

STRUCTURAL DESIGN OF STORM DRAINS

COMPUTER APPLICATION MANUAL



Los Angeles County Flood Control District

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STRUCTURAL DESIGN OF

STORM DRAINS

Computer Application Manual

Scope:

This manual presents the methods for the computerized structural design of storm drain components. In addition to outlining the specific procedures employed, sample problems are presented showing both input and output formats.

The structural design process is broken down into four separate programs: reinforced concrete box conduits, reinforced concrete open rectangular channel, ~~reinforced concrete arch sections~~, and reinforced concrete pipe. Details of each of these computer programs are presented along with the requirements and limitations of each.

Future Modifications:

The programs were initially written as three-phase programs for processing on an IBM 1620 computer. These were later converted to single programs for use on an IBM 360 (Model 40 or larger). It is anticipated that the programs will be further refined at a later date.

Structural Design of

Reinforced Concrete Box Conduits

Computer Program No. 0501

Purpose:

The purpose of Program No. 0501 is to furnish structural details for the construction of reinforced concrete box conduits and/or check structural calculations for these structures.

Scope:

The program is limited at the present time to single and double barrel boxes. The double barrel box may be either symmetrical or unsymmetrical.

The design phase of this program produces complete structural details including final member thicknesses, steel layout, and concrete and steel quantities.

The checking phase of this program calculates stresses at preset sections. The input data for this phase are previously calculated structural details.

The working stress design method is used.

The District's design criteria are set internally. These criteria are set forth in the District Structural Design Manual¹. Provisions have been made to override the allowable stress criteria and load specifications.

Live load may be zero, truck load or railroad load.

The installation condition may be trench, negative projection, or positive projection. Vertical earth loads are calculated in accordance with Marston's equations².

Design Criteria:

Two sets of basic design criteria are set forth internally. They consist of the following:

<u>DESCRIPTION</u>	<u>DISTRICT</u>	<u>ALTERNATE</u>
Ultimate Concrete Stress at 28 Days, f'c	4,000 psi	3,000 psi
Allowable Concrete Stress, fc	1,800 psi	1,000 psi
Yield Point Stress of Steel, fy	60,000 psi	40,000 psi
Allowable Steel Stress	24,000 psi	20,000 psi
Modular Ratio	8	10
Allowable Bond Stress	ACI 318-63 Sec. 1301	300 psi

<u>DESCRIPTION</u>	<u>DISTRICT</u>	<u>ALTERNATE</u>
Allowable Shear Stress	70 psi ACI 318-63 Sec. 1201	90 psi at face of support
Soil Density (Marston's Formula)	110 pcf	90 pcf
Lateral Soil Pressure	37 lb/ft EFP	30 lb/ft EFP
Minimum Top Slab Thickness	6.5"	6.5"
Minimum Invert Slab Thickness	7.0"	7.0"
Minimum Wall Slab Thickness	8.0"	8.0"
Positive Steel Cover, Top Slab and Wall	2"	2"
Negative Steel Cover, Top Slab and Wall	2"	2"
Positive Steel Cover, Invert Slab	2.5"	2.5"
Negative Steel Cover, Invert Slab	2.5"	2.5"
Trench Clearance	3'	3'
Settlement Ratio, rsd, Positive Projection	0.7	0.7
Settlement Ratio, rsd, Negative Projection	-0.5	-0.5
Soil Friction Coefficient, Ku	.15	.15

Option Design Criteria:

Use of the design criteria listed above is optional; the user may override any or all of them. For details, see input instructions.

Procedure:

The program is basically a six-part program: (1) single barrel box design, (2) single barrel box, check, (3) symmetrical double box design, (4) symmetrical double barrel box, check, (5) unsymmetrical double barrel box design, and (6) unsymmetrical double box, check. There are numerous routines, such as establishment of criteria, load calculations, moment distribution, etc., that are common to several or all of the above parts.

The program logic is based on the method of analysis set forth in detail in the District's Structural Design Manual. The following is a brief outline of the program procedure, with comments on significant items.

A. Establishment of Stress Criteria

1. District or alternate criteria are set.
2. Optional criteria are checked and any modifications indicated are set.

B. Calculation of Loads

1. Earth loads are checked in accordance with Marston's equations.
 - a. Trench condition - check made for wide trench.

- b. Negative projection.
 - c. Positive projection.
2. Live Loads.
- a. Zero.
 - b. Truck (variable axle load).
 - c. Railroad (variable axle load).

C. Loading Cases

- 1. Vertical and lateral earth, dead, internal water, and live loads are combined to give maximum stresses at critical sections. These are fixed combinations and cannot be modified by the user. The combinations are illustrated in Appendix 1.
- 2. The various cases are incremented.
- 3. Eleven locations along each member are analyzed. The loading case used at any point is that case that results in the maximum stress at that point.

D. Thicknesses Are Initialized

Initial thickness for each member is set. The values are based on empirical formulae.

E. Fixed-End Moments Are Set For The Loading Case Incremented

Fixed-end moments are based on center line spans.

F. Moments Are Distributed

A four-cycle Hardy Cross distribution is utilized.

G. Moments, Shears, And Thrusts Are Accumulated

Maximum values are retained. Design moment is at face of support.

H. Thicknesses Are Finalized

- 1. Thicknesses are calculated for each member. Thicknesses are based on shear and flexure requirements. The flexure check assumes balanced design and working stress theory.

2. Calculated thicknesses are checked against previously set values. If the differential is not within the set tolerance, steps B through H are rerun.

I. Design Variables Are Calculated

Moment, shear, thrust, area of steel requirements, etc., are calculated at eleven points in each member.

J. Steel Layout Is Developed

1. Numerous steel patterns are checked.
 - a. Minimum steel is No. 4 bars at 18-inch centers.
 - b. Minimum bar size is No. 4, maximum size No. 9.
 - c. Minimum bar spacing is 4 inches, maximum spacing 18 inches.
2. Longitudinal steel is set based on No. 4 bars.

K. Concrete And Steel Quantities Are Calculated

L. Output Is Printed

1. Title card.
2. Design criteria.
3. Concrete thickness.
4. Steel layout.
5. Quantities.

Input Data:

For using the design criteria (District or Alternate) with values noted above, only two cards are required.

Card No. 1 Title Card - Starting from card column 5 the spaces may be used in any desired manner for the title of the job.

Card No. 2 Data Card -

Card column 4; DC = Design Criteria
Alternate Criteria DC = 1
District Criteria DC = 2

Optional Alternate Criteria DC = 3
Optional District Criteria DC = 4

Card column 5; NB = Number of Barrels
Single Box NB = 1
Double Box NB = 2

Card column 6; IC = Installation Condition
Trench Condition IC = 1
Positive Projection Condition IC = 2
Negative Projection Condition IC = 3

Card column 7; LL = Type of Live Load
No Live Load LL = 1
Truck Live Load LL = 2 When depth of cover is greater than 10', the program sets Live Load = 0 automatically.

Railroad Live Load = 3

Card columns 8-13
Depth to Finish Grade (feet) for double box with unequal heights, code the depth to finish grade of the taller barrel.

Card columns 14-19
Depth to Natural Grade (feet)
For trench condition Depth to Finish Grade = Depth to Natural Grade.
For double box with unequal heights, code the depth to natural grade of the taller barrel.

Card columns 20-23
Axle Load (KIPS)
Example: H20-S16 Axle Load = 32
E-72 Axle Load = 72

Card columns 30-41
Left Barrel = Left Barrel Dimensions (feet)

Card columns 42-53
Right Barrel = Right Barrel Dimensions (feet)

Code right barrel dimensions only when it is an unsymmetrical double box; the barrel with the greater width will be the left barrel.

The symbol "▼" denotes the location of the decimal point. Decimals are set internally, and need not be placed on the form by the user. The internal decimal position may be overridden by placing a decimal point where required on the form; however, the added decimal will occupy a column space.

For using optional design criteria, two more data cards are required. (Cards with card code 016 -- see optional design criteria input form.) The computer program will override the corresponding stored criteria when optional criteria are placed in the appropriate data columns. If any optional criteria are unspecified, District (DC = 4) or Alternate (DC = 3) criteria will be used.

On Card No. 2 (Card Code 013) when DC = 3, the program checks shear at face of support. When DC = 4, the program checks shear at effective depth from face of support.

Output Description:

Refer to sample output and standard schematics of box design in Appendix 1. At the bottom of output sheet under Input Data and Design Criteria, reading from left to right and top to bottom, the values are:

1. Depth to finish grade.
2. Depth to natural grade.
3. Axle load.
4. Hydrostatic pressure head.
5. Interior width of box.
6. Interior height of box.
7. Minimum top slab thickness.
8. Minimum invert slab thickness.
9. Minimum wall thickness.
10. Positive steel cover - top slab.
11. Positive steel cover - invert slab.
12. Positive steel cover - wall.
13. Negative steel cover - top slab.
14. Negative steel cover - invert slab.
15. Negative steel cover - wall.
16. Trench clearance.
17. Positive projection settlement ratio.
18. Negative projection settlement ratio.
19. Soil friction coefficient.
20. Compressive concrete stress at 28 days, f'c.
21. Allowable concrete stress, fc.
22. Yield point steel stress, fy.
23. Allowable steel stress, fs.
24. Modular ratio.
25. Allowable bond stress.
26. Allowable shear stress.
27. Soil density.
28. Allowable bond stress top bar.
29. Lateral soil equivalent fluid pressure.

REINFORCED CONCRETE BOX CHECK PROGRAM ABSTRACT

Input Instructions

Cards with Card Code 012, 013, 014, and three to eight 015 cards are required for each section. The number of 015 cards used depends on the type of box and pattern of steel layout (refer to box schematics and input form in Appendix 1). Note that data for 3 bars are designated on one card.

The 012 and 013 cards for the structural check program are the same as those for the design program. The 014 card indicates thicknesses of R. C. box and the number of longitudinal bars.

Do not code the right barrel thicknesses unless the double box is unsymmetrical.

On Card 015, a "9" in Column 4 indicates the last card (LC). Check "yes" at the right end of the last card as an indicator to the key punch operator. Leave Column 4 blank, and check "no" at the right end of the card if it is not the last card.

When criteria other than the District or Alternate criteria are used, two 016 cards are also required. These are completed in the same manner as for the R.C. box design program, optional design criteria. (See input instructions for R.C. box design).

Program Output Description

The structural check program calculates various stresses based on input data and the applicable criteria for each case as follows:

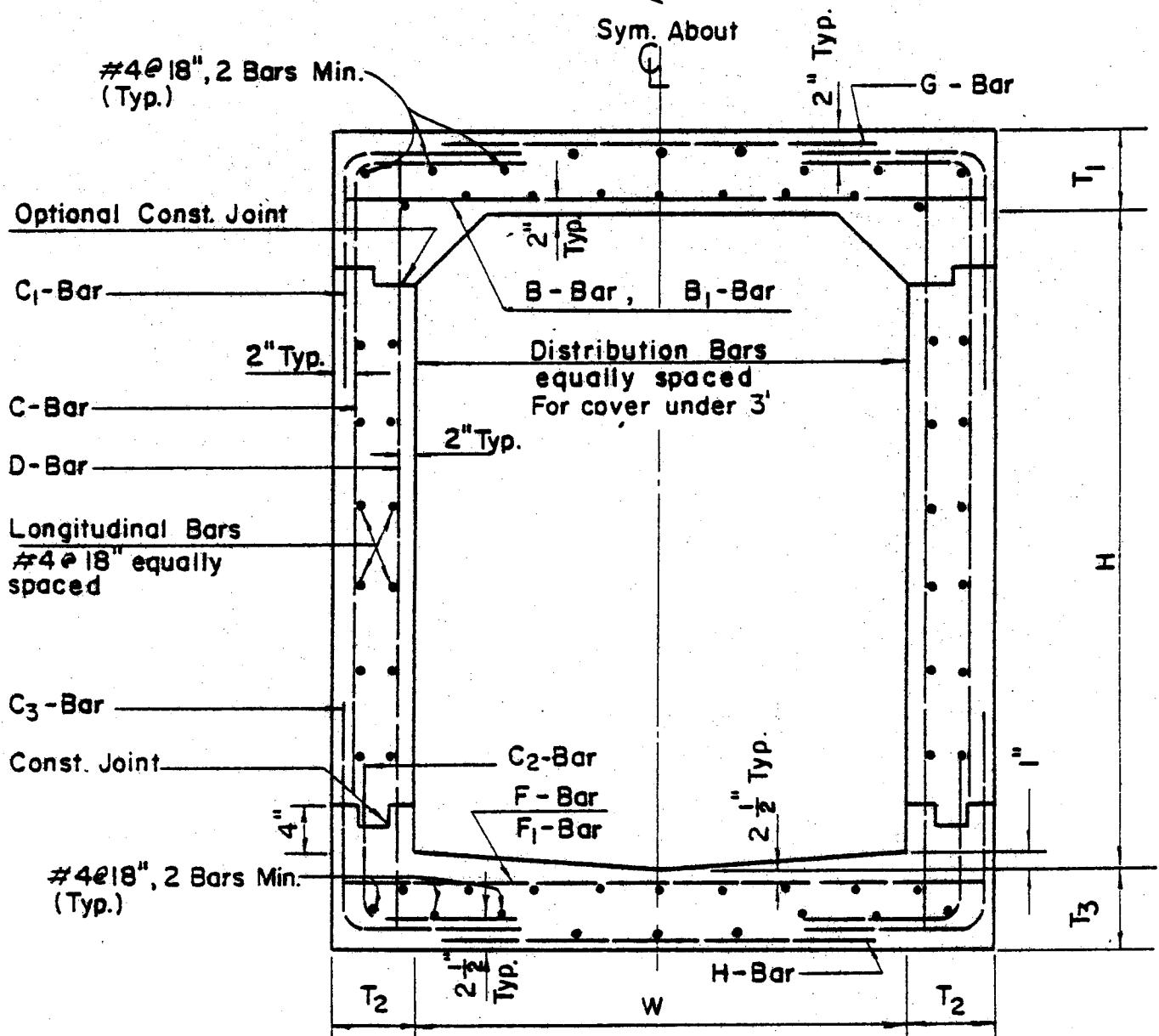
1. Stresses computed are: f_c - concrete compressive stress, f_s - reinforcement tensile stress, v = unit shearing stress, and u - bond stress.
2. Stresses are computed at all R.C. box corners based on the maximum negative moments.
3. Stresses are computed at midspan of the top and invert slabs based on the maximum positive moments.
4. Stresses are computed at the centerline of the walls based on maximum positive moment with axial load through the entire wall.

APPENDIX 1

Sample Problem:

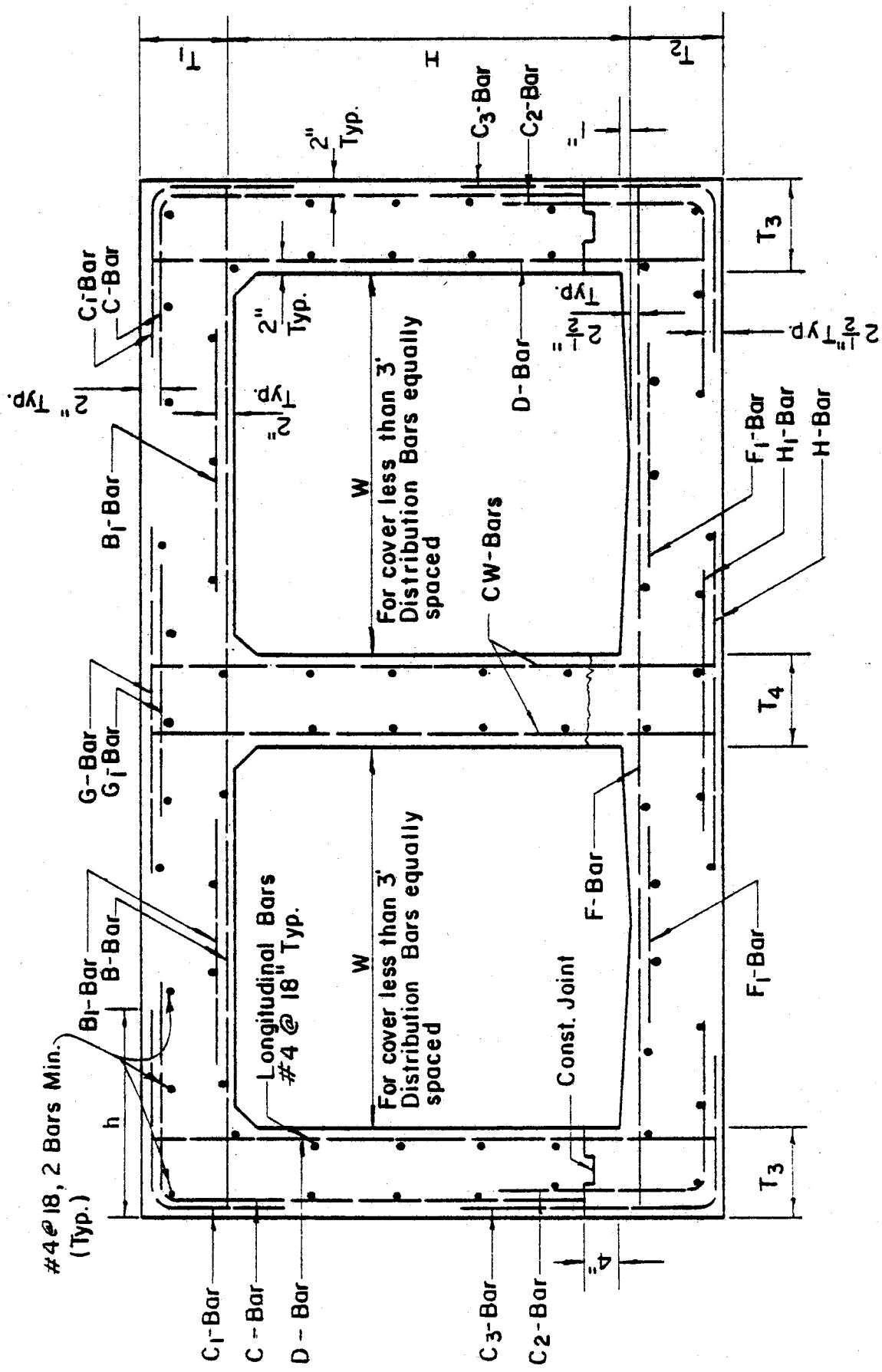
The input data and output values for the design of a 10'-0" wide by 12'-0" high single barrel reinforced concrete box conduit are shown.

