318-63

3) Topical Report BC-TOP-9A Rev. 2

4) Civil Calculation No. 88 Book 26, Pg. J23-J26 & J70-J78

5) Civil Calculation No. 11406-130

6) Reinforced Concrete Design by Wang & Salmon, Third Ed

7) Drawing No. C-206 Rev. 16

8) Drawing No. C-212 Rev. 9

9) AISC Eighth Edition

10) Design of Concrete Structures by Winter & Nilson

11) Calculation N0. 83-D-2200-11 Pg. 124 of 555

12) Specification 6600-C-302

NOTES AND ASSUMPTIONS:

1) f'_c = 4850 psi @ 28 days (Pour No. 517) (Ref. no. 11)
f'_c = 6230 psi @ 90 days (Pour No. 517) (Ref. no. 11)
f'_c = 6230 X 1.1 = 6850 psi @ 4 years (Ref. 10)
Use f'_c = 6500 psi @ 4 years (Conservative)
F_y = 48300 psi per mill test report (Ref. no. 5)

2) This calculation is to qualify the slabs between Column Lines B, C, and the north face of the Cask Pit which is located 3 feet north of Column Line D, and Column Lines 4 and 5. The span length between B and C is 27 feet. The span between C and the north face of the Cask Pit is 24 feet. Four cases were considered in this calculation:
Case # 1 : Span length = 24 feet and the cask drop location is at a distance equal to the effected depth of the slab from the face of the wall.
Case # 2 : Span length = 27 feet and the cask drop location is at a distance equal to the effected depth of the slab from the face of the wall.
Case # 3 : Span length = 24 feet and the cask drop location is at Mid Span.
Case # 4 : Span length = 27 feet and the cask drop location is at Mid Span.

These four (4) loading cases will provide worst condition stress in the slab for each load drop.

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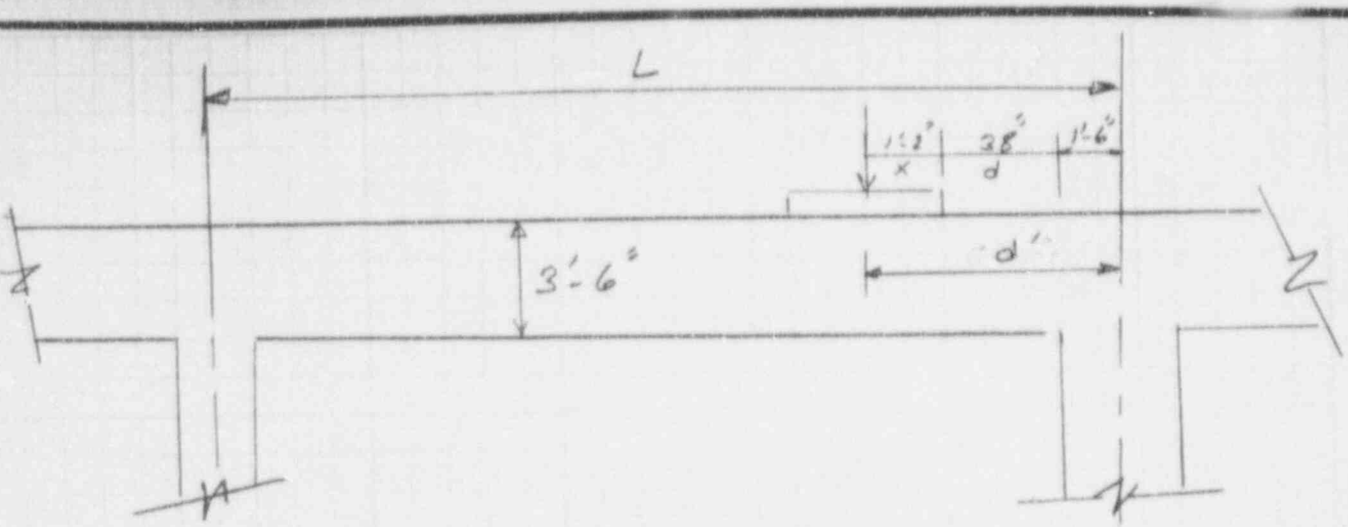


CASE # 1 & 2

X = ½ (DIA. OF CASK) = ½ (28") = 14" = 1'-2" (Ref. Pg. 2)

t = Slab Thickness = 3'-6" = 42" (Ref. # 7 & 8)

d = Effective Depth = t - 4" = 42" - 4" = 38" (Ref. # 7 & 8)

Reinforcing Rebars:

This slab has Top and Bottom reinforcing rebars. To be conservative, ignore the Top rebars. Bottom rebars are 3 # 11 per foot.
(Ref. # 7 & 8)

5 stirrups @ 3'-10" in E-W (Ref. # 7 & 8)
5 stirrups @ 1'-0" in N-S (Ref. # 7 & 8)

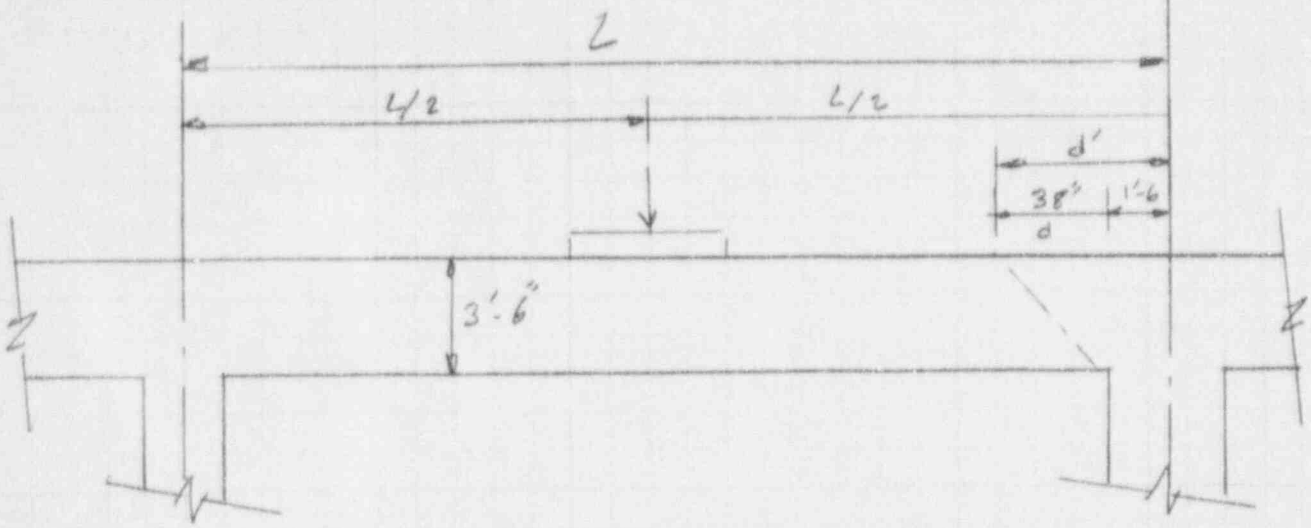
For this case, the critical location for moment and shear is @ a distance d from the face of the wall and the load is located at a distance (d') from the center of the wall. d' = X+d+½ wall thickness

d'= 1'-2" + 3'-2" + 1'-6" = 5'-10"

Used distance d' = 6'-0" from the center of the wall.

