CENTRAL FILES

PP&L

TWO NORTH NINTH STREET, ALLENTOWN, PA. 18101 PHONE: (215) 821-5151

July 6, 1979

50-387/388

Mr. Boyce H. Grier
Nuclear Regulatory Commission
631 Park Avenue
King of Prussia, Pennsylvania 19406

SUSQUEHANNA STEAM ELECTRIC STATION
RESPONSE TO NRC BULLETIN 79-02
ER 100450 FILE 840-4, 150-C72 PLA - 378

Dear Mr. Grier:

The following is our reply to IE Bulletin No. 79-02 dated March 8, 1979 for the Susquehanna Steam Electric Station. The subject bulletin requires all licensees and permit holders for nuclear power plants to review the design and installation procedures for concrete expansion anchor bolts used in pipe support base plates for Seismic Category I Systems.

All pipe anchors and support base plates using expansion anchor bolts were re-analyzed to account for plate flexibility, bolt stiffness, shear-tension interaction, minimum edge distance and proper bolt spacing. Several methods of analysis were used to determine the bolt design loads. The specific analytical method used was dependent on the complexity of the base plates. The majority were analyzed using a quasi analytical computer program, BOLTS, developed by Bechtel to be used for base plates with eight bolts or less. A description of this and the other analytical methods is given in the attachments to this letter.

The results of the analyses have revealed a relatively small percentage of pipe supports having loads greater than the allowables cited in the design specification. Attachment 1 presents a summary of the analyses of concrete expansion bolts.

For anchor bolts which, according to the re-analysis, have indicated loading greater than that permitted by the design specification, corrective actions will be initiated. Design details will be modified for those pipe supports which have not been installed. For pipe supports that have been installed, the design details will be modified and the base plate stiffness will be increased by hardware changes. The design effort will be completed by August 31, 1979. Pipe supports which require hardware modifications will be completed prior to fuel load.

Revision 1 of IE Bulletin 79-02 clarified those items dealing with anchor installation that require verification. Inspection of concrete expansion anchors is performed using the Quality Control Instructions outlined in QCI-C-1.50.

The Quality Control Instructions requires, among other items, the following:

(1) Review of latest applicable drawings, sketches, specifications, procedures, etc.

(2) Verification of minimum distance between anchor centers and the minimum distance from anchor centerline to the edge of the concrete.

All Seismic Category I piping support installations are 100% torque tested in accordance with Susquehanna construction procedures.

Provisions for checking plate bolt hole size exist. The piping support details, which specify bolt hole sizes, undergo a receiving inspection. Also, a dimensional check of the piping support is performed in the shop by a Bechtel inspector.

Minimum anchor embedment amongst other activities is checked on a surveillance basis. Typically, when Bechtel inspectors are unable to verify minimum anchor embedment, the supporting assembly is removed to verify proper embedment and then torque-tested. This also substantiates that the anchor does not come in contact with the back of the support plates. It has been Bechtel's experience that if the expansion anchors are not installed correctly, the anchor shells will rotate even if drawn up against the backing plates. There is presently no Susquehanna project requirement for checking the full expansion of the shell for shell type anchor bolts.

Although not a specific inspection activity, quality control inspectors are trained to verify minimum thread engagement. If expansion anchors with exposed bolts have the bolt flush with the nut or greater, it is considered acceptable.

Attachments 2 through 4 present Bechtel Power Corporation's generic response to the subject NRC Bulletin.

Attachment 2 is the generic Bechtel response to NRC Bulletin 79-02, Revision 1 supplemented by the Susquehanna response to Item 6 of the Bulletin.

Attachment 3 is to the Documentation package for "BOLTS" computer program.

Attachment 4 is the Description of the Strength Design Method. This method was used to analyze the base plates outside the scope of the "BOLTS" program.

Please let us know if you desire additional information regarding this matter.

Very truly yours,

NW Curtis

Norman W. Curtis
Vice President - Engineering and Construction

RWM-JDV/kes

Attachment 1.