The conduit is designed in accordance with District structural design criteria. The design earth cover is 8'-0" and the design live load is an A.A.S.H.O. H-20 S-16 44 truck. The output from the design phase was used as input data for the check phase.

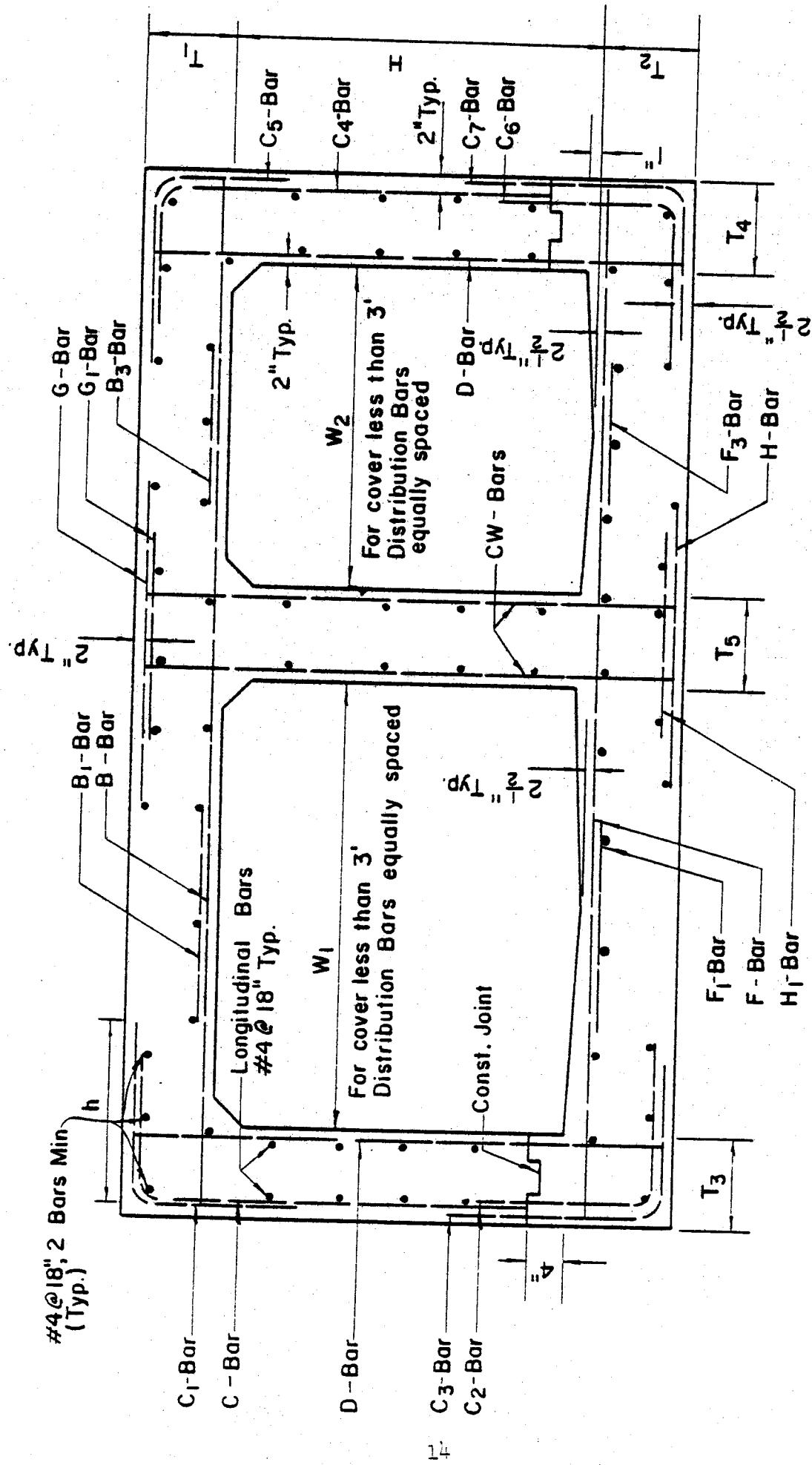


SCHEMATIC OF
SINGLE BOX

SCHEMATIC OF SYMMETRICAL DOUBLE BOX

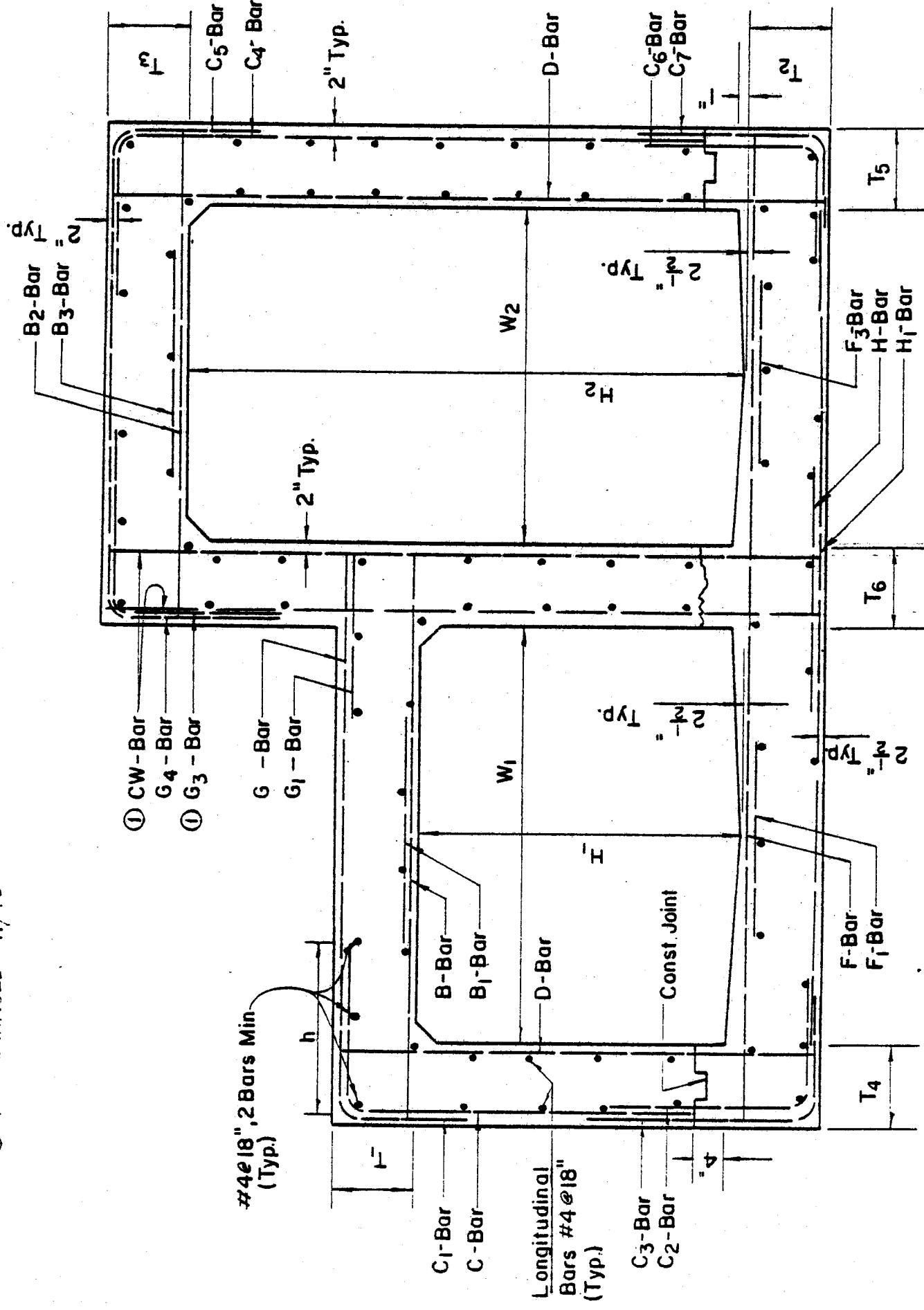


SCHEMATIC OF UNSYMMETRICAL DOUBLE BOX WITH UNEQUAL WIDTH

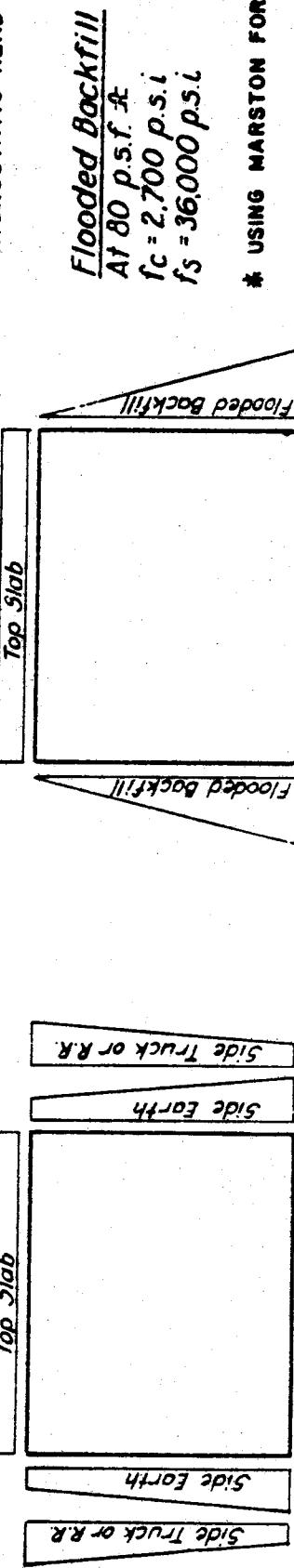
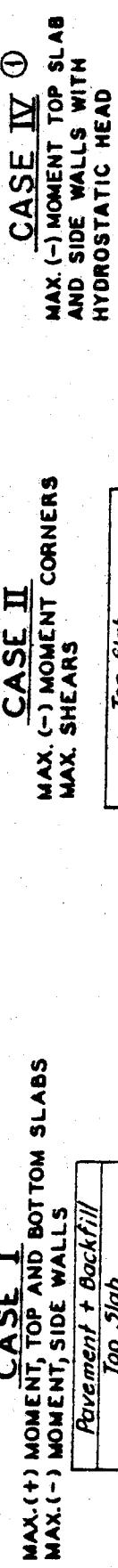
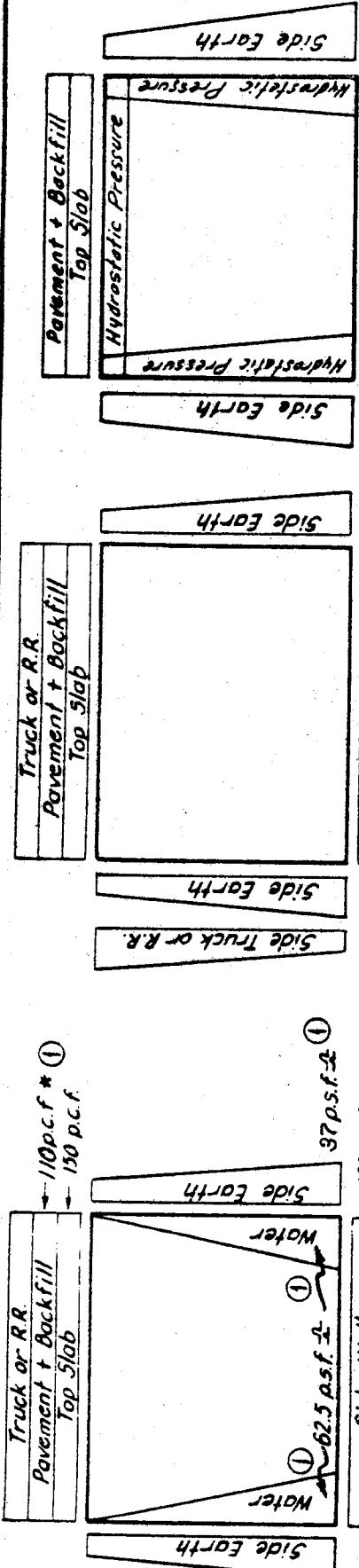


NOTE:

① WAS CHANGED 11/76



SCHEMATIC OF UNSYMMETRICAL DOUBLE BOX WITH UNEQUAL HEIGHT AND/OR WIDTH

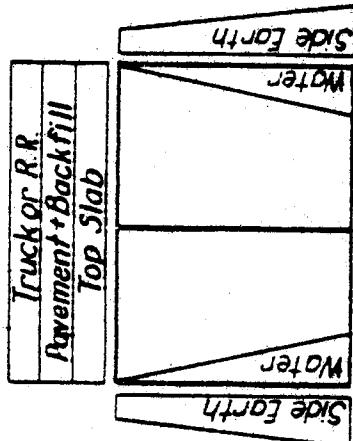
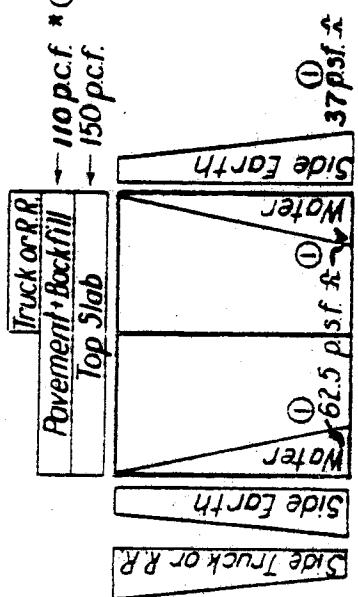


**STANDARD LOADING CONDITIONS
FOR DESIGN OF SINGLE
BARREL BOX CONDUIT**
L.A. COUNTY FLOOD CONTROL DISTRICT

- Note**
- (+) Indicates tension on inside of box.
 - (-) Indicates tension on outside of box.
 - ① Was changed 11/76

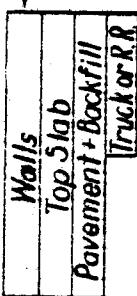
Special Conditions - All boxes

1. 0'-2' Cover, treat as bridge.
2. Box under hydrostatic head.



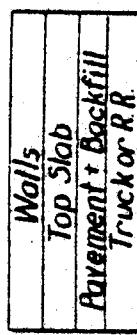
CASE II ①

MAX. (+) MOMENT, TOP AND BOTTOM SLABS.
MAX. (-) MOMENT, SIDE WALLS.
* USING MARSTON FORMULA



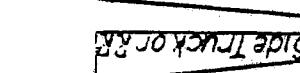
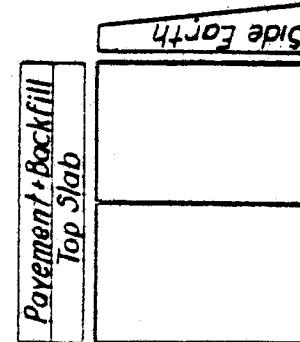
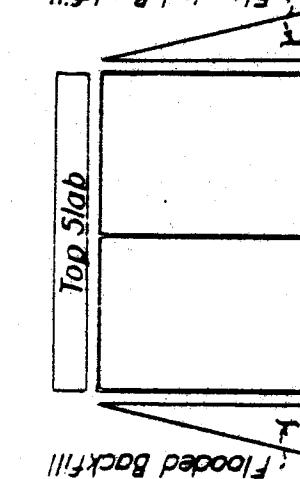
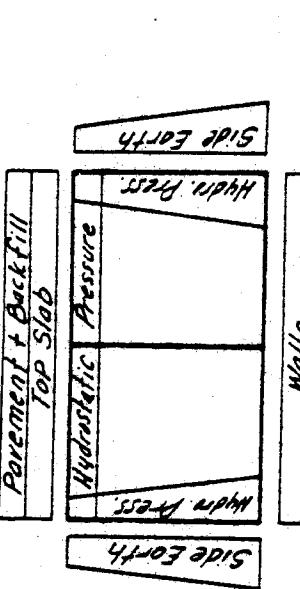
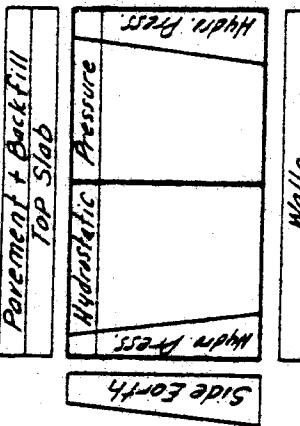
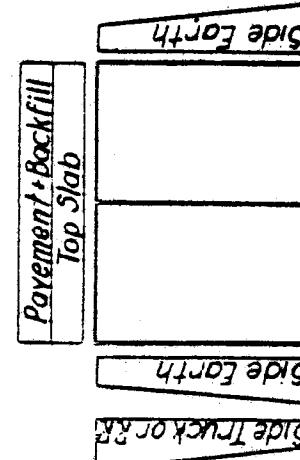
CASE I ①

MAX. (+) MOMENT, TOP AND BOTTOM SLABS AT CENTER WALLS.



CASE III ①

MAX. (-) MOMENT, CORNERS
MAX. SHEARS



Special Conditions - All Boxes

1. 0'-2' Cover, treat as bridge.
2. Box under hydrostatic head.

① Indicates tension on inside of box.

Note

(+) Indicates tension on outside of box.

(-) Indicates tension on outside of box.

(D) Changes in

CASE I ①
MAX. (-) MOMENT, TOP SLAB AND
SIDE WALLS. MAX. TENSION CENTER
WALL WHEN HYDRO. HEAD EXISTS.

CASE II ①
MAX. (+) MOMENT, TOP SLAB AND
SIDE WALLS. MAX. TENSION CENTER
WALL WHEN HYDRO. HEAD EXISTS.

