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RECIP.NAME RECIPIENT AFFILIATION
SCHWENCER,A.A. Licensing Branch 2

SUBJECT: Forwards supplemental calculations & Revision 1 pages to original calculations submitted to NRC on 800121 re design calculations of electrical tunnel.

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Southern California Edison Company

P. O. BOX 800
2244 WALNUT GROVE AVENUE
ROSEMEAD, CALIFORNIA 91770

July 16, 1980

K. P. BASKIN
MANAGER, NUCLEAR ENGINEERING
AND LICENSING

TELEPHONE
(213) 572-1401

Director of Nuclear Reactor Regulation
Attention: Mr. Albert A. Schwencer, Acting Branch Chief
Licensing Projects Branch 3, DPM
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Gentlemen:

Subject: Docket Nos. 50-361 and 50-362
San Onofre Nuclear Generating Station
Units 2 and 3

In the July 2, 1980 meeting in Bethesda, Maryland with SCE, the NRC Structural Engineering Branch identified several additional questions concerning the design calculations of the San Onofre Unit 3 electrical tunnel. Enclosed in response to these additional Structural Engineering Branch questions, are supplemental calculations and Revision 1 pages to the original calculations which were submitted to the NRC by letter dated January 21, 1980.

If you have any questions concerning this matter, please contact Mr. T. D. Mercurio (213-572-2645).

Very truly yours,

KP Baskin/jf

Enclosure

B001
S, 1/1

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SUPPLEMENTAL INFORMATION

SAN ONOFRE UNIT 3 ELECTRICAL TUNNEL

BECHTEL

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CALC. NO. C-260-5

SIGNATURE N. Chaudhry DATE 12-21-79 CHECKED R. Sun DATE 12-21-79

PROJECT SONGS 2 & 3 JOB NO. 10079-003

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ELECTRICAL TUNNEL

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BECHTEL

CALCULATION SHEET

1

CALC. NO. C-260-5

SIGNATURE N. Chaudhry DATE 12-28-79 CHECKED R. Sun DATE 12-28-79

PROJECT SONGS 2 & 3 JOB NO. 10079-003

SUBJECT ELECTRICAL TUNNEL SHEET 11 OF 51 SHEETS

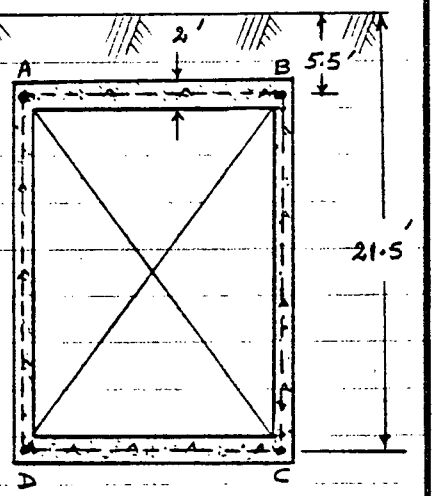
LOADS CONT'D

$P_s = C H$

$C = K_s \rho = .20 \times .120 = .024$ KCF

$P_s(A) = 0.024 \times 5.5 = 0.132$ KSF

$P_s(D) = 0.024 \times 21.5 = 0.516$ KSF



2. ACTIVE PRESSURE : DYNAMIC INCREMENT, P_D

STATIC PRESSURE (AT REST) = 0.045 KCF (PROVIDED BY SOIL CONSULTANTS FOR STATIC AND OBE CONDITIONS)

STATIC PRESSURE (ACTIVE) = 0.024 KCF

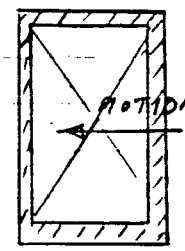
DYNAMIC INCREMENT = 0.021 KCF

$P_D(A) = 0.021 \times 5.5 = 0.116$ KSF

$P_D(D) = 0.021 \times 21.5 = 0.452$ KSF

3. INERTIAL PRESSURE, P_I

EFFECTIVE WT. OF STRUCTURE FOR INERTIAL PRESSURE, We



We = WT. OF, ROOF + FLOOR + TWO WALLS + EQUIPMENT.

$= 2 \times .150 \times 13 + 2 \times .150 \times 13 + 2 \times 1.5 \times .150 \times 14 + .28 \times 10$

$= 16.9^{K}$ OR $\frac{16.9}{16} = 1.06$ KSF ON WALL HEIGHT.

LOADS CONTD

P_I = We × Acc.

= 1.06 × 0.75 = 0.795 KSF

RESULTANT DESIGN PRESSURE, P_R

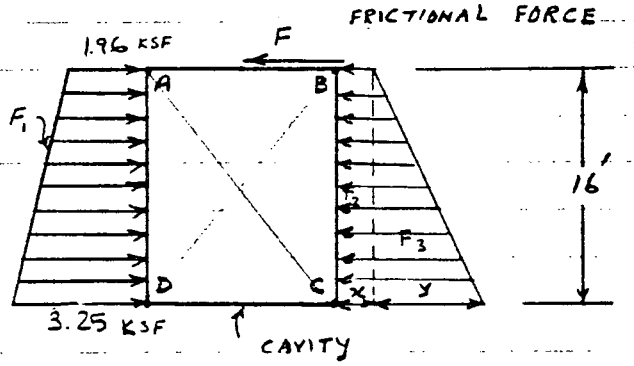
$P_R = 1.7 P_s + 1.9 P_D + 1.9 P_I$

P_R (A) = 1.7 × .132 + 1.9 × 0.116 + 1.9 × 0.795 = 1.96 KSF

P_R (D) = 1.7 × 0.516 + 1.9 × 0.452 + 1.9 × 0.795 = 3.25 KSF

DYNAMIC EQUILIBRIUM CONDITIONS

FOR DYNAMIC EQUILIBRIUM, LEFT HAND SIDE FORCES MUST BE BALANCED BY R.H.S. FORCES INCLUDING FRICTIONAL FORCE, F BETWEEN STRUCTURE AND TOP SOIL.



$F = \mu \times$ SOIL WT. = .4 × 0.54 × 13 = 2.8 K (SHT. 8)

FOR EQUILIBRIUM,

$F_1 = F + F_2 + F_3$

Σ MOMENTS ABOUT BASE = 0.

BECHTEL

CALCULATION SHEET

1

CALC. NO. C-260-5

SIGNATURE N. Chaudhry DATE 12-28-79 CHECKED R. Lum DATE 12-28-79

PROJECT SONGS 2 & 3 JOB NO. 10079-003

SUBJECT ELECTRICAL TUNNEL SHEET 13 OF 51 SHEETS

LOADS CONT'D

$F_1 = (1.96 + 3.25)\frac{1}{2} \times 16 = 41.68^{K}$

F , FRICTIONAL FORCE $= 2.8^{K}$

$F_2 = 16x = 16x$

$F_3 = \frac{1}{2} \times 16 \times y = 8y$

$F_2 + F_3 = 41.68 - 2.8 = 38.88^{K}$ (1)

$F_2 \times \frac{16}{2} + F_3 \times \frac{16}{3} = 1.96 \times 16 \times \frac{16}{2} + (3.25 - 1.96)\frac{16}{2} \times \frac{16}{3} - 2.8 \times 16$

$F_2 + .666 F_3 = 31.36 + 6.88 - 5.6$

$F_2 + .666 F_3 = 32.64$ (2)

$F_3 = 18.72^{K}$

$F_2 = 20.16^{K}$

CHECK

$F_1 = F + F_2 + F_3$

$41.68 = 2.8 + 20.16 + 18.72 = 41.68$ O.K

$F_2 = 16x = 20.16$ OR $x = 1.26^{KSF}$

$F_3 = 8y = 18.72$ OR $y = 2.34^{KSF}$

$x + y = 1.26 + 2.34 = 3.60^{KSF}$

BECHTEL

CALCULATION SHEET

1

CALC. NO. C-260-5

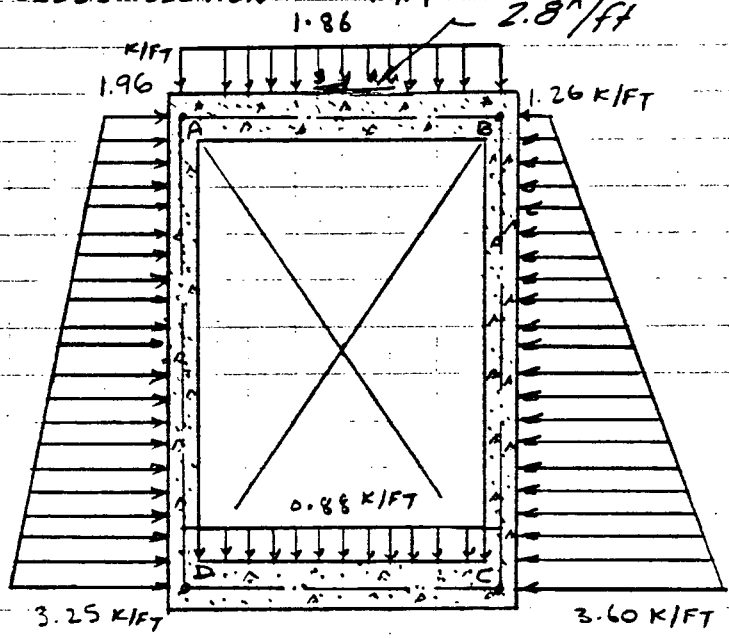
SIGNATURE N. Chaudhry DATE 12-28-79 CHECKED R. Sun DATE 12-28-79