SUMMARY OF ANALYSIS
CONCRETE EXPANSION BOLTS (CEB)

Large Pipe (2-1/2" and Larger) Supports:

No. of Pipe Supports with CEB	=	349
No. of Pipe Supports subject to reanalysis	=	349
No. of Pipe Supports with CEB analyzed by computer analysis ('Bolts' program)	=	329
No. of Pipe Supports subject to detailed analysis (Strength Design) and/or hardware modification	=	20
No. of Pipe Supports with CEB loading greater than permitted by Specification C-72	=	9

Small Pipe (2" and Smaller) Supports

No. of Pipe Supports with CEB	=	950
No. of groups of pipe supports with CEB based on standard base plates & bolt patterns	=	23
No. of groups of pipe supports subject to reanalysis	=	23
No. of groups of pipe supports with loading greater than permitted by Specification C-72	=	2
No. of pipe supports in the two groups above	=	99*

*Please note that individual analysis of these supports will decrease the number of CEB with loading greater than permitted by Specification C-72.

(J11-24/2)

A Report on

PIPE SUPPORT BASE PLATE DESIGNS

USING CONCRETE EXPANSION ANCHOR BOLTS

(In Response to: NRC IE Bulletin No. 79-02, dt. March 8, 1979

I. Introduction

This report is in response to NRC IE Bulletin 79-02, dated March 8, 1979, requiring all licensees and permit holders for nuclear power plants to review the design and installation procedures for concrete expansion anchor bolts used in pipe support base plates in systems defined as Seismic Category I by the NRC Regulatory Guide 1.29, "Seismic Design Classification", Revision 1, dated August, 1973 or by the applicable SAR.

In accordance with the intent of the Bulletin 79-02, the following types of supports have been considered in the present review.

a. Pipe Anchors (Seismic Category I)
b. Pipe Supports (Seismic Category I)

The design and installation of the expansion anchor bolts on the Susquehanna power station were governed by the following documents:

II. Response to Action Items

1. Verify that pipe support base plate flexibility was accounted for in the calculation of anchor bolt loads. In lieu of supporting analysis justifying the assumption of rigidity, the base plates should be considered flexible if the unstiffened distance between the member welded to the plate and the edge of the base plate is greater than twice the thickness of the plate. If the base plate is determined to be flexible, then recalculate the bolt loads using an appropriate analysis which will account for the effects of shear-tension interaction, minimum edge distance and proper bolt spacing. This is to be done prior to resting of anchor bolts. These calculated bolt loads are referred to hereafter as the bolt design loads.

RESPONSE: All pipe anchor and support base plates using expansion anchor/bolts were (re) analyzed to account for plate flexibility, bolt stiffness, shear-tension interaction, minimum edge distance, and proper bolt spacing. Depending on the complexity of the individual base plate configuration one of the following methods of analysis was used to determine the bolt forces:

(i) A quasi analytical method, developed by Bechtel was used for base plates with eight bolts or less. A review of the typical base plates based in supporting the subject piping systems indicate that the majority of them were anchored either by 4, 6 or 8 bolts. The plate thickness usually varied from 1/2" to 2" and are not generally stiffened. For these types of base plates an analytical formulation has been developed which treats the plates as a beam on multiple spring supports subjected to moments and forces in three orthogonal directions. Based on analytical considerations as well on the results of a number of representative finite element analyses of base plates (using the "ANSYS" Code), certain empirical factors were introduced in the simplified beam model to account for (a) the effect of concrete foundation (b) the two way action of load transfer in a plate. These factors essentially provided a way for introducing the interaction effect of such parametric variables as plate dimensions, attachments sizes, bolt spacings and stiffnesses on the distribution of external loads to the bolts.

The results of a number of case studies indicated excellent correlation between the results of the present formulation and those by the finite element method (using the "ANSYS" Code). The quasi analytical method generally gives the bolt loads greater than the FEM.

Although the effect of plate flexibility has been explicitly considered in the quasi analytical formulation described above, the impact of prying action on the anchor bolts was determined not to be critical for the following reasons:

a. Where the anchorage system capacity is governed by the concrete shear cone, the prying action would result in an appli-

cation of an external compressive load in the cone and would not therefore affect the anchorage capacity.

b. Where the bolt pull out determines the anchorage capacity, the additional load carried by the bolt due to the prying action will be self-limiting since the bolt stiffness decreases with increasing load. At higher loads the bolt expansion will be such that the corners of the base plate will lift off and the prying action will be relieved. This phenomena has been found to occur when the bolt stiffness in the Finite Element Analysis was varied from a high to a low value, to correspond typically to the initial stiffness and that beyond the allowable design load.