L = 24' for Case # 1

L = 27' for Case # 2



CASE # 3 & 4

X = ½ (DIA. OF CASK) = ½ (28") = 14" = 1'-2" (Ref. Pg. 2)

t = Slab Thickness = 3'-6" = 42" (Ref. # 7 & 8)

d = Effective Depth = t - 4" = 42" - 4" = 38" (Ref. # 7 & 8)

Reinforcing Rebars:

This slab has Top and Bottom reinforcing rebars. To be conservative, ignore the Top rebars. Bottom rebars are 3 # 11 per foot.
(Ref. # 7 & 8)

5 stirrups @ 3'-10" in E-W (Ref. # 7 & 8)
5 stirrups @ 1'-0" in N-S (Ref. # 7 & 8)

For this case, the critical location for moment is @ mid span and the critical location for shear is @ a distance d from the face of the wall or at a distance (d') from the center of the wall.
d' = d + ½ wall thickness

d'= 3'-2" + 1'-6" = 4'-8" (Ref. # 1, Sec. 11.1.3.1)

L = 24' for Case # 3

L = 27' for Case # 4

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CALCULATION:

CALCULATE THE BEAM properties

I. EFFECTIVE WIDTH OF BEAM = b

$b = T + 2d$

T = Dim. OF CASK = 710 mm = 2'-4" (Ref. Pg. 2)

d: distance FROM EXTREME COMPRESSION FIBER to the Centroid of the tension reinforcing.

d = 3'-2" (SEE PG 4-4a)

∴ b = 2'-4 + 2(3'-2") = 8'-8" = 8.66'

= 104 in

USING BC-TOP-9 (Ref # 3 FORMULA 4-2)

$$I_a = \frac{1}{2}(I_g + I_c) = \frac{1}{2}\left(\frac{bt^3}{12} + Fbd^3\right)$$

where:

I_a : AVERAGE MOMENT OF INERTIA

I_g : MOMENT OF INERTIA OF GROSS Concrete

I_c : MOMENT OF INERTIA OF THE CRACKED CONCRETE sec.

t : THICK. OF The BEAM : 42" = 3.5' (FLOOR)

F = COEFFICIENT FOR MOMENT OF INERTIA OF CRACKED SECTION w/ Tension reinforcing only.

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0	8/8/91	TD	KDB			

CALCULATION: (cont.)

$\rho = \frac{A_s}{bd}$ (Ref # 1; chapter 8)

3 where A_s = Area of Tensile reinforcing steel/i.e.
FOR 3 # 11 = 3 x 1.56 = 4.68 in² (see pg. 4-4a)

$\rho = \frac{3 \times 1.56}{12" \times 38"} = 0.010263$

$E_c = w^{1.5}\, 33 \sqrt{f'_c}$ (Ref # 1, 8.5.1), w = 145 lb/ft³ (Ref # 5)

3 $E_c = (145)^{1.5}\, 33 \sqrt{6500} = 4{,}887{,}733$ PSI

USE $E_c = 4888$ KSI (Ref # 5)

$E_s = 29 \times 10^6$ PSI

$n = \frac{E_s}{E_c} = \frac{29{,}000{,}000}{4{,}887{,}733} = 6$ 3

USE $n = 6$

FROM FIG. 4-1 OF BC-TOP-9 (Ref # 3)

($\rho = .010263$, $n = 6$) ⟹ F = 0.045

$\therefore\ I_a = \frac{1}{2}\left(\frac{104"(42")^3}{12} + .045 \times 104" \times 38"^3\right)$

$I_a = \frac{1}{2}(642096 + 256801)$

$I_a = 449448$ in⁴

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CALCULATION:

CALCULATE THE MAX. MOMENT CAPACITY OF THE SLAB (Mu) USING TENSION REINFORCEMENT ONLY

$Mu = \phi [A_s f_y (d - a/2)$ (Ref #6, EQ.3.3.4)

WHERE $\phi = 0.9$ (Ref #1)

A_s = AREA OF TENSION Steel = 4.68 in²/FT (Ref)

$a = \frac{A_s f_y}{.85 f'_c b} = \frac{4.68 \text{ in}^2/\text{FT} \times 8.66' \times 48.3 \text{ KSI}}{.85 \times 6.5 \text{ KSI} \times 8.66' \times 12''}$

$a = 3.41''$

$\Rightarrow MU = 0.9 [4.68 \text{ in}^2/\text{FT} \times 8.66 \text{ FT} \times 48.3 \text{ KSI} \times (3'' - \frac{3.41''}{2}) \times \frac{1 \text{ FT}}{12''}]$ △

$\boxed{Mu = 5328.6 \text{ K-FT}}$

USING BEAM FORMULAS, CALCULATE THE MAX. LOAD Pu THAT THE SLAB CAN TAKE, USING MAX. MOMENT CAPACITY OF THE BEAM MU.

CONSIDER A S.S. BEAM, FIND THE MAX. Pu IN ADDITION TO D.W. OF THE BEAM IN ALL FOUR CASES ADDRESSED ON SHT-3.

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CALCULATION:

PG NO 7 TO PG NO 8 CALCULATED, FOR EACH OF THE FOUR (4) CASES ADDRESSED ON PG 3, THE MAX. LOAD "Pu" THAT THE SLAB CAN TAKE, IN ADDITION TO THE D.W. OF THE SLAB, WHICH WILL IMPOSE A MOMENT equal TO THE MAX. CAPACITY OF THE SLAB Mu (see PG 6a)

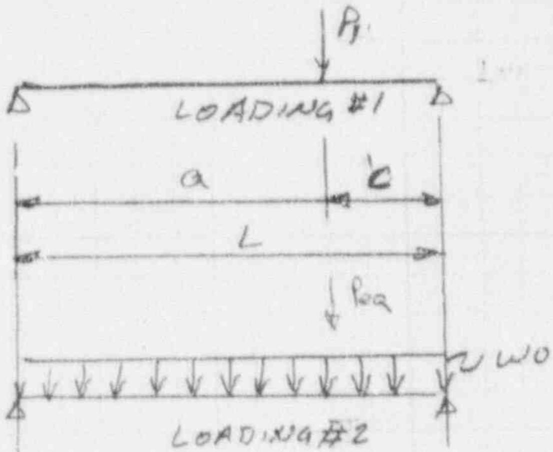
ALSO, DEFLECTIONS @ PT. OF LOAD Due to the MAX LOAD Pu (ULTimate) were CALCULATED, WHICH WILL be USED LATER IN THIS CALCULATION TO FIND THE KINETIC ENERGY THIS SLAB COULD ABSORBE IN EACH OF THE 4 CASES.

FOR CASE # 1 & 2, CALCULATE THE MAX LOAD P_u, in ADDITION TO D.W. OF THE BEAM, @ DISTANCE d FROM THE FACE OF THE WALL.

LOADING # 1

$$M_u = \frac{P_1 a c}{L} \quad \text{(Ref \# 9 PG. 2-116)}$$

$$\Rightarrow P_1 = \frac{M_u L}{a c}$$



LOADING # 2

W_0 = wt. of Concrete BEAM.

$W_0 = b \times H \times .15$ (USE wt. of Concrete .15 K/Ft³)

$W_0 = 8.66' \times 3.5' \times .15 \text{ K/Ft}^2 = 4.546 \text{ K/FT}$

⇒ EQuivelant Concent. LOAD OF 'P_{eq}'

$$\boxed{M_0 = \frac{W_0 \times a}{2}(L-a) = P_{eq}\frac{a \times c}{L}} \quad \text{--- Ref \# 9 PG. 2-114}$$

$$\Rightarrow P_{eQ} = \frac{M_0 L}{a c} = \frac{W_0 \times a}{2}(L-a)\left(\frac{L}{a \times c}\right)$$

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CALCULATION:

$$P_u = \frac{M_u L}{a \times c} - \tfrac{1}{2} w_0 \times a (L-a) \times \frac{L}{a+c}$$

$$\boxed{P_u = \frac{L}{a \times c} \left[M_u - \tfrac{1}{2} w_0 \times a (L-a) \right.}$$ — (1)

FOR $L = 24'$ (CASE # 1) Pg # 3

$a = 18' = (L-d') = 24-6'$ (see pg. 4)

$c = 6' = d'$

$$P_u = \frac{24'}{6' \times 18'} \left[5328.6\,k' - \tfrac{1}{2} \times (8.66' \times 3.5' \times .15\,k/ft^3) \times 18'(24'-18') \right]$$

$$\boxed{P_u = 1184.1 - 54.56^k = 1129.6\ k.}$$

- CALCULATE THE DEFLECTION Δu DUE TO P_u & D.W.

$$\Delta u = \frac{P_u a^2 c^2}{3 E_c I_a L} + \Delta_0 \quad \text{(Ref \# 9)}$$

$$P_{eq}\ D.W = \left[\tfrac{1}{2} \times (8.66' \times 3.5' \times .15\,k/ft^3) \times 18' (24-18)\right] \left[\frac{24'}{6' \cdot 18'}\right] = 54.56^k$$

Δ_0 = DEF DUE TO D.W.

$$\boxed{\Delta_0 = \frac{w c}{24 E_c I_g} (\ell^3 - 2\ell c^2 - c^3)}$$ — (2) (Ref - 9) 2-114

$$\Delta_0 = \frac{(8.66' \times 3.5' \times .15\,k/ft^3) \times 6'}{24' \times 4888\,KSI \times 449{,}448\,in^4} \left[(24')^3 - 2(24')(6')^2 + (6')^3 \right] \left(\frac{12''}{FT}\right)^3$$

$$\boxed{\Delta_0 = 0.011''\ \text{Due to D.W. } P_{eq}\ 54.56^k}$$

$$\Delta u = \frac{1129.6^k \times (6' \times 18')^2 (12''/FT)^3}{3 \times 4888\,KSI \times 449448\,in^4 \times 24'} + .011'' =$$

$$\boxed{\Delta u = .156''}$$

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CALCULATION cont.

