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 Manual[1]. 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 equations[2].

Design Criteria:

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

DESCRIPTION	DISTRICT	ALTERNATE
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

DESCRIPTION	DISTRICT	ALTERNATE
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 overriden 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: fc - concrete compressive stress, fs - 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.

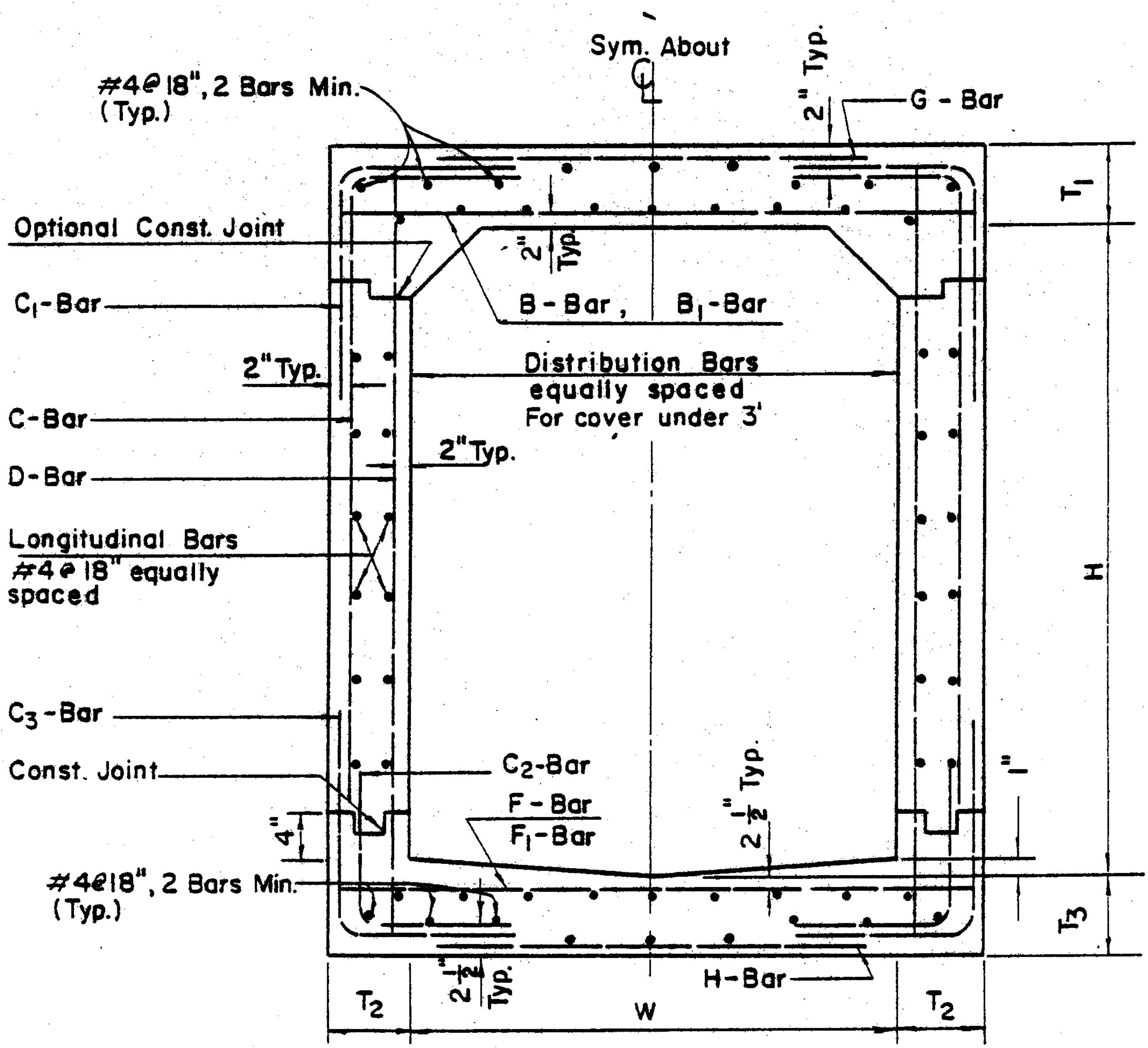
4. Stresses are computed at the centerline of the walls based on maximum positive moment with axial load through the entire wall.

APPENDIX 1

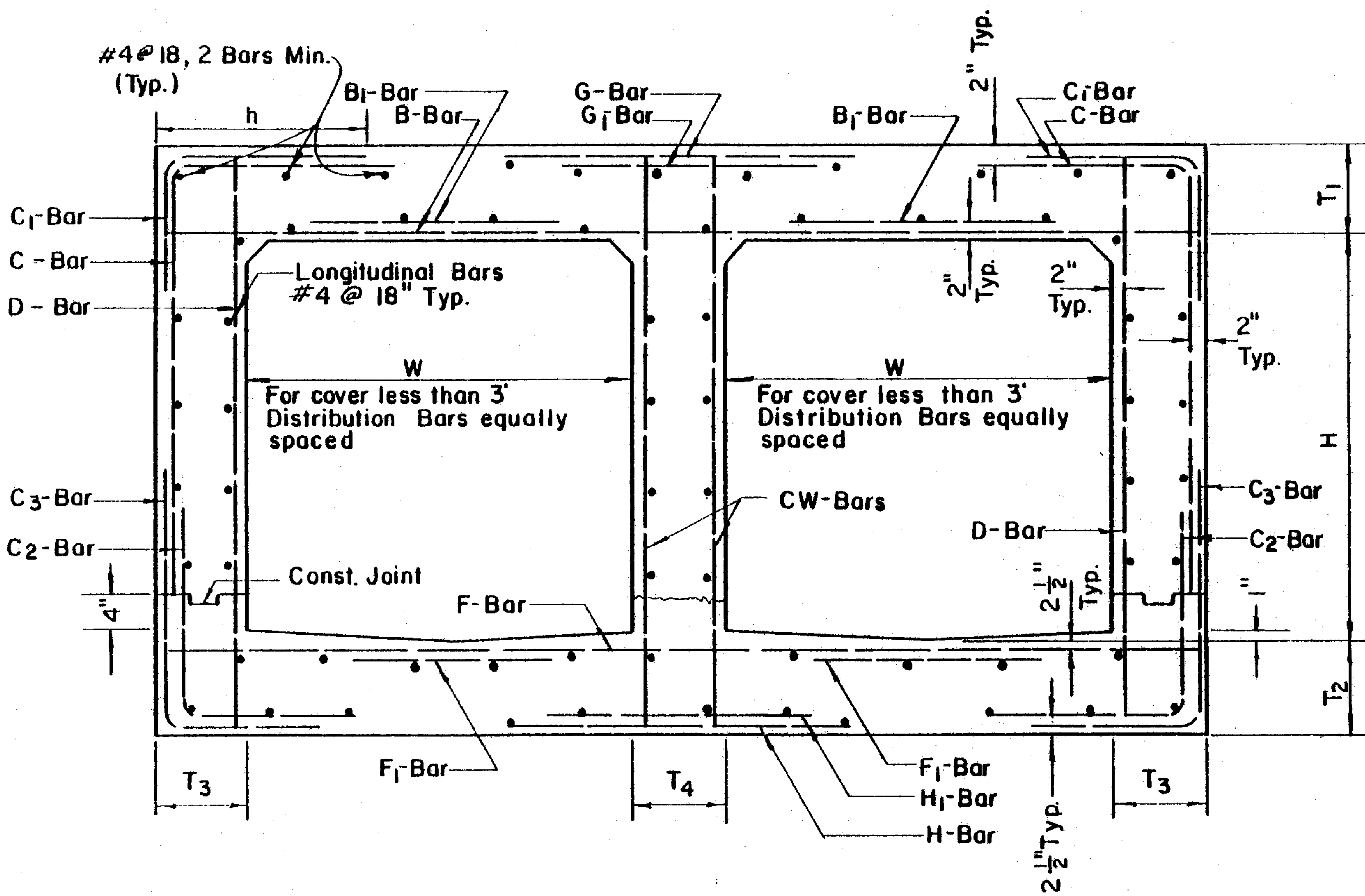
Sample Problem:

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.

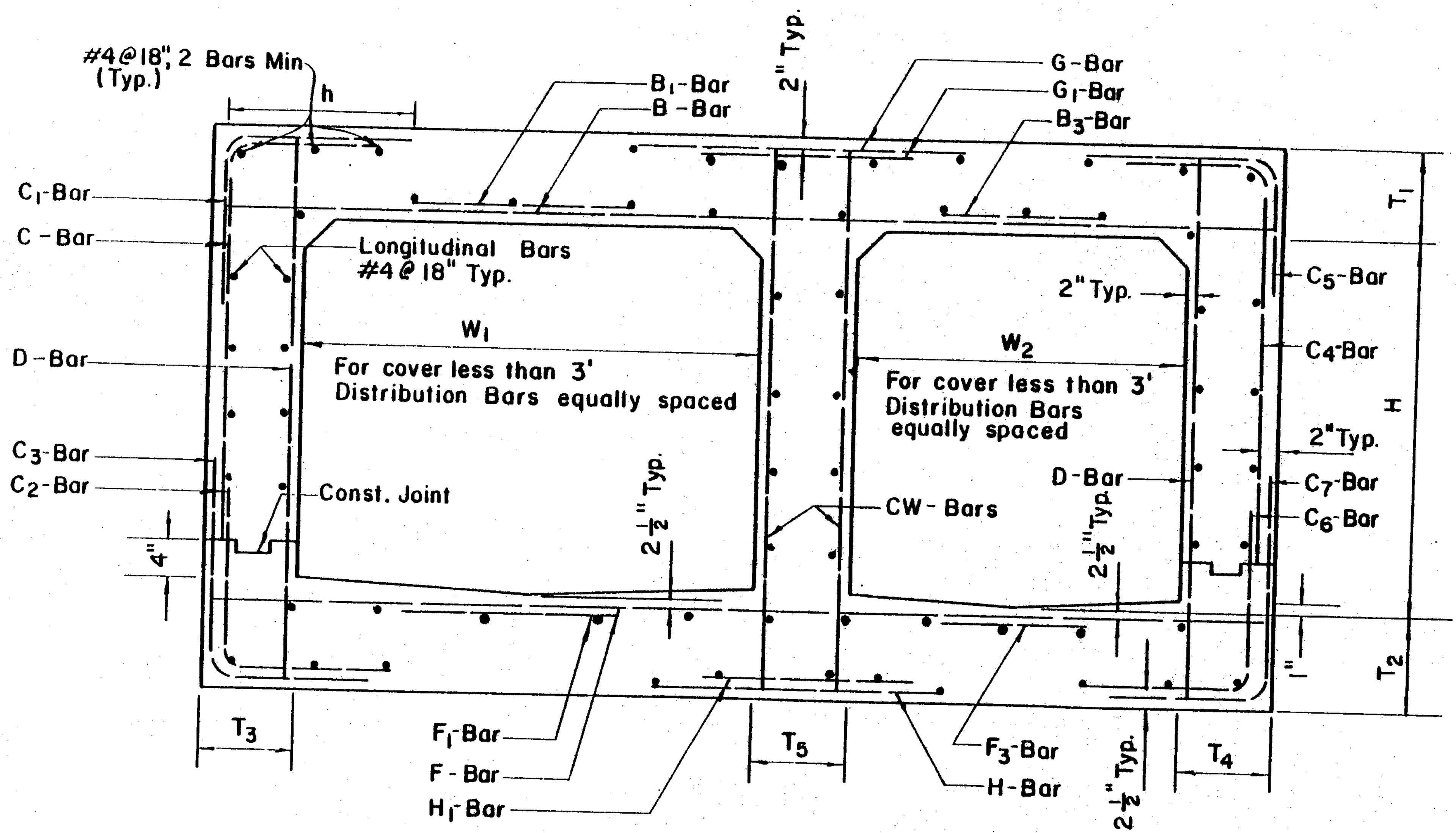
The conduit is designed in accordance with District structural design criteria. The design earth cover is 8'-0" and the design live load is an A.A.S.H.O. H-20 S-16 44 truck. The output from the design phase was used as input data for the check phase.