A computer program for the analytical technique described above has been implemented for determining the bolt loads for routine applications. The program requires plate dimensions, number of bolts, bolt size, bolt spacing, bolt stiffness, the applied forces and the allowable bolt shear and tension loads as inputs. The allowable loads for a given bolt are determined based on the concrete edge distance, bolt spacing, embedment length, shear cone overlapping, manufacturer's ultimate capacity, and a design safety factory. The program computes the bolt forces and calculates a shear-tension interaction value based on the allowable loads.

The shear-tensions interaction in the anchor bolts has been accounted for in the following manner:

1. Where the applied shear force is less than the frictional force developed in the shear plane between the steel and the concrete surface for balancing the imposed loads, no additional provisions are required for shear.

2. Otherwise, the total applied shear is required to be carried by the bolts in accordance with the following interaction formula.

$$\left(\frac{T}{T_A}\right)^2 + \left(\frac{S}{S_A}\right)^2 \leq 1.0$$

Where T and S are the calculated tensile and shear forces and T_A and S_A are the respective allowable values.

(ii) For special cases where the design of the support didn't lend itself to the foregoing method, the finite element method using the "ANSYS" code and/or other standard engineering analytical techniques with conservative assumption were employed in the analysis.

(iii) Other cases were solved using an approach based on the strength design method given in the ACI 318-77 code.

2. Verify that the concrete expansion anchor bolts have the following minimum factor of safety between the bolt design load and the bolt ultimate capacity determined from static load tests (e.g., anchor bolt manufacturer's) which simulate the actual conditions of installation (i.e., type of concrete and its strength properties):

   a. Four - Four wedge and sleeve type anchor bolts.

   b. Five - For shell type anchor bolts.

RESPONSE

In the current design review, factors of safety (i.e. ratio of bolt ultimate capacity to design load) four for wedge type and five for shell type anchor bolts were used for service load cases. When extreme environmental loads are included, a factor of safety of three is acceptable in accordance with Section B.7.2 of the Proposed Addition to Code Requirements for Nuclear Safety Related Concrete Structures (ACI 349-76) August 1978.

Further, where an effective program of 100% verification of accetable anchor bolts had been implemented, a factor of safety of two is considered satisfactory with extreme environmental loads.

3. Describe the design requirements if applicable for anchor bolts to withstand cyclic loads (e.g. seismic loads and high cycle operating loads).

RESPONSE

In the original design of the piping systems (Bechtel) considered deadweight, thermal stresses, seismic loads, and dynamic loads in the generation of the pipe support design loads. To the extent that these loads include cyclic considerations, these effects would be included in the design of the hangers, base plates and anchorages.

The safety factors used for concrete expansion anchors, installed on supports for safety related piping systems, were not increased for loads which are cyclic in nature. The use of the same safety factor for cyclic and static loads is based on the FFTF Tests*. The test results indicate:

1. The expansion anchors successfully withstood two million cycles of long term fatique loading at a maximum intensity of 0.20 of the static ultimate capacity. When the maximum load intensity was steadily increased beyond the aforementioned value and cycled for 2,000 times at each load step, the observed failure load was about the same as the static ultimate capacity.

2. The dynamic load capacity of the expansion anchors, under simulated seismic loading, was about the same as their corresponding static ultimate capacities.

4. Verify from existing QC documentation that design requirements have been met for each anchor bolt in the following areas:

   (a) Cyclic loads have been considered (e.g., anchor bolt preload is equal to or greater than bolt design load). In the case of the shell type, assure that it is not in contact with the back of the support plate prior to preload testing.

   (b) Specified design size and type is correctly installed (e.g., proper embedment depth).

If sufficient documentation does not exist, then initiate a testing program that will assure that minimum design requirements have been met with respect to sub-items (a) and (b) above. A sampling technique is acceptable. One acceptable technique is to randomly select and test one anchor bolt in each base plate (i.e. some supports may have more than one base plate). The test should provide verification of sub-items (a) and (b) above. If the test fails, all other bolts on the base plate should be similiarly

tested. In any event, the test program should assure that each Seismic Category I system will perform its intended function.

RESPONSE: It is not necessary that the bolt preload be equal to or greater than the bolt design load. Pipe supports and anchors are subjected to static and dynamic loads. The dynamic loads are seismic loads which are short duration cyclic loads. This type of cyclic load is not a fatigue load, so the amount of preload on the bolts will not greatly affect the performance of the anchorage. (In addition, preload is lost over the life of the plant due to creep and other similar phenomena). Therefore, if the initial installation torque on the bolt accomplishes the purpose of setting the wedge, then the ultimate capacity of the bolt is not affected by the amount of preload present in the bolt at the time of the cyclic loading. For vibratory loads during plant operation, the expansion anchors have successfully withstood long term fatigue environment as discussed in the previous section.