USING THE SAME METHOD AS IN CASE # 1, CACULATE MAX. P_u & Δ_u FOR CASE # 2

FOR $L = 27'$ (CASE # 2, SEE PG. 3)

$a = L - d' = 27' - 6' = 21'$

$c = d' = 6'$

FROM EQ. 1 ON PG 7a

$$P_u = \frac{27}{21 \times 6'}\left[5328.6\ K - \tfrac{1}{2} \times (8.66' \times 3.5' \times .15\ K/FT) \times 21'(27'-21')\right]$$

$$\boxed{P_u = 1141.8 - 61.38^{*} = 1080.5\ KIPS}$$

* equiv. D.W. LOAD = 61.38

$$\Delta_u = \frac{P a^2 c^2}{3 E_c I_g L} + \Delta_0 \quad (\text{Ref } \# 9, P.2\text{-}116)$$

FROM EQ. 2 ON PG. 7a

$$\Delta_0 = \frac{(8.66' \times 3.5' \times .15\ K/FT^3) \times 6'}{24' \times 4888\ KSI \times 449448\ in^4}\left[(27')^3 - 2(27')(6')^2 + (6')^3\right]\left(\frac{12''}{1FT}\right)^3$$

$$\boxed{\Delta_0 = 0.016''}$$

$$\Delta_u = \frac{1080.5\ K\ (6')^2 (21)^2 (12''/FT)^3}{3 \times 4888\ KSI \times 449448\ in^3 \times 27'} + .016''$$

$$\boxed{\Delta_u = .182''}$$

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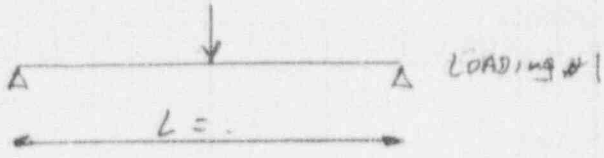
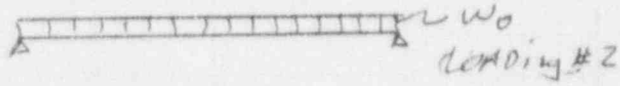
FOR "L"-SPAN & LOAD @ MID SPAN.

LOADING #1



$M = \frac{PL}{4} \Rightarrow$ (Ref-#9) PG. 2-116 (7)

$= \frac{Mu \times 4}{L}$



LOADING #2

$w_0 = b \times H \times .15$

$w_0 = 8.66' \times 3.5' \times .15\ ^{K}/_{FT^3}$

$M @ \text{MID SPAN} = \frac{wL^2}{8} = P_{eq} \frac{\times L}{4}, \Rightarrow P_{eq} = \frac{4wL^2}{8L}$ (Ref #9) PG. 2-114 (1)

P_u = LOADING #1 − LOADING #2

$P_u = \frac{Mu \times 4}{L} - \frac{wL^2}{8} \times \frac{4}{L}$

$\boxed{P_u = \frac{4}{L}\left[Mu - \frac{wL^2}{8}\right]}$ —— 3

FOR L = 24' (CASE #3)

$P_u = \frac{4}{24'}\left[5328.6 \text{KIPS} - 1/8\ (8.66' \times 3.5' \times .15\ ^{K}/_{FT^3})(24')^2\right]$

$P_u : 881.1^K - 54.56^{K*} = 819.5$

$\boxed{P_u = 833\ 5 \text{ KIPS}}$

$\Delta_u = \frac{PL^3}{48 E_c I_a} + \Delta_0$ (Ref # 9) PG. 2-116 (7)

$\Delta_0 = \frac{5wL^4}{384 E_c I_a}$ (Ref # 9) PG. 2-114 (1)

* equiv. P For D.W = 54.56^K ← pg 7a

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CALCULATION (CONT)

$$\Delta_o = \frac{5 \times (8.66' \times 3.5' \times .15\ K/FT^3) \times (24')^4 \times (12''/1FT)^3}{384 \times 4888\ KSI \times 449448\ in^4} = .0154''$$

$$\Delta_u = \frac{833.5^K \times (24')^3 \times (12''/1FT)^3}{48 \times 4888\ ksi \times 449448\ in^4} + .0154 =$$

$$\boxed{\Delta_u = .204}$$

FOR $L = 27'$ (CASE # 4)

USING EQ. NO 3 ON PG. 7C

$$P_u = \frac{4}{27'}\left[5328.6K - 1/8\,(8.66' \times 3.5' \times .15\ K/FT^3)(27')^2\right]$$

$$\boxed{P_u = 789.4^K - 61.38^{K*} = 728.0\ KIPS.}$$

* CAL. P FOR D.W = 61.38^K ← PG. 7b

$$\Delta_u = \frac{PL^3}{48 E_c I_a} + \Delta_o \qquad \text{(Ref \# 9, PG. 2-116 (7))}$$

$$\Delta_o = \frac{5WL^4}{384 E_c I_a} = \frac{5 \times (8.66' \times 3.5' \times .15\ K/FT^3)(27')^4 (12''/FT)^3}{384 \times 4888\ KSI \times 449448}$$

$$\Delta_o = .0246''$$

$$\Delta_u = \frac{728^K \times (27')^3 (12''/FT)^3}{48 \times 4888\ KSI \times 449448\ in^4} + .0246'' = .260''$$

$$\boxed{\Delta_u = .260''}$$

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CALCULATION (CONT.)

CALCULATE THE MAX. SHEAR CAPACITY OF THE SLAB

II MAX. SHEAR CAPACITY

a) SHEAR CARRIED BY CONCRETE)

$$V_c = \Phi \left(1.9\sqrt{f'_c} + 2500\, \rho \frac{Vd}{m}\right) bd \quad \left(\text{Ref \#1, eq 11-6}\right)$$

where $\frac{Vd}{m} = 1$ (Ref #1, section 11) ($\rho = .010263$ pg. 6)

$\Phi = .85$ For SHEAR (Ref #1 sec. 11)

$$V_c = .85\left(1.9\sqrt{6500\,psi} + 2500 \times .010263\right)(104'' \times 38'')$$

$$V_c = 600{,}760\ Lb < 3.5\sqrt{f'_c} \times bd = 1{,}115{,}171\ Lb$$

$= 3.5\sqrt{6500\,psi}\,(104'' \times 38'') = 1{,}115{,}171\ Lb$ OK

(Ref #1, eq. 11-6)

$$\boxed{\therefore V_c = 600.76\ KIPS}$$

b) SHEAR CARRIED BY WEB REINFORCEMENT

(#5 STIRRUP @ 3'-10" in E-W = 46" (Ref 38)
1'-0" in N-S = 12" (Ref 38)