PROJECT SONGS 2 & 3 JOB NO. 10079-003

SUBJECT ELECTRICAL TUNNEL SHEET 14 OF 51 SHEETS

LOADS CONTD

C : A TYPICAL CROSS SECTION



DESIGN LOADS ACTING ON THE TYPICAL CROSS-SECTION FOR GOVERNING LOADING CASE OF:

$$U = 1.4D + 1.7L + 1.9E$$

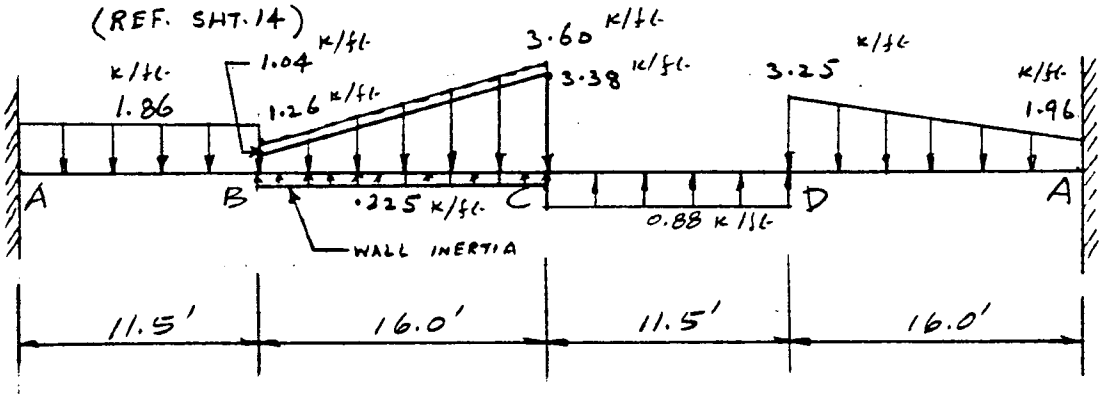
WHERE, $E = \pm 1.0H \pm 0.4V$

NOTE:

THOUGH INERTIA LOADS FROM ROOF AND FLOOR SLABS HAVE NO EFFECT ON ACTIVE PRESSURE SIDE WALL OF THE TUNNEL, BUT FOR CONSERVATISM THESE LOADS ALONG WITH WALL INERTIA LOADS ARE ASSUMED UNIFORMLY ACTING ON THIS WALL. THIS ASSUMPTION IS NOT CONSERVATIVE FOR ROOF SLAB, BUT ROOF SLAB DOES NOT GOVERN, ONLY SIDE WALL IS CRITICAL FOR LATERAL LOADS.

7. CAVITY EFFECTS

CASE 2 : A TYPICAL CROSS SECTION FOR LOSS OF SOIL UNDER FLOOR SLAB. (REF. SHT. 14)



STIFFNESS :

$$K_{AB} = K_{CD} = 0.7 \qquad K_{BC} = K_{AD} = 0.21$$

DISTRIBUTION FACTOR

$$AB = BA = CD = DC = 0.769$$

$$BC = CB = DA = AD = 0.231$$

$$FEM_{AB} = FEM_{BA} = \frac{1}{12}(1.86)(11.5)^2 = 20.5^{1-K}$$

$$FEM_{BC} = \frac{1}{12}(1.04)(16)^2 + \frac{(3.38-1.04)(16)^2}{30} = 42.15^{1-K}$$

$$FEM_{CB} = \frac{1}{12}(1.04)(16)^2 + \frac{(3.38-1.04)(16)^2}{20} = 52.14^{1-K}$$

$$FEM_{AD} = \frac{1}{12}(1.96)(16)^2 + \frac{(3.25-1.96)(16)^2}{30} = 52.82^{1-K}$$

$$FEM_{DA} = \frac{1}{12}(1.96)(16)^2 + \frac{(3.25-1.96)(16)^2}{20} = 58.33^{1-K}$$

$$FEM_{CD} = FEM_{DC} = \frac{1}{12}(0.88)(11.5)^2 = 9.7^{1-K}$$

CALCULATION SHEET

CALC. NO. C-260-5

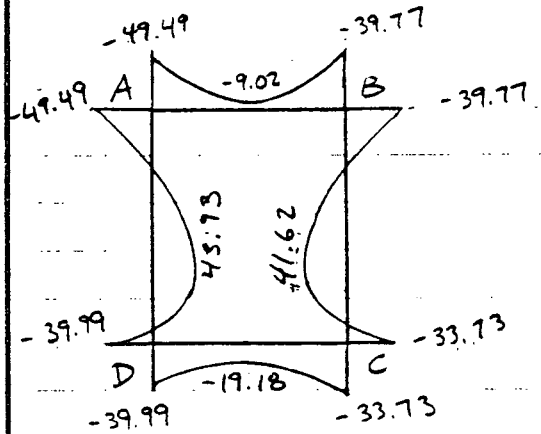
SIGNATURE R. SUN DATE 12-28-79 CHECKED N. Chowdhury DATE 1-2-80

PROJECT SONGS 2 & 3 JOB NO. 10079-003

SUBJECT ELECTRICAL TUNNEL SHEET 21 OF 51 SHEETS

7. CAVITY EFFECTS

JOINT	A	B		C		D		A
MEMBER	AB	BA	BC	CB	CD	DC	DA	AD
D.F.	0.769	0.769	0.231	0.231	0.769	0.769	0.231	0.231
	-20.5	+20.5	-42.15	+52.14	+9.7	-9.7	-58.33	+52.82
	-24.88	+16.65	+5.00	-14.29	-47.55	+52.32	+15.71	-7.44
	+8.33	-12.44	-7.15	+2.50	+26.16	-23.78	-3.72	+7.85
	-12.44	+15.06	+4.53	-6.62	-22.04	+21.15	+6.35	-3.74
Σ	-49.49	+39.77	-39.77	+33.73	-33.73	+39.99	-39.99	+49.49



POSITIVE MOMENTS

$$M_{AB} = \frac{(1.86)(11.5)^2}{8} - 39.77 = -9.02 \text{ 'K}$$

$$M_{CD} = \frac{(0.86)(11.5)^2}{8} - 33.73 = -19.18$$

$$M_{BC} = \frac{(1.04)(16)^2}{8} + 0.0642(3.6 - 1.04)(16)^2 - 33.73$$

$$= 33.28 + 42.07 - 33.73 = 41.62$$

$$M_{AD} = \frac{(1.96)(16)^2}{8} + 0.0642(3.25 - 1.96)(16)^2 - 39.99$$

$$= 62.72 + 21.2 - 39.99 = 43.93 \text{ 'K}$$

BECHTEL

CALCULATION SHEET

CALC. NO. C-260-5

SIGNATURE R. SUN DATE 12-31-79 CHECKED N. Choudhry DATE 1-2-80

PROJECT SONGS 2 & 3 JOB NO. 10079-003

SUBJECT ELECTRICAL TUNNEL SHEET 22 OF 51 SHEETS

7 CAVITY EFFECTS

(a) ROOF SLAB Ref. FLEXURE 1.3

$t = 24''$ $d = 24'' - 3'' = 21''$

$M = -49.5^{1-K}$ (NEGATIVE MOMENT GOVERNS)

$$F = \frac{bd^2}{12000} = \frac{12 \times 21^2}{12000} = 0.441$$

$$K_4 = \frac{49.5}{0.441} = 112.24 \qquad \rho \geq 0.002$$

REQ'D $A_s = 0.002 \times 12 \times 21 = 0.51\ \square''$

PROVIDED #9 @12" = 1.0 $\square''$ > REQ'D A_s O.K.