SCHEMATIC OF SINGLE BOX

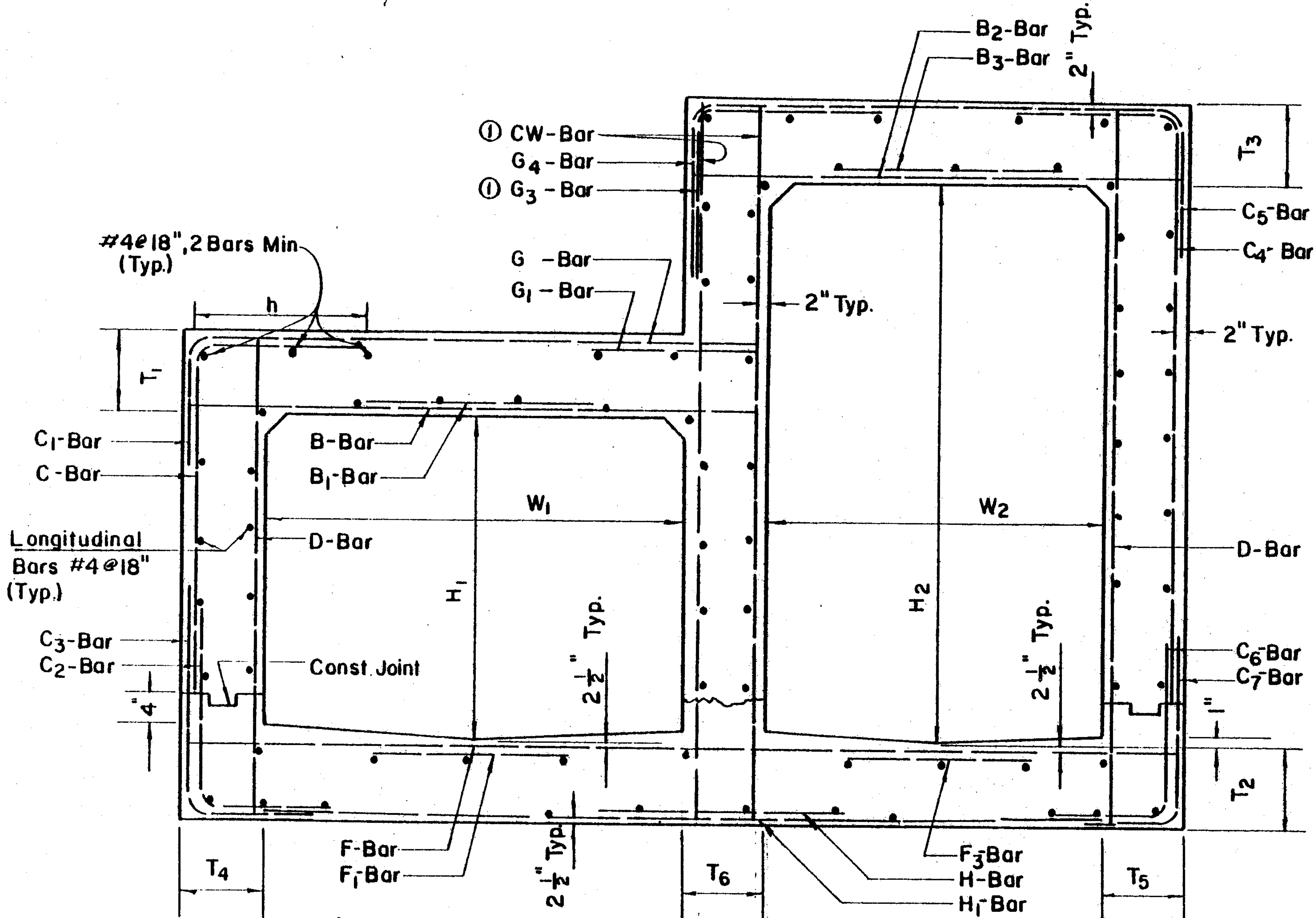


SCHEMATIC OF
SYMMETRICAL DOUBLE BOX

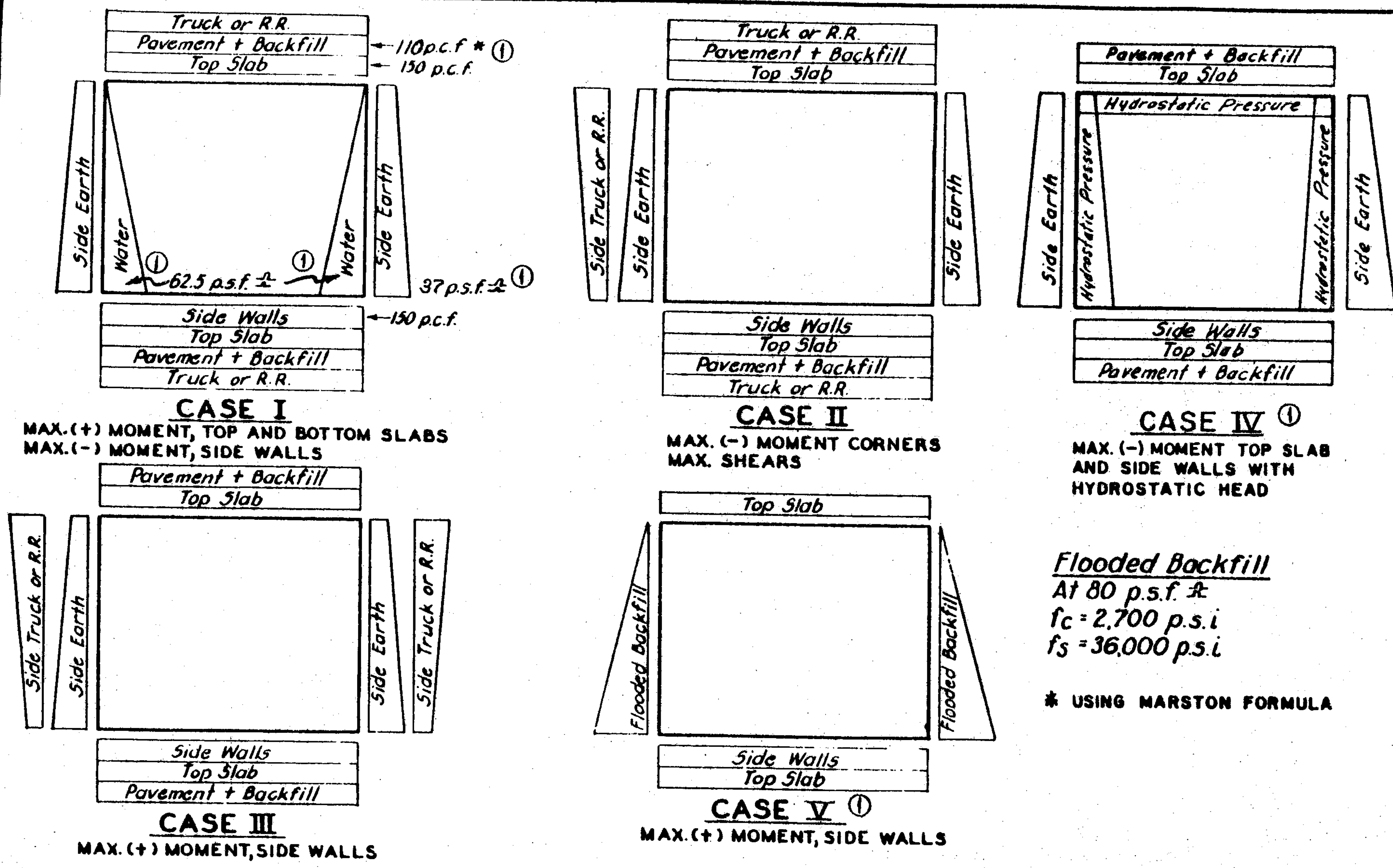


SCHEMATIC OF UNSYMMETRICAL DOUBLE BOX WITH UNEQUAL WIDTH

NOTE:
① WAS CHANGED 11/76



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

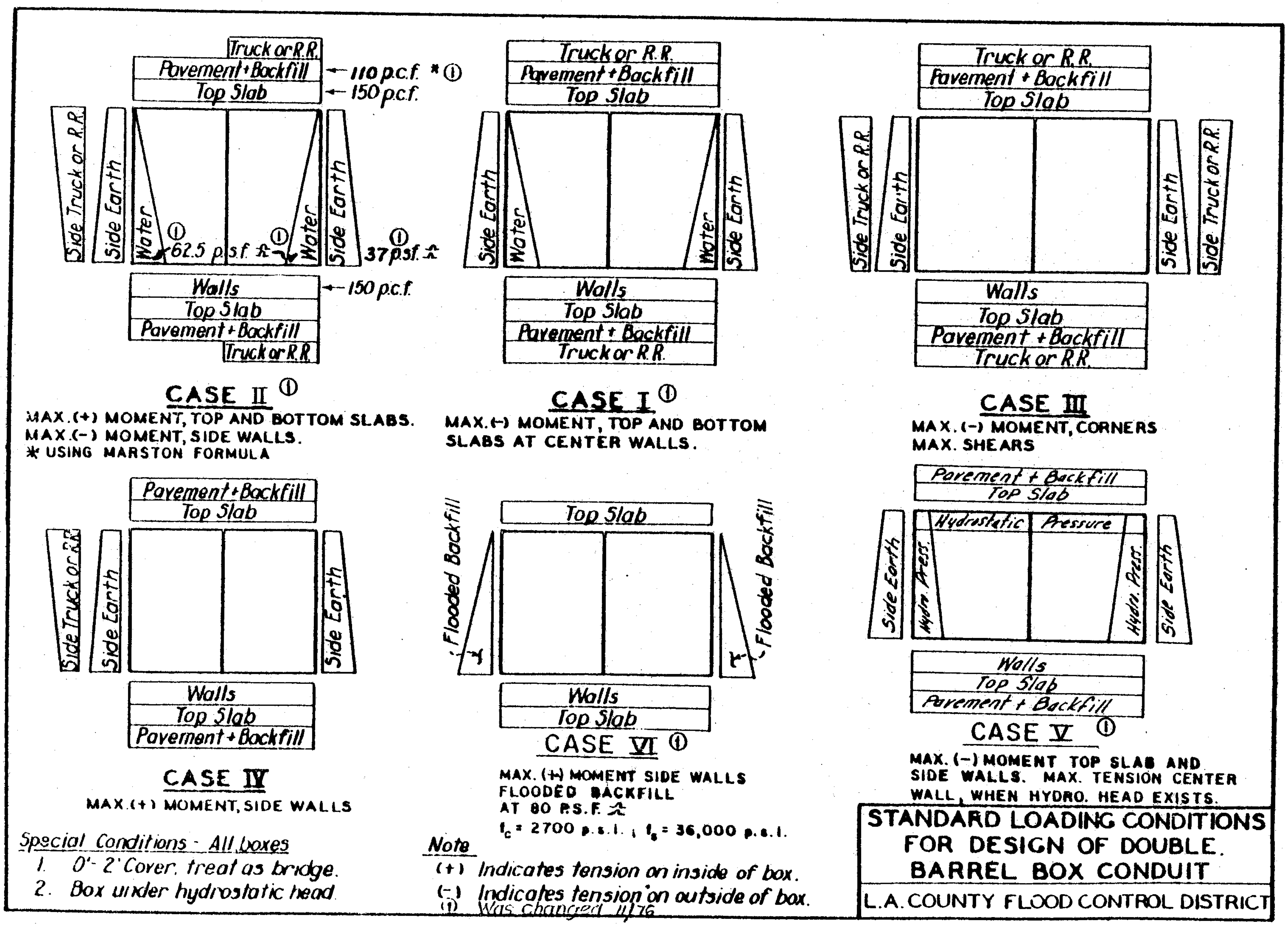


Special Conditions - All boxes
1. 0'-2' Cover, treat as bridge.
2. Box under hydrostatic head.

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

STANDARD LOADING CONDITIONS FOR DESIGN OF SINGLE BARREL BOX CONDUIT

L.A. COUNTY FLOOD CONTROL DISTRICT



Truck or R.R.
Pavement + Backfill
Top Slab
110 p.c.f. * ①
150 p.c.f.
Side Truck or R.R.
Side Earth
Water
① 62.5 p.s.f. ft.
①
37 p.s.f. ft.
150 p.c.f.
Walls
Top Slab
Pavement + Backfill
Truck or R.R.
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
MAX.(-) MOMENT, CORNERS
MAX. SHEARS
CASE IV
MAX.(+) MOMENT, SIDE WALLS
Flooded Backfill
CASE VI ①
MAX. (+) MOMENT SIDE WALLS
FLOODED BACKFILL
AT 80 P.S.F. ft.
f_c = 2700 p.s.i. ; f_s = 36,000 p.s.i.
Hydrostatic Pressure
Hydr. Press.
CASE V ①
MAX. (-) MOMENT TOP SLAB AND SIDE WALLS. MAX. TENSION CENTER WALL, WHEN HYDRO. HEAD EXISTS.
Special Conditions - All boxes
1. 0'- 2' Cover, treat as bridge.
2. Box under hydrostatic head
Note
(+) Indicates tension on inside of box.
(-) Indicates tension on outside of box.
① Was changed 11/76
STANDARD LOADING CONDITIONS FOR DESIGN OF DOUBLE BARREL BOX CONDUIT
L.A. COUNTY FLOOD CONTROL DISTRICT

BOX PROGRAM – INPUT FORM

Design Phase - Standard Criteria

Card (cols 1–3)	TITLE (cols 4–70)
0 1 2	SAMPLE PROBLEM FOR DESIGN MANUAL

Card (cols 1–3)	DC (4)	NR (5)	IC (6)	LL (7)	DEPTH TO FINISH GRADE (8–13)	DEPTH TO NATURAL GRADE (14–19)	AXLE LOAD (20–23)	PRESSURE HEAD (24–29)	LEFT BARREL WIDTH (30–35)	LEFT BARREL HEIGHT (36–41)	RIGHT BARREL WIDTH (42–47)	RIGHT BARREL HEIGHT (48–53)	(54–70)
0 1 3	2	1	1	2	8.	8.	32.	0	10.	12.			
0 1 2													
0 1 3													
0 1 2													
0 1 3													
0 1 2													
0 1 3													

BOX PROGRAM - INPUT FORM

Design Phase - Optional Criteria

012	TITLE

									Left Barrel		Right Barrel	
013	DC	NB	LC	LT	DEPTH TO FIN. GRADE	DEPTH TO NATURAL GRADE	AXLE LOAD	PRESSURE HEAD	WIDTH	HEIGHT	WIDTH	HEIGHT