CASE III ①
MAX. (-) MOMENT, CORNERS
MAX. SHEARS

CASE IV ①
MAX. (-) MOMENT, CORNERS
MAX. SHEARS

CASE V ①
MAX. (-) MOMENT, CORNERS
MAX. SHEARS

CASE VI ①
MAX. (-) MOMENT, CORNERS
MAX. SHEARS

CASE VII ①
MAX. (-) MOMENT, CORNERS
MAX. SHEARS

CASE VIII ①
MAX. (-) MOMENT, CORNERS
MAX. SHEARS

CASE IX ①
MAX. (-) MOMENT, CORNERS
MAX. SHEARS

CASE X ①
MAX. (-) MOMENT, CORNERS
MAX. SHEARS

**STANDARD LOADING CONDITIONS
FOR DESIGN OF DOUBLE
BARREL BOX CONDUIT**
L.A. COUNTY FLOOD CONTROL DISTRICT

BOX PROGRAM - INPUT FORM

Design Phase - Standard Criteria

SAMPLE PROBLEM FOR DESIGN MANUAL

BOX PROGRAM - INPUT FORM

Design Phase - Optional Criteria

TITLE									
RIGHT BARREL									
DEPTH TO FIN. GRADE	AXLE LOAD	PRESSURE HEAD	LEFT BARREL WIDTH	HEIGHT	RIGHT BARREL WIDTH	HEIGHT	NEGATIVE STEEL COVER INVERT SLAB (in)	POSITIVE STEEL COVER INVERT SLAB (in)	NEGATIVE STEEL COVER TOP SLAB (in)
012	010	008	006	004	002	000	000	000	000
123	101	079	057	035	013	000	000	000	000
234	212	190	168	146	124	000	000	000	000
345	323	301	279	257	235	000	000	000	000
456	434	412	390	368	346	000	000	000	000
567	545	523	501	479	457	000	000	000	000
678	656	634	612	589	567	000	000	000	000
789	767	745	723	700	678	000	000	000	000
890	868	846	823	800	777	000	000	000	000
901	880	858	836	813	789	000	000	000	000
1012	960	938	916	893	869	000	000	000	000
1113	1040	1018	996	973	949	000	000	000	000
1214	1120	1108	1086	1063	1039	000	000	000	000
1315	1202	1180	1158	1135	1111	000	000	000	000
1416	1284	1262	1240	1217	1193	000	000	000	000
1517	1366	1344	1322	1299	1275	000	000	000	000
1618	1448	1426	1404	1381	1357	000	000	000	000
1719	1530	1508	1486	1463	1439	000	000	000	000
1820	1612	1590	1568	1545	1521	000	000	000	000
1921	1694	1672	1650	1627	1603	000	000	000	000
2022	1776	1754	1732	1709	1685	000	000	000	000
2123	1858	1836	1814	1791	1767	000	000	000	000
2224	1940	1918	1896	1873	1849	000	000	000	000
2325	2022	2000	1978	1955	1931	000	000	000	000
2426	2104	2082	2060	2037	2013	000	000	000	000
2527	2186	2164	2142	2119	2095	000	000	000	000
2628	2268	2246	2224	2201	2177	000	000	000	000
2729	2350	2328	2306	2283	2259	000	000	000	000
2830	2432	2410	2388	2365	2341	000	000	000	000
2931	2514	2492	2470	2447	2423	000	000	000	000
3032	2596	2574	2552	2529	2505	000	000	000	000
3133	2678	2656	2634	2611	2587	000	000	000	000
3234	2760	2738	2716	2693	2669	000	000	000	000
3335	2842	2820	2798	2775	2751	000	000	000	000
3436	2924	2902	2880	2857	2833	000	000	000	000
3537	3006	2984	2962	2939	2915	000	000	000	000
3638	3088	3066	3044	3021	2997	000	000	000	000
3739	3170	3148	3126	3103	3079	000	000	000	000
3840	3252	3230	3208	3185	3161	000	000	000	000
3941	3334	3312	3290	3267	3243	000	000	000	000
4042	3416	3394	3372	3349	3325	000	000	000	000
4143	3498	3476	3454	3431	3407	000	000	000	000
4244	3580	3558	3536	3513	3489	000	000	000	000
4345	3662	3640	3618	3595	3571	000	000	000	000
4446	3744	3722	3700	3677	3653	000	000	000	000
4547	3826	3804	3782	3759	3735	000	000	000	000
4648	3908	3886	3864	3841	3817	000	000	000	000
4749	3990	3968	3946	3923	3899	000	000	000	000
4850	4072	4050	4028	4005	3981	000	000	000	000
4951	4154	4132	4110	4087	4063	000	000	000	000
5052	4236	4214	4192	4169	4145	000	000	000	000
5153	4318	4296	4274	4251	4227	000	000	000	000
5254	4390	4368	4346	4323	4299	000	000	000	000
5355	4472	4450	4428	4405	4381	000	000	000	000
5456	4554	4532	4510	4487	4463	000	000	000	000
5557	4636	4614	4592	4569	4545	000	000	000	000
5658	4718	4696	4674	4651	4627	000	000	000	000
5759	4790	4768	4746	4723	4699	000	000	000	000
5860	4872	4850	4828	4805	4781	000	000	000	000
5961	4954	4932	4910	4887	4863	000	000	000	000
6062	5036	5014	4992	4969	4945	000	000	000	000
6163	5118	5096	5074	5051	5027	000	000	000	000
6264	5190	5168	5146	5123	5099	000	000	000	000
6365	5272	5250	5228	5205	5181	000	000	000	000
6466	5354	5332	5310	5287	5263	000	000	000	000
6567	5436	5414	5392	5369	5345	000	000	000	000
6668	5518	5496	5474	5451	5427	000	000	000	000
6769	5590	5568	5546	5523	5499	000	000	000	000
6870	5672	5650	5628	5605	5581	000	000	000	000
6971	5754	5732	5710	5687	5663	000	000	000	000
7072	5836	5814	5792	5769	5745	000	000	000	000
7173	5918	5896	5874	5851	5827	000	000	000	000
7274	5990	5968	5946	5923	5899	000	000	000	000
7375	6072	6050	6028	6005	5981	000	000	000	000
7476	6154	6132	6110	6087	6063	000	000	000	000
7577	6236	6214	6192	6169	6145	000	000	000	000
7678	6318	6296	6274	6251	6227	000	000	000	000
7779	6390	6368	6346	6323	6300	000	000	000	000
7880	6472	6450	6428	6405	6381	000	000	000	000
7981	6554	6532	6510	6487	6463	000	000	000	000
8082	6636	6614	6592	6569	6545	000	000	000	000
8183	6718	6696	6674	6651	6627	000	000	000	000
8284	6790	6768	6746	6723	6699	000	000	000	000
8385	6872	6850	6828	6805	6781	000	000	000	000
8486	6954	6932	6910	6887	6863	000	000	000	000
8587	7036	7014	6992	6969	6945	000	000	000	000
8688	7118	7096	7074	7051	7027	000	000	000	000
8789	7190	7168	7146	7123	7099	000	000	000	000
8890	7272	7250	7228	7205	7181	000	000	000	000
8991	7354	7332	7310	7287	7263	000	000	000	000
9092	7436	7414	7392	7369	7345	000	000	000	000
9193	7518	7496	7474	7451	7427	000	000	000	000
9294	7590	7568	7546	7523	7499	000	000	000	000
9395	7672	7650	7628	7605	7581	000	000	000	000
9496	7754	7732	7710	7687	7663	000	000	000	000
9597	7836	7814	7792	7769	7745	000	000	000	000
9698	7918	7896	7874	7851	7827	000	000	000	000
9799	7990	7968	7946	7923	7899	000	000	000	000
9899	8072	8050	8028	8005	7981	000	000	000	000
9999	8154	8132	8110	8087	8063	000	000	000	000
0000	8236	8214	8192	8169	8145	000	000	000	000
0001	8318	8296	8274	8251	8227	000	000	000	000
0002	8390	8368	8346	8323	8299	000	000	000	000
0003	8472	8450	8428	8405	8381	000	000	000	000
0004	8554	8532	8510	8487	8463	000	000	000	000
0005	8636	8614	8592	8569	8545	000	000	000	000
0006	8718	8696	8674	8651	8627	000	000	000	000
0007	8790	8768	8746	8723	8699	000	000	000	000
0008	8872	8850	8828	8805	8781	000	000	000	000
0009	8954	8932	8910	8887	8863	000	000	000	000
0010	9036	9014	8992	8969	8945	000	000	000	000
0011	9118	9096	9074	9051	9027	000	000	000	000
0012	9190	9168	9146	9123	9099	000	000	000	000
0013	9272	9250	9228	9205	9181	000	000	000	000
0014	9354	9332	9310	9287	9263	000	000	000	000
0015	9436	9414	9392	9369	9345	000	000	000	000
0016	9518	9496	9474	9451	9427	000	000	000	000
0017	9590	9568	9546	9523	9499	000	000	000	000
0018	9672	9650	9628	9605	9581	000	000	000	000
0019	9754	9732	9710	9687	9663	000	000	000	000
0020	9836	9814	9792	9769	9745	000	000	000	000
0021	9918	9896	9874	9851	9827	000	000	000	000
0022	9990	9968	9946	9923	9899	000	000	000	000
0023	0072	0050	0028	0005	0027	000	000	000	000
0024	0154	0							

Box Program - Input Form
Check Phase

SAMPLE PROBLEM FOR DESIGN MANUAL											
		DEPTH TO FIN. GRADE		AXLE LOAD		PRESSURE HEAD		LEFT BARREL		RIGHT BARREL	
012	1	012	1	012	1	012	1	012	1	012	1
013	2	1	1	2	1	0	1	10	1	12	1
014	3	1	1	3	2	0	1	10	1	12	1
015	4	1	1	4	3	1	1	10	1	12	1
016	5	1	1	5	4	1	1	10	1	12	1
017	6	1	1	6	5	1	1	10	1	12	1
018	7	1	1	7	6	1	1	10	1	12	1
019	8	1	1	8	7	1	1	10	1	12	1
020	9	1	1	9	8	1	1	10	1	12	1
021	10	1	1	10	9	1	1	10	1	12	1
022	11	1	1	11	10	1	1	10	1	12	1
023	12	1	1	12	11	1	1	10	1	12	1
024	13	1	1	13	12	1	1	10	1	12	1
025	14	1	1	14	13	1	1	10	1	12	1
026	15	1	1	15	14	1	1	10	1	12	1
027	16	1	1	16	15	1	1	10	1	12	1
028	17	1	1	17	16	1	1	10	1	12	1
029	18	1	1	18	17	1	1	10	1	12	1
030	19	1	1	19	18	1	1	10	1	12	1
031	20	1	1	20	19	1	1	10	1	12	1
032	21	1	1	21	20	1	1	10	1	12	1
033	22	1	1	22	21	1	1	10	1	12	1
034	23	1	1	23	22	1	1	10	1	12	1
035	24	1	1	24	23	1	1	10	1	12	1
036	25	1	1	25	24	1	1	10	1	12	1
037	26	1	1	26	25	1	1	10	1	12	1
038	27	1	1	27	26	1	1	10	1	12	1
039	28	1	1	28	27	1	1	10	1	12	1
040	29	1	1	29	28	1	1	10	1	12	1
041	30	1	1	30	29	1	1	10	1	12	1
042	31	1	1	31	30	1	1	10	1	12	1
043	32	1	1	32	31	1	1	10	1	12	1
044	33	1	1	33	32	1	1	10	1	12	1
045	34	1	1	34	33	1	1	10	1	12	1
046	35	1	1	35	34	1	1	10	1	12	1
047	36	1	1	36	35	1	1	10	1	12	1
048	37	1	1	37	36	1	1	10	1	12	1
049	38	1	1	38	37	1	1	10	1	12	1
050	39	1	1	39	38	1	1	10	1	12	1
051	40	1	1	40	39	1	1	10	1	12	1
052	41	1	1	41	40	1	1	10	1	12	1
053	42	1	1	42	41	1	1	10	1	12	1
054	43	1	1	43	42	1	1	10	1	12	1
055	44	1	1	44	43	1	1	10	1	12	1
056	45	1	1	45	44	1	1	10	1	12	1
057	46	1	1	46	45	1	1	10	1	12	1
058	47	1	1	47	46	1	1	10	1	12	1
059	48	1	1	48	47	1	1	10	1	12	1
060	49	1	1	49	48	1	1	10	1	12	1
061	50	1	1	50	49	1	1	10	1	12	1
062	51	1	1	51	50	1	1	10	1	12	1
063	52	1	1	52	51	1	1	10	1	12	1
064	53	1	1	53	52	1	1	10	1	12	1
065	54	1	1	54	53	1	1	10	1	12	1
066	55	1	1	55	54	1	1	10	1	12	1
067	56	1	1	56	55	1	1	10	1	12	1
068	57	1	1	57	56	1	1	10	1	12	1
069	58	1	1	58	57	1	1	10	1	12	1
070	59	1	1	59	58	1	1	10	1	12	1
071	60	1	1	60	59	1	1	10	1	12	1
072	61	1	1	61	60	1	1	10	1	12	1
073	62	1	1	62	61	1	1	10	1	12	1
074	63	1	1	63	62	1	1	10	1	12	1
075	64	1	1	64	63	1	1	10	1	12	1
076	65	1	1	65	64	1	1	10	1	12	1
077	66	1	1	66	65	1	1	10	1	12	1
078	67	1	1	67	66	1	1	10	1	12	1
079	68	1	1	68	67	1	1	10	1	12	1
080	69	1	1	69	68	1	1	10	1	12	1
081	70	1	1	70	69	1	1	10	1	12	1
082	71	1	1	71	70	1	1	10	1	12	1
083	72	1	1	72	71	1	1	10	1	12	1
084	73	1	1	73	72	1	1	10	1	12	1
085	74	1	1	74	73	1	1	10	1	12	1
086	75	1	1	75	74	1	1	10	1	12	1
087	76	1	1	76	75	1	1	10	1	12	1
088	77	1	1	77	76	1	1	10	1	12	1
089	78	1	1	78	77	1	1	10	1	12	1
090	79	1	1	79	78	1	1	10	1	12	1
091	80	1	1	80	79	1	1	10	1	12	1
092	81	1	1	81	80	1	1	10	1	12	1
093	82	1	1	82	81	1	1	10	1	12	1
094	83	1	1	83	82	1	1	10	1	12	1
095	84	1	1	84	83	1	1	10	1	12	1
096	85	1	1	85	84	1	1	10	1	12	1
097	86	1	1	86	85	1	1	10	1	12	1
098	87	1	1	87	86	1	1	10	1	12	1
099	88	1	1	88	87	1	1	10	1	12	1
100	89	1	1	89	88	1	1	10	1	12	1
101	90	1	1	90	89	1	1	10	1	12	1
102	91	1	1	91	90	1	1	10	1	12	1
103	92	1	1	92	91	1	1	10	1	12	1
104	93	1	1	93	92	1	1	10	1	12	1
105	94	1	1	94	93	1	1	10	1	12	1
106	95	1	1	95	94	1	1	10	1	12	1
107	96	1	1	96	95	1	1	10	1	12	1
108	97	1	1	97	96	1	1	10	1	12	1
109	98	1	1	98	97	1	1	10	1	12	1
110	99	1	1	99	98	1	1	10	1	12	1
111	100	1	1	100	99	1	1	10	1	12	1
112	101	1	1	101	100	1	1	10	1	12	1
113	102	1	1	102	101	1	1	10	1	12	1
114	103	1	1	103	102	1	1	10	1	12	1
115	104	1	1	104	103	1	1	10	1	12	1
116	105	1	1	105	104	1	1	10	1	12	1
117	106	1	1	106	105	1	1	10	1	12	1
118	107	1	1	107	106	1	1	10	1	12	1
119	108	1	1	108	107	1	1	10	1	12	1
120	109	1	1	109	108	1	1	10	1	12	1
121	110	1	1	110	109	1	1	10	1	12	1
122	111	1	1	111	110	1	1	10	1	12	1
123	112	1	1	112	111	1	1	10	1	12	1
124	113	1	1	113	112	1	1	10	1	12	1
125	114	1	1	114	113	1	1	10	1	12	1
126	115	1	1	115	114	1	1	10	1	12	1
127	116	1	1	116	115	1	1	10	1	12	1
128	117	1	1	117	116	1	1	10	1	12	1
129	118	1	1	118	117	1	1	10	1	12	1
130	119	1	1	119	118	1	1	10	1	12	1
131	120	1	1	120	119	1	1	10	1	12	1
132	121	1	1	121	120	1	1	10	1	12	1
133	122	1	1	122	121	1	1	10	1	12	1
134	123	1	1	123	122	1	1	10	1	12	1
135	124	1	1	124	123	1	1	10	1	12	1
136	125	1	1	125	124	1	1	10	1	12	1
137	126	1	1	126	125	1	1	10	1	12	1
138	127	1	1	127	126	1	1	10	1	12	1
139	128	1	1	128	127	1	1	10	1	12	1
140	129	1	1	129	128	1	1	10	1	12	1
141	130	1	1	130	129	1	1	10	1	12	1
142	131	1	1	131	130	1	1	10	1	12	1
143	132	1	1	132	131	1	1	10	1	12	1
144	133	1	1	133	132</						

SAMPLE PROBLEM DESIGN OUTPUT

LOS ANGELES COUNTY FLOOD CONTROL DISTRICT

DESIGN DIVISION
DESIGN OF SINGLE BARREL REINFORCED CONCRETE BOX
BARREL # 1

SAMPLE PROBLEM FOR DESIGN MANUAL

10.00 WIDE BY 12.00 HIGH	DESIGN COVER 8.0 FT
TYPE INSTALLATION TRENCH	
PROJECTION RATIO 0.0	SOIL DENSITY .110 KCF
LTVF LOAD TRUCK	AXLE LOAD 32.0 KIPS
TOTAL DESIGN VERTICAL LOAD TOP 13.23 KIPS	INVERT 14.50 KIPS
PRESSURF HEAD 0.0 FT	
DESIGN STRESSFS FC = 1800. PSI	FS = 24000. PSI

THICKNESSES (IN) TOP 8.75 INV(C.L.) 9.75 LW 8.00 RW 8.00

STEEL LAYOUT				
BAR DESIGNATION	BAR SIZE	BAR SPACING (IN)	HORIZONTAL LENGTH (FT)(IN)	VERTICAL LENGTH (FT)(IN)
B	7.	10.0	11. 1.0	0. 0.0
B1	4.	10.0	5. 11.5	0. 0.0
C	4.	11.0	4. 2.5	12. 2.0
C1	6.	11.0	2. 0.5	2. 10.0
C2	4.	11.0	4. 2.5	2. 3.0
C3	6.	11.0	2. 8.5	2. 5.0
D	5.	11.0	0. 0.0	13. 3.5
F	9.	14.0	11. 1.0	0. 0.0
F1	5.	14.0	6. 2.5	0. 0.0
G	4.	11.0	5. 0.0	0. 0.0
H	4.	11.0	5. 0.0	0. 0.0

LONGITUDINAL BARS 66. NO. 4 BARS
IN TOP SLAB 17. IN INVERT SLAB 17. IN WALLS 32.