SHEAR

$$V = \frac{1.86 \times 10}{2} = 9.3^{K}$$

$$v_w = \frac{V}{\phi bd} = \frac{9.3 \times 1000}{0.85 \times 12 \times 21} = 43.4 < 2\sqrt{f_c'} = 126 \text{ psi}$$

O.K.

7. CAVITY EFFECTS

(b) WALL $t = 18''$ $d = 18'-3'' = 15''$

(1) POSITIVE MOMENT $M = 44^{1-K}$ (M_{AD} GOVERNS)

$$F = \frac{bd^2}{12000} = \frac{12 \times 15^2}{12000} = 0.225 \qquad a_u = 4.38$$

$$K_u = \frac{44}{0.225} = 195.6 \qquad \rho = 0.00375$$ [ACI-SP-17-73 FLEXURE 1.3]

REQ'D $A_s = 0.00375 \times 12 \times 15 = 0.670 \square''$ (INSIDE FACE)

$A_s = M/a_u d = 44/4.38 \times 15 = .67\ in^2$

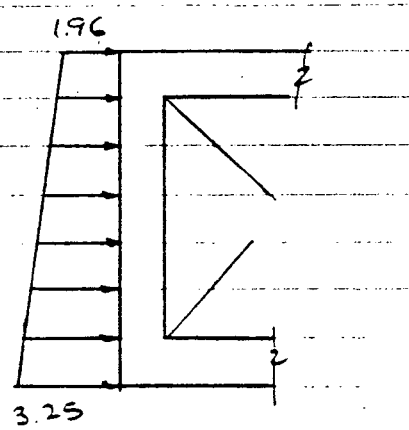
PROVIDED #7 @12" = 0.6 □" ≈ REQ'D A_s O.K.

(2) NEGATIVE MOMENT $M = 49.5^{1-K}$

$$K_u = \frac{49.5}{0.225} = 220 \qquad \rho = 0.0042$$

REQ'D $A_s = 0.0042 \times 12 \times 15 = 0.76 \square''$

PROVIDED #9 @ 12" = 1.0 □" > REQ'D A_s O.K.



SHEAR

$$V = \frac{1.96(14)}{2} + \frac{(3.25 - 1.96) \times 14}{2} \times \frac{2}{3}$$

$$= 13.72 + 6.02 = 19.74\ K$$

$$v_u = \frac{19.74 \times 1000}{0.85 \times 12 \times 15} = 129.0 \approx 2\sqrt{f_c'} = 126\ psi$$

O.K.

BECHTEL

CALCULATION SHEET

CALC. NO. C-260-5

SIGNATURE R. SUN DATE 12-31-79 CHECKED N. Chaudhry DATE 1-2-80

PROJECT SONGS 2 & 3 JOB NO. 10079-003

SUBJECT ELECTRICAL TUNNEL SHEET 24 OF 51 SHEETS

7. CAVITY EFFECTS

(C) FLOOR SLAB

$t = 24"$ $d = 24" - 3" = 21"$

$M = 40.00$ (NEGATIVE MOMENT GOVERNS)

$F = 0.441$

$K_u = \frac{40}{0.441} = 90.7$ $\rho = 0.0015 < \rho_{min} = 0.0018$

REQ'D $A_s = 0.0018 \times 12 \times 21 = 0.454$ □"

PROVIDED #7 @12 = 0.6 □" > REQ'D A_s O.K.

SHEAR

$$V = \frac{0.88 \times 10}{2} = 4.4^K$$

$$v_u = \frac{4.4 \times 1000}{0.85 \times 12 \times 21} = 20.54 < 2\sqrt{f'_c} = 126 \text{ PSI}$$

O.K.

BECHTEL

CALCULATION SHEET

CALC. NO. C-260-5

SIGNATURE N. Chaudhry DATE 7-16-80 CHECKED R. Sun DATE 7-16-80

PROJECT SONGS 2 & 3 JOB NO. 10079-003

SUBJECT ELECTRICAL TUNNEL SHEET 30A OF 51 SHEETS

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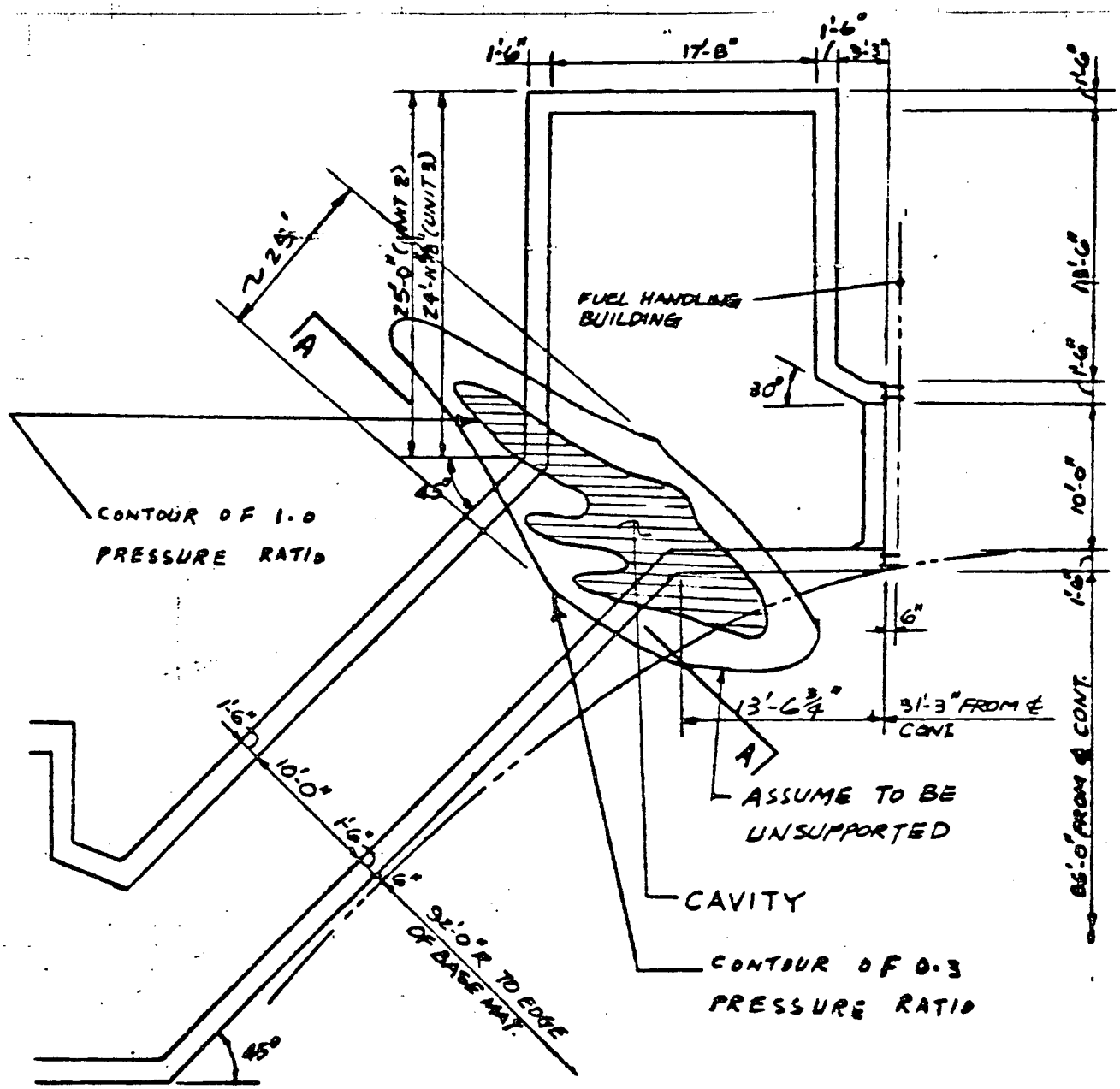
PROJECT SONGS 2 & 3 JOB NO. 10079-003

SUBJECT ELECTRICAL TUNNEL SHEET 31 OF 51 SHEETS

LATERAL LOADS ANALYSIS



TUNNEL PLAN

BECHTEL

CALCULATION SHEET

CALC. NO. C-260-5

SIGNATURE N. Chaudhry DATE 7-10-80 CHECKED T. Dodd DATE 7/16/80

PROJECT SONGS 2 & 3 JOB NO. 10079-003

SUBJECT ELECTRICAL TUNNEL SHEET 32 OF 51 SHEETS

LATERAL LOADS CONTD

BOUNDED SOLUTION FOR M(-) max. AND M(+) max., CONSIDERING THE BOUNDS OF FLEXURAL MOMENT THAT RESULT AT THE TRANSITION FROM THE TYPICAL SECTION WITH MOMENT OF INERTIA I_1, TO THE ENLARGED PORTION AT END OF TUNNEL WITH LARGER I_2.