All concrete expansion anchors are designed, installed and verified as per Specification 8856-C-72. Installation, verification and testing procedures along with acceptance criteria are given in sections 4.0, 5.0 and 6.0 of this specification.

Also, expansion anchors are tested for preload using a sampling technique specified in Section 6.0 of the specification or as per the attached sampling program. The proper documentation, indicating the location of expansion anchor and group represented, method of test (torque or tension), test results, type of failure when applicable, date of test along with name and signature of the inspector, are maintained at the jobsite.

SAMPLING PROGRAM

A random sampling inspection procedure is established to determine the acceptability of concrete expansion anchor installations. An upper confidence limit on D, the number of defects in the population, N, is constructed based on the hypergeometric distribution (Jaech, J. L., "Statistical Methods in Nuclear Material Control". TID-26298, Exxon Nuclear Company, Richland, Wash., 1973).

*Drilled - In Expansion Bolts Under Static and Alternating Loads. Report No. BR-5853-C-4 by Bechtel Power Corp., January, 1975.

JUL 2 '79 106276

$$\sum_{X=0}^{X_o} \frac{\binom{D}{X}\binom{N-D}{n-X}}{\binom{N}{n}} \leqslant \alpha$$

Where X_o = the number of observed defects in the sample, n = the sample size and (1-X)100 = confidence level. The acceptance criteria is a 95% confidence level that there are less than 5% defective in the total population (i.e. D/N $\leq$ 0.05).

6. For CEB which have shown loading greater than permitted by Specification C-72, corrective actions will be initiated. For those pipe supports which have not been installed, design details will be modified. For pipe supports that have been installed, the design details will be modified and base plate stiffness will be increased by hardware changes.

The design effort will be completed by August 31, 1979.

The pipe supports which require hardware modifications will be completed prior to fuel load.

ATTACHMENT 3 (47 PAGES)

BECHTEL

CALCULATION COVER SHEET

JUL 2 '79 106276

PROJECT CIVIL STAFF GENERIC CALC JOB NO. – DISCIPLINE CIVIL

SUBJECT CINCH (EXPANSION) ANCHOR COMPUTER PROG. VERIFICATION FILE NO. CALC/1

CALC. NO. C-1979-3

ORIGINATOR Scott Close / Ed Mahoney DATE 4/20/79

CHECKER Ed Mahoney / Scott Close DATE 4/20/79 NO. OF SHEETS 47

RECORD OF ISSUES

NO.	DESCRIPTION	BY	DATE	CHKD	DATE	APPRD	DATE	DATE FILMED
0	"BOLTS" PROGRAM VERIFICATION	EHM/S.C.	4/20/79	EHM/S.C.	4/20/79	K Lee	4/21/79	
1	"BOLTS" REVISION & VERIFICATION	EHM/S.C.	5/15/79	EHM/S.C.	5/15/79	K Lee	6/8/79	
2	TESTCASE #7 ADDED	EHM/S.C.	6/9/79	S.C./EHM	6/9/79	K Lee	6/11/79	

PRELIMINARY CALC. ☐ COMMITTED PRELIMINARY DESIGN CALC. ☐

SUPERSEDED CALC. ☐ FINAL CALC. ☒

RECORD OF ISSUES (calculation Revision and associated Computer program version)

Calc Rev NO.	COMPUTER PROGRAM VERSION	DESCRIPTION
0	VERSION (A)	– ORIGINAL Release
1	VERSION (B)	– Warning on PLATE Flexibility removed – Second Non-linear interaction equation added – Distribution factors for axial tension (F2) revised – ability to input a 10 character title added
2	VERSION (C)	– Equation limiting the moment arm included

CONTROLLED COPY

GPD-2704 Rev. 9 (2D-1)

2'79_106276

CALCULATION SHEET

BECHTEL

CALC. NO. C-1979-3 REV. NO. 0

ORIGINATOR Scott Close DATE 4/11/79 CHECKED Ed Mehorney DATE 4/18/79

PROJECT Civil Staff JOB NO. —

SUBJECT CINCH ANCHOR COMPUTER Prog SHEET NO. 1

BOLTS COMPUTER PROGRAM

INTRODUCTION:

A Fortran computer program has been developed which will determine anchor bolt Loads and interaction values for base plates with 4, 6, or 8 bolt patterns. The program resides on the CDC-NOS computer system (family KA) and may be accessed by any one qualified on that system.