QUANTITIES
CONCRETE 1.26 CU. YDS./FT. REINFORCING STEEL 217.2 LBS./FT.

INPUT DATA & DESIGN CRITERIA:

8.00000	8.00000	32.00000	0.0	10.00000
12.00000	6.50000	7.00000	8.00000	2.00000
2.50000	2.00000	2.00000	2.50000	2.00000
3.00000	0.70000	-0.50000	0.15000	4000.00000
1800.00000	60000.00000	24000.00000	8.00000	500.00000
70.00000	0.11000	350.00000	0.03700	

SAMPLE PROBLEM CHECK OUTPUT

SAMPLE PROBLEM FOR DESIGN MANUAL

CASE NUMBER 1

RESULTANT STRESSES (P.S.I.)

	CONCRETE	RE-STEEL	UNIT SHEAR	BOND
--	----------	----------	------------	------

TOP SLAB

CORNER	680.	12196.	68.0	235.0
MIDSPAN	1594.	23635.		

WALL

TOP	775.	12959.	17.9	61.5
CENTERLINE	0.	0.		
BOTTOM	622.	10400.	11.8	38.4

INVERT SLAB

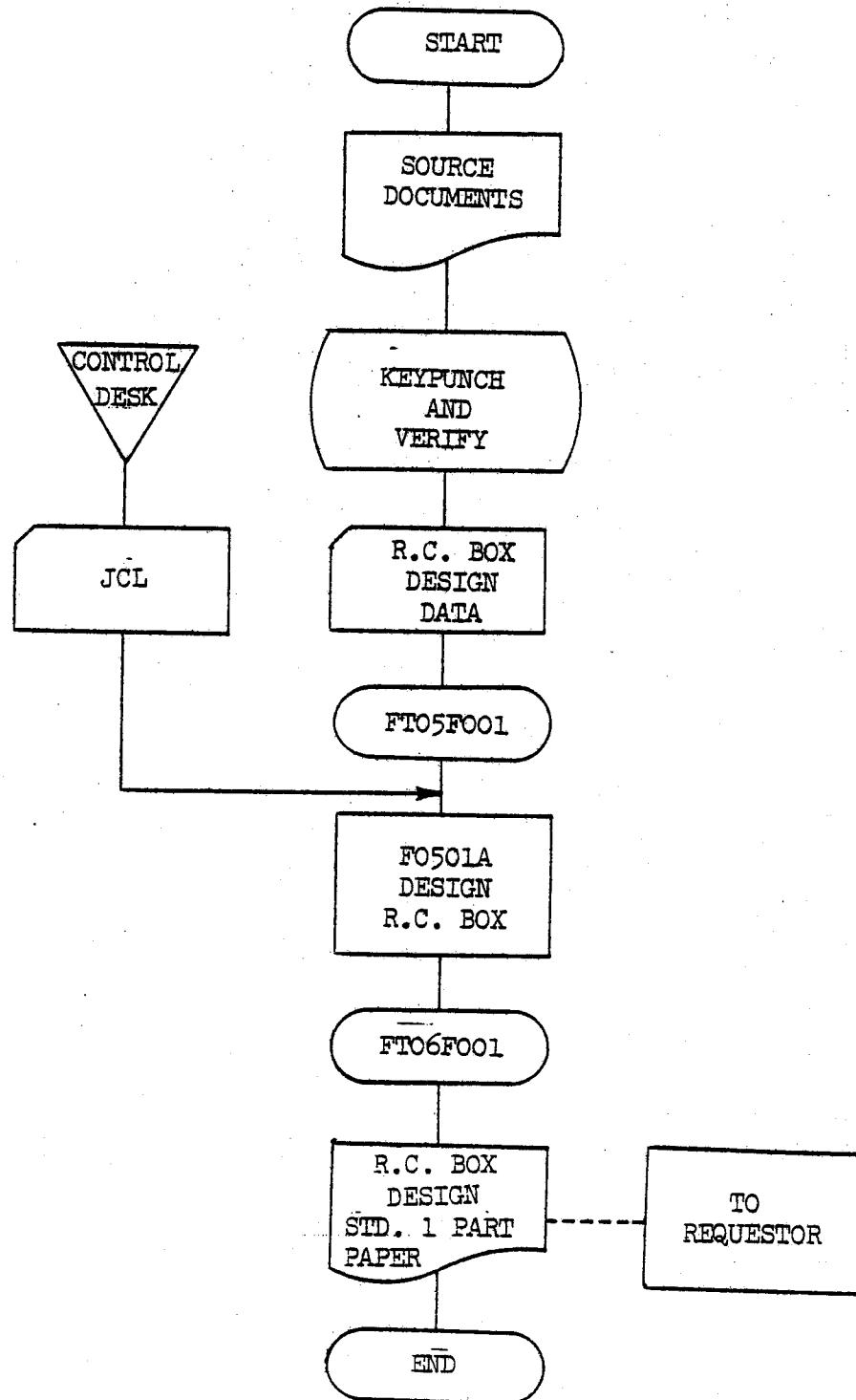
CORNER	463.	8662.	68.8	238.9
MIDSPAN	1642.	23176.		

NOTE:

SIMILAR SHEET IS PRODUCED FOR EACH
LOADING CASE.

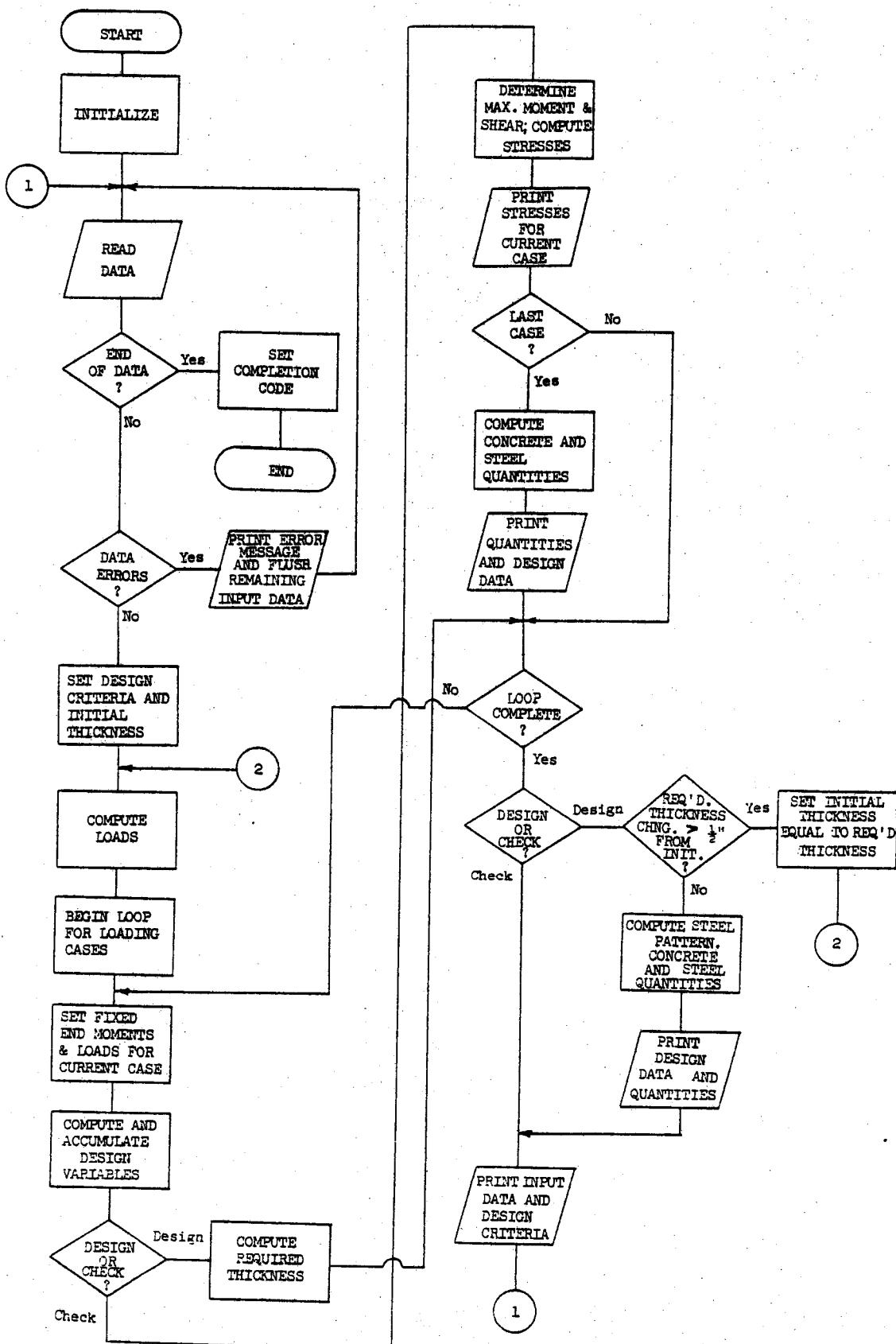
REINFORCED CONCRETE BOX DESIGN AND CHECK

SYSTEM FLOWCHART



REINFORCED CONCRETE BOX DESIGN AND CHECK

GENERAL FLOWCHART



JOB CONTROL LANGUAGE

REINFORCED CONCRETE BOX DESIGN AND CHECK (F0501A)
JCL LISTING TO COMPILE LINK-EDIT AND GO
/*PRIORITY 9
//F0501T JOB (0400,A108),'G L WALTON,400-19N',PRTY=9,CLASS=F
// EXEC FORTGCLG,PARM.FORT=(MAP, ID),
// COND.GO=((7,LT,FORT),(8,LT,LKED)) 1
//FORT.SYSIN DD * SOURCE DECKS FOLLOW
/* END OF SOURCE DECKS
//LKED,MODLIB DD DSN=SYSAF.FLOODLIB,DISP=OLD
//LKED.SYSIN DD * LINKAGE EDITOR CONTROL CARDS FOLLOW
INCLUDE MODLIB(F0501A)
INSERT MAIN,PAGEHD,TODAY,ROUND,MAXVAL
INSERT SEARCH
OVERLAY A
INSERT LOADER
INSERT SYMBOX
INSERT BONDFI
OVERLAY A
INSERT DESIG
INSERT BOND
INSERT DBLBOX
INSERT TOPBOT
INSERT RSTEEL
OVERLAY B
INSERT CAS1
INSERT MOD1
INSERT SGLBOX
OVERLAY B
INSERT CASS2
INSERT MODS2
OVERLAY B
INSERT CASN2
INSERT MODN2
OVERLAY A
INSERT MASTER
INSERT BB1
INSERT CC1G
INSERT D
INSERT GG1
INSERT BRON
ENTRY MAIN
/* END OF LINKAGE EDITOR CONTROL CARDS
//GO.SYSIN DD * DATA CARDS FOLLOW
/* END OF DATA CARDS

REINFORCED CONCRETE BOX DESIGN AND CHECK (F0501A)
JCL LISTING TO STORE OBJECT MODULE IN LIBRARY

```
*PRIORITY 9
//F0501T1 JOB (0400,A108), 'G L WALTON, 400-19N', PRTY=9, CLASS=F
//      EXEC FORTGCL, PARM.FORT=(MAP, ID), COND.IKED=(3, LT, FORT),      1
//  SYSIMOD='SYSAF.FLOODLIB(F0501A)', LMODISP=OLD
//FORT.SYSIN      DD * SOURCE DECKS FOLLOW
/* END OF SOURCE DECKS
//IKED.MODLIB     DD DSN=SYSAF.FLOODLIB, DISP=OLD
//IKED.SYSIN      DD * LINKAGE EDITOR CONTROL CARDS FOLLOW
INCLUDE MODLIB(F0501A)
INSERT MAIN, PAGEHD, TODAY, ROUND, MAXVAL
INSERT SEARCH
OVERLAY A
INSERT LOADER
INSERT BONDFI
INSERT SYMBOX
OVERLAY A
INSERT DESIG
INSERT BOND
INSERT DBLBOX
INSERT TOPBOT
INSERT RSTEEL
OVERLAY B
INSERT CAS1
INSERT MOD1
INSERT SGLBOX
OVERLAY B
INSERT CASS2
INSERT MODS2
OVERLAY B
INSERT CASN2
INSERT MODN2
OVERLAY A
INSERT MASTER
INSERT BB1
INSERT CC1G
INSERT D
INSERT GGI
INSERT BRION
ENTRY MAIN
/* END OF LINKAGE EDITOR CONTROL CARDS
```

REINFORCED CONCRETE BOX DESIGN AND CHECK (FO501A)

JCL LISTING TO EXECUTE OBJECT MODULE

```
11   (0400,A108), 'DESIGN,409-900', CLASS=F, PRIV=11
      DSN=SYSAF.FLOODLIB,DISP=SHR
      PGM=FO501A
      EXEC  SYSOUT=A
      DD    * DATA CARDS FOLLOW
      DD
      //F106FO01 DD
      //F105FO01 DD
      /* END OF DATA CARDS
```

/*PRIORITY

//FO501P JOB

DD //JOBLIB

EXEC //F106FO01

DD //F105FO01

DD /* END OF DATA CARDS

F0501FO0

F0501P01

F0501P02

F0501P03

F0501P04

F0501P05

F0501P06

Structural Design of
Reinforced Concrete
Open Rectangular Channel

Computer Program No. 0502

Purpose:

The purpose of Program No. 0502 is to furnish complete structural details, including quantities, for the construction of symmetrical rectangular reinforced concrete channels.

Scope:

The calculations and structural details furnished are for a "U" channel. The walls are designed as cantilever members and the slab is designed as a series of beams on an elastic foundation. Thicknesses of members are calculated, steel patterns developed, and concrete and reinforcing steel quantities calculated.

Procedure:

The program is basically divided into three parts: (1) calculation of design variables for walls, (2) calculation of design variables for the slab, and (3) development of the steel layout and calculation of quantities.

Two loading cases are analyzed: (1) channel empty and (2) channel flowing full. For the case with the channel empty, a triangular load based on an equivalent fluid pressure of 62.5 p.s.f. is imposed. For the case with the channel flowing full, the design is based on a net triangular outward load of 40 p.s.f. equivalent fluid pressure.

The slab is designed as a beam on an elastic foundation subjected to concentrated loads and applied moments. Equations used for soil pressure distribution and moment determination are based on the theory presented by M. Hetenyi³. The equations are for a beam of uniform moment of inertia and finite length. The moment of inertia used in these equations is based on the slab thickness at the inside face of the wall. In actuality, the thicknesses at the wall and center line are computed to provide balanced design, except where minimums control, and the slab varies uniformly between these points. The slab thickness at the face of the wall is initialized at a value equal to the thickness of the base of the wall plus one-half inch; an iterative routine is introduced to develop final thicknesses.

Design variables at the ends and tenth points of the walls and ends and twentieth points of the slabs are calculated and stored. These values will be printed only if the number 2 appears in the first card column of the first data card.

Three steel patterns are developed: one for the earth faces of the wall and slab, one for the channel face of the wall, and one for the channel face of the slab. For each pattern, 250 layouts representing various combinations of bar sizes and spacing are developed. Each layout is basically a three-bar layout. Utilizing various parameters, such as minimum bar size, maximum bar size, minimum and maximum bar spacing, and least weight, the optimum pattern is selected and listed in the output.

The number of longitudinal bars is calculated and listed in the output. The number of longitudinal bars is based on an 18-inch spacing in each reinforced face. Where transverse reinforcing steel terminates in the earth face of the invert slab, longitudinal bars are not placed beyond the end of this steel.

Concrete and reinforcing steel quantities are calculated and listed in the output.

Design Criteria:

The basic District design criteria¹ are set internally, and cannot be modified by the user. The criteria are listed below:

<u>Description</u>	<u>Value</u>
Allowable Concrete Stresses	1,800 p.s.i.
Allowable Steel Stress	24,000 p.s.i.
Modular Ratio	8
Uniform Inward Load	0
Triangular Inward Load	62.5 p.s.f. Equiv. Fluid Pressure
Triangular Outward Load	40.0 p.s.f. Equiv. Fluid Pressure
Steel Cover to Center Line of Bar	
Wall, Inside	2.0"
Wall, Outside	2.0"
Slab, Inside	2.5"
Slab, Outside	2.5"
Foundation Modulus	165.0 p.s.f.

Input Data:

Only two cards are required.

Card No. 1 Title Card - Card Column No. 1 - 1 if design variables are not to be printed, 2 if they are to be printed.

Starting from card Column No. 2, the spaces may be used in any desired manner for the title of the project, name of the engineer, etc.

Card No. 2 Data Card - Card Column No. 1 through 7 - Channel width in feet.

Card Column No. 8 through 14 - Channel height in feet. Height is measured at inside face of wall.

Refer to Appendix 2 for sample input sheet.