THE CAVITY LOCATION IS AT THE LOCATION OF THE TUNNEL CROSS SECTION TRANSITION POINT, AND TWO CASES WILL BE CONSIDERED FOR FLEXURAL SPAN OVER CAVITY. VERTICAL LOADING (CONSIDERING CAVITY UNDER TUNNEL) AND LATERAL LOADING (CONSIDERING CAVITY ALONG SIDE OF TUNNEL) WILL BE CONSIDERED SEPARATELY AND THEN COMBINED.

CASE 1. FOR M(-) MAX.

THE 25 FT. EFFECTIVE SPAN FOR CAVITY IS TOTALLY UNDER BOX SECTION OF LOWER I_1.

BOUNDARY CONDITIONS: FULL FIXITY AT ONE END TO REPRESENT THE EXTREME EFFECT OF THE WIDER, MORE RIGID TUNNEL SECTION (I_2)

CALCULATION SHEET

CALC. NO. C-260-5

SIGNATURE N. Chaudhry DATE 7-10-80 CHECKED T. DoQ DATE 7/16/80

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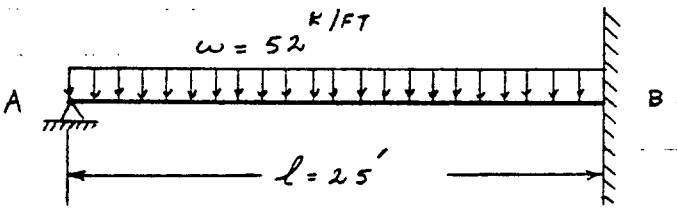
SUBJECT ELECTRICAL TUNNEL SHEET 33 OF 51 SHEETS

LATERAL LOADS CONT'D

AND SIMPLY SUPPORTED AT THE OTHER END.



UNIFORM LOAD, $w = 52$ K/FT (REF. SHT. NO. 19)

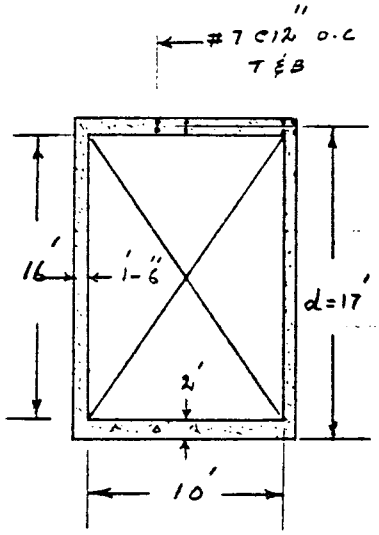
$M_{(-)\,MAX.} = M_B = \frac{w\ell^2}{8}$

$= \frac{52 \times 25^2}{8} = 4062.5$ 1-K

EFFECTIVE DEPTH, $d = 17'$

MOMENT ARM, $a = Jd$

USE $J = .7$ (CONSERVATIVE, THE C-C DISTANCE BETWEEN SLABS, COULD BE USED)



TOTAL TENSIN IN REINF., $T = \frac{M}{Jd} = \frac{4062.5}{.7 \times 17} = 341.4$ K

A_s REQD. $= \frac{T}{\phi f_y b} = \frac{341.4}{.9 \times 60 \times 13} = 0.49$ IN²/FT

A_s PROVIDED, #7 @12" O.C. T&B IN FLOOR AND ROOF SLABS.

A_s PROVIDED $= 2 \times 0.6 \times 12/12 = 1.2$ IN²/FT

A_s PROVIDED $= 1.2$ IN²/FT $>$ A_s REQD. $= 0.49$ IN²/FT. O.K

(M(+) CHECK AND COMBINATION WITH LATERAL LATER)

CALCULATION SHEET

CALC. NO. C-260-5

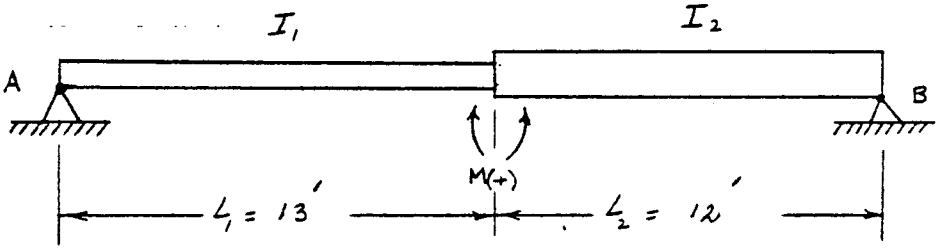
SIGNATURE N. Chaudhry DATE 7-10-80 CHECKED T. Dodd DATE 7/16/80

PROJECT SONGS 2 & 3 JOB NO. 10079-003

SUBJECT ELECTRICAL TUNNEL SHEET 34 OF 51 SHEETS

CASE 2. FOR $M_{(+)}$ MAX: SIMPLY SUPPORTED CASE CONSIDERED TO MAXIMIZE CENTER SPAN MOMENT.

THE PORTION OF THE TUNNEL TRANSITION WITH RESPECT TO THE CAVITY, AS IT WOULD BE REPRESENTED BY I_1 & I_2 SEGMENTS WITHIN THE 25 FT. SPAN, IS NOT RELEVENT FOR THE STATICALLY DETERMINATE CASE CONSIDERED.



REGARDLESS OF I_1 & I_2, L_1 & L_2,

$$M_{(+)\,MAX} = \frac{w\ell^2}{8} \quad \text{WHERE} \quad \ell = L_1 + L_2$$

WHICH IS IDENTICAL TO PREVIOUS CASE.

BECHTEL

CALCULATION SHEET

CALC. NO. C-260-5

SIGNATURE N. Chaudhry DATE 7-10-80 CHECKED T. Dod DATE 7/16/80

PROJECT SONGS 2 & 3 JOB NO. 10079-003

SUBJECT ELECTRICAL TUNNEL SHEET 35 OF 51 SHEETS

LATERAL LOADS ON TUNNEL

IT IS CONSIDERED THAT DURING THE OCCURANCE OF A SEISMIC EVENT, THERE WILL BE LOSS OF SOIL SUPPORT ON ONE SIDE OF THE 25' LONG TUNNEL SECTION AS WELL AS UNDERNEATH THE SAME LENGTH. THIS WILL INTRODUCE LATERAL LOADS FROM SIDE SOIL PRESSURE (ACTIVE SOIL PRESSURE & DYNAMIC PRESSURE INCREMENT), AND INERTIAL FORCE OF TUNNEL ITSELF.