016	MIN. TOP SLAB THICKNESS (in)	MIN. INVERT SLAB THICKNESS (in)	MIN. WALL THICKNESS (in)	POSITIVE STEEL COVER TOP SLAB (in)	POSITIVE STEEL COVER INVERT (in)	POSITIVE STEEL COVER WALL (in)	NEGATIVE STEEL COVER TOP SLAB (in)	NEGATIVE STEEL COVER INVERT SLAB (in)	NEGATIVE STEEL COVER WALL (in)	TRENCH CLEARANCE (ft)	POSITIVE PROJECTION SETTLEMENT RATIO	NEGATIVE PROJECTION SETTLEMENT RATIO

016	SOIL FRICTION COEFFICIENT	COMPRESSIVE CONCRETE STRESS AT 28 DAYS f'c (psi)	ALLOWABLE CONCRETE STRESS fc (psi)	YIELD POINT STRESS OF STEEL (psi)	ALLOWABLE STEEL STRESS (psi)	MODULAR RATIO	ALLOWABLE BOND STRESS (psi)	ALLOWABLE SHEAR STRESS (psi)	SOIL DENSITY (Kips/ft)	ALLOWABLE BOND STRESS TOP BARS (psi)	LATERAL SOIL PRESSURE Kips/ft EFP.	

Box Program – Input Form
Check Phase

Card		TITLE
0 1 2	1	SAMPLE PROBLEM FOR DESIGN MANUAL

Card	DC	NB	IC	DEPTH TO FIN. GRADE	DEPTH TO NATURAL GRADE	AXLE LOAD	PRESSURE HEAD	LEFT BARREL WIDTH	LEFT BARREL HEIGHT	RIGHT BARREL WIDTH	RIGHT BARREL HEIGHT
0 1 3	2	1	1 2	8	8.	32.	0	10.	12.		

Card	LEFT BARREL THICKNESS TOP SLAB	LEFT BARREL THICKNESS INVERT SLAB	LEFT BARREL THICKNESS LEFT WALL	LEFT BARREL THICKNESS RIGHT WALL	RIGHT BARREL THICKNESS TOP SLAB	RIGHT BARREL THICKNESS INVERT SLAB	RIGHT BARREL THICKNESS LEFT WALL	RIGHT BARREL THICKNESS RIGHT WALL	LONG. BARS
0 1 4	8.75	9.75	8.	8.					66.

Card	LC	Bar	No.	SIZE	SPACING	H LENGTH FT.	H LENGTH IN.	V LENGTH FT.	V LENGTH IN.	Bar	No.	SIZE	SPACING	H LENGTH FT.	H LENGTH IN.	V LENGTH FT.	V LENGTH IN.	Bar	No.	SIZE	SPACING	H LENGTH FT.	H LENGTH IN.	V LENGTH FT.	V LENGTH IN.	LAST CARD
0 1 5		B BAR	1	7	10	11	1			B_1 BAR	2	4	10	5	11 5			C BAR	3	4	11	4	25	12	2	
0 1 5		C_1 BAR	4	6	11	2	05	2	10	C_2 BAR	5	4	11	4	25	2	3	C_3 BAR	6	6	11	2	85	2	5	
0 1 5		D BAR	7	5	11			13	35	F BAR	8	9	14	11	1			F_1 BAR	9	5	14	6	25			Yes __ No ✓
① 0 1 5	9	G BAR	10	4	11	5				G_1 BAR	11							H BAR	12	4	11	5				Yes ✓ No __
0 1 5		H_1 BAR	13							CW BAR	27							B_2 BAR	14							Yes __ No __
0 1 5		B_3 BAR	15							C_4 BAR	16							C_5 BAR	17							Yes __ No __
0 1 5		C_6 BAR	18							C_7 BAR	19							D_1 BAR	20							Yes __ No __
0 1 5		F_2 BAR	22							G_3 BAR	23							G_4 BAR	24							Yes __ No __

0223 FCD3/73

① WAS CHANGED 11/76

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
LIVE LOAD TRUCK AXLE LOAD 32.0 KIPS
TOTAL DESIGN VERTICAL LOAD TOP 13.23 KIPS INVERT 14.50 KIPS
PRESSURE HEAD 0.0 FT
DESIGN STRESSES 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