Output Description:

The output lists the following data:

1. Design variables (optional).
2. Title card.
3. Member thicknesses.
4. Size spacing, vertical length, and horizontal length of transverse steel.
5. Number of longitudinal bars in walls, slab, and section.
6. Concrete and steel quantities.
7. Principal design criteria.

Refer to Appendix 2 for sample output sheet.

Detailed Computer Procedure:

The program consists of three basic parts: (1) MAIN, Design of Walls, (2) PART 2, Design of Slab, and (3) PART 3, Steel layout and quantities. The following is a summary of the steps followed in the program:

MAIN

1. Read basic input.
2. Calculate wall thickness.
3. Increment loading cases.
4. Calculate design variables for wall.
5. Print design variables for wall (if requested).
6. Call for PART 2, slab design.
7. Call for PART 3, steel layout and quantities.
8. Print output.

PART 2

1. Calculate loads and moments on slab.
2. Increment loading cases.

3. Calculate slab thicknesses.
4. Calculate design variables for slab.
5. Print design variables for wall (if requested).

PART 3

1. Increment cases for steel patterns.
 - 1 - Earth face, wall
 - 2 - Earth face, slab
 - 3 - Channel face, wall
 - 4 - Channel face, slab
2. Set constants for each case.
3. Increment steel spacing.
4. Increment Bar No. 1.
5. Increment Bar No. 2.
6. Calculate Bar No. 3.
7. Calculate cutoff points.
8. Calculate lengths.
9. Calculate weight of pattern.
10. Check for optimum pattern.
11. Calculate longitudinal bars.
12. Calculate quantities.

APPENDIX 2

Sample Problem:

The design of an 11'-0" by 18'-0" wide channel is illustrated.

The input data for this section are on two cards - a title card and a card indicating the width and height of the section. The input and output data are shown.

OPEN RECTANGULAR CHANNEL INPUT SHEET

COMPUTER PROGRAM NO. F0502

Project No. _____

Division _____

Data entered by _____

Checked by _____

Date _____
E-mail _____

Ext. No. 52562-A 52562-B

Prog. No. 0502A 0502P

Prog. No. 0502A 0502P 0502B

CARD NO. I

TITLE CARD

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44
0571

CARD NO. 2

CARD NO. 1

TITLE CARD

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44
0 5 7 1

CARD NO. 2

CARD NO. 1

TITLE CARD

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44
0 5 7 |

CARD NO. 2

CARD NO. I

TITLE CARD

0571

CARD NO. 2

SAMPLE PROBLEM DESIGN OUTPUT

LOS ANGELES COUNTY FLOOD CONTROL DISTRICT

*** DESIGN DIVISION ***

18.00 WIDE BY 11.00 HIGH RECTANGULAR R.C. CHANNEL

SAMPLE PROBLEM

THICKNESSES

TOP OF WALL	8.00 INS.
BASE OF WALL	9.00 INS.
SLAB AT CENTER LINE	9.00 INS.
SLAB AT FACE OF WALL	9.25 INS.

*** STEEL LAYOUT ***

BAR DESIGNATION	BAR SIZE	BAR SPACING INS.	HORIZONTAL LENGTH FT.	HORIZONTAL LENGTH INS.	VERTICAL LENGTH FT.	VERTICAL LENGTH INS.
B-1	4	10.00	6.	6.75	11.	5.25
B-2	5	10.00	5.	3.50	5.	8.50
B-3	6	10.00	3.	7.25	3.	5.50
B-4	4	16.00	0.	11.50	11.	5.25
B-5	5	16.00	0.	11.50	5.	8.75
B-6	6	16.00	0.	11.50	3.	5.75
B-7	4	9.00	20.	3.00		
B-8	4	9.00	6.	1.75		
B-9	4	9.00	4.	2.75		

61 NO. 4 LONGITUDINAL BARS
29 IN SLAB 32 IN WALLS

QUANTITIES

R. CONCRETE 1.15 CU. YDS./FT.
RE-STEEL 192.1 LBS./FT.

DESIGN CRITERIA

FC = 1800. P.S.I.
FS = 24000. P.S.I.

N = 8.

LATERAL LOAD

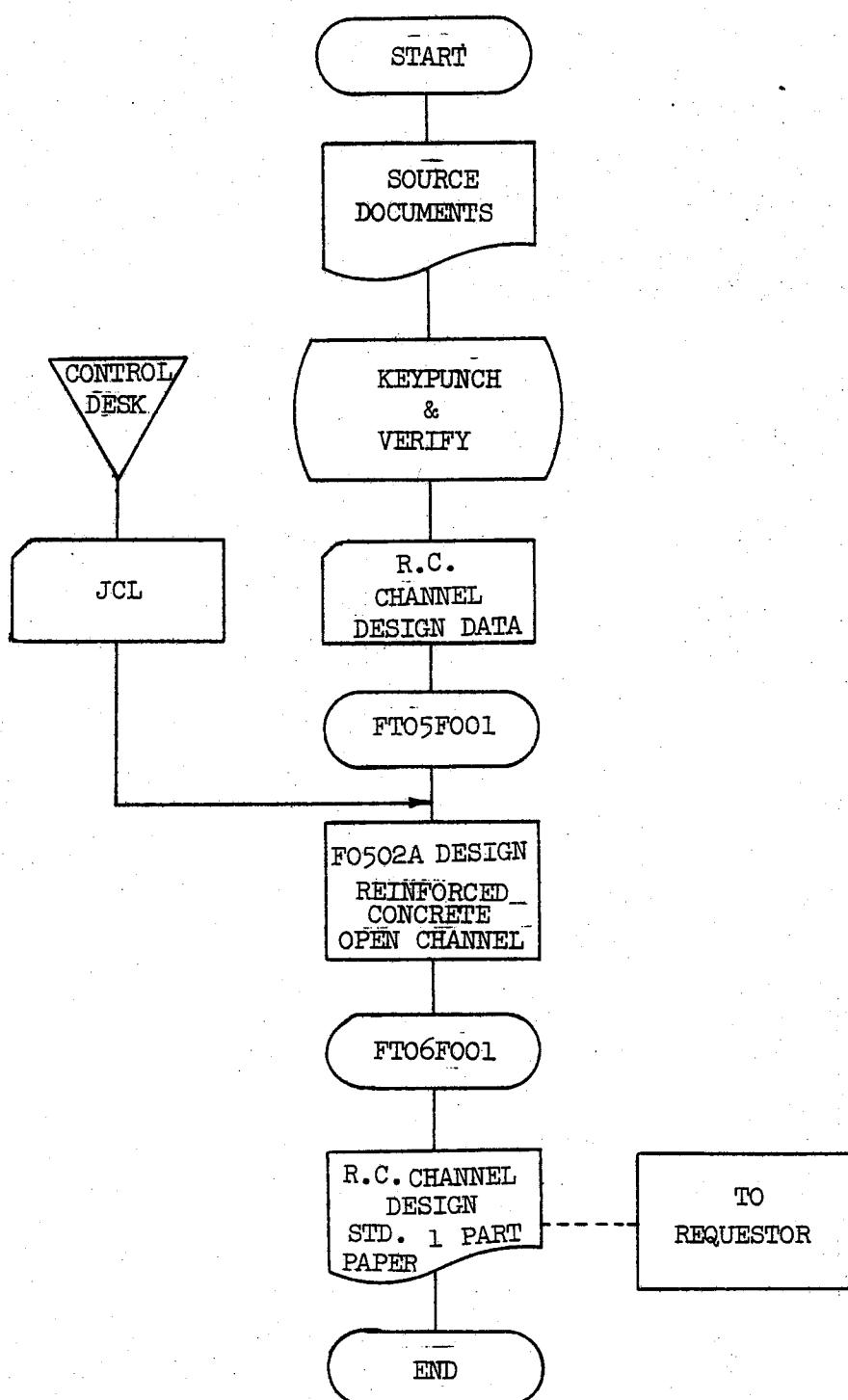
OUTWARD (NET) = 40.0 P.S.F. E.F.P.R.
INWARD (TRI.) = 62.5 P.S.F. E.F.P.R.
(UN.) = 0.0 P.S.F.

STEEL COVER (INS. TO CENTER LINE OF BAR)

WALL INSIDE = 2.00 WALL OUTSIDE = 2.00
SLAB TOP FACE = 2.50 SLAB LOWER FACE = 2.50

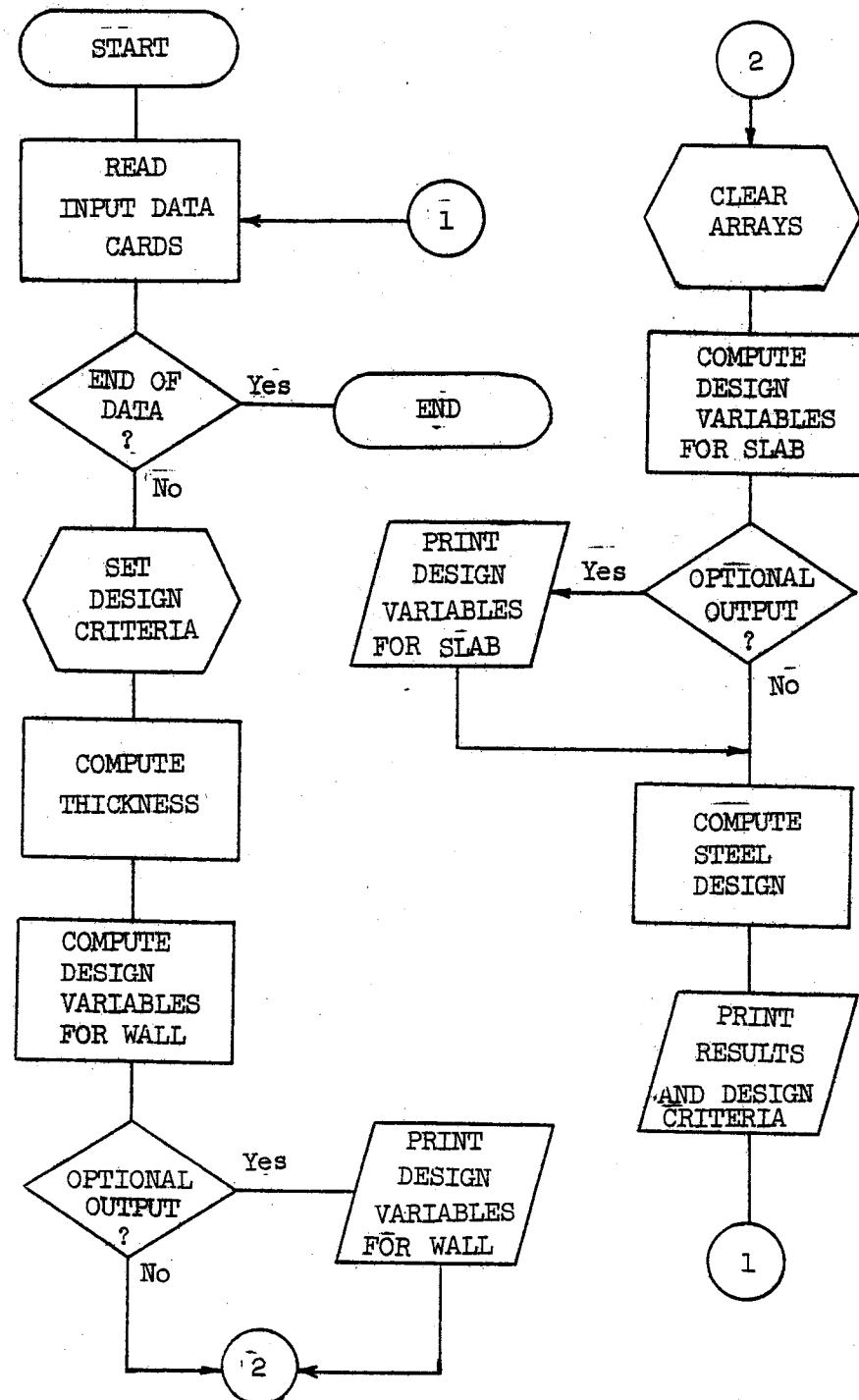
REINFORCED CONCRETE OPEN CHANNEL DESIGN

SYSTEM FLOWCHART



REINFORCED CONCRETE OPEN CHANNEL DESIGN

GENERAL FLOWCHART



JOB CONTROL LANGUAGE

R. C. OPEN CHANNEL DESIGN (F0502A)
JCL LISTING TO COMPILE LINK- EDIT AND GO
//FO502T JOB (0400,A108),'J. COSTA,400-18N',PRTY=9,CLASS=F
 EXEC FORTGCLG, PARM.FORT=(BCD,MAP,TD),COND.GO=(7,LT,FORT)
//FORT.SYSIN DD * SOURCE DECKS FOLLOW
/* END OF SOURCE DECKS
//GO.SYSIN DD * DATA CARDS FOLLOW
/* END OF DATA CARDS

R. C. OPEN CHANNEL DESIGN (F0502A)
JCL LISTING TO STORE OBJECT MODULE IN LIBRARY
/*PRIORITY 9
//FO502T1 JOB (0400,A108), 'COSTA,400-18N',PRTY=9,CLASS=F
 EXEC FORTGCL, PARM.FORT=(MAP, ID,BCD),COND.IKED=(3,LT,FORT), 1
 SYSIMOD='SYSAF.FLOODLIB(F0502A)',LMODISP=OLD
//FORT.SYSIN DD * SOURCE DECKS FOLLOW
/* END OF SOURCE DECKS

R. C. OPEN CHANNEL DESIGN (F0502A)
JCL LISTING TO EXECUTE OBJECT MODULE
/*PRIORITY 11
//FO502P1 JOB (0400,A108), 'DESIGN,409-900', PRTY=11, CLASS=D
 DSN=SYSAF.FLOODLIB,DISP=SHR
 EXEC PGM=F0502A
//FT06FO01 DD SYSOUT=A
//FT05FO01 DD * DATA CARDS FOLLOW
/* END OF DATA CARDS

F0502P00
F0502P01
F0502P02
F0502P03
F0502P04
F0502P05
F0502P06

Structural Design of
Reinforced Concrete Arch Sections
Computer Program No. 0504

Purpose:

The purpose of Program No. 0504 is to furnish or check required concrete thicknesses, bar perimeters, steel areas, etc., for horseshoe-shaped reinforced concrete arch sections.

Scope:

The program is essentially a two-phase procedure: a design phase and a check phase. The output consists of design variables at 15 set sections around the perimeter of the half-section. The design variables are moment, thrust, shear, thickness, concrete stress, unit shear, perimeter required, area of compressive steel, and area of tensile steel.

The design phase of the program will adjust thicknesses to meet design criteria; the check phase bypasses the routine for establishing thicknesses, calculating moments and thrusts based on original thickness.

At the present time the program is applicable to two types of sections: (1) a horseshoe exterior with horseshoe interior, and (2) a horseshoe exterior with circular interior. Essentially all allowable stresses, steel, covers, loads, etc., are input values.

Procedure:

The design is based on the elastic theory and the method of analysis is that set forth in "Analysis of Arches, Rigid Frames and Sewer Sections" publication ST-53 of the Portland Cement Association⁴. The program is basically divided into three parts: (1) calculation of the geometric properties of the section, (2) calculation of moments, shears, and thrusts, and (3) calculation of final thickness, unit shear, perimeter, and steel areas at 15 points along the perimeter of the half-section.

The present status of this program is such that the engineer's judgment is required if an economical section is to be obtained. In the design phase of this program, final thicknesses are derived. Initial thicknesses are entered as input and an iterative routine is introduced to arrive at thicknesses that will result in a balanced design. There are, of course, infinite combinations of crown, side and invert thickness that will meet this requirement. The determined thicknesses will depend to a large extent on the initial thicknesses set as input; therefore, unless the engineer has considerable experience in setting the initial values, it will be necessary to run the program several times if economical and practical sections are to be obtained.

Design Criteria:

The design procedure and criteria are those set forth in the District Structural Design Manual; however, in order to maintain a degree of flexibility the following criteria are input requirements and are therefore, variable: allowable concrete stress, allowable reinforcing steel stress, modular ratio, and concrete cover on reinforcing steel.