OBE CONDITIONS

1. LIVE LOADS (EQUIVALENT FLUID PRESSURE)

AT REST SOIL PRESSURE (SHT. 11) = 0.045 KCF

ACTIVE SOIL PRESSURE (L.L) = 0.024 KCF

2. DYNAMIC PRESSURE INCREMENT (OBE) = 0.021 KCF

DBE CONDITIONS

1. LIVE LOADS

AT REST PRESSURE (SHT. 15) = 0.075 KCF

ACTIVE PRESSURE (L.L) = 0.024 KCF

2. DYNAMIC PRESSUR INCREMENT = 0.051 KCF

CALCULATION SHEET

CALC. NO. C-260-5

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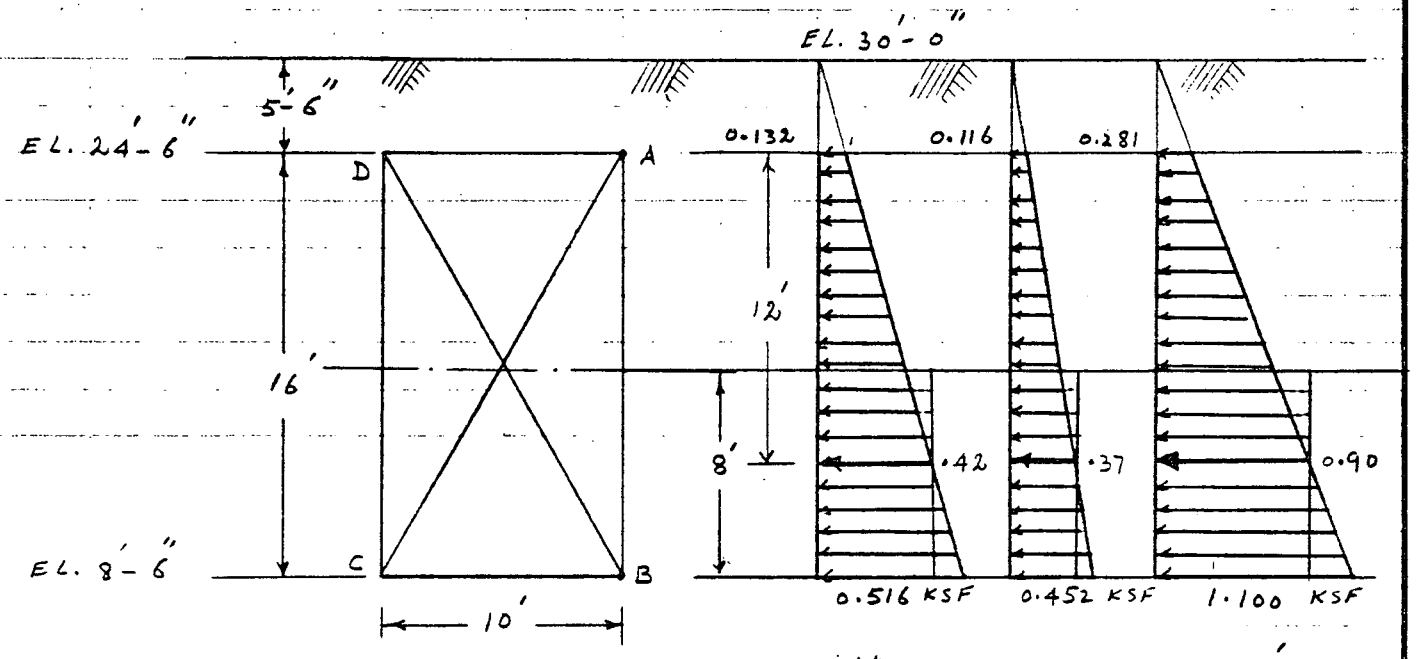
PROJECT SONGS 2 & 3 JOB NO. 10079-003

SUBJECT ELECTRICAL TUNNEL SHEET 36 OF 51 SHEETS

LATERAL LOADS



AS LOWER HALF OF THE TUNNEL IS MORE HEAVILY LOADED AS COMPARED TO THE UPPER HALF SECTION, THE AVERAGE PRESSURE ACTING ON THE LOWER HALF WILL BE CONSIDERED AS A UNIFORM LATERAL LOAD ON THE TUNNEL.

1. LIVE LOAD, $H = \left(\frac{.132+.516}{2} + 0.516\right)\frac{1}{2}$ $= 0.42$ KSF/FT

2. E (OBE) $= \left(\frac{.116+.452}{2} + .452\right)\frac{1}{2}$ $= 0.37$ KSF/FT

3. E' (OBE) $= \left(\frac{.281+1.1}{2} + 1.1\right)\frac{1}{2}$ $= 0.90$ KSF/FT

THES ACT ON SIDE AB AT THE ABOVE UNIFORM RATES.

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SUBJECT ELECTRICAL TUNNEL SHEET 37 OF 51 SHEETS

LATERAL LOADS CONTD

4. INERTIAL LOADS

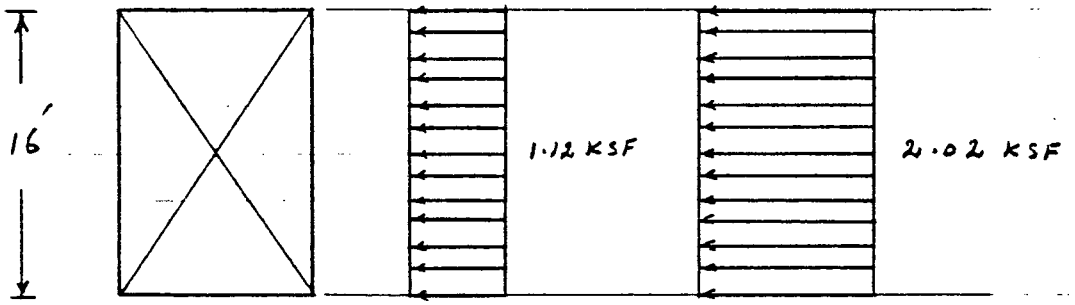
D.L = 23.92 K/FT. (REF. SHT. 8 - 6TH LINE FROM BOTTOM)

HORIZ. ACC. (OBE) = 0.75 g

HORIZ. ACC. (DBE) = 1.35 g

E = 23.92 × .75 / 16 = 1.12 KSF

E' = 23.92 × 1.35 / 16 = 2.02 KSF



HORIZONTAL INERTIA LOADS

CALCULATION SHEET

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PROJECT SONGS 2 & 3 JOB NO. 10079-003

SUBJECT ELECTRICAL TUNNEL SHEET 38 OF 51 SHEETS

LATERAL LOADS

FOR LATERAL PRESSURE LOAD CONSIDER A UNIFORM LOAD CORRESPONDING TO THE LOAD AT THE LOWER HALF OF THE WALLS. THIS LOAD IS HIGHER THAN THE AVERAGE UNIFORM LATERAL LOAD AND IS INTRODUCED TO RECOGNIZE THE HIGHER LOAD APPLIED ON THE LOWER HALF HEIGHT OF WALLS DUE TO THE TRAPEZOIDAL LOAD DISTRIBUTION.

LOADING COMBINATIONS

1. $U = 1.7H + 1.9E$

$= 1.7 \times .42 + 1.9(.37 + 1.12) = 3.55$ KSF/FT

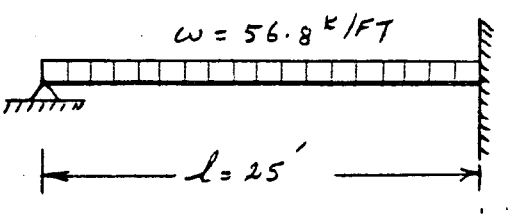
2. $U = H + E'$

$= .42 + (0.90 + 2.02) = 3.34$ KSF/FT

COMBINATION NO. 1 GOVERNS.

$W = 3.55 \times 16 = 56.8$ K/FT (UNIFORM LOAD PER FT SPAN OF TUNNEL)

$M_{(-)MAX.} = \frac{wl^2}{8} = \frac{56.8 \times 25^2}{8} = 4437.5$ FT-K



EFFECTIVE DEPTH, $d = 12.25'$

MOMENT ARM $= jd = .7 \times 12.25$

$T = \frac{M}{jd} = \frac{4437.5}{.7 \times 12.25} \times \frac{1}{16} = 32.34$ K/FT

AS REQD. $= \frac{T}{\phi f_y} = \frac{32.34}{.9 \times 60} = 0.60$ IN^2/FT

CALCULATION SHEET

CALC. NO. C-260-S

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PROJECT SONGS 2 & 3 JOB NO. 10079-003

SUBJECT ELECTRICAL TUNNEL SHEET 39 OF 51 SHEETS

INTEGRITY EVALUATION

(BY FACTORED COMBINATION OF VERTICAL & HORIZONTAL SEISMIC LOADS APPLIED ON THE AREA OF REINFORCING REQUIRED IN EACH CASE)

1. VERTICA LOADING CASE

$U = 1.4D + 1.7L + 1.9E = 1.4 \times 2.08 \times \frac{11.5}{13} + 1.7 \times 0.1 + 1.9 \times 2.08 \frac{11.5}{13} \times .51 = 4.5$

$U(D+L) = 2.7$ KSF/FT AND $U(E_V) = 1.8$ KSF/FT

W TOTAL $= 52$ K/FT

$W(D+L) = 2.7 \times 11.5 = 31.3$ K/FT

$W(E_V) = 1.8 \times 11.5 = 20.7$

$A_s = 0.49$ IN^2/FT

$A_s(D+L) = .49 \times \frac{31.3}{52} = 0.294$ IN^2

$A_s(E_V) = .49 \times \frac{20.7}{52} = 0.196$ IN^2

2. HORIZ. LOADING CASE

$U = 3.55$ KSF SHT. 38

$U = 1.7H + 1.9E$ OR $U(H) = 0.714$ KSF, $U(E) = 2.831$ KSF

$W = 56.8$ OR $W(H) = 0.714 \times \frac{56.8}{3.55} = 11.42$ K/FT

$W(E_H) = 2.831 \frac{56.8}{3.55} = 45.38$ K/FT

$A_s = 0.60$ IN^2

$A_s(H) = 0.60 \times \frac{11.42}{56.8} = 0.12$ IN^2

$A_s(E_H) = 0.60 \times \frac{45.38}{56.8} = 0.48$ IN^2

CALCULATION SHEET

CALC. NO. C-260-5

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PROJECT SONGS 2 & 3 JOB NO. 10079-003