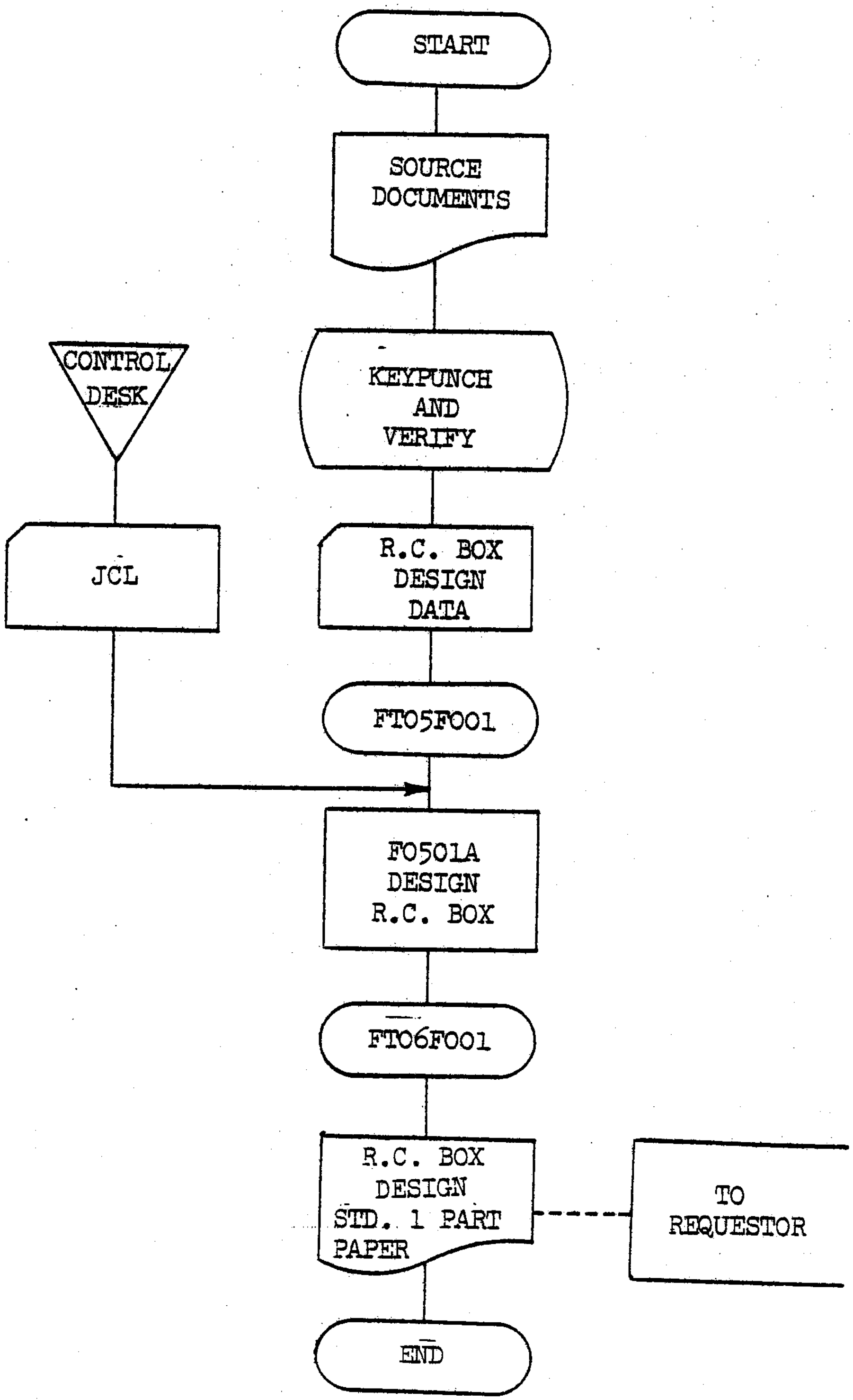
	RESULTANT STRESSES (P.S.I.)			
	CONCRETE	RE-STEEL	UNIT SHEAR	BOND
TOP SLAB				
CORNER	680.	12196.	68.0	235.0
MIDSPAN	1594.	23635.		
WALL				
TOP	775.	12959.	17.9	61.5
CENTERLINE	0.	0.		
BOTTOM	622.	10400.	11.8	38.4
INVERT SLAB				
CORNER	463.	8662.	68.8	238.9
MIDSPAN	1642.	23176.		

NOTE:

SIMILAR SHEET IS PRODUCED FOR EACH LOADING CASE.

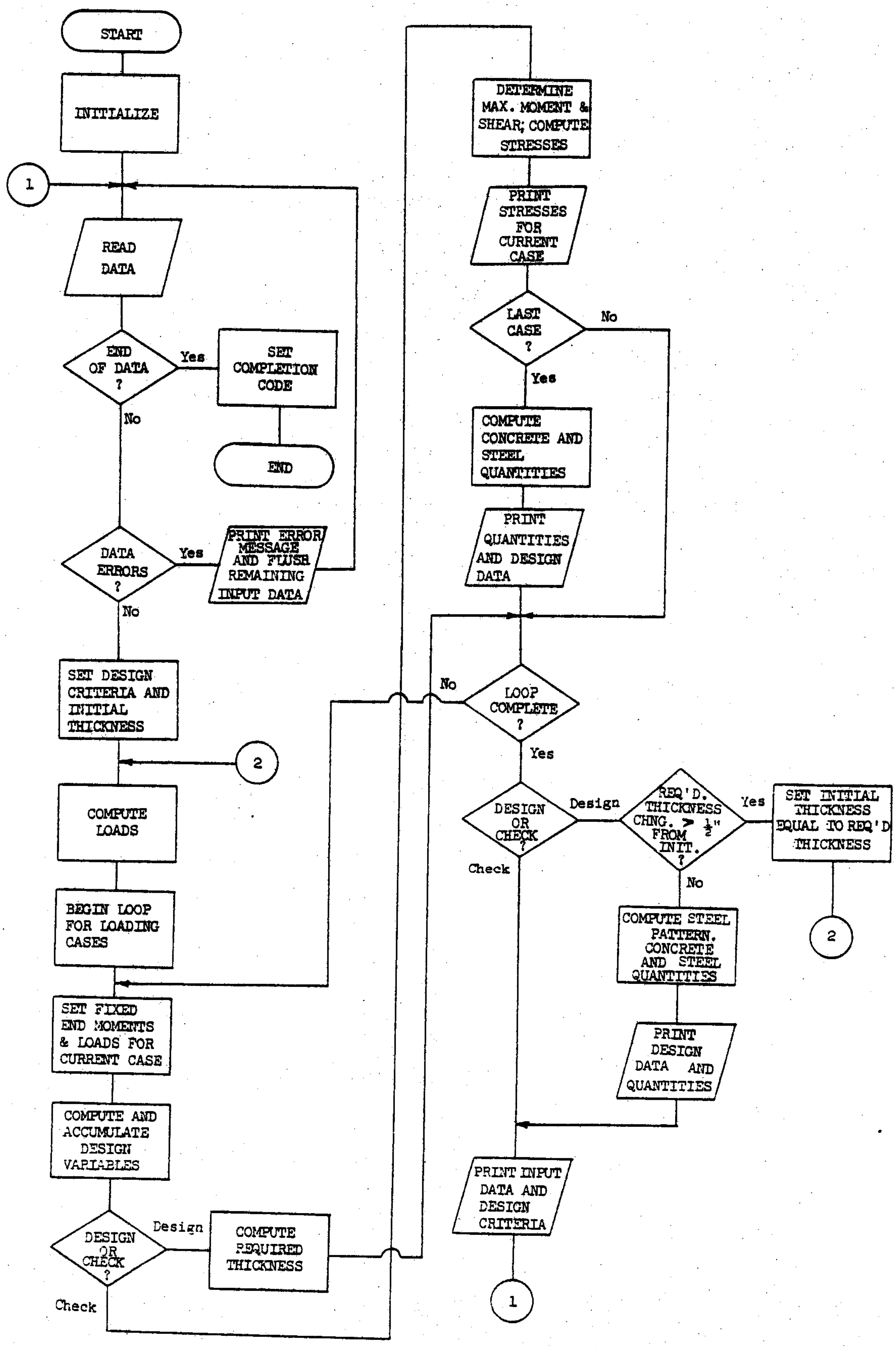
REINFORCED CONCRETE BOX DESIGN AND CHECK

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),                         1
// COND.GO=((7,LT,FORT),(8,LT,IKED))
//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    BRLON
     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.LKED=(3,LT,FORT),        1
// SYSLMOD='SYSAF.FLOODLIB(F0501A)',LMODISP=OLD
//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    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    GG1
     INSERT    BRLON
     ENTRY     MAIN
/* END OF LINKAGE EDITOR CONTROL CARDS
```

REINFORCED CONCRETE BOX DESIGN AND CHECK (F0501A)

JCL LISTING TO EXECUTE OBJECT MODULE

```
/*PRIORITY      11                                              F0501P00
//F0501P   JOB  (0400,A108),'DESIGN,409-900',CLASS=F,PRTY=11    F0501P01
//JOBLIB   DD   DSN=SYSAF.FLOODLIB,DISP=SHR                     F0501P02
//         EXEC PGM=F0501A                                      F0501P03
//FT06F001 DD   SYSOUT=A                                        F0501P04
//FT05F001 DD   * DATA CARDS FOLLOW                             F0501P05
/* END OF DATA CARDS                                            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. Hetenyi[3]. 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 criteria[1] are set internally, and cannot be modified by the user. The criteria are listed below:

Description	Value
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 heighth 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 ____________________

Ext. No. ____________________

Prog. No. ☐ 0502 A ☐ 0502 P ☐ 0502 B

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

WIDTH										HEIGHT						
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0	5	8					.							.		

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

WIDTH										HEIGHT						
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0	5	8					.							.		

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

WIDTH										HEIGHT						
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0	5	8					.							.		

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

WIDTH										HEIGHT						
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0	5	8					.							.		

CD 6/73

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.	INS.	VERTICAL LENGTH FT.	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		