The program has the following features:

- It only considers the idealized cases of 4, 6, and 8 Bolt anchor bolt patterns described in Appendix A of this report.
- Can use either linear or non-linear interation equation
- all input is in free field and separated by Commas
- all units are in Kips and inches
- An analysis costs approximatly 30 cents/plate

To execute the program a user, after Logging on to the CDC-NOS System, should follow these Steps, where LFN is any 7 character name.

TYPE:

```
GET, LFN= BOLTS / UN=SCOTTDC, PW=RUNSETZ.
PRIMARY, LFN.
FTNTS
RNH
```

JUL 2 '79 106276

BECHTEL

CALCULATION SHEET

CALC. NO. C-1979-3 REV. NO. 0

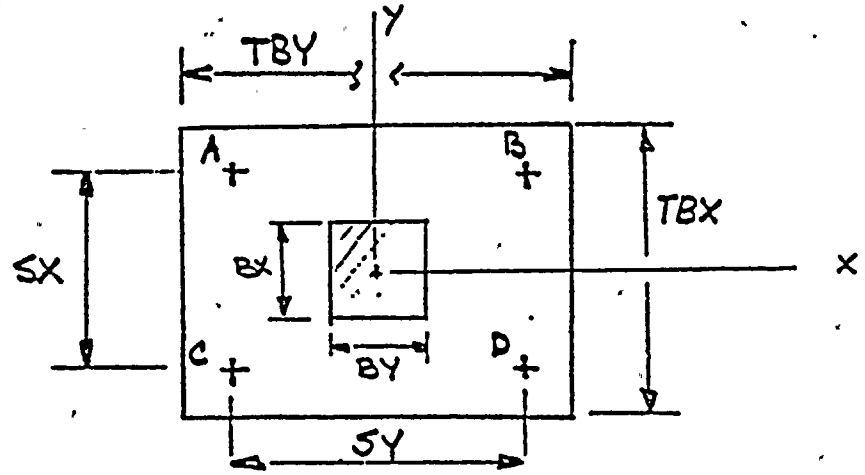
ORIGINATOR Scott Closa DATE 4/11/79 CHECKED EJ Mahoney DATE 4/18/79

PROJECT Civil Staff JOB NO. —

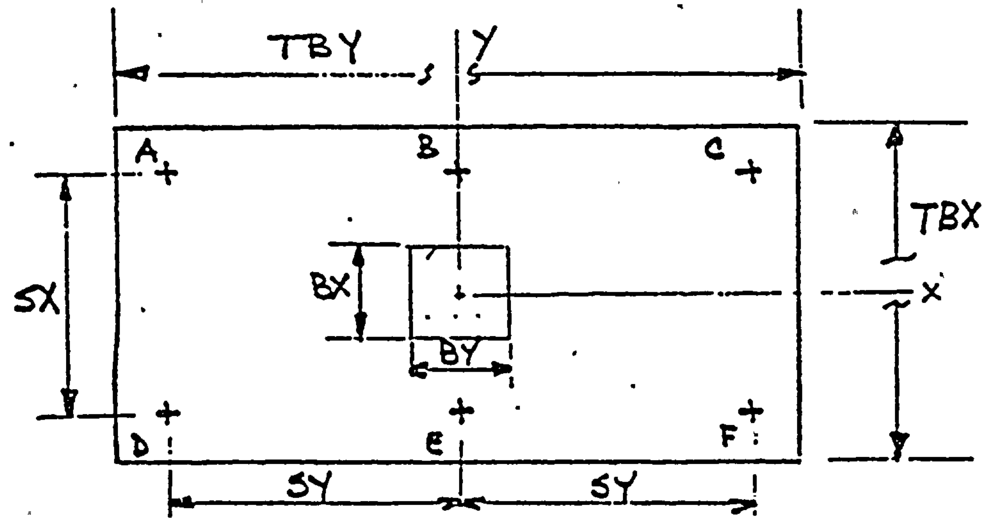
SUBJECT CINCH ANCHOR COMPUTER PROGRAM SHEET NO. 2

Program Notation:

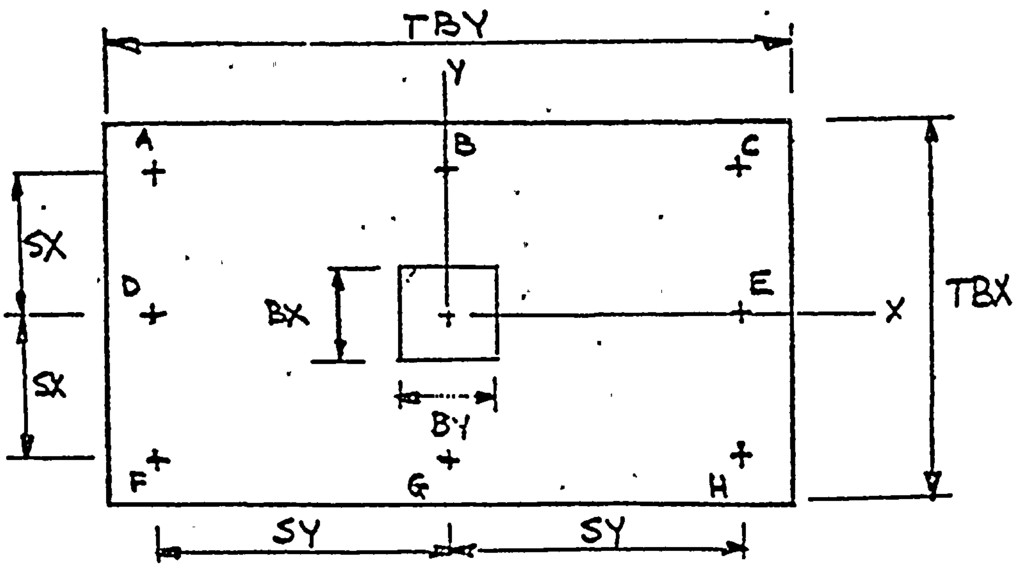
4 - BOLT OPTION



6 - BOLT OPTION



8 - BOLT OPTION



JUL 2 '79 106276

BECHTEL

CALCULATION SHEET

CALC. NO. C-1979-3 REV. NO. 0

ORIGINATOR Scott Close DATE 4/11/79 CHECKED [signature] DATE 4/18/79

PROJECT Civil Staff JOB NO. –

SUBJECT CINCH ANCHOR COMPUTER PROGRAM SHEET NO. 3

PROGRAM NOTATION (CONT'D)

The following variables were also used in the program:

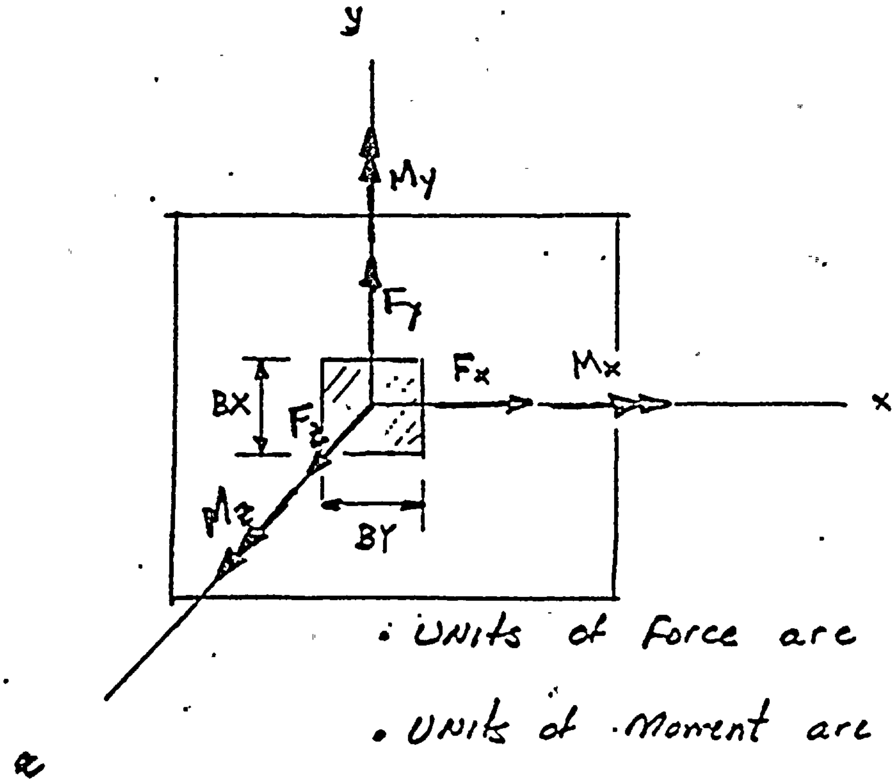
THK = thickness of base plate (in inches)