SUBJECT ELECTRICAL TUNNEL SHEET 40 OF 51 SHEETS

INTEGRITY EVALUATION CONTD

SUMMARY OF RESULTS

1. VERTICAL

$M_{D+L} = \frac{31.3}{52} \times 4062.5 = 2445.3^{1-K}$

$M_E = 20.7/52 \times 4062.5 = 1617.2^{1-K}$

LOAD	M FT-K	As (REQD.) IN^2/FT	As (PROV.) IN^2	As (REQD) / As (PROV.)
D+L	2445.3	0.294	1.2	0.245
E_V	1617.2	0.196	1.2	0.163

2. HORIZONTAL.

$M_H = \frac{11.42}{56.8} \times 4437.5 = 892.2^{1-K}$

$M_E = \frac{45.38}{56.8} \times 4437.5 = 3545.3^{1-K}$

LOAD	M FT-K	As REQUIRED IN^2/FT	As PROVIDED IN^2/FT	As REQD. / As PROV.
H	892.2	0.12	1.2	0.10
E_H	3545.3	0.48	1.2	0.40

BECHTEL

CALCULATION SHEET

CALC. NO. C-260-5

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SUBJECT ELECTRICAL TUNNEL SHEET 41 OF 51 SHEETS

INTEGRITY EVALUATION CONTD

3. COMBINATIONS FOR MAX. A_s REQUIRED

(i) FACTORS METHOD

$$A_{s1} = A_s(D+L) + A_s(H) + 1.0\,A_s(E_V) + 0.4\,A_s(E_H)$$

$$A_{s2} = A_s(D+L) + A_s(H) + 0.4\,A_s(E_V) + 1.0\,A_s(E_H)$$

$A_{s1} = 0.294 + 0.12 + 1.0 \times .196 + 0.4 \times .48 = 0.802$ IN²/FT

$A_{s2} = 0.294 + 0.12 + 0.4 \times .196 + 1.0 \times .48 = 0.97$ IN²/FT

A_s PROVIDED = 1.2 IN²/FT (THIS IS THE LEAST LONGITUDINAL REINFORCING PROVIDED IN FLOOR & ROOF SLABS; WALLS HAVE HIGHER LONGITUDINAL REINF)

$$\text{SAFETY FACTOR} = \frac{1.2}{0.97} = 1.24 \quad \text{O.K}$$

(ii) SRSS METHOD.

$$A_s = A_s(D+L) + A_s(H) + \sqrt{A_s(E_V)^2 + A_s(E_H)^2}$$

$$= 0.294 + 0.12 + \sqrt{0.196^2 + 0.48^2}$$

$$= 0.93 \text{ IN}^2/\text{FT} \quad \text{DOES NOT GOVERN}$$

4. CONCLUSION : FACTORS METHOD GOVERN.

A_s REQD = .97 IN²/FT < A_s PROVIDED = 1.2 IN²/FT O.K

CALCULATION SHEET

CALC. NO. C-260-5

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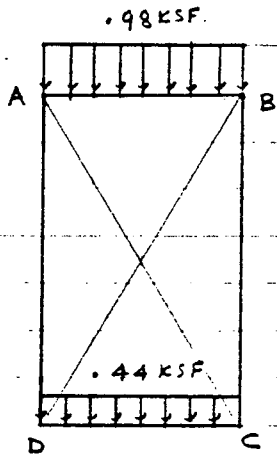
PROJECT SONGS 2 & 3 JOB NO. 10079-003

SUBJECT ELECTRICAL TUNNEL SHEET 42 OF 51 SHEETS

TYPICAL TUNNEL CROSS-SECTION

CASE 1 : DEAD LOAD

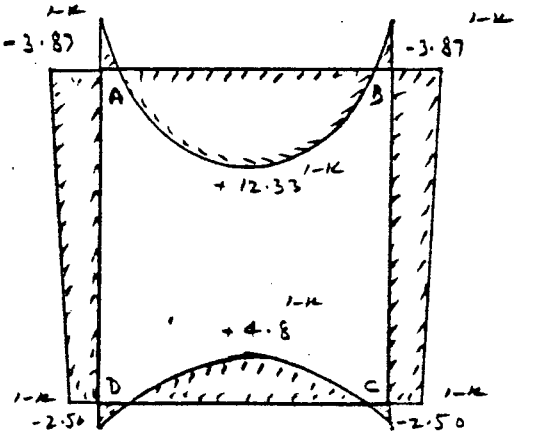


FEM (AB=BA) = $\frac{1}{12} \times .98 \times 11.5^2$ = 10.8 1-K

FEM (CD=DC) = $\frac{1}{12} \times .44 \times 11.5^2$ = 4.85 1-K

JOINT	A	B		C		D		A
MEMB.	AB	BA	BC	CB	CD	DC	DA	AD
D.F	.77	.77	.23	.23	.77	.77	.23	.23
	-10.8	+10.80			+4.85	-4.85		
	+8.32	-8.32	-2.48	-1.12	-3.73	+3.73	+1.12	2.48
	-4.16	+4.16	-0.56	-1.24	+1.86	-1.86	+1.24	0.56
	+2.77	-2.77	-0.83	-0.14	-0.48	+0.48	+0.14	0.83
	-3.87	+3.87	-3.87	-2.50	+2.50	-2.50	+2.50	+3.87

$M+ (AB) = \frac{1}{8} \times .98 \times 11.5^2 - 3.87$ = 12.33 1-K , $M+ (CD) = \frac{1}{8} \times .44 \times 11.5^2 - 2.5$ = 4.8 1-K



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PROJECT SONGS 2 & 3 JOB NO. 10079-003

SUBJECT ELECTRICAL TUNNEL SHEET 43 OF 51 SHEETS

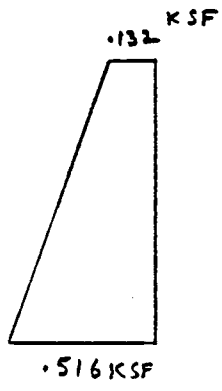
A TYPICAL TUNNEL CROSS SECTION (COMBINED EFFECT OF E_V & E_H)

A. LOADING CASE 2 : LIVE LOADS ONLY

(i) ROOF SLAB (SHT. NO. 17) = 0.05 KSF

(ii) FLOUR SLAB (SHT. NO. 17) = 0.05 KSF

(iii) WALLS



DISTRIBUTION FACTORS

AB = BA = CD = DC = 0.77

BC = CB = DA = AD = 0.23

F.E.M (AB) = $\frac{1}{12} \times .05 \times 11.5^2$ = 0.55 1-K

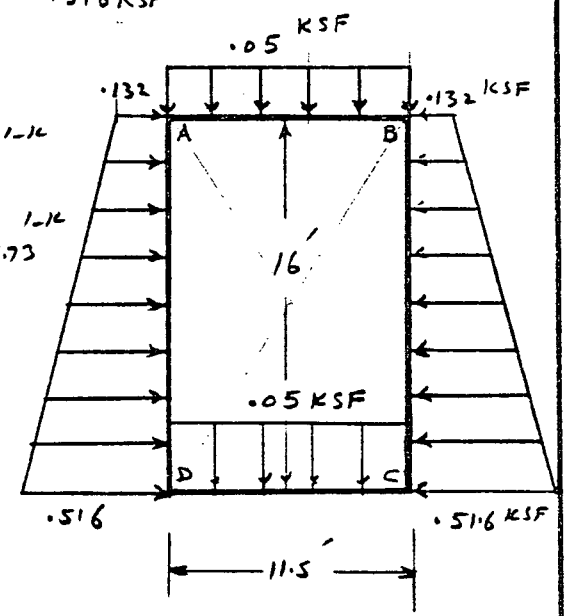
F.E.M (BC) = $\frac{1}{12} \times .132 \times 16^2 + \frac{(.516 - .132)\,16^2}{30}$ = 6.1 1-K

F.E.M (CB) = $\frac{1}{12} \times .132 \times 16^2 + \frac{(.516 - .132)}{20} \times 16^2$ = 7.73 1-K