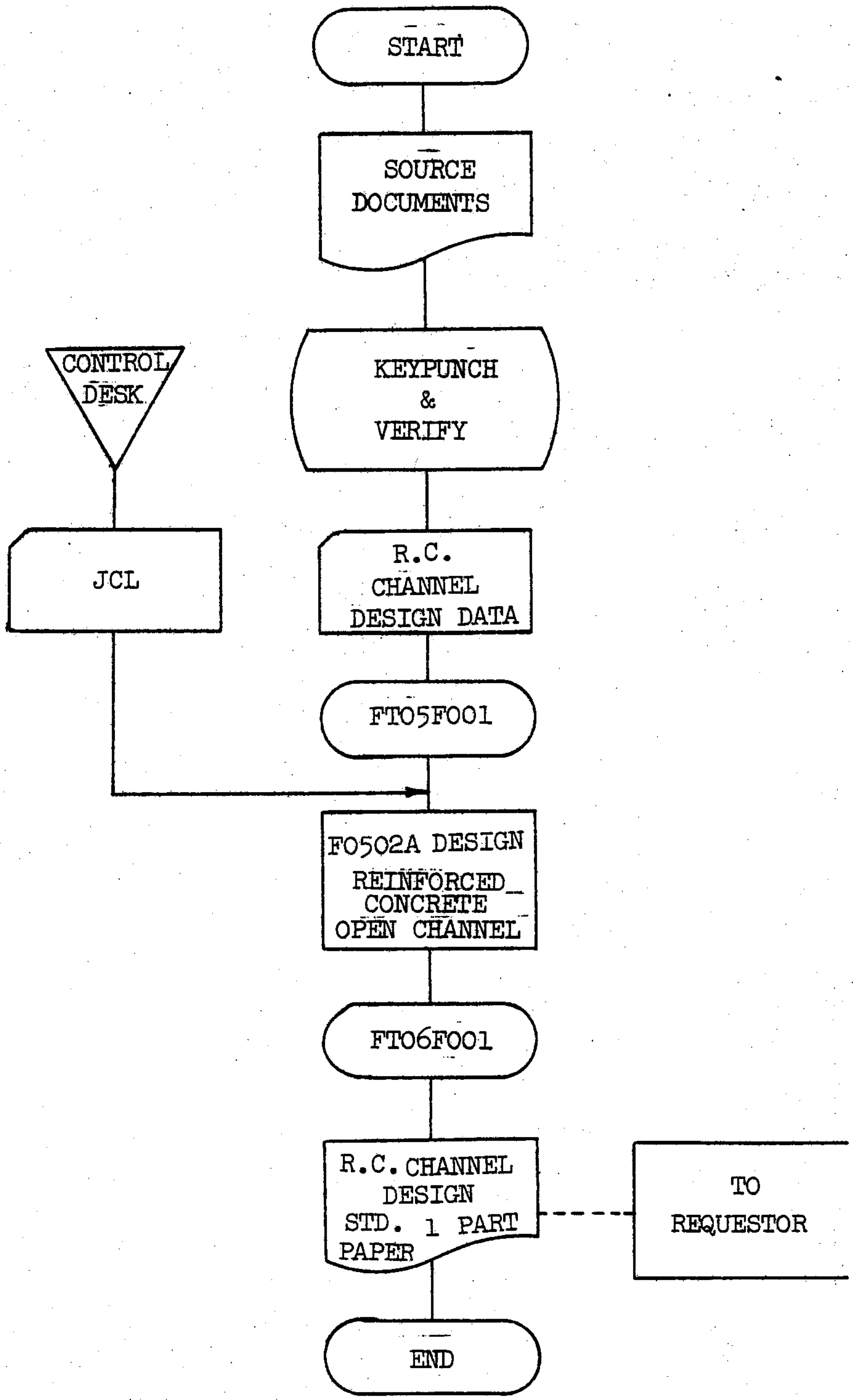
61 NO. 4 LONGITUDINAL BARS
29 IN SLAB 32 IN WALLS

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.PR.
INWARD (TRI.) = 62.5 P.S.F. E.F.PR.
(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

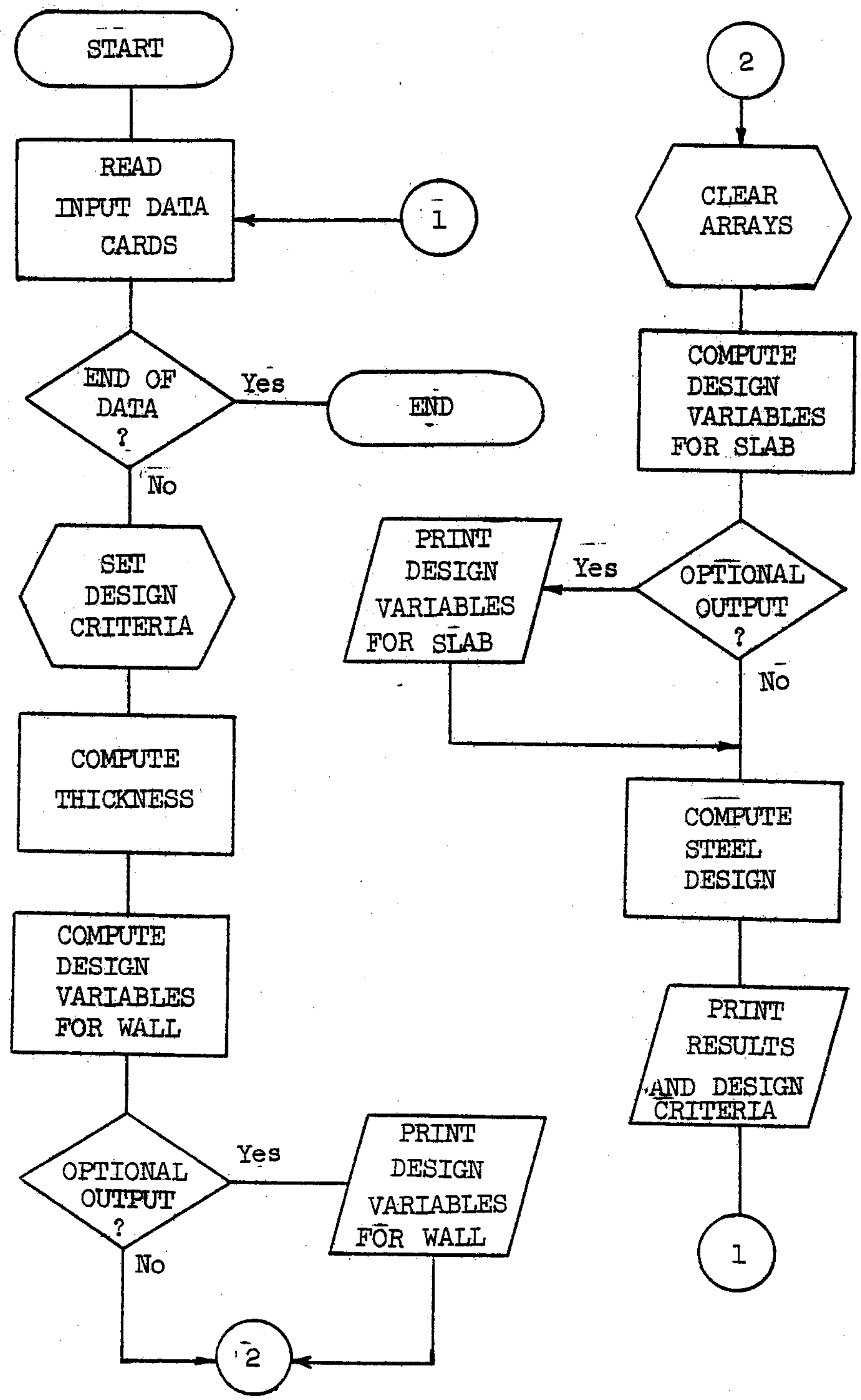
REINFORCED CONCRETE OPEN CHANNEL DESIGN

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
//F0502T   JOB  (0400,A108),'J. COSTA,400-18N',PRTY=9,CLASS=F
//         EXEC FORTGCLG,PARM.FORT=(BCD,MAP,ID),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
//F0502T1  JOB  (0400,A108),'COSTA,400-18N',PRTY=9,CLASS=F
//         EXEC FORTGCL,PARM.FORT=(MAP,ID,BCD),COND.LKED=(3,LT,FORT),    1
// SYSLMOD='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                                                  F0502P00
//F0502P1  JOB  (0400,A108),'DESIGN,409-900',PRTY=11,CLASS=D       F0502P01
//JOBLIB   DD   DSN=SYSAF.FLOODLIB,DISP=SHR                        F0502P02
//         EXEC PGM=F0502A                                         F0502P03
//FT06F001 DD   SYSOUT=A                                           F0502P04
//FT05F001 DD   * DATA CARDS FOLLOW                                F0502P05
/* END OF DATA CARDS                                               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 Association[4]. 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[1]; 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):

Symbol	Name
R	Radius (Ft)
T1	Crown thickness (Ins.)
T2	Spring line thickness (Ins.)
T3	Invert thickness (Ins.)
AN	Angle to tangent (Deg.)
Os1	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.)
X1WAT	Internal water (k.c.f.)
XPRHD	Pressure head (Ft.)
XZN	Modular ratio
ATY	Section to be run 1 - Horseshoe 2 - Circular 3 - Both
1D	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.

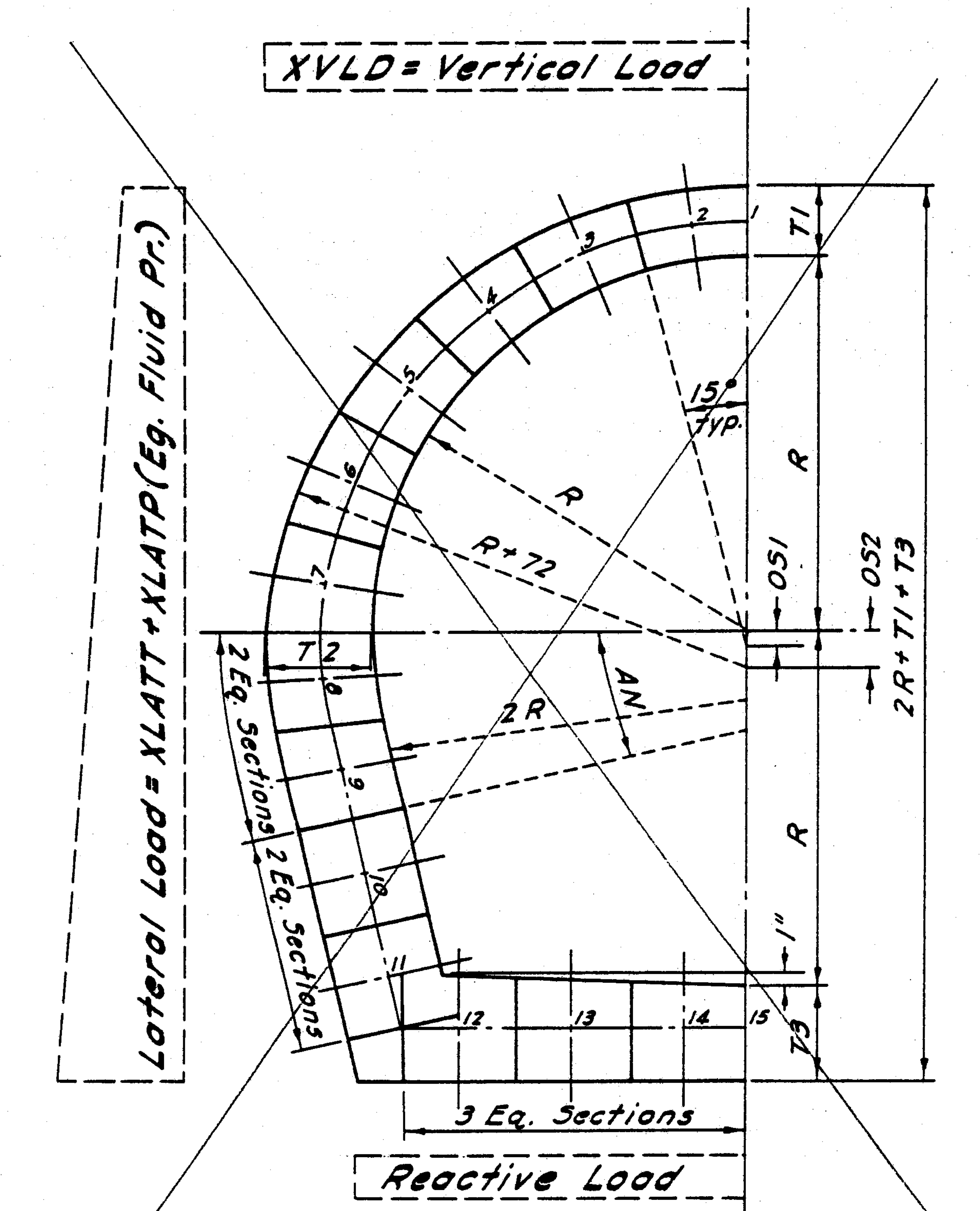
APPENDIX 3

Sample Problem:

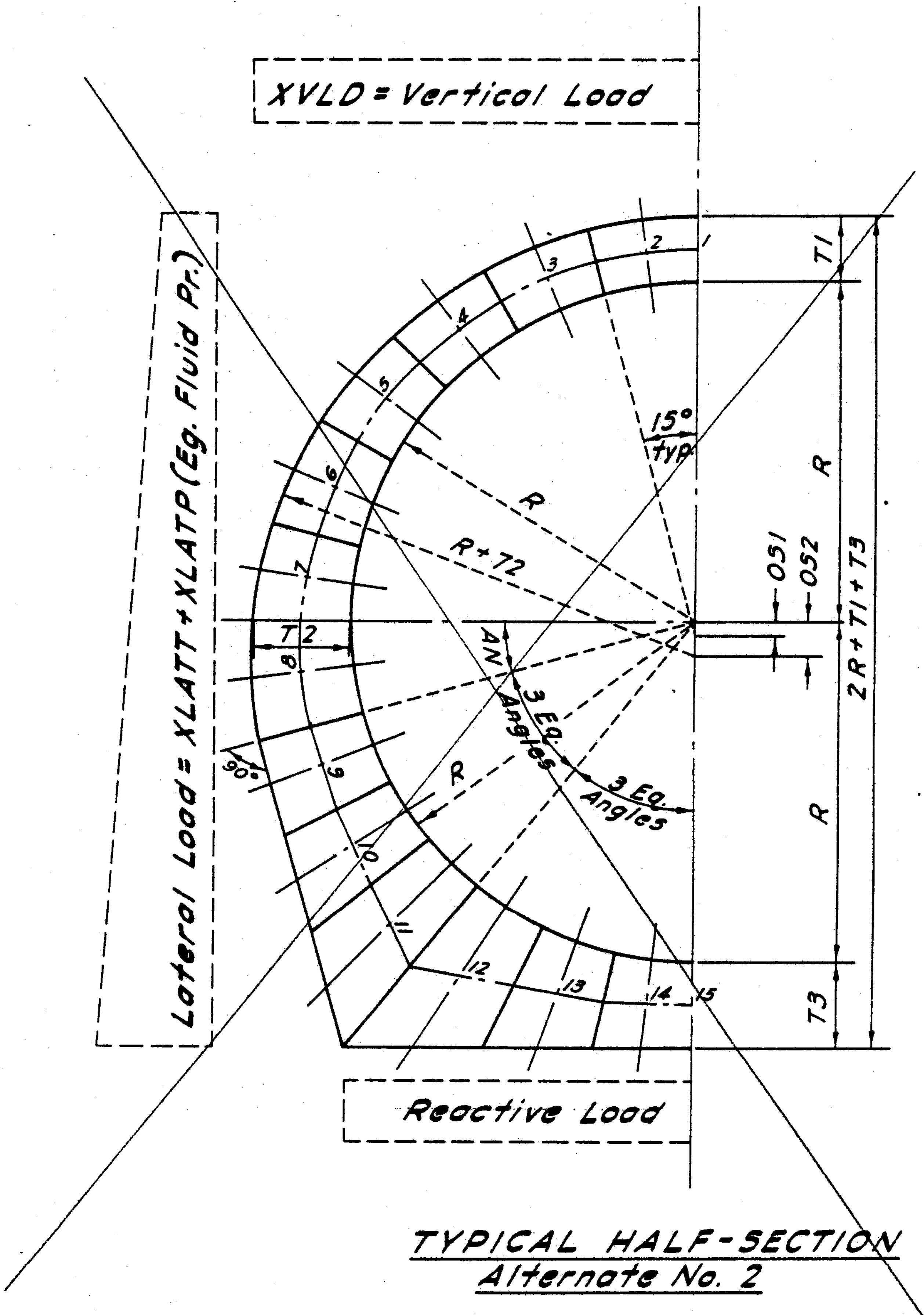
The design of a 12'-0" horseshoe arch with either a circular or a horseshoe interior is shown, including input data and output values.

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



TYPICAL HALF-SECTION
Alternate No 1



TYPICAL HALF-SECTION
Alternate No. 2

BOND ISSUE

DESIGN OF REINFORCED CONCRETE ARCH

COMPUTER PROGRAM NO. 0504

PROJECT: SAMPLE PROBLEM DATA ENTERED BY: R.J. SMITH

CHECKED BY: V. MARTINEZ DIVISION: DESIGN DATE: DEC. 1, 1970

DEFINITION OF INPUT VALUES

SYMBOL	NAME	SYMBOL	NAME
R	RADIUS (FT.)	XCONC	A. CONCRETE STRESS (P.S.I.)
T1	CROWN THICK. (INS.)	XSTL	A. STEEL STRESS (P.S.I.)
T2	SPR.LINE THICK (INS.)	XVLD	VERTICAL LOAD (K.S.F.)
T3	INVERT THICK (INS.)	XLATT	UNIF. LATERAL LOAD (K.S.P.)
AN	ANGLE TO TANGENT (DEG.)	XLATP	TRI. LATERAL LOAD (K.S.P.)
OS1	CENTERLINE OFFSET (INS.)	XIWAT	INTERNAL WATER (K.C.F.)
OS2	EXTERIOR RADIUS OFFSET (INS.)	XPRHD	PRESSURE HEAD (FT.)
		XZN	MODULAR RATIO
XSC1	STEEL COVER ARCH IN. (INS.)	ATY	SECTION TO BE RUN 1 — HORSESHOE 2 — CIRCULAR 3 — BOTH
XSC2	STEEL COVER ARCH OUT. (INS.)		
XSC3	STEEL COVER INV. IN. (INS.)		
XSC4	STEEL COVER INV. OUT. (INS.)		
		ID	1-IN COL. 62 FOR CHECKING BLANK IN COL. 62 FOR DESIGN

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

SECOND CARD - DIMENSIONS

R (1–6)	T1 (7–12)	T2 (13–18)	T3 (19–24)	AN (25–30)	OS1 (31–36)	OS2 (37–42)	XSC1 (43–47)	XSC2 (48–52)	XSC3 (53–57)	XSC4 (58–62)
6.	8.	9.	10.	15.	.5	1.	2.	2.	2.	2.

THIRD CARD - CRITERIA

XCONC (1–7)	XSTL (8–14)	XVLD (15–21)	XLATT (22–28)	XLATP (29–36)	XIWAT (37–44)	XPRHD (45–52)	ATY (53)	XZN (54–59)	ID (60–62)
1800.	24000.	2.	.6	.03	.062	.0	3	8.	

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	THRUST	SHEAR	THICKNESS	C. STRESS	UNIT SHEAR	PERIMETER	COMPRESSION STEEL	TENSION STEEL
	FT. KIPS	KIPS	KIPS	INS.	P.S.I.	P.S.I.	INS.	SQ. INS.	SQ. INS.
1	14.72	4.79	0.0	9.32	1798.	0.0	0.0	0.0	1.03
2	14.21	4.93	1.22	9.34	1759.	15.87	0.63	0.0	0.99
3	10.12	6.19	3.31	9.38	1470.	42.73	1.71	0.0	0.63
4	3.14	8.37	4.42	9.42	903.	56.80	2.27	0.0	0.04
5	-4.70	10.85	4.22	9.46	1099.	53.91	2.16	0.0	0.10
6	-11.06	12.95	2.72	9.50	1623.	34.52	1.38	0.0	0.53
7	-13.93	13.70	3.41	9.54	1819.	43.02	1.72	0.00	0.72
8	-12.62	14.38	1.74	9.56	1738.	21.94	0.88	0.0	0.61
9	-8.82	14.45	2.99	9.56	1475.	37.64	1.51	0.0	0.32
10	-3.09	14.79	3.26	9.57	1022.	41.00	1.64	0.0	0.0
11	1.87	15.47	2.50	9.60	922.	31.39	1.26	0.0	0.0
12	17.12	2.02	12.93	15.87	919.	88.83	3.55	0.0	0.66
13	34.10	2.02	7.53	15.47	1393.	53.28	2.13	0.0	1.40
14	42.58	2.02	2.51	15.07	1645.	18.31	0.73	0.0	1.82
15	48.82	2.02	0.0	14.87	1819.	0.0	0.0	0.00	2.12

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. = 1800.   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 INS.	C. STRESS P.S.I.	UNIT SHEAR P.S.I.	PERIMETER INS.	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	0.00	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	525.	41.21	1.65	0.0	0.0
12	34.45	9.74	12.50	27.60	760.	46.49	1.86	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