Input Data:

The following input data is required (for format, sequence, etc., refer to the input form in Appendix 3):

<u>Symbol</u>	<u>Name</u>
R	Radius (Ft)
T1	Crown thickness (Ins.)
T2	Spring line thickness (Ins.)
T3	Invert thickness (Ins.)
AN	Angle to tangent (Deg.)
Osl	Center line offset (Ins.)
XSC1	Steel cover, arch inside (Ins.)
XSC2	Steel cover, arch outside (Ins.)
XSC3	Steel cover, invert inside (Ins.)
XSC4	Steel cover, invert outside (Ins.)
XCONC	Allowable concrete stress (p.s.i.)
XSTL	Allowable steel stress (p.s.i.)
EVLD	Vertical load (k.s.f.)
XLATT	Uniform lateral load (k.s.f.)
XLATP	Triangular lateral load (k.s.f.)
XIWAT	Internal water (k.c.f.)
XPRHD	Pressure head (Ft.)
XZN	Modular ratio
ATY	Section to be run 1 - Horseshoe 2 - Circular 3 - Both
LD	1-in Col. 62 for checking, blank in Co. 62 for design

Output Description:

The output lists the following data at each point:

Location designation
Moment
Thrust
Shear

~~Member thickness
Concrete stress
Unit shear
Perimeter
Compression steel area
Tensile steel area~~

~~The location of each point is set internally for each type section.
Refer to the sketches in Appendix 3 for the location of points 1 through
15.~~

~~The design and load criteria are printed.~~

~~A typical output sheet is shown in Appendix 3.~~

APPENDIX 3

Sample Problem:

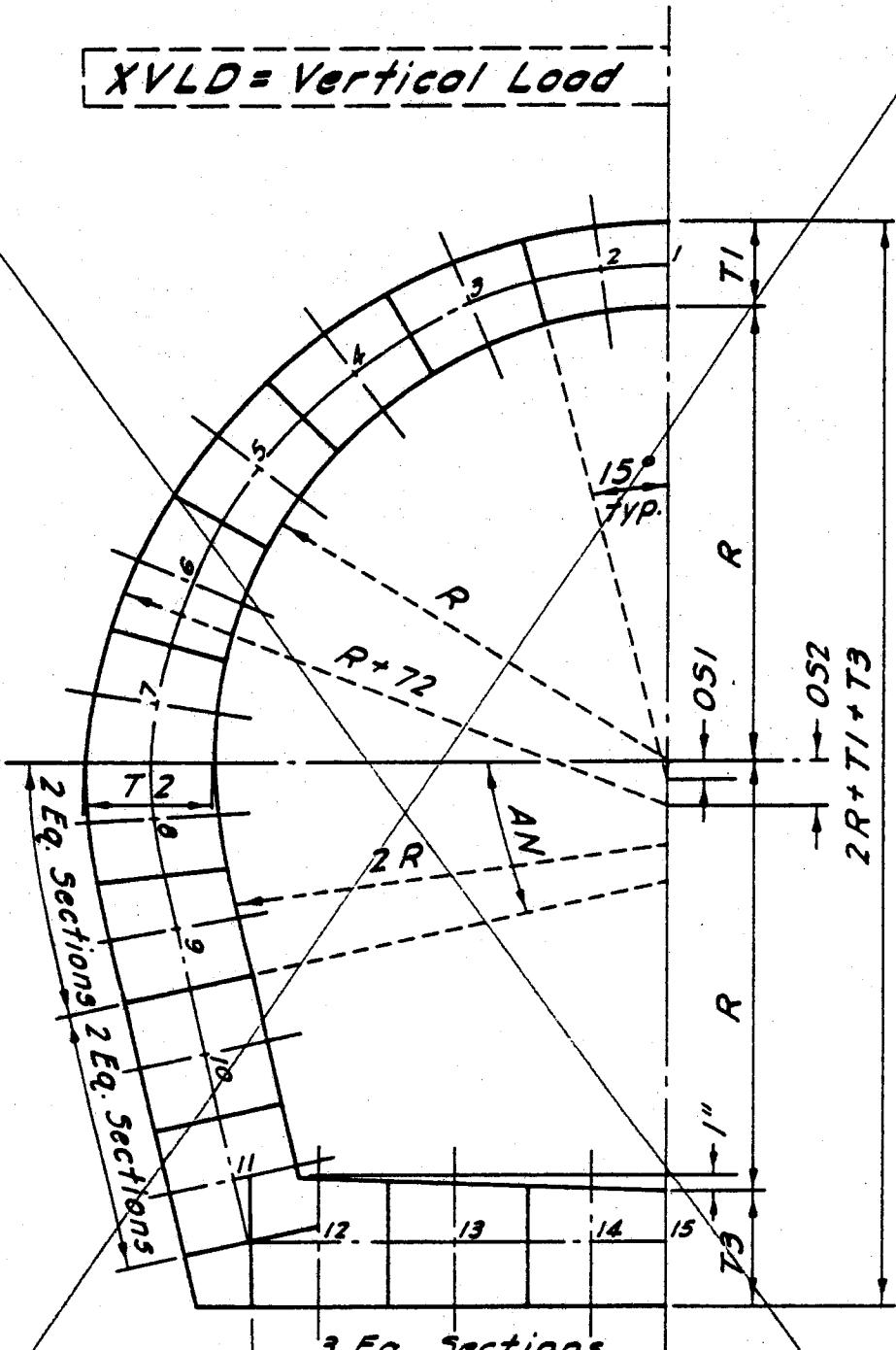
The design of a 12'-0" horseshoe arch with either a circular or a horseshoe interior is shown, including input data and output values.

The arch is designed in accordance with the following criteria:

Allowable concrete stress	1,800 p.s.i.
Allowable steel stress	24,000 p.s.i.
Modular ratio	8
Steel cover	2 Ins.
Uniform vertical load	2,000 p.s.f.
Trapezoidal lateral load	
Top	600 p.s.f.
Rate of increase	30 p.s.f.
Internal water	Full

Lateral Load = $X_{LATT} + X_{LATP}$ (Eq. Fluid Pr.)

$XVLD$ = Vertical Load

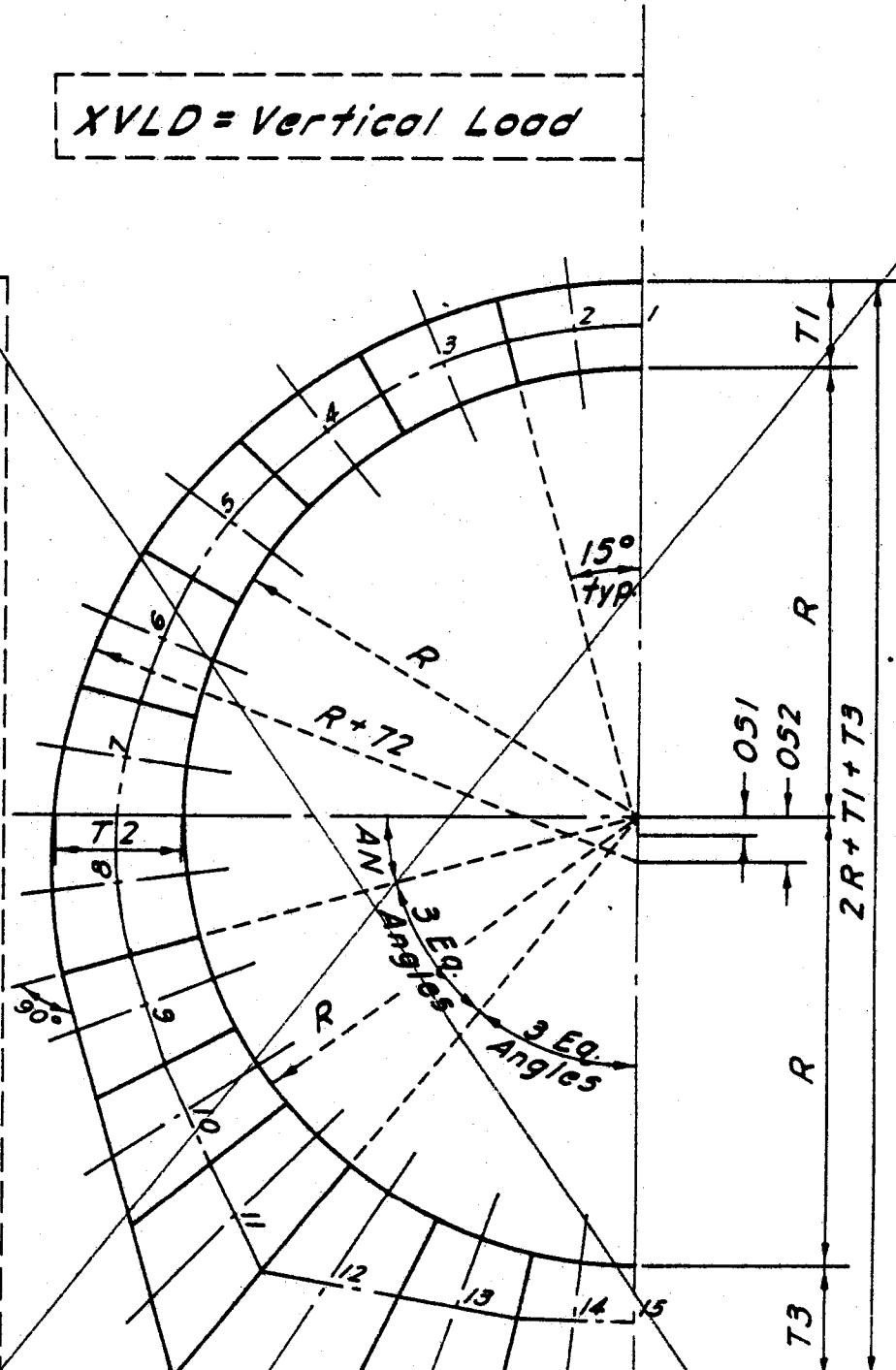


Reactive Load

TYPICAL HALF-SECTION
Alternate No 1

$XVLD = \text{Vertical Load}$

Lateral Load = $XLATT + XLATP$ (Eq. Fluid Pr.)



Reactive Load

TYPICAL HALF-SECTION
Alternate No. 2

DEFINITION OF INPUT VALUES

<u>SYMBOL</u>	<u>NAME</u>
R	RADIUS (FT.)
T1	CROWN THICK. (INS.)
T2	SPR. LINE THICK (INS.)
T3	INVERT THICK (INS.)
AN	ANGLE TO TANGENT (DEG.)
OS1	CENTERLINE OFFSET (INS.)
OS2	EXTERIOR RADIUS OFFSET (INS.)

XSCI STEEL COVER ARCH IN. (INS.)
XSC2 STEEL COVER ARCH OUT. (INS.)
XSC3 STEEL COVER INV. IN. (INS.)
XSC4 STEEL COVER INV. OUT. (INS.)

TITLE CARD

SYMBOL

DEFINITION OF INPUT VALUES

SECTION TO BE RUN

1 - HORSESHOE

2 - CIRCULAR

I-IN COL. 62 FOR CHECKING
BLANK IN COL. 62 FOR DESIGN

8

BLANK IN COL. 62 FOR DESIGN

22

SECOND CARD - DIMENSIONS

S A M P L E P R O B L E M

R	T ₁	T ₂	T ₃	A _N	O _{S1}	O _{S2}	X _{S1}	X _{S2}	X _{S3}	X _{S4}
6.	6.	6.	6.	6.	9.	9.	10.	10.	10.	10.
7.	7.	7.	7.	7.	8.	8.	9.	9.	9.	9.
8.	8.	8.	8.	8.	9.	9.	10.	10.	10.	10.
9.	9.	9.	9.	9.	10.	10.	11.	11.	11.	11.
10.	10.	10.	10.	10.	11.	11.	12.	12.	12.	12.
11.	11.	11.	11.	11.	12.	12.	13.	13.	13.	13.
12.	12.	12.	12.	12.	13.	13.	14.	14.	14.	14.
13.	13.	13.	13.	13.	14.	14.	15.	15.	15.	15.
14.	14.	14.	14.	14.	15.	15.	16.	16.	16.	16.
15.	15.	15.	15.	15.	16.	16.	17.	17.	17.	17.
16.	16.	16.	16.	16.	17.	17.	18.	18.	18.	18.
17.	17.	17.	17.	17.	18.	18.	19.	19.	19.	19.
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19.	19.	19.	19.	19.	20.	20.	21.	21.	21.	21.
20.	20.	20.	20.	20.	21.	21.	22.	22.	22.	22.
21.	21.	21.	21.	21.	22.	22.	23.	23.	23.	23.
22.	22.	22.	22.	22.	23.	23.	24.	24.	24.	24.
23.	23.	23.	23.	23.	24.	24.	25.	25.	25.	25.
24.	24.	24.	24.	24.	25.	25.	26.	26.	26.	26.
25.	25.	25.	25.	25.	26.	26.	27.	27.	27.	27.
26.	26.	26.	26.	26.	27.	27.	28.	28.	28.	28.
27.	27.	27.	27.	27.	28.	28.	29.	29.	29.	29.
28.	28.	28.	28.	28.	29.	29.	30.	30.	30.	30.
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31.	31.	31.	31.	31.	32.	32.	33.	33.	33.	33.
32.	32.	32.	32.	32.	33.	33.	34.	34.	34.	34.
33.	33.	33.	33.	33.	34.	34.	35.	35.	35.	35.
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35.	35.	35.	35.	35.	36.	36.	37.	37.	37.	37.
36.	36.	36.	36.	36.	37.	37.	38.	38.	38.	38.
37.	37.	37.	37.	37.	38.	38.	39.	39.	39.	39.
38.	38.	38.	38.	38.	39.	39.	40.	40.	40.	40.
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42.	42.	42.	42.	42.	43.	43.	44.	44.	44.	44.
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46.	46.	46.	46.	46.	47.	47.	48.	48.	48.	48.
47.	47.	47.	47.	47.	48.	48.	49.	49.	49.	49.
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49.	49.	49.	49.	49.	50.	50.	51.	51.	51.	51.
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51.	51.	51.	51.	51.	52.	52.	53.	53.	53.	53.
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53.	53.	53.	53.	53.	54.	54.	55.	55.	55.	55.
54.	54.	54.	54.	54.	55.	55.	56.	56.	56.	56.
55.	55.	55.	55.	55.	56.	56.	57.	57.	57.	57.
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57.	57.	57.	57.	57.	58.	58.	59.	59.	59.	59.
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60.	60.	60.	60.	60.	61.	61.	62.	62.	62.	62.
61.	61.	61.	61.	61.	62.	62.	63.	63.	63.	63.
62.	62.	62.	62.	62.	63.	63.	64.	64.	64.	64.

THIRD CARD - CRITERIA

XCONC	XSTL	XVLD	XLATT	XLATP	XIWAT	XPRHD	ATY	XZN	ID
-	-	-	-	-	-	-	62	6.	62
-	-	-	-	-	-	-	61	6.	61
-	-	-	-	-	-	-	60	6.	60
-	-	-	-	-	-	-	59	6.	59
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-	-	-	-	-	-	-	3	6.	3
-	-	-	-	-	-	-	2	6.	2
-	-	-	-	-	-	-	1	6.	1

ARCH PROGRAM
OUTPUT FOR SAMPLE PROBLEM

SAMPLE PROBLEM

L.A.C.F.C.D. DESIGN DIVISION
REINFORCED CONCRETE ARCH DESIGN

HORSESHOE INTERIOR

SECTION NO.	MOMENT FT. KIPS	THRUST KIPS	SHEAR KIPS	THICKNESS INS.	C. STRESS P.S.I.	UNIT SHEAR P.S.I.	PERIMETER SQ. INS.		COMPRESSION STEEL SQ. INS.	TENSION STEEL SQ. INS.
							H.S.	M.S.		
1	14.72	4.79	0.0	9.32	1798.	0.0	0.0	0.0	1.03	0.0
2	14.21	4.93	1.22	9.34	1759.	15.87	0.63	0.0	0.99	0.0
3	10.12	6.19	3.31	9.38	1470.	42.73	1.71	0.0	0.63	0.04
4	3.14	8.37	4.42	9.42	903.	56.80	2.27	0.0	0.10	0.0
5	-4.70	10.85	4.22	9.46	1099.	53.91	2.16	0.0	0.53	0.0
6	-11.06	12.95	2.72	9.50	1623.	34.52	1.38	0.0	0.72	0.0
7	-13.93	13.70	3.41	9.54	1819.	43.02	1.72	0.0	0.61	0.0
8	-12.62	14.38	1.74	9.56	1738.	21.94	0.88	0.0	0.32	0.0
9	-8.82	14.45	2.99	9.56	1475.	37.64	1.51	0.0	0.0	0.0
10	-3.09	14.79	3.26	9.57	1022.	41.00	1.64	0.0	0.0	0.0
11	1.87	15.47	2.50	9.60	922.	31.39	1.26	0.0	0.0	0.0
12	17.12	2.02	12.93	15.87	919.	66.83	3.55	0.0	0.66	0.0
13	34.10	2.02	7.53	15.47	1393.	53.28	2.13	0.0	1.40	0.0
14	42.58	2.02	2.51	15.07	1645.	18.31	0.73	0.0	1.82	0.0
15	48.82	2.02	0.0	14.87	1819.	0.0	0.0	0.0	2.12	0.0

AN = 15. DEG. RAD. = 72.0 INS.

THICK. (INS.) CROWN = 9.32 S. LINE = 9.56 INV. = 14.87

ST. COVER (INS.)

ARCH IN. = 2.0 OUT. = 2.0
INV. IN. = 2.0 OUT. = 2.0

LOADS (K.S.F.) VERT. = 2.00 U. LAT. = 0.60 T. LAT. = 0.030
WATER = 0.862 PR. HEAD = 0.0 FT.

A. STRESSES (P.S.I.)
CONC. = 1600. RE-STEEL = 24000.

MODULAR RATIO = 8.0

**ARCH PROGRAM
OUTPUT FOR SAMPLE PROBLEM**

SAMPLE PROBLEM

L.A.C.F.C.D. DESIGN DIVISION
REINFORCED CONCRETE ARCH DESIGN

CIRCULAR INTERIOR

SECTION NO.	MOMENT FT. KIPS	THRUST KIPS	SHEAR KIPS	THICKNESS IN.	C. STRESS P.S.I.	UNIT SHEAR P.S.I.	PERIMETER IN.	COMPRESSION STEEL SQ. INS.	TENSION STEEL SQ. INS.
1	13.63	4.90	0.0	9.32	1723.	0.0	0.0	0.0	0.95
2	13.13	5.03	1.21	9.34	1683.	15.69	0.63	0.0	0.90
3	9.21	6.29	3.27	9.38	1401.	42.20	1.69	0.0	0.56
4	2.52	8.46	4.36	9.42	841.	55.96	2.24	0.0	0.0
5	-4.93	10.92	4.14	9.46	1120.	52.83	2.11	0.0	0.11
6	-10.88	12.99	2.62	9.50	1611.	33.26	1.33	0.0	0.51
7	-13.38	13.68	3.51	9.54	1782.	44.35	1.77	0.0	0.68
8	-11.00	14.51	2.79	8.87	1801.	38.64	1.55	0.0	0.56
9	-7.84	14.57	5.80	14.96	874.	42.64	1.71	0.0	0.03
10	-0.80	14.28	8.83	22.30	475.	41.40	1.66	0.0	0.0
11	11.94	13.49	12.04	29.81	925.	41.21	1.65	0.0	0.0
12	34.45	9.74	12.50	27.60	760.	46.49	1.66	0.0	0.58
13	52.34	4.79	8.57	19.12	1374.	47.65	1.91	0.0	1.65
14	61.04	2.08	3.05	15.32	1998.	21.79	0.87	0.02	2.57
15	65.17	2.08	0.0	14.87	2173.	0.0	0.0	0.04	2.85

AN = 15. DEG. RAD. = 72.0 INS.

THICK. (INS.) CROWN = 9.32 S. LINE = 9.56 INV. = 14.87

ST. COVER (INS.)