F.E.M (AD) = F.E.M (BC) = 6.1 1-K

F.E.M (DA) = FEM (BC) = 7.73 1-K

FEM (CD) = $\frac{1}{12} \times .05 \times 11.5^2$ = 0.55 1-K



CALCULATION SHEET

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PROJECT SONGS 2 & 3 JOB NO. 10079-003

SUBJECT ELECTRICAL TUNNEL SHEET 44 OF 51 SHEETS

LIVE LOADS

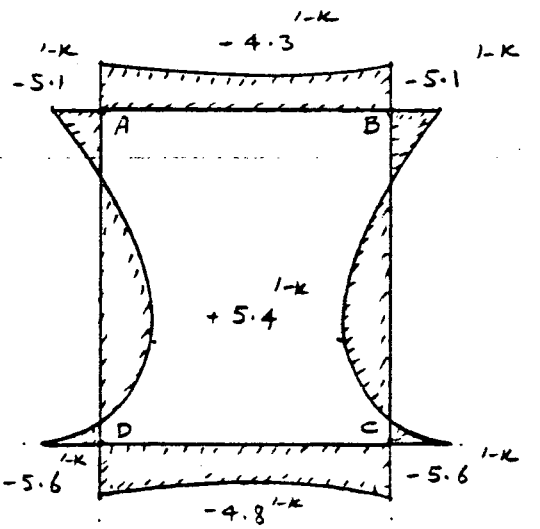
JOINT	A	B		C		D		A
MEMBER	AB	BA	BC	CB	CD	DC	DA	AD
D.F	0.77	0.77	0.23	0.23	0.77	0.77	.23	.23
	-0.55	+0.55	-6.10	+7.73	+0.55	-0.55	-7.73	6.1
	-4.27	+4.27	+1.28	-1.90	-6.38	+6.38	+1.90	-1.28
	+2.13	-2.13	-0.95	+0.64	+3.19	-3.19	-0.64	0.95
	-2.37	+2.37	+0.71	-0.88	-2.95	+2.95	0.88	-0.71
	-5.1	+5.1	-5.1	+5.6	-5.6	+5.6	-5.6	+5.1

POSITIVE MOMENTS

$M_{AB} = \frac{1}{8} \times .05 \times 11.5^2 - 5.1 = (-)\ 4.3^{1-K}$

$M_{CD} = \frac{1}{8} \times .05 \times 11.5^2 - 5.6 = (-)\ 4.8^{1-K}$

$M_{AD} = M_{BC} = \frac{1}{8} \times .132 \times 16^2 + 0.0642(.516 - .132)16^2 - 5.1 = 5.4^{1-K}$



CALCULATION SHEET

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SUBJECT ELECTRICAL TUNNEL SHEET 45 OF 51 SHEETS

B. LOADING CASE 3 : HORIZONTAL SEISMIC E_H

DYNAMIC PRESSURE INCREMENT (SHT. 11) = 0.021 KCF

p AT "A" = 0.021 x 5.5 = .116 KSF/FT

p AT "D" = 0.021 x 21.5 = .452 KSF/FT

INERTIAL PRESSURE

W_e (A) OR p_i (D) = 0.86 KSF/FT OF WALL HEIGHT.

p_i = We x Acc (SHT. 12) = 0.86 x .75 = 0.645 KSF (UNIFORM)

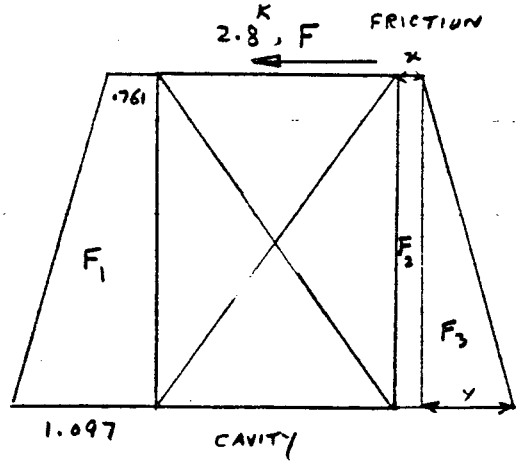
RESULTANTS

P AT A = .116 + .645 = 0.761 KSF

P AT D = .452 + .645 = 1.097 KSF

REF. SHT. 12

F = 2.8 K



FOR EQUILIBRIUM

$F_1 = F + F_2 + F_3$

ΣM ABOUT BASE = 0

F = 2.8 K

F_1 = $(1.097 + .761)\frac{1}{2} \times 16$ = 14.864 K

CALCULATION SHEET

CALC. NO. C-260-5

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SUBJECT ELECTRICAL TUNNEL SHEET 46 OF 51 SHEETS

HORIZ. SEISMIC

$F_2 = 16x$

$F_3 = \frac{1}{2} \times 16 \times y = 8y$

$F_2 + F_3 = F_1 - F = 14.864 - 2.8 = 12.064^K$ — I

ΣM ABOUT BASE

$8F_2 + 5.33F_3 = .761 \times 16 \times 16 \times \frac{1}{2} + (1.097 - .761) \times 16 \times \frac{16}{3} \times \frac{1}{2} - 2.8 \times 16$

$F_2 + 0.67F_3 = 12.2 + 1.8 - 5.6 = 8.4$ — II

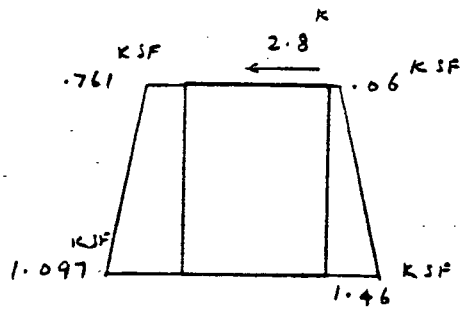
$0.33F_3 = 3.7$

$F_3 = 11.2^K$

$F_2 = 0.9^K$

$x = F_2/16 = 0.9/16 = 0.06^{KSF}$

$y = F_3/8 = 11.2/8 = 1.4^{KSF}$



CHECK

$2.8 + (.06 + 1.46)\frac{1}{2} \times 16$

$= 14.96^K \simeq F_1 = 14.9$ O.K.

CALCULATION SHEET

CALC. NO. C-260-5

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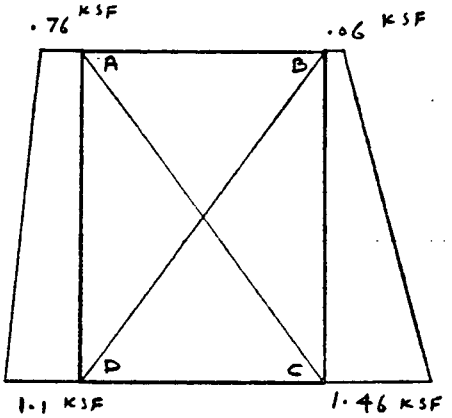
SUBJECT ELECTRICAL TUNNEL SHEET 47 OF 51 SHEETS

HORIZONTAL SEISMIC LOADS



FEM BC

$$\frac{1}{12} \times .06 \times 16^2 + (1.46 - .06)\, 16^2/30$$

$$= 13.2^{1-K}$$

FEM CB

$$\frac{1}{12} \times .06 \times 16^2 + (1.46 - 0.06)\, \frac{16^2}{20}$$

$$= 19.2^{1-K}$$

FEM AD

$$\frac{1}{12} \times .76 \times 16^2 + (1.1 - .76)\, \frac{16^2}{30}$$

$$= 19.1^{1-K}$$

FEM DA

$$\frac{1}{12} \times .76 \times 16^2 + (1.1 - .76)\, \frac{16^2}{20}$$

$$= 20.6^{1-K}$$

JOINT	A	B		C		D		A
MEM	AB	BA	BC	CB	CD	DC	DA	AD
D.F	.77	.77	.23	.23	.77	.77	.23	.23
	-14.7	+10.2	-13.2 +3.0	+19.2 -4.5	-14.7	-15.9	-20.6 +4.7	+19.1 -4.4
	+5.1	-7.3	-2.2	+1.5	-7.9	-7.3	-2.2	+2.3
	-5.7	+7.3	+2.2	+1.5	+4.9	+7.3	+2.2	-1.7
	-15.3	+10.2	-10.2	+17.7	-17.7	-15.9	-15.9	+15.3