$A_v = 0.31\ in^2$ (consider one leg)

$$V'_c = \Phi \frac{A_v f_y}{b\, s} bd \quad (\text{Ref \#6, 5.10.7})$$

$$\boxed{V'_c = .85 \times \frac{.31\ in^2 \times 48300\ psi}{46'' \times 12''} \times 104'' \times 38'' = 91{,}118\ Lb = 91.1\ K}$$

$$\boxed{V_{max} = V_c + V'_c = 600.76^K + 91.1^K = 691.86^K}$$

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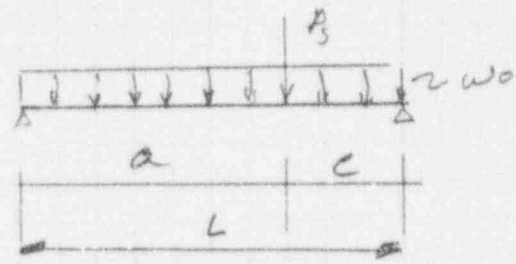
FOR ALL 4 CASES MAX. SHEAR WILL OCCUR @ a DISTANCE d FROM THE FACE OF THE WALL (SEE P.G. 4-A) (REF. #1, SECT 11.1.3.1)

CALCULATE THE MAX. LOAD "P_s", in ADDITION TO THE D.W. OF THE SLAB, THAT WILL CAUSE A SHEAR OF 691.8 KIPS @ distance d FROM THE FACE OF WALL. ($d' = 1'\text{-}6 + 38''$) $= 56'' = 4.7'$

CASE # 1 & 2



V_{MAX} = SHEAR Due TO P_s + SHEAR DUE TO DW (w_0)

V_{MAX} = 691.86 KIPS (Ref PG 8a)

SHEAR Due TO P_s = $P_s \times \frac{a}{L}$ (Ref #9, 2-...)

SHEAR Due TO D.W = $[\frac{1}{2}(L)(w_0) - d'(w_0)]$ --- Ref #9 2-114

$w_0 = b \times H \times .15 = 8.66' \times 3.5' \times .15\ ^K/_{FT^3} = 4.5465\ K/FT$

$$\therefore \boxed{V_{max} = P_s \frac{a}{L} + \frac{1}{2} L (4.5465) - d'(4.5465)} \quad \text{--- } (4)$$

CASE # 1 , $L = 24'$, $a = 18'$

$$691.86 = P_s \times \frac{18'}{24'} + \frac{1}{2}(24')(4.5465\ K/FT) - 4.7'(4.5465\ K/F)$$

$$\Rightarrow \boxed{P_s = 878.2\ KIPS}$$

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CASE # 2

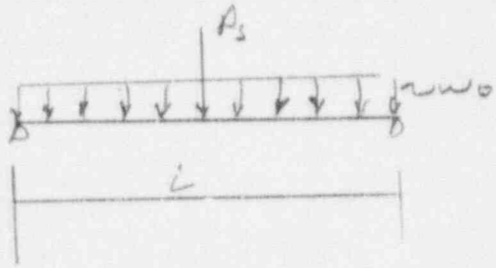
$L = 27'$, $a = 21'$

USING EQ. 4 ON PG. 8B

$$P_s Max \times \frac{21'}{27'} + (1/2 \times 27' \times 4.5465 \text{ K/FT}) - 4.7' \times 4.5465 \text{ K/FT} = 691.86^K$$

$$\boxed{P_s = 838.1 \text{ KIPS}}$$

CASE # 3 & 4



CALCULATE THE SHEAR @ d' WHEN THE LOAD @ MIDSPAN

V due to $P_s = \frac{P_s}{2}$ - - - (Ref #9, PG. 2-114

V due TO DW $= w_0(\frac{L}{2} - d')$ — —— (Ref #F PG. 2-116)

$$\boxed{\frac{P_s}{2} + w_0(\frac{L}{2} - d') = V_{max} = 691.86 \text{ KIPS}} \text{ —— } (5)$$

CASE # 3

$$\frac{P_s}{2} + 4.5465^{K/FT}(\frac{24'}{2} - 4.7') = 691.86 \text{ KIPS}$$

$\Rightarrow \boxed{P_s = 1317.2 \text{ KIPS}} >$ P_u due to ULTIMATE moment $= 533.5$ KIPS (PG. 7C)

CASE # 4 , USING EQ. 5

$$\frac{P_s}{2} + 4.5465 \text{ K/FT} (\frac{27'}{2} - 4.7') = 691.86 \text{ KIP}$$

$\Rightarrow \boxed{P_s = 1315.5 \text{ KIPS}} >$ P_u due to ULT. moment $= 728.0$ KIP (PG. 8)

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CALCULATE DEFLECTION IN ALL 4 CASES

CASE # 1

$L = 24$ FT., LOAD @ dist. d' (see PG 4)

FOR $P_u = 1129.6^K \Rightarrow \Delta = .156''$ (Ref PG 7a),

$P_s = 878.2^K \Rightarrow \Delta = \frac{878.2}{1129.6} \times .156 = .121''$ (Ref PG 8b)

$P_{D.L} = 54.56^K \Rightarrow \Delta = .011''$, (Ref PG 7a)

CASE # 2

$L = 27$ FT, LOAD @ dist d' (see PG. 4)

For $P_u = 1080.5^K \Rightarrow \Delta = .182''$ (Ref PG 7b)

$P_s = 838.1^K \Rightarrow \Delta = \frac{838.1}{1080.5} \times .182 = .141''$ (Ref PG. 9)

$P_{DL} = 61.38^K \Rightarrow \Delta = .016''$ (Ref PG. 7b)

CASE # 3

$L = 24$ Ft, LOAD @ MID SPAN (see PG 4a)

FOR $P_u = 833 \Rightarrow \Delta = .204''$ (Ref PG 7c)

$P_{D.L} = 54.56 \Rightarrow \Delta = .0154''$ (Ref PG 7c)

CASE # 4

$L = 27'$, LOAD @ MID SPAN (see PG. 4a)

For $P_u = 728^K \Rightarrow \Delta = .260''$ (Ref PG 8)

$P_{DL} = 61.38^K \Rightarrow \Delta = .0246''$ (Ref PG 8)

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CALCULATION (CONT.)

CHECK BOND STRESS @ FACE OF COLUMN

$$V_u = \frac{V}{(N\pi d_b)\,Jd} \leq \frac{9.5\sqrt{f'_c}}{d_b} \leq 800\,PSI$$

$V = 691.86 + Dw.$ (Ref #6 SEC. 6.3.2)

d = dist. d from The WALL (6.4.2 & TABLE 6.9.2)

N = NO OF BARS = 3 (per foot) ∴ x b eff. width of beam

d_b = DIA OF BAR

$J = 1 - \frac{K}{3}$ (Ref # 6)

$$K = \frac{1}{1 + (f_y / n f'_c)} = \frac{1}{1 + (48.3\,ksi / 6 \times 6.5\,ksi)} = 0.44''$$

$$J = 1 - \frac{0.444}{3} = .852''$$

$$V_u = \frac{691.86'\,KIP + (\overset{w}{4.5465\,K/FT} \times \overset{d}{3.2'}) \times 1000\,{}^{lbs}/_{k}}{(3\pi \times 1.41'') \times 8.66' \times (.852 \times 38'')}$$