ARCH IN. = 2.0 OUT. = 2.0
INV. IN. = 2.0 OUT. = 2.0

LOADS (K.S.F.)

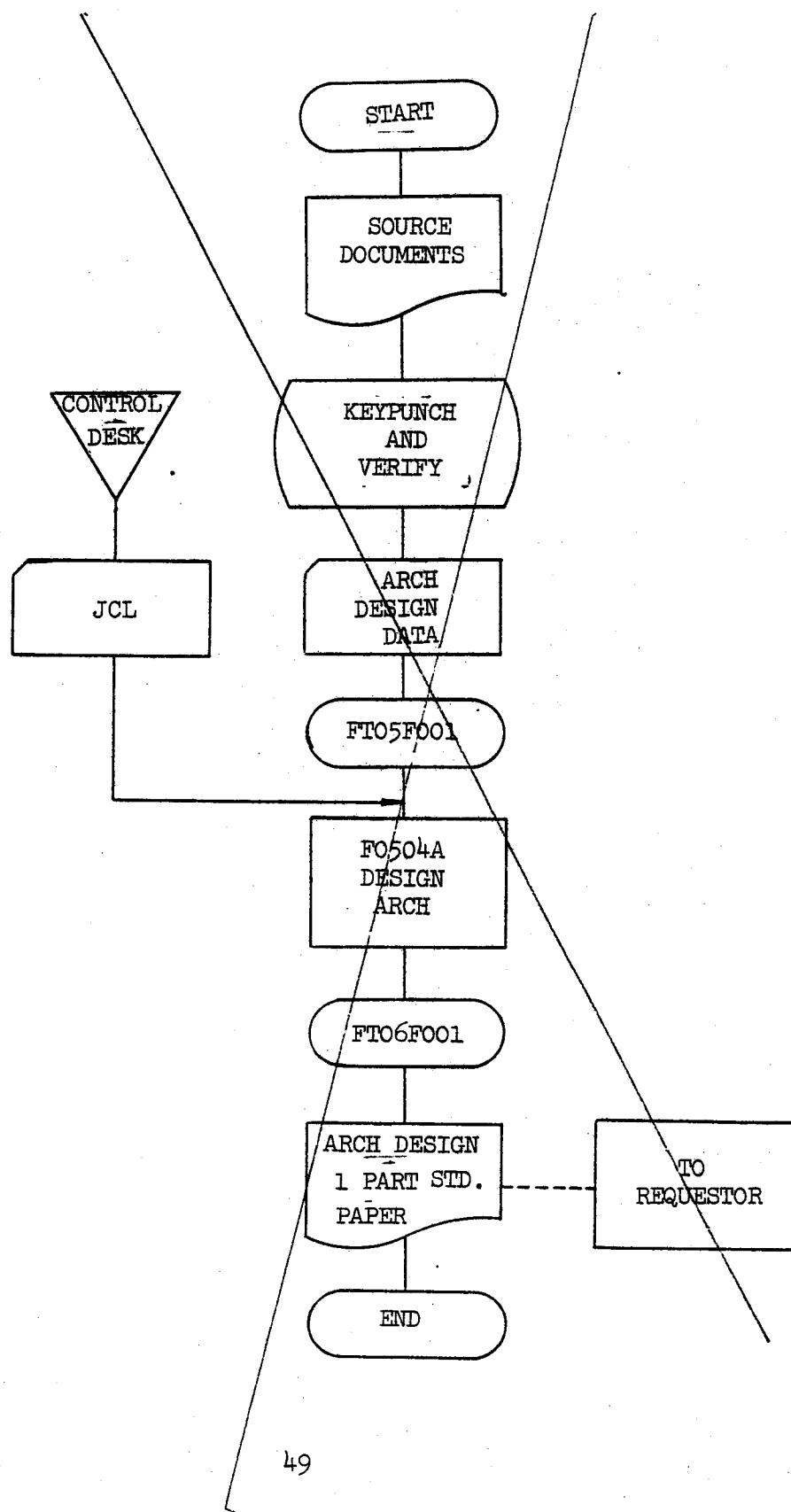
VERT. = 2.00 U. LAT. = 0.60 T. LAT. = 0.030
WATER = 0.062 PR. HEAD = 0.0 FT.

A. STRESSES (P.S.I.)
CONC. = 18000 RE-STEEL = 24000

MODULAR RATIO = 8.0

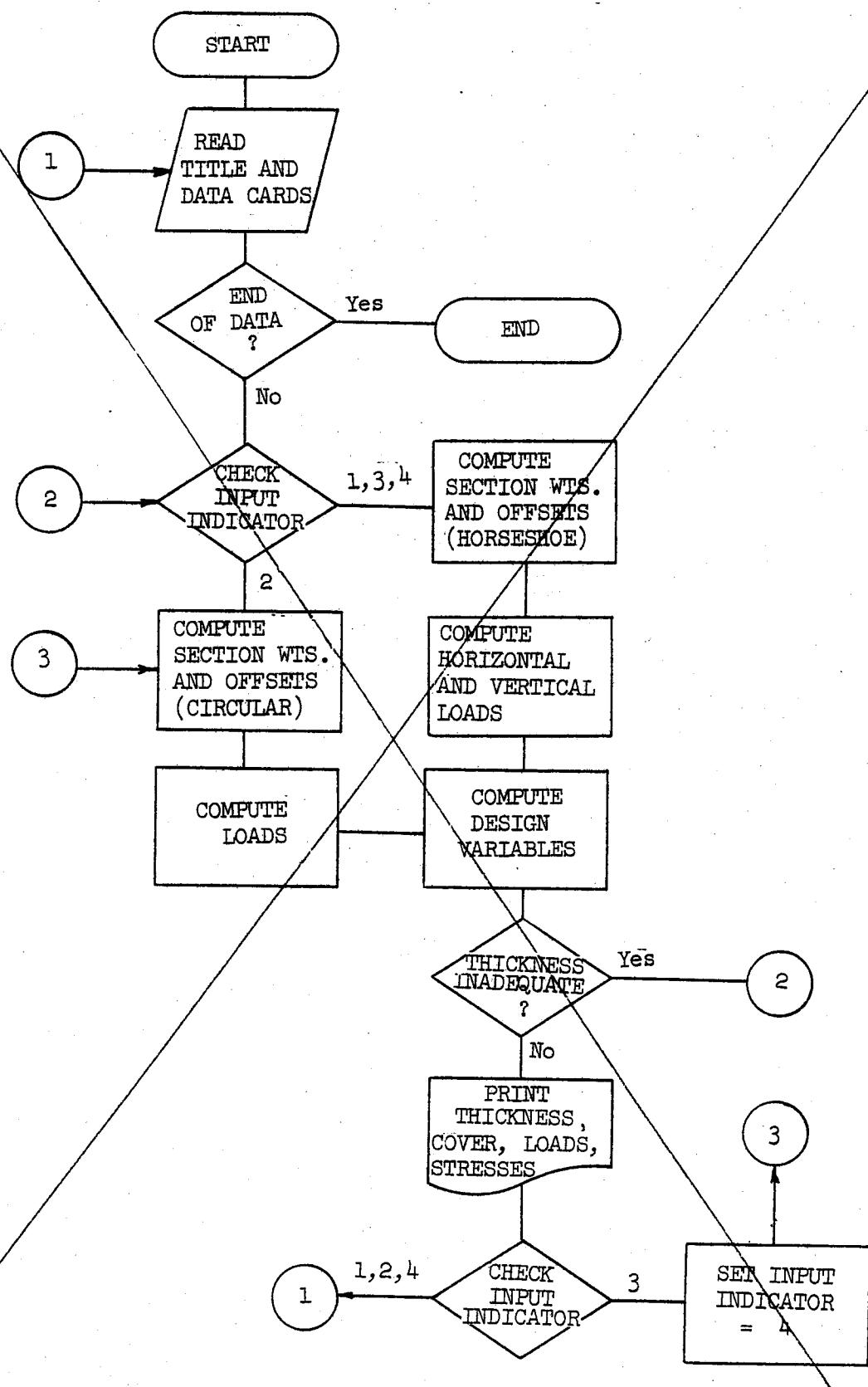
REINFORCED CONCRETE ARCH DESIGN

SYSTEM FLOWCHART



REINFORCED CONCRETE ARCH DESIGN

GENERAL FLOWCHART



JOB CONTROL LANGUAGE

R. C. ARCH DESIGN (F0504A)

JCL LISTING TO EXECUTE OBJECT MODULE
(0400,A108), 'DESIGN,409-5241N', CLASS=F, PRTY=10
DSN=SYSAF.FLOODLIB, DISP=SHR
EXEC PGM=F0504A
//F0504P JOB //J0LIB DD
//F0504P1 EXEC DD
//F0504P1 //F0504P1 DD * DATA CARDS FOLLOW - PRODUCTION
/* END OF DATA CARDS

504AQG01
504AQG02
504AQG03
504AQG04
504AQG05
504AQG06

R. C. ARCH DESIGN (F0504A)

JCL LISTING TO STORE OBJECT MODULE IN LIBRARY
(0400,A108), 'DESIGN,409-5241N', CLASS=F, PRTY=10
EXEC FORTGCLG,FARM.FORT=(BCD,MAP, ID), COND.IKED=(3,LT, FORT),
SYSIMOD='SYSAF.FLOODLIB(F0504A)', LIMOSISP=OLD
//F0504P1 FORT.SYSIN DD * SOURCE PROGRAM FOLLOWS - STORE PROG ON LIB
/* END OF SOURCE PROGRAM

R. C. ARCH DESIGN (F0504A)

JCL LISTING TO COMPILE LINK-EDIT AND GO
(0400,A108), 'DESIGN,409-5241N', CLASS=F
EXEC FORTGCLG,FARM.FORT=(BCD,MAP, ID), COND.GO=(7,LT, FORT)
//F0504P2 FORT.SYSIN DD * SOURCE PROGRAM FOLLOWS
/* END OF SOURCE
//F0504P2 //F0504P2 DD * DATA FOLLOWS
/* END OF DATA

Structural Design of
Reinforced Concrete Pipe
Computer Program No. 0505

Purpose:

The purpose of Program No. 0505 is to furnish steel areas to be used in the construction of large diameter reinforced concrete pipe.

Scope:

The program was primarily intended to develop data for the preparation of design charts; however, it is applicable to single designs.

The diameter of the pipe is an input value and is not limited.

Earth loads are calculated in accordance with Marston's equations.² Installation condition may be trench, negative projection or positive projection. Projection condition loads are limited to values based on a settlement ratio of +0.7, vertical load angle to 180 degrees, and support angle to 90 degrees.

Live load may be zero, truck, or railroad.

Allowable stresses are variable.

The design is based on the working stress theory.

Procedure:

A. General:

The basic procedure is that set forth in the District Structural Design Manual¹.

B. Method of Design:

Moments and thrusts are determined by use of the Engineering News Record formulae.

The section is assumed to be subjected to combined axial thrust and bending. Design is based on the elastic theory using working stress theory.

Compression steel calculations use an effective modular ratio of $2n$ to transform the compression reinforcement. Compression steel is not considered unless it is required to maintain the concrete stress within the allowable.

C. Pipe Diameter:

The program will design pipe of all diameters. The pipe diameter is the input variable "1ID".

D. Range of Covers:

Depth of cover can be any value. The number of designs obtained is dependent on the input values of "XF1", "XF2", and "XFX". The output will include designs for all depths from the input value of "XF1" to "XF2" in the increment indicated by "XFX". For a single design, "XF1" and "XF2" should be the depth desired and "XFX" should be set equal to zero.

E. Loading Conditions:

One loading condition is analyzed per run. The weight of the conduit, a vertical load angle of 180 degrees, and a support angle of 90 degrees are written into the program. All other loads are controlled by the input values.

F. Earth Load:

Earth loads are computed in accordance with Marston's Theory. The load is calculated for the trench condition, negative projection, or positive projection condition as indicated by the input value of "1LN". The soil density used is as indicated by the input value of "LSD". The trench width used is as indicated by the input value of "1W". Only lateral load due to earth is used. The value used is dependent on the input value of "XLAT".

G. Live Load:

Live load used is as indicated by the input value of "1LL". Any truck weight up to and including 29 tons may be used. Any railroad axle load from 31 to 99 kips may be used. Live load is neglected if "1LL" is set equal to 30. Truck live load distribution is according to the District's Structural Design Manual. The railroad loading is based on the following assumptions: (1) axle load equal to the input value for "1LL", (2) longitudinal distribution equal to 5 feet, transverse distribution equal to 8 feet plus the depth of fill, (3) impact equal to 40 percent for fills 1.69 feet or less in depth; this is reduced 5 percent for each additional foot of cover. The program utilizes a single track.

The values for live load are directly proportional to the input value of "1LL". Therefore, as an example, if the design live load due to an H-20 truck is 500 pounds per square foot and it

is desirable to add 700 pounds per square foot to the design live load, set the input value of "LLL" at 28 (i.e., 20 x 700/500).

H. Internal Water and Pressure Head:

The conduit is analyzed empty, flowing full or under pressure. If the input variable "XIW" is 0, internal water is not considered. If "XIW" is set equal to 1, the conduit is assumed flowing full. For pressure flow, set "XIW" equal to 1 and "XPH" equal to the pressure head, measured from the soffit of the pipe in feet.

I. Loading Angles:

Vertical loads are assumed to be acting on the upper 180 degrees and supported on the lower 90 degrees.

Design Criteria:

The design procedure and criteria are those set forth in the District Structural Design Manual. However, in order to maintain a degree of flexibility, certain criteria are input requirements. Refer to the input form in Appendix 4.

The concrete stress, reinforcing steel stress, and modular ratio used are equal to the input values of "XCONC", "XSTL", and "XN", respectively. There is no limitation for these variables. In the elliptical alternates, the steel stress "XSTL" is reduced, where required, to limit the concrete stress to "XCONC".

Input Data:

A typical input form is included in Appendix 4. This form defines the input variables and shows the required format for the data.

Output Description:

A typical output sheet is also included. The following items are given:

Pipe diameter
Pipe wall thickness
Depth of fill
Required steel areas
Design criteria

Steel areas for three alternates are always given in the output. In the case of pipe under extremely heavy load, the steel area may be greater than can be placed. It is left to the designer's judgment to ignore these designs. In general, it is felt 3.00 square inches is the practical limit for the steel area in a cage.

APPENDIX 4

Sample Problem:

It is required to design a 132-inch reinforced concrete pipe with a wall thickness of 11.5 inches for covers of 2, 8, and 14 feet. The pipe is to be installed in a trench equal in width to the outside pipe diameter plus 20 inches, backfilled with soil with a density of 110 p.c.f., and subjected to loads imposed by an A.A.S.H.O. H-20 truck. A design is obtained for a double circular cage alternate, a circular cage and elliptical cage alternate, and a single elliptical cage alternate. The required input data for the solution of this problem and the output are shown.

DESIGN OF REINFORCED CONCRETE PIPE

BOND ISSUE

COMPUTER PROGRAM 0505

DEFINITIONS: OF INPUT VALUES

<u>CARD NO. 1</u>	<u>SYMBOL</u>	<u>NAME</u>
XID		INSIDE DIAMETER (INCHES)
XT		THICKNESS (INCHES)
XFI		MINIMUM FILL (FEET)
XFZ		MAXIMUM FILL (FEET)
XFX		FILL INCREMENT (FEET)
XCONC		CONCRETE STRESS (P.S.I.)
XSTL		STEEL STRESS (P.S.I.)
XN		MODULAR RATIO
XLAT		LATERAL LOAD (P.S.F.)
XPH		PRESSURE HEAD (FEET)
XIW		INTERNAL WATER 0-NONE 1-FULL

CARD NO. 2

<u>SYMBOL</u>	<u>NAME</u>
ISD	SOIL DENSITY (P.C.F.)
IW	TRENCH CLEARANCE (INCHES - TOTAL)
PRA	PROJECTION RATIO
SRA	SETTLEMENT RATIO
IIN	TYPE INSTALLATION 1. TRENCH 2. POS. PROJ. 3. NEG. PROJ.
ILL	LIVE LOAD 30 ZERO 20 H-20, ETC. 65 E-65, ETC.
XCOV	STEEL COVER (TO 2 BAR)