HORIZONTAL SEISMIC

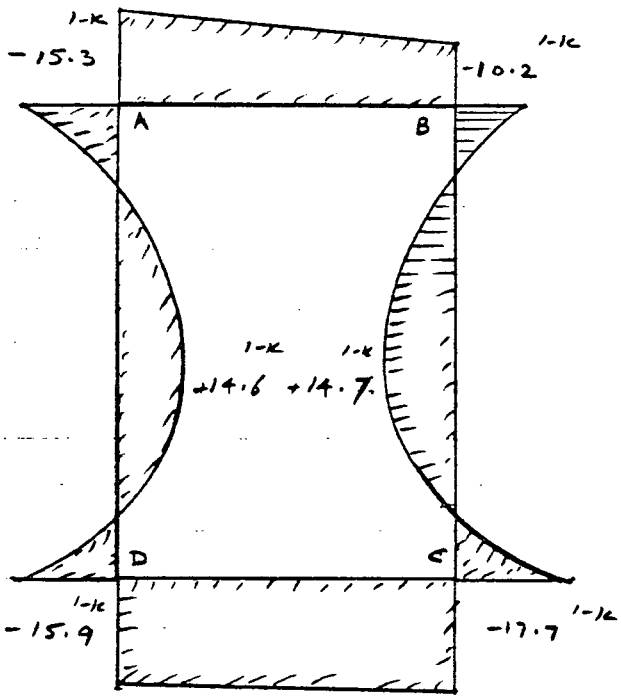
POSITIVE MOMENTS

$M_{BC} = \frac{1}{8} \times .06 \times 16^2 + 0.0642 (1.46 - .06) 16^2 - 10.2$

$= 1.92 + 23.00 - 10.2 = 14.7^{1-K}$

$M_{AD} = \frac{1}{8} \times .76 \times 16^2 - (1.1 - .76) .0642 \times 16^2 - 15.3$

$= 24.32 + 5.6 - 15.3 = 14.6^{1-K}$



HORIZONTAL SEISMIC LOAD MOMENTS.

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SUBJECT ELECTRICAL TUNNEL SHEET 49 OF 51 SHEETS

C. LOADING CASE 4 : VERTICAL SEISMIC, Eu.

1. ROOF SLAB

	w × Acc.	
TOP SOIL	= 0.54 × 0.34	= 0.18
SELF WT.	= 0.30 × 0.34	= 0.102
CABLES ETC	= 0.140 × 0.34	= 0.048
TOTAL	=	0.33 KSF

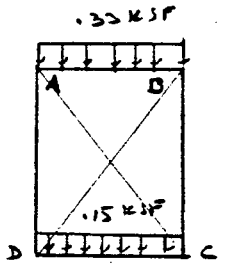
2. FLOOR SLAB

SELF WT.	= 0.300 × .34	= .102
CABLES ETC.	= 0.140 × .34	= 0.048
TOTAL		= .150 KSF

FEM (AB) = $\frac{1}{12} \times .33 \times 11.5^2$ = 3.64 $^{1-k}$

FEM (CD) = $\frac{1}{12} \times .35 \times 11.5^2$ = 1.65 $^{1-k}$

M(+) = $\frac{1}{8} \times .33 \times 11.5^2 - 1.31$ = 4.1 $^{1-k}$



JOINT	A	B		C		D		A
MEMB.	AB	BA	BC	CB	CD	DC	DA	AD
D.F	.77	.77	.23	.23	.77	.77	.23	.23
	-3.64 +2.80	+3.64 -2.80	-0.84	-0.38	+1.65 -1.27	-1.65 +1.27	+0.38	+0.84
	-1.40 +0.93	+1.40 -0.93	-0.19 -0.28	-0.42 -0.05	+0.63 -0.16	-0.63 +0.16	+0.42 +0.05	+0.19 +0.28
	-1.31	+1.31	-1.31	-0.85	+0.85	-0.85	+0.85	+1.31

CALCULATION SHEET

CALC. NO. C-260-5

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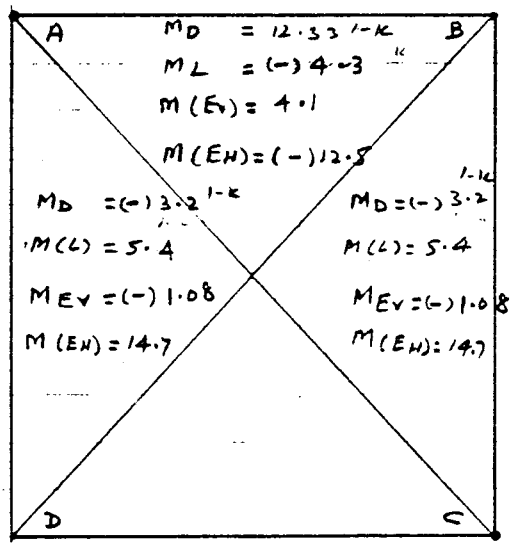
PROJECT SONGS 2 & 3 JOB NO. 10079-003

SUBJECT ELECTRICAL TUNNEL SHEET 50 OF 51 SHEETS

TYPICAL TUNNEL CROSS-SECTION CONT'D

1. SUMMARY OF RESULTS

$M(D) = (-)\ 3.9$ 1-K	$M(D) = (-)\ 3.9$ 1-K
$M(L) = (-)\ 5.1$	$M(L) = (-)\ 5.1$
$M(E_V) = (-)\ 1.31$	$M(E_V) = (-)\ 1.31$
$M(E_H) = (-)\ 15.3$	$M(E_H) = (-)\ 10.20$



$M(D) = (-)\ 2.50$ 1-K	$M(D) = (-)\ 2.50$ 1-K
$M(L) = (-)\ 5.60$	$M(L) = (-)\ 5.60$
$M(E_V) = (-)\ 0.85$	$M(E_V) = (-)\ 0.85$
$M(E_H) = (-)\ 15.90$	$M(E_H) = (-)\ 17.70$

CALCULATION SHEET

CALC. NO. C-260-5

SIGNATURE N. Chaudhry DATE 7-15-80 CHECKED R. Lum DATE 7-16-80

PROJECT SONGS 2 & 3 JOB NO. 10679-003

SUBJECT ELECTRICAL TUNNEL SHEET 51 OF 51 SHEETS

TYPICAL TUNNEL CROSS-SECTION CONTD

2. COMBINATIONS

AT CORNER C

(i) FACTORS METHOD

FOR $M_{(-)}$ MAX.

$M_1 = 1.4 M_D + 1.7 M_L + 1.9(.4 \times M_{EV} + 1.0 M_{EH})$

$= 1.4 \times 2.5 + 1.7 \times 5.60 + 1.9 (.4 \times 0.85 + 1.0 \times 17.70) = 47.3$ 1-K

GOVERNS

$M_2 = 1.4 M_D + 1.7 M_L + 1.9 (1.0 M_{EV} + 0.4 M_{EH})$

$= 1.4 \times 2.5 + 1.7 \times 5.6 + 1.9 (.85 + 0.4 \times 17.70) = 28.1$ 1-K

FOR $M_{(+)}$ MAX.

WALLS $M = 1.4 M_D + 1.7 M_L + 1.9 M_E$

$M_E = 1.0 M_V + 0.4 M_H$ OR $0.4 M_V + 1.0 M_H$

BUT : $M_D = (-) 3.2$ & $M_V = (-) 1.08$, IGNORE $M_{(-)}$ AND $M_E = 1.0 M_H$

$M_{(+)}$ MAX $= 1.7 M_L + 1.9 M_H = 1.7 \times 5.4 + 1.9 \times 14.7 = +37.11$ 1-K

ROOF SLAB

$M_+ = 1.4 M_D + 1.7 M_L + 1.9 M_E$

$M_E = 1.0 M_V + 0.4 M_H$ OR $.4 M_V + 1.0 M_H$

$M_L = (-) 4.3$ & $M_H = (-) 12.5$ (IGNORE)

$M_E = 1.0 M_V = 4.1$ 1-K

$M_+ = 1.4 \times 12.33 + 1.9 \times 4.1 = +25.0$ 1-K

(ii) SRSS METHOD FOR $M_{(-)}$ MAX. AT CORNER C

$M_E = (M_V^2 + M_H^2)^{1/2} = (.85^2 + 17.7^2)^{1/2} = 17.72$ 1-K

$M_{(-)} = 1.4 M_D + 1.7 M_L + 1.9 M_E$

$= 1.4 \times 2.5 + 1.7 \times 5.6 + 1.9 \times 17.72 = 46.7$ 1-K (FACTOR METHOD GOVERNS)

$M_{(-)}$ BY FACTORS METHOD GOVERNS THE DESIGN