$$\boxed{V_u = 189.6\,PSI} < \frac{9.5\sqrt{6500}}{1.41} = 543.2\,PSI$$

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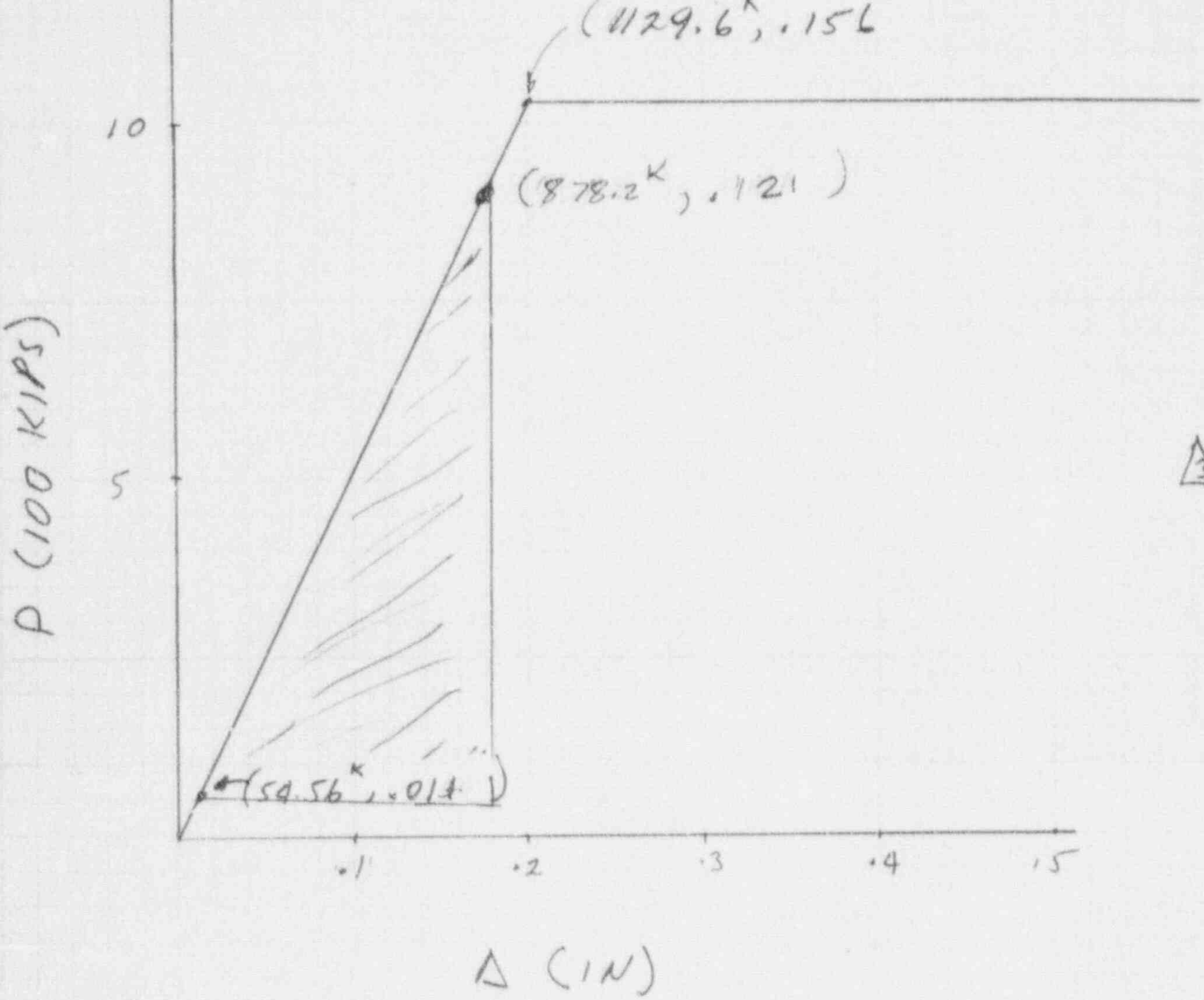

3

CASE # 1

LOAD vr. DEFLECTION

THE SHADED AREA IS = TO KINETIC ENERGY THAT THE BEAM CAN ABSORB @ CASE#1 (Ref# 3)

3

				Entergy Operations	CALCULATION NUMBER
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0	8/8/91	TD	KDB		PAGE NUMBER 10 OF 19
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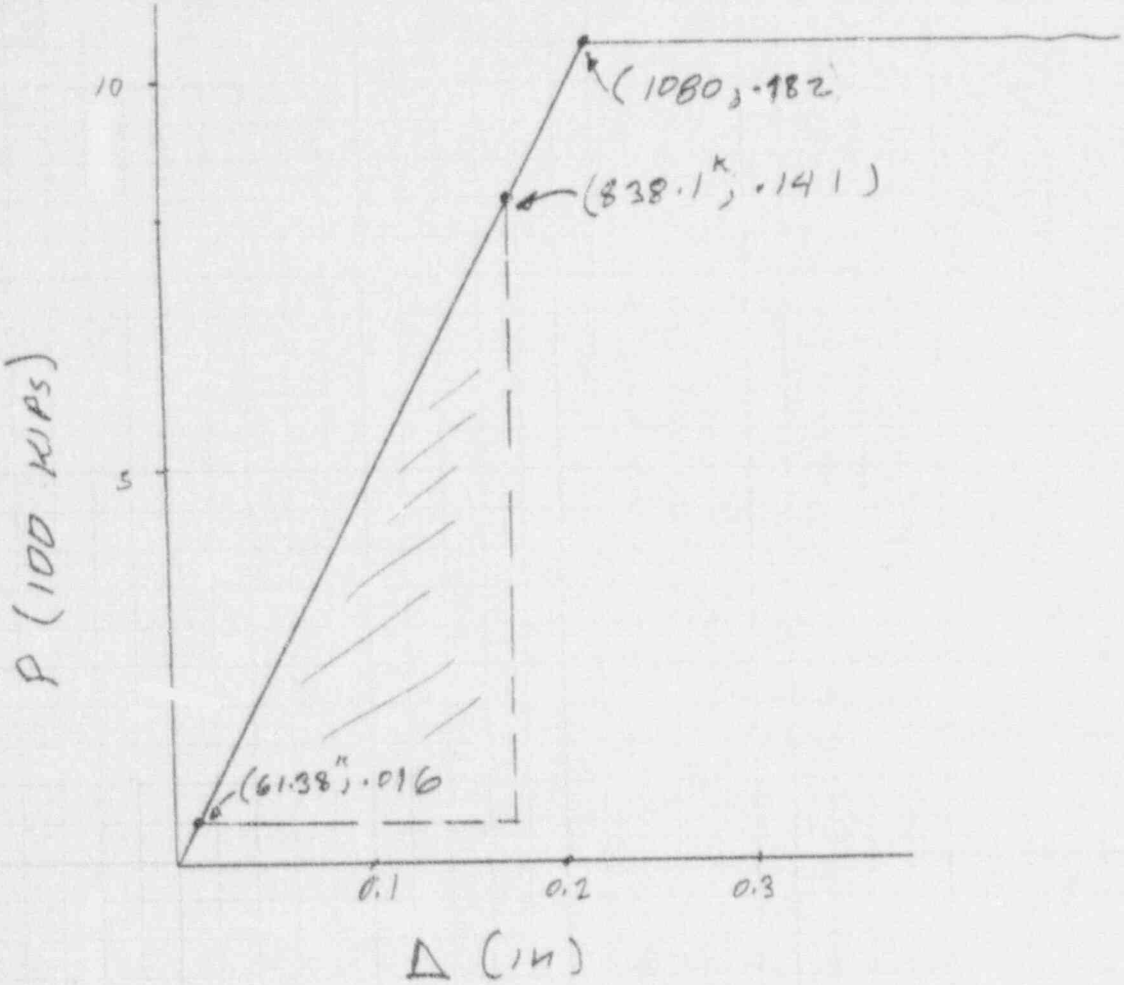

LOAD VS. DEFLECTION

(CASE # 2)