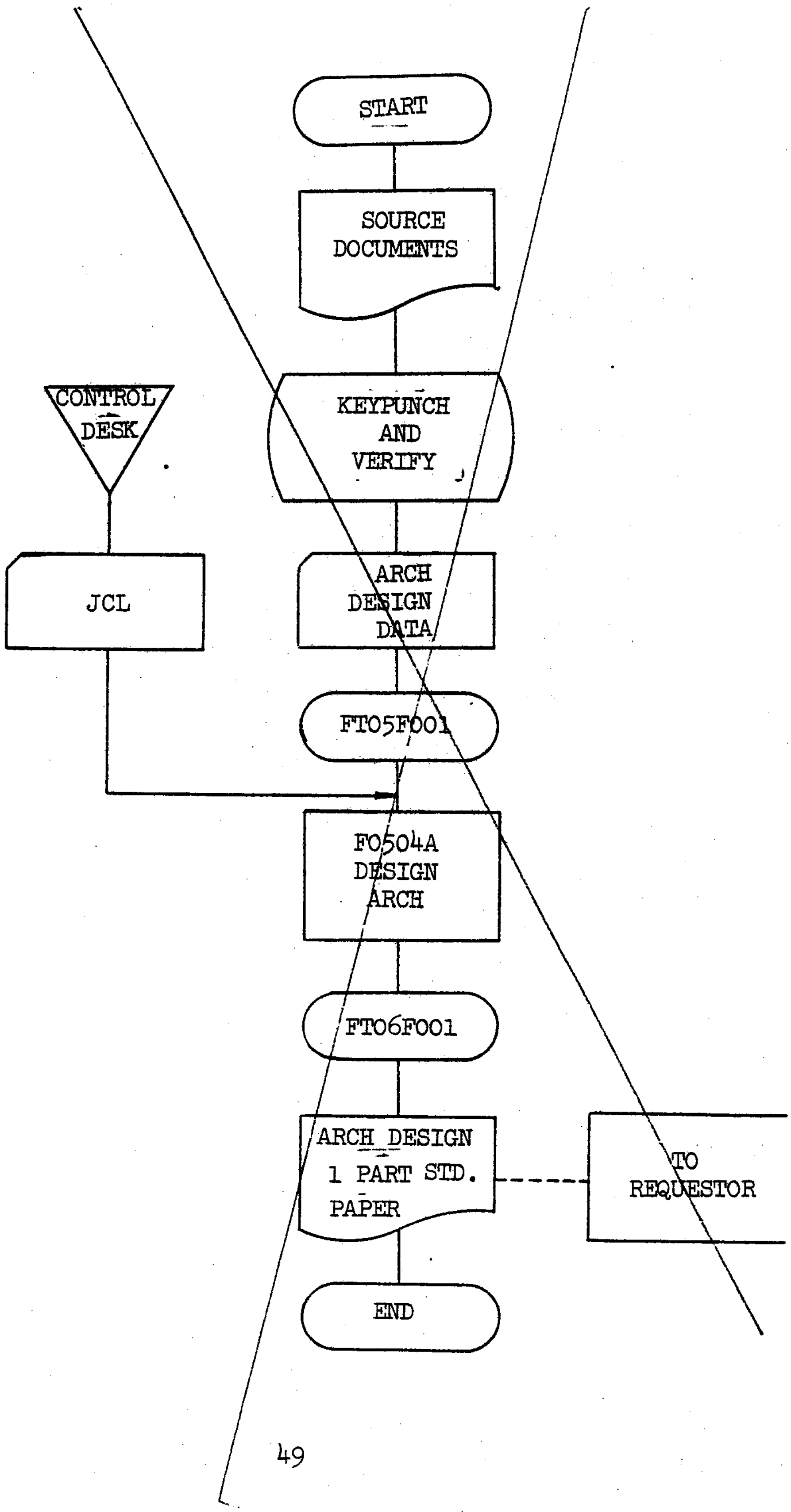
LOADS (K.S.F.)
VERT. = 2.00   U. LAT. = 0.60   T. LAT. =0.030
WATER =0.062   PR. HEAD = 0.0 FT.

A. STRESSES (P.S.I.)
CONC. = 1800.   RE-STEEL = 24000.

MODULAR RATIO = 8.0

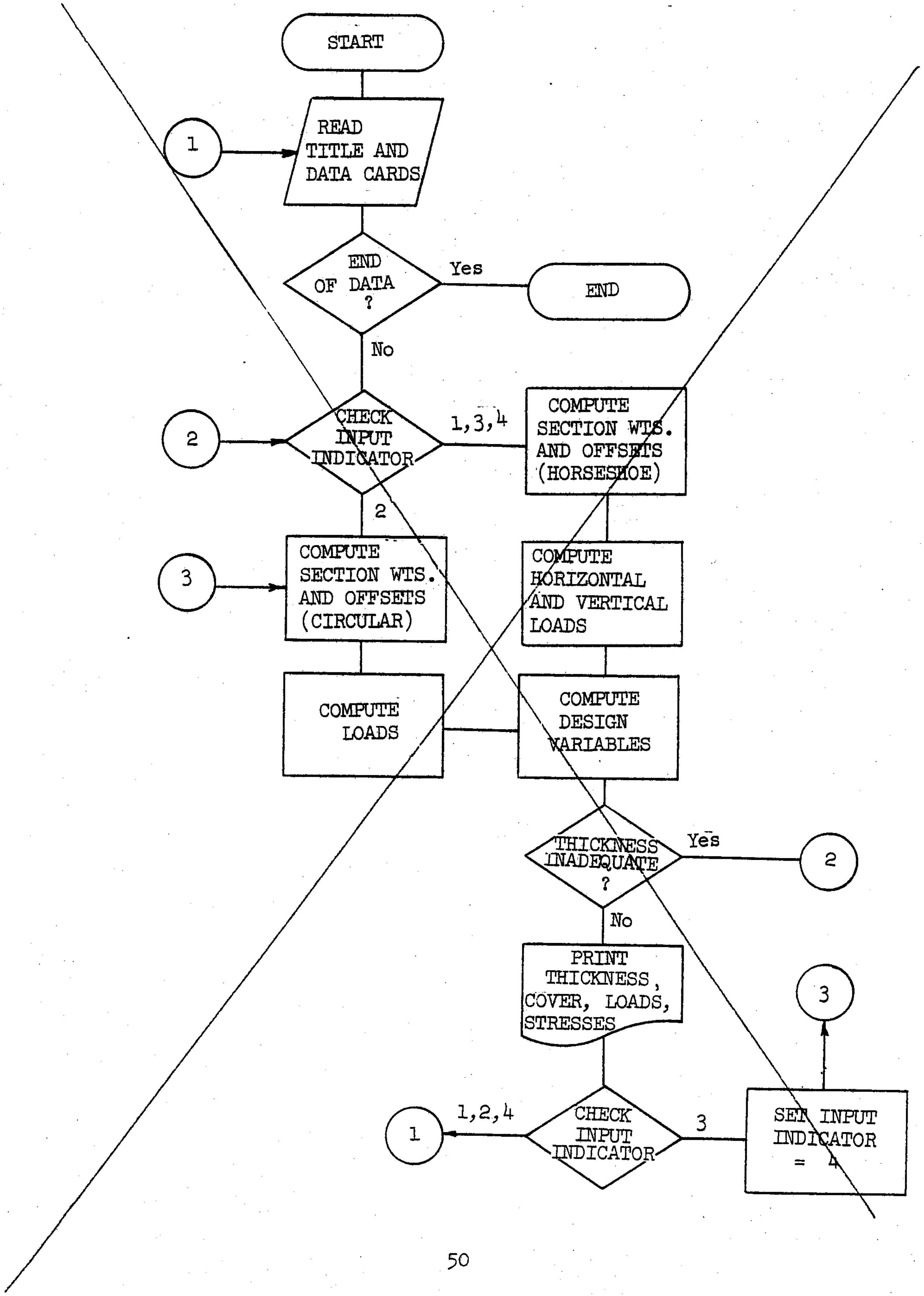
REINFORCED CONCRETE ARCH DESIGN

SYSTEM FLOWCHART



REINFORCED CONCRETE ARCH DESIGN

GENERAL FLOWCHART



JOB CONTROL LANGUAGE

R. C. ARCH DESIGN (F0504A)

JCL LISTING TO EXECUTE OBJECT MODULE

```
//F0504P  JOB   (0400,A108),'DESIGN,409-5241N',CLASS=F,PRTY=10          504A0G01
//JOBLIB  DD    DSN=SYSAF.FLOODLIB,DISP=SHR                             504A0G02
//        EXEC  PGM=F0504A                                              504A0G03
//FT06F001 DD   SYSOUT=A                                                504A0G04
//FT05F001  DD  *   DATA CARDS FOLLOW - PRODUCTION                      504A0G05
/*  END OF DATA CARDS                                                   504A0G06
```

R. C. ARCH DESIGN (F0504A)

JCL LISTING TO STORE OBJECT MODULE IN LIBRARY

```
//F0504P1 JOB   (0400,A108),'DESIGN,409-5241N',CLASS=F,PRTY=10          504A0ST1
//         EXEC FORTGCLG,PARM.FORT=(BCD,MAP,ID),COND.LKED=(3,LT,FORT),  1504A0ST2
// SYSLMOD='SYSAF.FLOODLIB(F0504A)',LMODISP=OLD                         504A0ST3
//FORT.SYSIN    DD  *   SOURCE PROGRAM FOLLOWS  -  STORE PROG ON LIB    504A0ST4
//*   END OF SOURCE PROGRAM                                             504A0ST5
```

R. C. ARCH DESIGN (F0504A)

JCL LISTING TO COMPILE LINK-EDIT AND GO

```
//F0504P2 JOB   (0400,A108),'DESIGN,409-5241N',CLASS=F                  505ACLG1
//         EXEC FORTGCLG,PARM.FORT=(BCD,MAP,ID),COND.GO=(7,LT,FORT)     505ACLG2
//FORT.SYSIN  DD  *   SOURCE PROGRAM FOLLOWS                            505ACLG3
/*   END OF SOURCE                                                      505ACLG4
//GO.SYSIN  DD *   DATA FOLLOWS                                         505ACLG5
/*  END OF DATA                                                         505ACLG6
```

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 Manual[1].

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 "11D".

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 "11N". The soil density used is as indicated by the input value of "1SD". 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 "1LL" 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 "X1W" is 0, internal water is not considered. If "X1W" is set equal to 1, the conduit is assumed flowing full. For pressure flow, set "X1W" 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.

PROJECT: *SAMPLE PROBLEM* DATA ENTERED BY: *R. J. SMITH*

CHECKED BY: *V. MARTINEZ* DIVISION: *DESIGN* DATE: *DEC. 1, 1970*

BOND ISSUE

DESIGN OF REINFORCED CONCRETE PIPE

COMPUTER PROGRAM *0505*

DEFINITIONS: OF INPUT VALUES

CARD NO. 1

SYMBOL	NAME
IID	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

SYMBOL	NAME
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 ℄ BAR)

CARD NO. 1

IID	XT	XFI	XFZ	XFX	XCONC	XSTL	XN	XLAT	XIW	XPH
1–4	5–10	11–16	17–22	23–28	29–35	36–42	43–48	49–54	55–60	61–66
132	11.5	2.	14.	6.	2025.	24000.	8.	.0	1.	.0

CARD NO. 2

ISD	IW	PRA	SRA	IIN	ILL	XCOV
1–4	5–10	11–16	17–22	23–25	26–28	29–34
110	24	.	.	1	20	1.5

DESIGN OF REINFORCED CONCRETE PIPE

PIPE DIAMETER INS.	WALL THICKNESS INS.	DEPTH OF FILL FT.	STEEL REQUIREMENTS IN SQ. INS./LIN. FT. DOUBLE CIRCULAR INN. CIR.	OUT. CIR.	CIR. AND ELLIPTICAL CIR.	ELL.	ELL. ONLY ELL.
132	11.50	2.0	1.21	0.82	0.39	0.82	1.21
132	11.50	8.0	1.18	0.80	0.38	0.80	1.18
132	11.50	14.0	1.52	1.04	0.48	1.04	1.52

DESIGN CRITERIA

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

MODULAR RATIO 8.