CARD NO. 1

IID	XT	XFI	XFZ	XFX	XCONC	XSTL	XN	XLAT	XIW	XPH
1	10	6	2	2	30	32	3.0	42	0	66
2	10	6	2	2	30	32	3.0	42	0	65
3	10	6	2	2	30	32	3.0	42	0	64
4	10	6	2	2	30	32	3.0	42	0	63
5	10	6	2	2	30	32	3.0	42	0	62
6	10	6	2	2	30	32	3.0	42	0	61
7	10	6	2	2	30	32	3.0	42	0	60
8	10	6	2	2	30	32	3.0	42	0	59
9	10	6	2	2	30	32	3.0	42	0	58
10	10	6	2	2	30	32	3.0	42	0	57
11	10	6	2	2	30	32	3.0	42	0	56
12	10	6	2	2	30	32	3.0	42	0	55
13	10	6	2	2	30	32	3.0	42	0	54
14	10	6	2	2	30	32	3.0	42	0	53
15	10	6	2	2	30	32	3.0	42	0	52
16	10	6	2	2	30	32	3.0	42	0	51
17	10	6	2	2	30	32	3.0	42	0	50
18	10	6	2	2	30	32	3.0	42	0	49
19	10	6	2	2	30	32	3.0	42	0	48
20	10	6	2	2	30	32	3.0	42	0	47
21	10	6	2	2	30	32	3.0	42	0	46
22	10	6	2	2	30	32	3.0	42	0	45
23	10	6	2	2	30	32	3.0	42	0	44
24	10	6	2	2	30	32	3.0	42	0	43
25	10	6	2	2	30	32	3.0	42	0	42
26	10	6	2	2	30	32	3.0	42	0	41
27	10	6	2	2	30	32	3.0	42	0	40
28	10	6	2	2	30	32	3.0	42	0	39
29	10	6	2	2	30	32	3.0	42	0	38
30	10	6	2	2	30	32	3.0	42	0	37
31	10	6	2	2	30	32	3.0	42	0	36
32	10	6	2	2	30	32	3.0	42	0	35
33	10	6	2	2	30	32	3.0	42	0	34
34	10	6	2	2	30	32	3.0	42	0	33
35	10	6	2	2	30	32	3.0	42	0	32
36	10	6	2	2	30	32	3.0	42	0	31
37	10	6	2	2	30	32	3.0	42	0	30
38	10	6	2	2	30	32	3.0	42	0	29
39	10	6	2	2	30	32	3.0	42	0	28
40	10	6	2	2	30	32	3.0	42	0	27
41	10	6	2	2	30	32	3.0	42	0	26
42	10	6	2	2	30	32	3.0	42	0	25
43	10	6	2	2	30	32	3.0	42	0	24
44	10	6	2	2	30	32	3.0	42	0	23
45	10	6	2	2	30	32	3.0	42	0	22
46	10	6	2	2	30	32	3.0	42	0	21
47	10	6	2	2	30	32	3.0	42	0	20
48	10	6	2	2	30	32	3.0	42	0	19
49	10	6	2	2	30	32	3.0	42	0	18
50	10	6	2	2	30	32	3.0	42	0	17
51	10	6	2	2	30	32	3.0	42	0	16
52	10	6	2	2	30	32	3.0	42	0	15
53	10	6	2	2	30	32	3.0	42	0	14
54	10	6	2	2	30	32	3.0	42	0	13
55	10	6	2	2	30	32	3.0	42	0	12
56	10	6	2	2	30	32	3.0	42	0	11
57	10	6	2	2	30	32	3.0	42	0	10
58	10	6	2	2	30	32	3.0	42	0	9
59	10	6	2	2	30	32	3.0	42	0	8
60	10	6	2	2	30	32	3.0	42	0	7
61	10	6	2	2	30	32	3.0	42	0	6
62	10	6	2	2	30	32	3.0	42	0	5
63	10	6	2	2	30	32	3.0	42	0	4
64	10	6	2	2	30	32	3.0	42	0	3
65	10	6	2	2	30	32	3.0	42	0	2
66	10	6	2	2	30	32	3.0	42	0	1
67	10	6	2	2	30	32	3.0	42	0	0

CARD NO. 2

ISD	IW	PRA	SRA	IIN	ILL	XCOV
-0	-0	-0	-0	-0	-0	-0
-1	-1	-1	-1	-1	-1	-1
-2	-2	-2	-2	-2	-2	-2
-3	-3	-3	-3	-3	-3	-3
-4	-4	-4	-4	-4	-4	-4
-5	-5	-5	-5	-5	-5	-5
-6	-6	-6	-6	-6	-6	-6
-7	-7	-7	-7	-7	-7	-7
-8	-8	-8	-8	-8	-8	-8
-9	-9	-9	-9	-9	-9	-9
-10	-10	-10	-10	-10	-10	-10

DESIGN OF REINFORCED CONCRETE PIPE

PIPE DIAMETER INS.	WALL THICKNESS INS.	DEPTH OF FILL FT.	STEEL REQUIREMENTS IN SQ. INS./LIN. FT.		
			DOUBLE CIRCULAR	CIR. AND ELLIPTICAL	ELL. ONLY
			INN. CIR. OUT. CIR.	CIR.	ELL.
132	11.50	2.0	1.21	0.82	1.21
132	11.50	8.0	1.18	0.80	1.18
132	11.50	14.0	1.52	1.04	1.52

DESIGN CRITERIA

ALLOWABLE STRESSES
CONCRETE 2025. PSI.
RE-STEEL 24000. PSI.

MODULAR RATIO 8.
COVER ON STEEL 1.50 INS.

ANGLE OF LOADING
TOP 180 DEG.
BOTTOM 90 DEG.

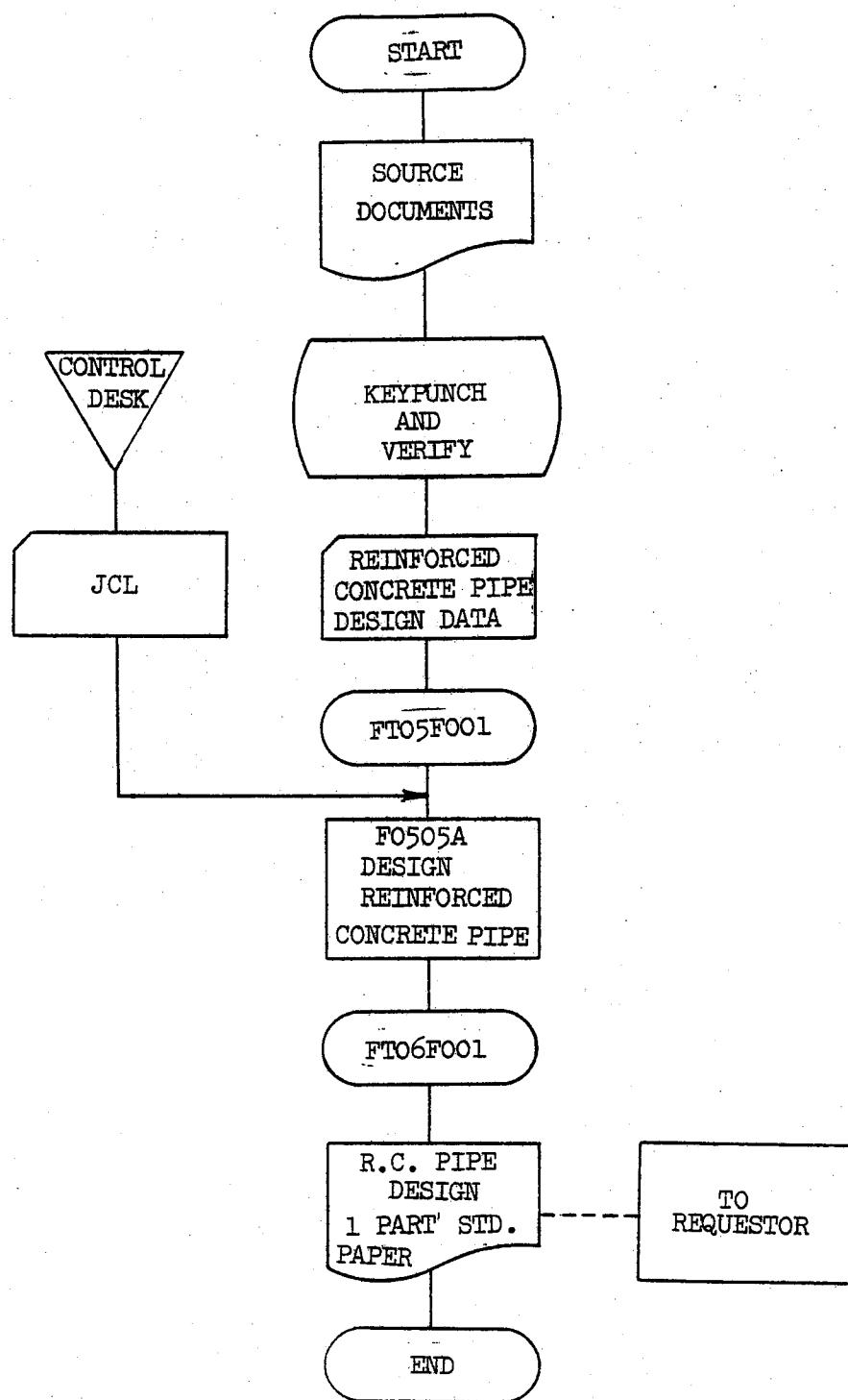
LIVE LOAD
A.A.S.H.O. H- 20

EARTH LOAD
LATERAL 0.0 PSF. E.F.P.
VERTICAL (MARSTONS)
SOIL DENSITY 110 PCF.
TRENCH

0, DIA. + 24 INS.
CONDUIT FULL PRESSURE HEAD = 0.0 FT.

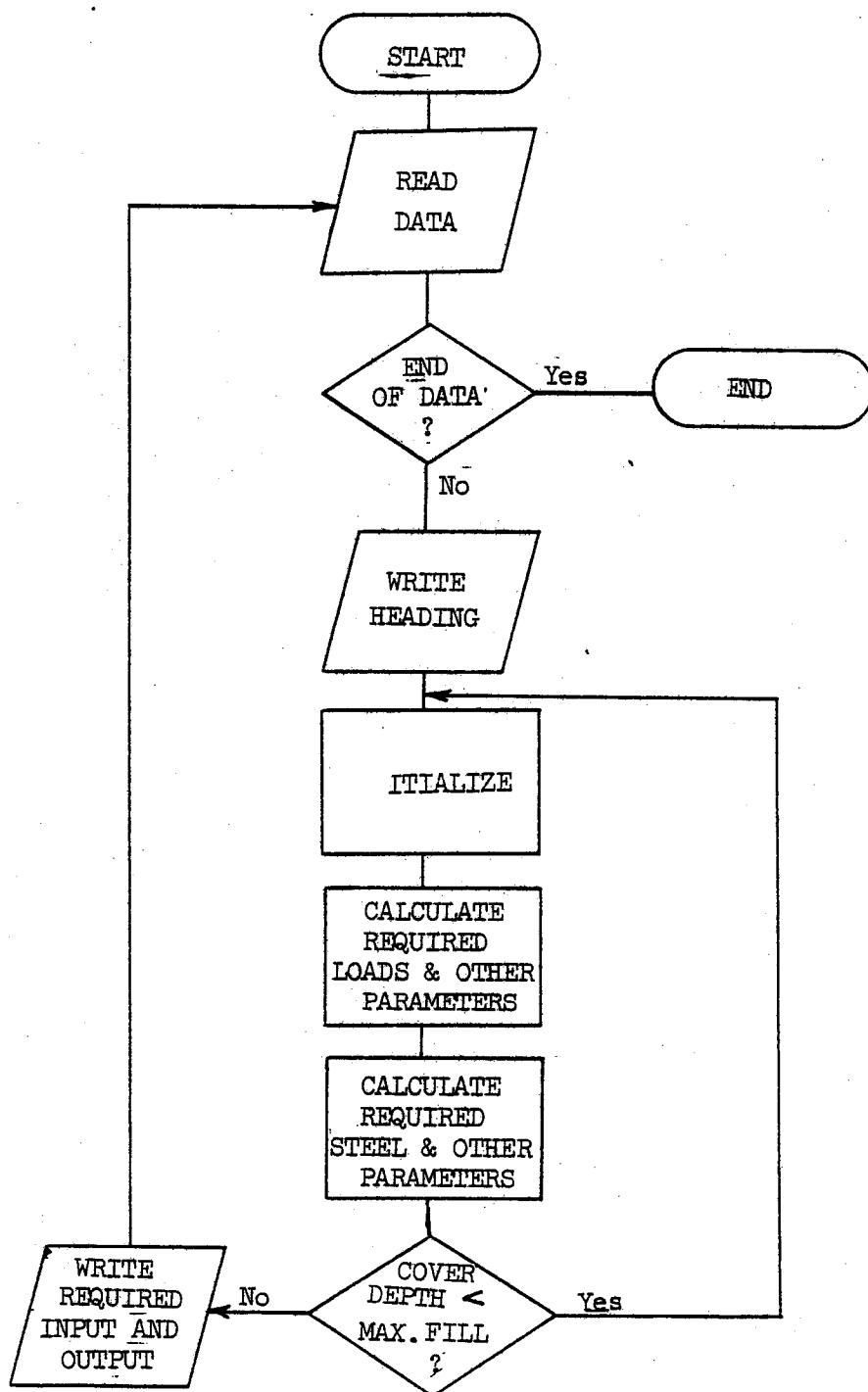
REINFORCED CONCRETE PIPE DESIGN

SYSTEM FLOWCHART



REINFORCED CONCRETE PIPE DESIGN

GENERAL FLOWCHART



JOB CONTROL LANGUAGE

REINFORCED CONCRETE PIPE DESIGN (FO505A)
JCL LISTING TO EXECUTE OBJECT MODULE
(0400,A108), 'DESIGN,409-950N', CLASS=D, PRTY=10
505AOG01
505AOG02
505AOG03
505AOG04
505AOG05
505AOG06

//FO505P JOB (0400,A108) 'DESIGN,409-950N', CLASS=F, PRTY=10
DSN=SYSAF.FLOODLIB,DISP=SHR
EXEC PGM=FO505A
//JOBLIB DD SYSOUT=A
//FT06F001 DD * DATA CARDS FOLLOW - PRODUCTION
//FT05F001 DD * DATA CARDS FOLLOW - PRODUCTION
/* END OF DATA CARDS

REINFORCED CONCRETE PIPE DESIGN (FO505A)
JCL LISTING TO STORE OBJECT MODULE IN LIBRARY
(0400,A108), 'DESIGN,409-950N', CLASS=F, PRTY=10
505AOST1
505AOST2
505AOST3
505AOST4
505AOST5
505AOST6

//FO505P1 JOB (0400,A108), 'DESIGN,409-950N', CLASS=F, PRTY=10
EXEC FORTGCL, PARM.FORT=(BCD,MAP, ID), COND.IKED=(3,LT,FORT),
SYSMOD='SYSAF.FLOODLIB(FO505A)',IMODISP=OLD
//FORT.SYSIN DD * SOURCE PROGRAM FOLLOWS - STORE FROG ON LIB
/* END OF SOURCE PROGRAM

REINFORCED CONCRETE PIPE DESIGN (FO505A)
JCL LISTING TO COMPILE LINK-EDIT AND GO
(0400,A108), 'DESIGN,409-5241N', CLASS=F
505ACLG1
505ACLG2
505ACLG3
505ACLG4
505ACLG5
505ACLG6

//FO505P2 JOB (0400,A108), 'DESIGN,409-5241N', CLASS=F
EXEC FORTGCL, PARM.FORT=(BCD,MAP, ID), COND.GO=(7,LT,FORT)
//FORT.SYSIN DD * SOURCE PROGRAM FOLLOWS
/* END OF SOURCE
//GO.SYSIN DD * DATA FOLLOWS
/* END OF DATA

COMPUTER REQUIREMENTS

EDP JOB NUMBER:	F0501A
TITLE:	Reinforced Concrete Box Design and Check
NUMBER OF PROGRAM MODULES:	1 Main and 25 Sub-routines
MAXIMUM CORE USED:	110 K
EDP JOB NUMBER:	F0502A
TITLE:	Reinforced Concrete Open Channel Design
NUMBER OF PROGRAM MODULES:	1 Main and 3 Sub-routines
MAXIMUM CORE USED:	50 K
EDP JOB NUMBER:	F0504A
TITLE:	Reinforced Concrete Arch Design
NUMBER OF PROGRAM MODULES:	1 Main and 1 Sub-routine
MAXIMUM CORE USED:	49 K
EDP JOB NUMBER:	F0505A
TITLE:	Reinforced Concrete Pipe Design
NUMBER OF PROGRAM MODULES:	1 Main and 1 Sub-routine
MAXIMUM CORE USED:	33 K
COMPUTER SYSTEM:	IBM S/360 Model 40 (OS)
PROGRAMMING LANGUAGE:	FORTRAN IV (G)
I/O DEVICES USED:	Card Reader, Printer
PROGRAM CONCEPTS DEVELOPED BY:	Richard Smith, Design Division
PROGRAMMING:	Gary Walton and Hal Doss, under the direction of David Tom, Data Processing Section
DIRECT INQUIRIES TO:	Management Systems Division Los Angeles County Flood Control District P. O. Box 2418, Terminal Annex Los Angeles, California 90054 Any problems should be brought to this Division's attention.

REFERENCES

1. Los Angeles County Flood Control District Structural Design Manual, Los Angeles, California; November, 1970.
2. Iowa Engineering Experiment Station (Iowa State College) Bulletin No. 96, "The Theory of External Loads on Closed Conduits in the Light of the Latest Experiments" by Anson Marston; Ames, Iowa; February, 1930.
3. "Beams on Elastic Foundations" by M. Hetenyi; University of Michigan Press; Ann Arbor, Michigan; 1946.
4. "Analysis of Arches, Rigid Frames and Sewer Sections", Portland Cement Association Publication ST-53; Chicago, Illinois.

Warning Messages

Warning messages are produced by the steel design subroutines. These messages are produced when the maximum size and minimum spacing for a given bar cannot satisfy the steel area or perimeter requirement.

Error Messages

Error messages produced by this program are of the following form:

TITLE CARD (76 characters) ERROR NO. E

where TITLE CARD is the information from the first input card and E equals the condition code assigned to the error.

Permissible values of E are 1 - 4 as defined below:

Error No. 1

Title Card Errors:

1. Card columns 1-3 do not contain 012.
2. Card column 4 does not contain either blank, 0, or 1.

Error No. 2

Design Data Card Errors:

1. Card columns 1-3 do not contain 013.
2. Design criteria indicator (card column 4) is not 1-4.
3. Number of barrels (card column 5) is not 1 or 2.
4. Installation condition indicator (card column 6) is not 1-3.
5. Live load indicator (card column 7) is not 1-3.
6. Depth to finish grade (card columns 8-13) is negative.
7. Axle load (card columns 20-23) is negative.
8. Pressure head (card columns 24-29) is negative.
9. Interior dimensions (card columns 30-53) are either negative or greater than 50.

Error No. 3

Check Thickness Data Card Errors:

1. Card columns 1-3 do not contain 014.

Check Bar Data Card Errors:

1. Card columns 1-3 do not contain 015.
2. Bar subscript (card columns 5-6, 27-28, or 49-50) is negative or greater than 27.

Error No. 4

Design Criteria Card Errors:

1. Card columns 1-3 do not contain 016.

Error No. 5

Premature End of File on Card Reader:

1. Design data card missing.
2. Check specified (1 in cc4 on title card) and thickness and/or bar cards missing or incomplete.
3. Alternate design criteria specified (3 or 4 in cc4 on design data card) and design criteria cards missing or incomplete.
4. The last bar data card did not have 9 in cc4.