THE SHADED AREA IS = TO THE KINETIC ENERGY THAT THE BEAM CAN ABSORB @ CASE#2 (Ref#3

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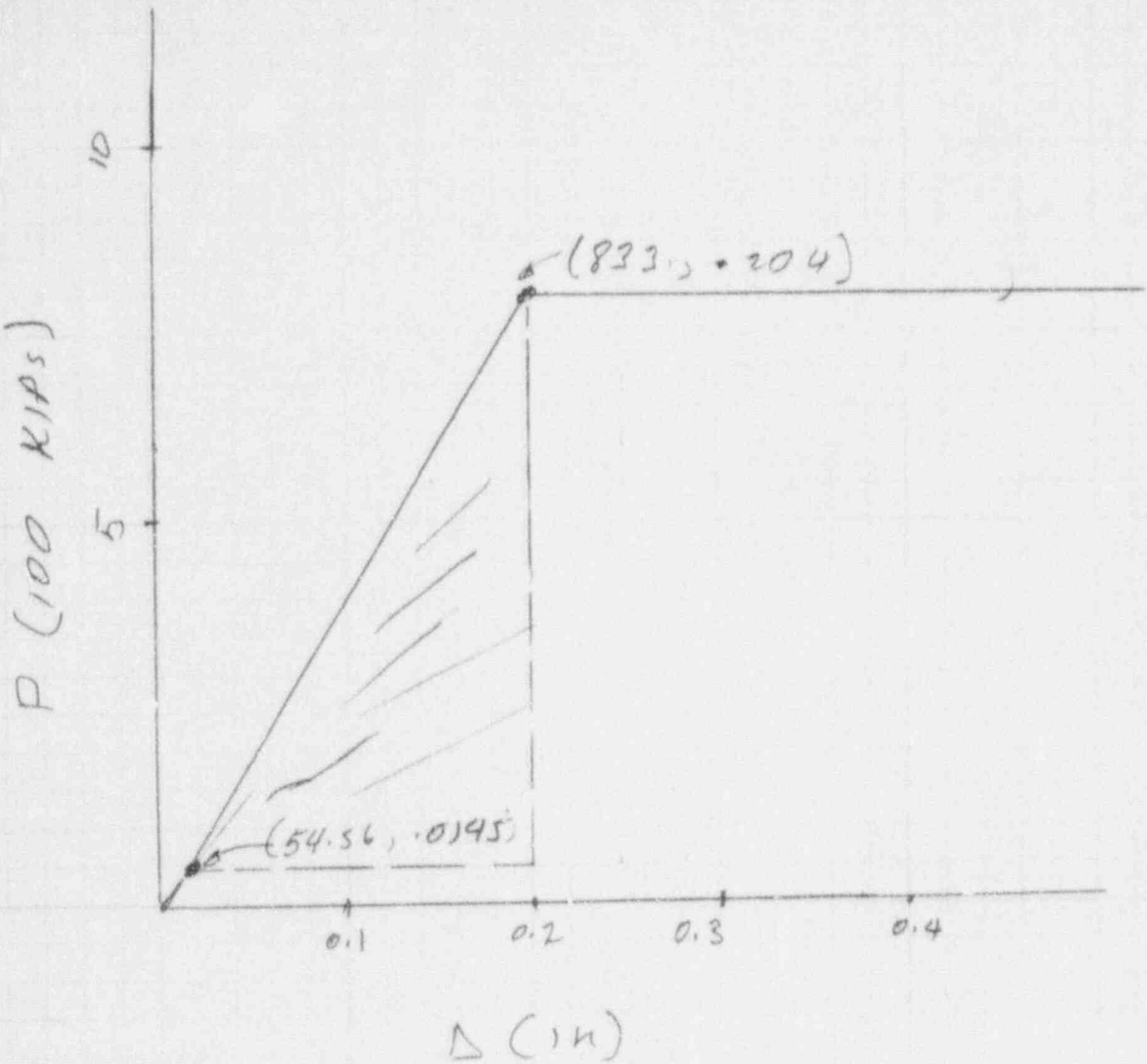
3	10/10/91	TD	VSS		PAGE NUMBER 10G OF 19



CASE # 3

THE SHADED AREA = KINETIC ENERGY

3	10/10/91	TD	[illegible]	
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ARKANSAS NUCLEAR ONE

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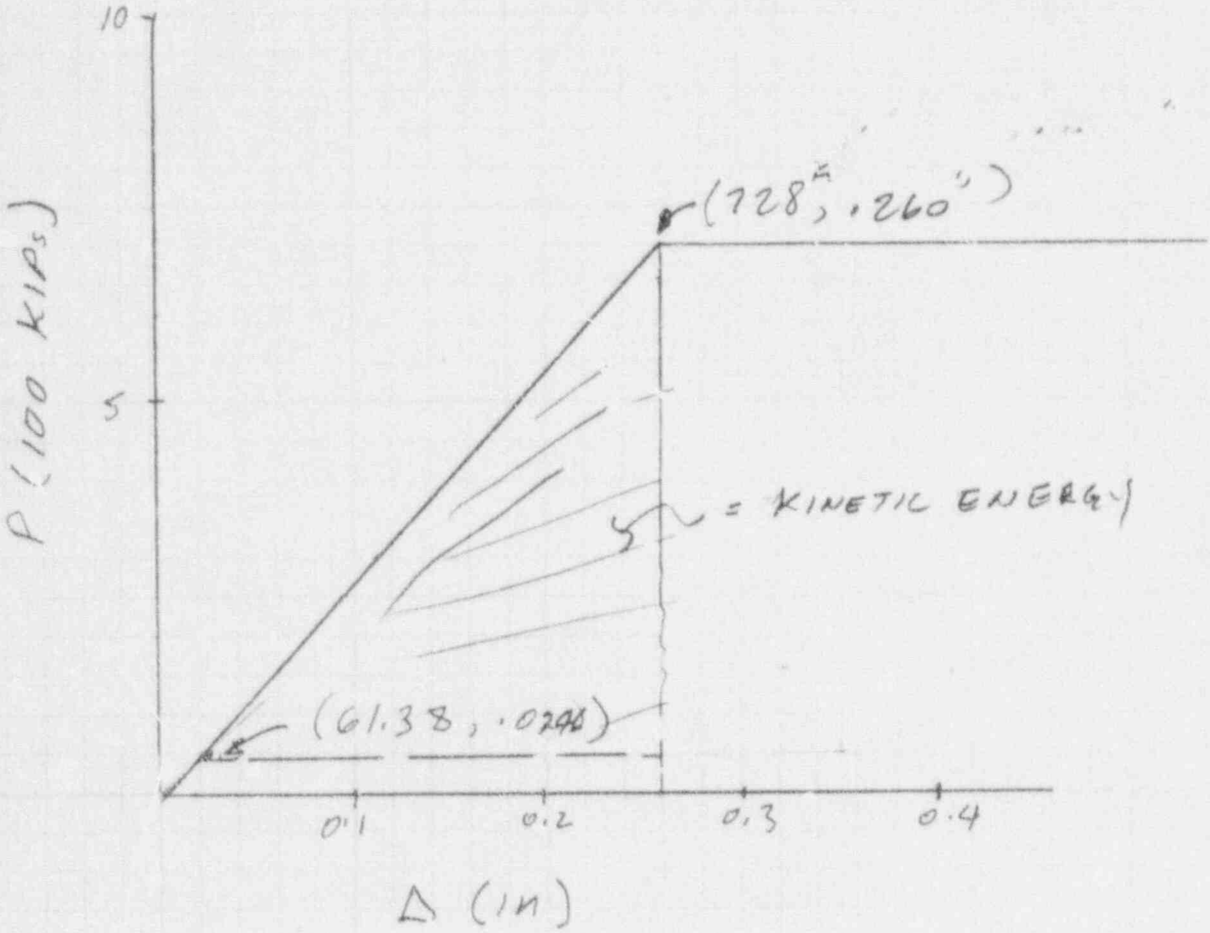

(CASE # 4)

CALCULATE THE MAX HEIGHT OF DROP THAT THE SLAB CAN TAKE in each of the 4 cases, which will cause A STRAIN ENERGY equal TO THE KINETIC ENERGY THE SLAB COULD ABSORB

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CALCULATION (CONT.)