EARTH LOAD
LATERAL 0.0 PSF. E.F.P.
VERTICAL (MARSTONS)
SOIL DENSITY 110 PCF.
TRENCH
O. DIA. + 24 INS.

ANGLE OF LOADING
TOP 180 DEG.
BOTTOM 90 DEG.

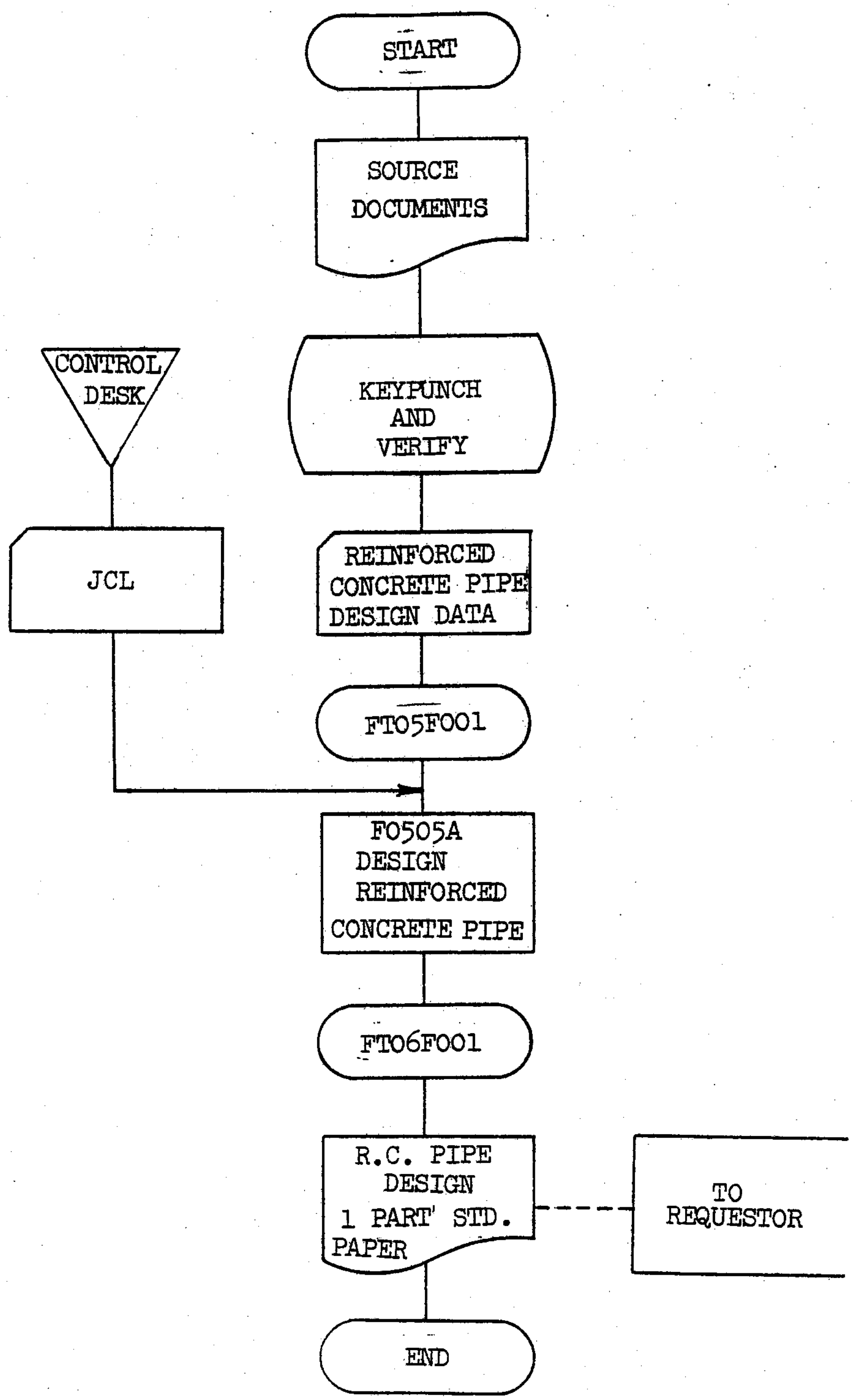
COVER ON STEEL 1.50 INS.

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

CONDUIT FULL PRESSURE HEAD = 0.0 FT.

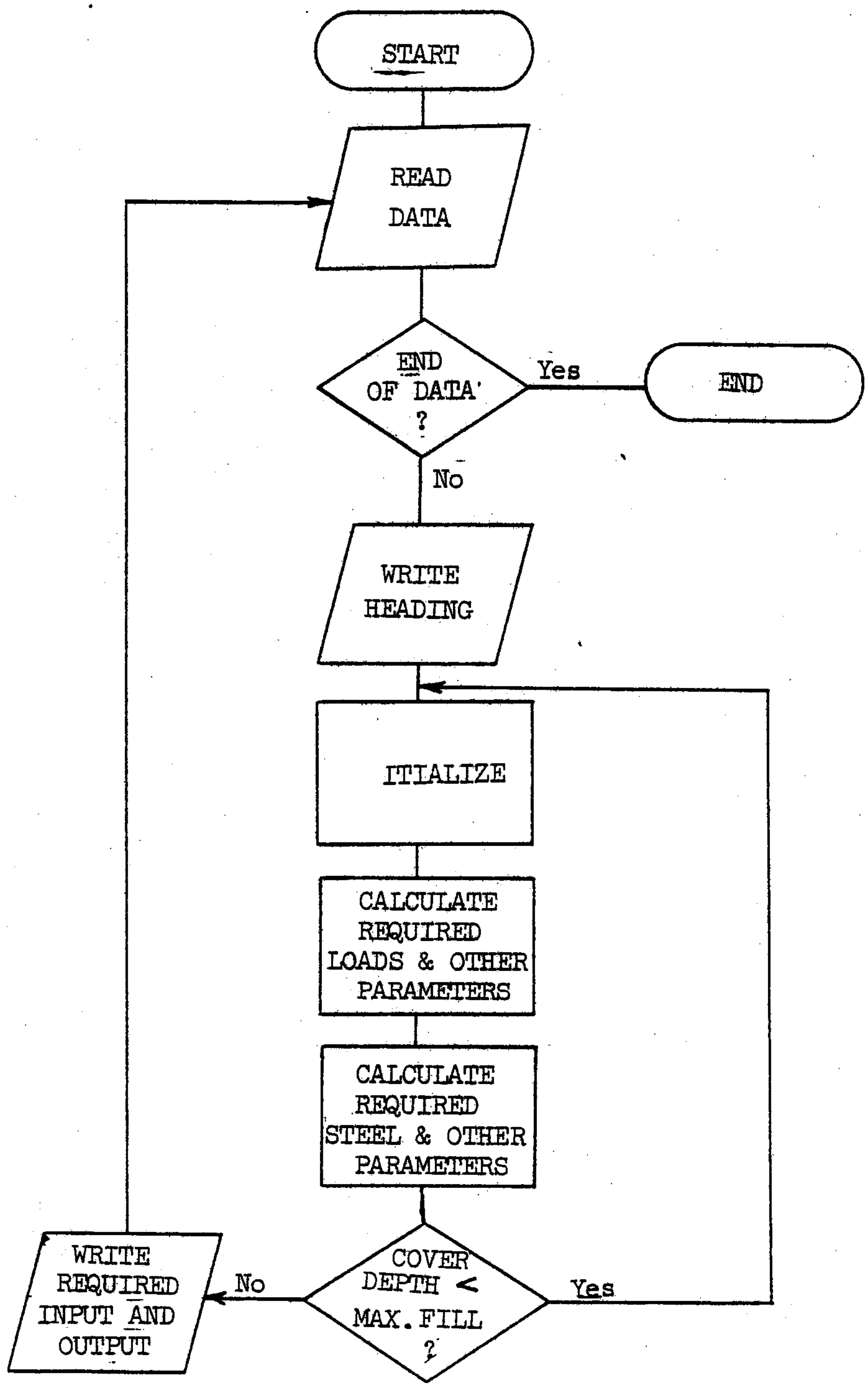
REINFORCED CONCRETE PIPE DESIGN

SYSTEM FLOWCHART



REINFORCED CONCRETE PIPE DESIGN

GENERAL FLOWCHART



JOB CONTROL LANGUAGE

```
                    REINFORCED CONCRETE PIPE DESIGN  (F0505A)
                JCL LISTING TO EXECUTE OBJECT MODULE
//F0505P    JOB   (0400,A108),'DESIGN,409-950N',CLASS=D,PRTY=10          505A0G01
//JOBLIB    DD    DSN=SYSAF.FLOODLIB,DISP=SHR                            505A0G02
//          EXEC  PGM=F0505A                                             505A0G03
//FT06F001   DD   SYSOUT=A                                               505A0G04
//FT05F001    DD  *   DATA CARDS FOLLOW - PRODUCTION                     505A0G05
/*  END OF DATA CARDS                                                    505A0G06

                    REINFORCED CONCRETE PIPE DESIGN  (F0505A)
                JCL LISTING TO STORE OBJECT MODULE IN LIBRARY
//F0505P1 JOB   (0400,A108),'DESIGN,409-950N',CLASS=F,PRTY=10            505A0ST1
//         EXEC FORTGCLG,PARM.FORT=(BCD,MAP,ID),COND.LKED=(3,LT,FORT),  1505A0ST2
// SYSLMOD='SYSAF.FLOODLIB(F0505A)',LMODISP=OLD                          505A0ST3
//FORT.SYSIN    DD  *   SOURCE PROGRAM FOLLOWS  -  STORE PROG ON LIB     505A0ST4
//*   END OF SOURCE PROGRAM                                              505A0ST

                    REINFORCED CONCRETE PIPE DESIGN  (F0505A)
                JCL LISTING TO COMPILE  LINK-EDIT AND GO
//F0505P2 JOB    (0400,A108),'DESIGN,409-5241N',CLASS=F                  505ACLG1
//         EXEC  FORTGCLG,PARM.FORT=(BCD,MAP,ID),COND.GO=(7,LT,FORT)     505ACLG2
//FORT.SYSIN   DD  *   SOURCE PROGRAM FOLLOWS                            505ACLG3
/*   END OF SOURCE                                                       505ACLG4
//GO.SYSIN  DD *   DATA FOLLOWS                                          505ACLG5
/*  END OF DATA                                                          505ACLG6
```

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 minumum spacing for a given bar cannot satisfy the steel area or perimiter 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.

Permissable 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.