II ALLOWABLE HEIGHT OF DROP

$V_s^2 = 2gh$ (Ref # 3 EQ 3-4)

where

V_s = CASK STRIKING VELOCITY

h = MAX. HEIGHT

$\boxed{M_m = \frac{35^k}{g} = \text{MASS OF CASK}}$

Me = Average effective mass

$= \frac{\gamma_c T}{g} (D_x + 2T)(D_y + 2T)$ (Ref # 3 EQ. 3-15)

Since The CASK is CIRCLE, DIA = 28" = 2.33' (Ref 2)

$\Rightarrow M_e = \frac{\gamma_c T}{g} \left(\frac{\pi (D+2T)^2}{4} \right)$

where

γ_c = weight per unit volume OF Concrete = .15 $^k/_{ft^3}$

T = Thickness OF FLOOR

$M_e = \frac{.15 \times 3.5}{g} \times \frac{\pi}{4} (2.33 + 7)^2 =$

$\boxed{M_e = \frac{35.92}{g}}$

CALCULATION (CONT.)

$$ES = \frac{M_m^2 \; V_s^2}{2(m_m + m_c} \qquad (\text{Ref \#3 EQ 3-8})$$

E_S = STRAIN ENERGY = Σ KINETIC ENERGY
= SHADED AREA (PG: 10-10c)

FOR CASE #1, L = 24', LOAD @ dist. ①'

$$ES = \frac{(35/g)^2 (29h)}{2\left(\frac{35}{g} + \frac{35.9}{g}\right)} = \tfrac{1}{2}(878.2^k - 54.56^k)(.121'' - .011'')$$

$$ES = \frac{\frac{1225}{g} + 29h}{2(70.9)} = 45.5$$

$\Rightarrow$ 17.278 h = 45.5

$\Rightarrow \boxed{h = 2.62''}$

FOR CASE # 2 (USING THE SAME EQ'S AS CASE #1

$$ES = \frac{\left(\frac{35}{g}\right)(29h)}{2\left(\frac{35+35.9}{g}\right)} = \tfrac{1}{2}(838.1^k - 61.38^k)(.141'' - .016'')$$

17.278 h = 48.50

$\Rightarrow \boxed{h = 2.8''}$

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CASE # 3

$$17.278\,h = \tfrac{1}{2}(833^{k} - 54.56^{k})(.204'' - .0154'')$$

$$17.278\,h = 73.4$$

$$\Rightarrow \boxed{h = 4.24''}$$

CASE # 4

$$17.278\,h = \tfrac{1}{2}(728^{k} - 61.38^{k})(.26'' - .0246'')$$

$$17.278\,h = 78.5$$

$$\boxed{h = 4.5''}$$

$\boxed{\therefore \text{ CASE \# 1 IS Governing; } h = 2.62''}$

& HONEYCOMB ENERGY OBSORPTION MAT'L IS REQUIRED FOR 9" DROP

III CALCULATE THE REQUIRED THICKNESS OF HONEYCOMB FOR 9' DROP

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CALCULATION:

$$K.E. = f_{cr}\, A\, (.7)\, t_c \qquad (\text{Ref \#5 PG-20})$$

$$\Rightarrow t_c = \frac{K.E.}{f_{cr}\, A\, (.7)} \quad , \text{ USE } f_{cr} = 260 \text{ PSI}$$

$$K.E. = \frac{M_m V_s^2}{2} \qquad (\text{Ref \#3 EQ. 3-5})$$

(wt. cask = 35K lbs)

$$\Rightarrow t_c = \frac{\frac{1}{2}\left(\frac{35000^{\text{lbs}}}{g}\right)(2)(g)(9)}{260\,(28)^2\left(\frac{\pi}{4}\right)(.7)}$$

$$\boxed{t_c = 2.80'' \quad \text{USE } 3 \text{ in}}$$

∴ 2.8" OF 260 PSI HEXCELL HONEYCOMB MAT'L IS REQUIRED FOR 9" DROP OF 17.5 TON CASK.

THE REST OF THIS CALCULATION IS TO CALCULATE THE SAFETY FACTORS USING 3" OF 260 PSI HEXCELL HONEYCOMB MAT'L @ THE BOTTOM OF THE CASK.

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1	9/19/91	TD	VLB	ARKANSAS NUCLEAR ONE	PAGE NUMBER 13 OF 19
0	8/8/91	TD	KLB		
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CALCULATION: (cont.)

SUMMARY OF STRESSES FOR 17.5 TON CASK DROP

DATA: $f'_c = 6500$ PSI @ 4 years

$f_y = 48{,}300$ PSI (MILL CERTIFICATE)

(1) Calculate the LOAD P THAT the slab will see as a result OF 2.5" Drop For ALL 4 CASES Addressed on PG. 2

CASE #1

$L = 24'$, DROP LOCATION = 6'-0" FROM END SUPPORT WHICH will have the max. Shear.

$$E_s = \frac{M_m^2 V_s^2}{2(M_m + M_c)} = \tfrac{1}{2}(P - 54.56^K)(\Delta_P - .011'')$$

$$M_m = \frac{35^K}{g}, \quad V_s^2 = 2gh, \quad M_c = \frac{35.92}{g}$$

$$\Rightarrow \frac{\left(\frac{35}{g}\right)^2 \times 2g(2.5)}{2\left(\frac{35}{g} + \frac{35.9}{g}\right)} = \tfrac{1}{2}(P - 54.56^K)\left(\frac{P}{1129.6}(.155') - .011''\right)$$

$$43.2 = \frac{.156}{2259.2}P^2 - \frac{21}{2259.2}P + \frac{678}{2259.2}$$

$$.156 - 21P - 96919 = 0$$

$$P = \frac{21 + \sqrt{(21)^2 + 4(.156)(96919)}}{2(.156)} = 858.3^{KIPS}$$

USE EQ (4) ON PG 8b

$$V_{max} = \frac{18}{24}(858.3^K) + \tfrac{1}{2}(24')(4.5465^{K/FT}) - 4.7'(4.5465^{K/FT})$$

$\boxed{V_{MAX} = 637 \text{ KIPS}}$

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CALCULATION (cont.)

ALLOWABLE COMBINED SHEAR CAPACITY OF Concrete & WEB REINFORCEMENT $= 691.86^K$ (PG. 8b)

$$\boxed{S.F. = \frac{691.86^K}{677^K} = 1.022}$$

- MAX. MOMENT & SAFETY FACTOR

MOMENT @ DROP PT. = MAX. MOMENT FOR THIS CASE

$$M = \frac{858^K \times 18' \times 6'}{24'} + (1/2)(8.66' \times 3.5' \times .15^{K/FT} \times 18')(24' - 18')$$

$$\boxed{M = 3861^{K'} + 245.5^{K'} = 4106.5 \text{ K-FT}}$$

ALLOW. MOMENT CAPACITY = 5328.6 K-FT (PG. 7)

$$\boxed{S.F. = \frac{5328.6^{K'}}{4106.5K'} = 1.3}$$

CASE #2

$L = 27'$

USING THE SAME EQ. AS IN CASE #1

$$E_S = \frac{M_m^2 V_s^2}{2(M_m - M_e)} = 1/2\,(P - 61.38^K)(\Delta P - .016'')$$

$$\Rightarrow \frac{\left(\frac{35}{9}\right)^2 \times 29(25)}{2\left(\frac{35}{9} + \frac{35.9}{9}\right)} = 1/2\,(P - 61.38)\left(\frac{P}{1080.5^K}(.182'') - .016\right)$$

$$43.2 = \frac{.182}{2161}P^2 - \frac{28.5}{2161}P + \frac{1061}{2161}$$

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3	7/91	TD	VAS		PAGE NUMBER 14a OF 19

CALCULATION: (cont.)

$$.182P^2 - 28.5P - 92294 = 0$$

$$P = \frac{28.5 + \sqrt{(28.5)^2 + 4(.182)(92294)}}{2(.182)}$$

$\boxed{P = 795 \text{ KIPS}}$

USING EQ. 4 ON PG.

$$V_{max} = \frac{21'}{27'}(795) + \tfrac{1}{2}(27' \times 4.5465\,K/F) - 4.7(4.5465\,K/F)$$

$\boxed{V_{max} = 658 \text{ KIPS}}$ $< 677^{k}$ (CASE #1) PG. 14

ALLOW. Shear = 691.86K (PG. 8b)

$$\boxed{S.F. = \frac{691.86}{658} = 1.05}$$

- MAX MOMENT

$$M = \frac{795^{k} \times 21' \times 6'}{27'} + (\tfrac{1}{2})(8.66')(3.5')(.15^{K/F})(21')(27'-21')$$

$\boxed{M = 3996.4\ \text{K-FT}}$ $< 4106.5^{k'}$ (CASE #1) PG. 14a

Allow moment = $5328.6^{k'}$ (PG. 7)

$$\boxed{S.F. = \frac{5328.6}{3996.4}\ 1.33}$$

$\therefore$ MOMENT & SHEAR IN CASE #1 IS Controlling.

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CALCULATION (CONT.)

CASE #3

L = 24', DROP LOCATION @ MID SPAN

MAX. MOMENT IS LOCATED @ MID SPAN & MAX. SHEAR @ DISTANCE d FROM THE FACE OF THE WALL.

$$E_s = \frac{M_m^2 V_s^2}{2(M_m - M_c)} = \tfrac{1}{2}(P - 54.56)(\Delta_P - .0188)$$

$$E_s = \frac{\left(\frac{35^k}{9}\right)^2 (29(2.5''))}{2\left(\frac{35^k}{9} + \frac{35.9^k}{9}\right)} = \tfrac{1}{2}(P - 54.56)\left(\frac{P}{833} \times .204 - .0154\right)$$

$$43.2 = \frac{.204}{1666} P^2 - \frac{24}{1666} - \frac{700}{1666}$$

$$\Rightarrow \quad .204 P^2 - 24 - 71271 = 0$$

$$P = \frac{24 + \sqrt{(24)^2 + 4(.204)(71271)}}{2(.204)}$$

$\boxed{P = 652.8 \text{ KIPS}}$ < 677 KIP (MAX. SHEAR) (CASE #1) (PG. 14)

∴ SHEAR IN CASE #1 IS CONTROLING

$$M = \frac{PL}{4} = \frac{652^k \times 24'}{4} = 3912 \text{ K-FT}$$ (Ref #9 2.11A)

$\boxed{M = 3912 \text{ K}'}$ < $4106.5^{k'}$ (CASE #1) (PG. 14a)

∴ MOMENT IN CASE #1 IS CONTROLING.

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CALCULATION (CONT.)

CASE # 4

L = 27', DROP LOCATED @ MID SPAN

MAX. MOMENT IS LOCATED @ MID SPAN & MAX SHEAR @ Distance d From The Face OF The WALL

$$ES = \frac{M_m^2 V_s^2}{2(M_m - M_e)} = \tfrac{1}{2}(P - 61.38)(DP - .0246)$$

$$= \frac{\left(\frac{35^K}{3}\right)^2 (29(2.5))}{2\left(\frac{35^K}{3} + \frac{35.9}{3}\right)} = \tfrac{1}{2}(P - 61.38^K)\left(\frac{P}{728} \times .269'' - .246''\right)$$

$$43.2 = \frac{.26}{1456}P^2 - \frac{33.87}{1456}P - \frac{1099.2}{1456}$$

$$\Rightarrow .26P^2 - 33.87P - 61800 = 0$$

$$P = \frac{33.87 + \sqrt{(33.87)^2 + 4(.26)(61800)}}{2(.26)} =$$

$\boxed{P = 556.9 \text{ KIPS}} < 673\text{ K}$ (CASE # 1 (MAX. Shear)) (PG. 10)

∴ Shear in CASE # 1 is controling

$$M = \frac{PL}{4} = \frac{556.9 \times 27}{4} = 3759 \text{ K-FT}$$

$\boxed{M = 3759 \text{ K-FT}} < 4106.5^{K'}$ (CASE # 1) (PG. 14a)

∴ MOMENT IN CASE # 1 is controling

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CAlculation (cont.)

Since CASE #1 is Governing, CHECK THE 9" DROP W/ "3" THICK, f_{cr} = 260 PSI HEXCELLS", FOR case # 1 only.

$K.E. = f_{cr} A \times .7\, t_c$ (see pg. 13)

$V_s^2 = 2gh$

$$f_{cr} = \frac{KE}{A \times .7\, t_c}$$

$h = 9"$

$$K.E = \frac{M_m V_s^2}{2} = \frac{1}{2} \times \frac{35000}{g} (2)\, g\, (9)$$

$KE = 315000$ k.in

$$f_{cr} = \frac{315000}{(28)^2 \frac{\pi}{4} \times .7 \times 3} = 243.6 \text{ PSI} < 260 \text{ PSI}$$

$$P = 260 \times (28)^2 \times \frac{\pi}{4} = 160095^{\#} = 160.1$$

– MAX. SHEAR FORCE AND SAFETY FACTORS

USE EQ 4 on pg 8b

$$V_{max} = \frac{18}{24}(160.1^k) + \frac{1}{2}(24')(4.5465 \text{ K/FT}) - 4.7(4.5465 \text{ K/FT})$$

$$\boxed{V_{MAX} = 153.26 \text{ KIPS}}$$

ALLOW. combined shear CAPACITY = 691.86 (PG 8b)

$$\boxed{\text{SAFETY FACTOR} = \frac{691.86}{153.26} = 1.51}$$

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CALCULATION (CONT.)

- MAX. MOMENT AND SAFETY FACTOR:

M_{max} @ DROP pt.
USE EQ.

$M_{max} = \frac{160.1 \times 18 \times 6}{24} + \frac{1}{2} \times 8.66' \times 3.5' \times .15^{K/FT} \times 18(24'-18')$

3 $M_{max} = 965.96\ K'$

ALLOW. MOMENT CAPACITY = 5243.6 K' (PG 7)

$\boxed{\text{SAFETY FACTOR} = \frac{5328.2^{K'}}{965.96^{K'}} = 5.82}$

(C) BOND STRESS, USE THE SAME EQ. AS ON PG 9b

$U = \frac{V}{N\pi d_b j d}$ (PG. 9b)

$V = \frac{18'}{24'}(160.1^K) + \frac{1}{2} \times 24' \times 8.66' \times 3.5' \times .15^{K/FT} - 1.5' \times 8.66' \times 3.5' \times .15^{K/FT}$

$\boxed{V = 167.813^K}$

$U = \frac{167813}{3 \times \pi \times 1.41 \times 8.66 \times .852 \times 38} = 45.0$ PSI

ALLOW BOND STRESS = 543.2 PSI (PG. 9b)

$\boxed{\text{SAFETY FACTOR} = \frac{543.2}{45.0} = 12.06}$

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CONCLUSION:

- Drop evaluation is performed in this calculation for all the four cases addressed on page 3. Case # 1 is found to be the most critical case for the 17 Ton cask drop.

- Drop evaluation summaries for the 17 Ton handling cask (28" diameter) at elevation 404 (Over the U-1 Control Room) are listed below:

CONDITION-A - A drop evaluation for 2.5" travel height with no hexagonal honeycomb.

CONDITION-B - A drop evaluation for 9" travel height with 3" of hexagonal honeycomb.

	CONDITION-A	CONDITION-B
$\frac{\text{Shear Capacity}}{\text{Shear Computed}}$	$= \frac{691.36 \text{ kips}}{677.0 \text{ kips}} = 1.022$;	$\frac{691.86 \text{ kips}}{153.26 \text{ kips}} = 4.51$
$\frac{\text{Moment Capacity}}{\text{Moment Computed}}$	$= \frac{5328 \text{ kip-ft}}{4106.5 \text{ kip-ft}} = 1.3$;	$\frac{5328 \text{ kip-ft}}{966.0 \text{ kip-ft}} = 5.8$
$\frac{\text{Bond Stress Capacity}}{\text{Bond Stress Computed}}$	$= \frac{543.20 \text{ psi}}{184.7 \text{ psi}} = 2.94$;	$\frac{543.20 \text{ psi}}{45.0 \text{ psi}} = 12.06$
$\frac{\text{Development Length Provided (Ref. \# 5)}}{\text{Development Length Required (Ref. \# 5)}}$	$= \frac{33 \text{ in.}}{30 \text{ in.}} = 1.10$;	$\frac{33 \text{ in.}}{30 \text{ in.}} = 1.10$

- The maximum allowable travel for 17 Ton cask drop, 2'-4" Dia., with no hexagonal honeycomb = 2.5".

- The minimum thickness of a 260 psi hexagonal honeycomb required for the 17 Ton cask drop of 9 inches travel = 3".

- Spalling is designed not to occur because the analysis of the above cases that the slab stays in elastic range.

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