KB = Anchor bolt stiffness (in K/in)

FTALL = allowable tensile force in bolt (K)

FSALL = allowable shear force in bolt (K)

Applied loading sign convention:



- Units of Force are kips
- Units of Moment are in-kips
- Units of Length are in inches

279 106276

CALCULATION SHEET

BECHTEL

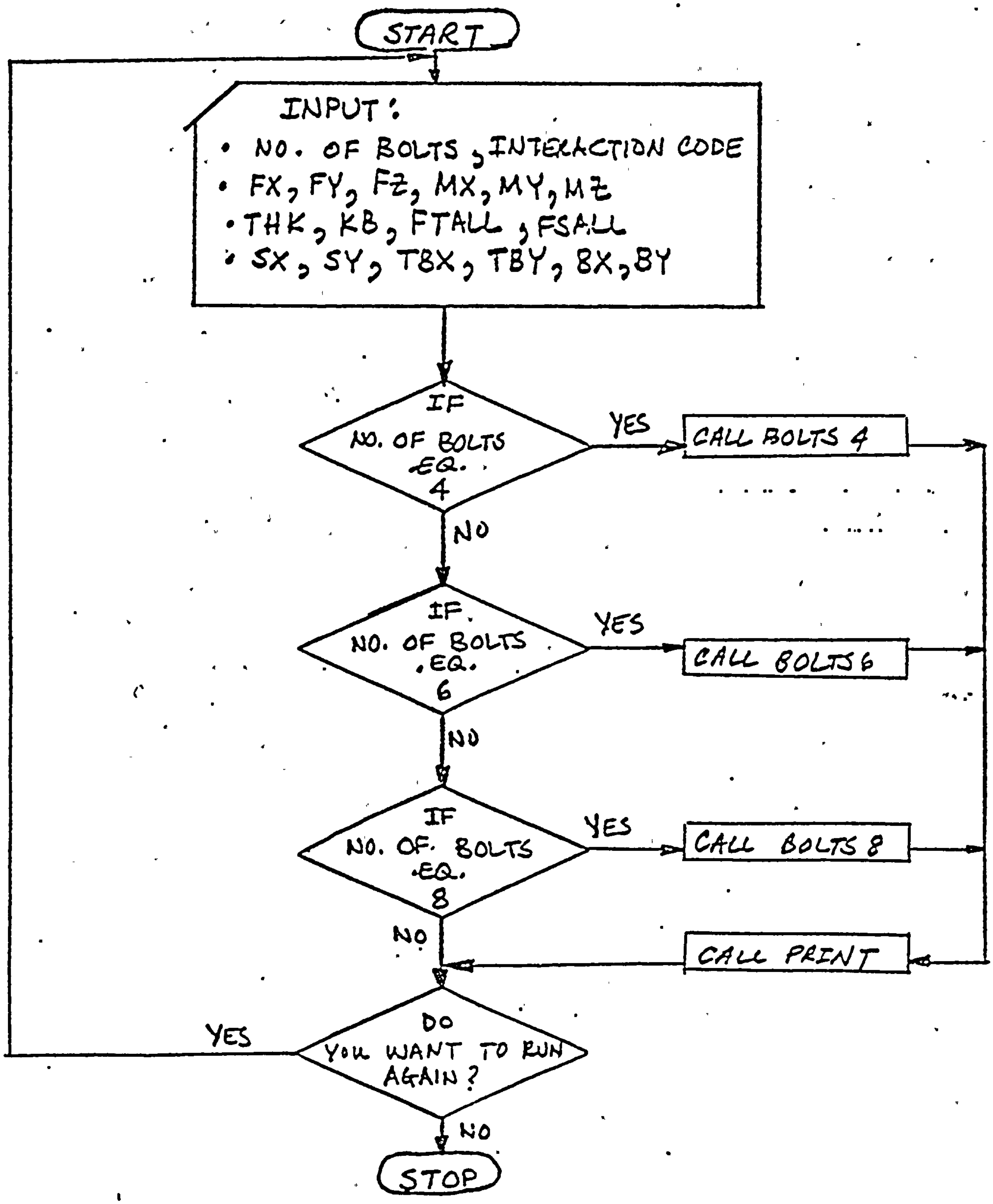
CALC. NO. C-1979-3 REV. NO. 0

ORIGINATOR Scott Close DATE 4/18/79 CHECKED Ed Maloney DATE 4/18/79

PROJECT Civil Staff JOB NO. —

SUBJECT CINCH ANCHOR COMPUTER PROGRAM SHEET NO. 4

Simplified Flow chart:



JUL 2 '79 - 106276

CALCULATION SHEET

BECHTEL

CALC. NO. C-1979-3 REV. NO. 1

ORIGINATOR Scott Close DATE 5/14/79 CHECKED Ed Maloney DATE 5/15/79

PROJECT Civil Staff JOB NO. —

SUBJECT Cinch Anchor Computer Program SHEET NO. 4A

Special Considerations:

Interaction equations: Three equations are available as an input option to describe linear or 2 forms of non-linear interaction. They are as follows:

code 1 - interaction (linear)

$$\left(\frac{\text{Total Tensile force}}{\text{allowable tension}}\right) + \left(\frac{\text{Total Shear force}}{\text{allowable Shear}}\right) \leq 1.0$$

code 2 - interaction (non-linear)

$$\left(\frac{\text{total tensile force}}{\text{allowable tension}}\right)^{5/3} + \left(\frac{\text{total Shear force}}{\text{allowable shear}}\right)^{5/3} \leq 1.0$$

code 3 - interaction (non-linear)

$$\left(\frac{\text{total tensile force}}{\text{allowable tension}}\right)^{2} + \left(\frac{\text{Total Shear force}}{\text{allowable shear}}\right)^{2} \leq 1.0$$

Shear force Calculations: The total shear force is calculated by dividing the torsional moment into components at each bolt, adding the shear force due to Fx and Fy, and determining the resultant shear.

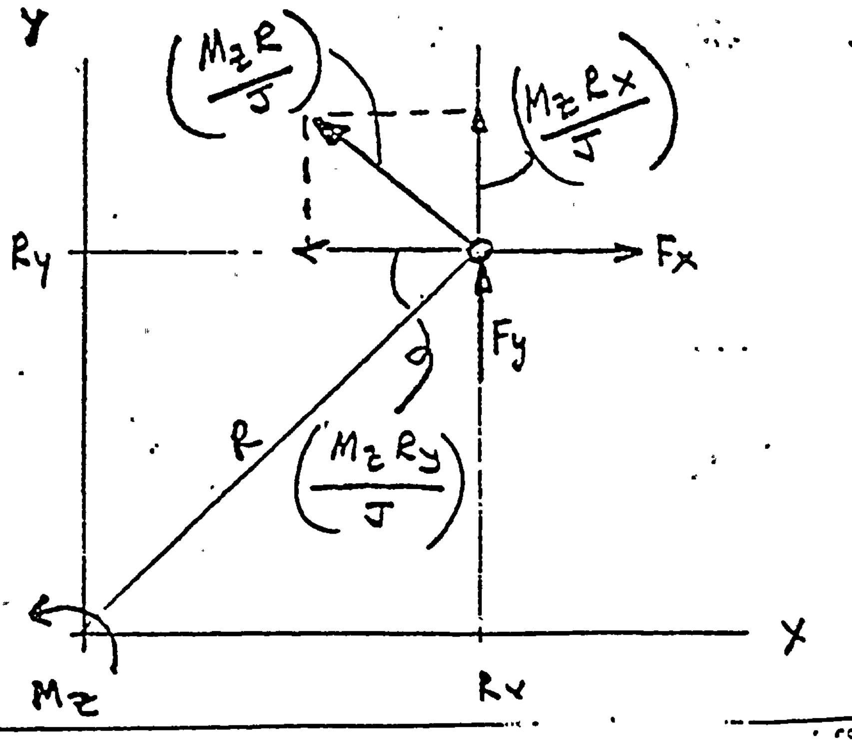
R_x = Distance From center of Plate in x-direction

R_y = Distance From Center of Plate in y-direction

$$R = \left((R_x)^2 + (R_y)^2\right)^{1/2}$$

$$J = \Sigma(R_x)^2 + \Sigma(R_y)^2$$

n = # of Bolts



BECHTEL

CALCULATION SHEET

CALC. NO. C-1979-3 REV. NO. 2

ORIGINATOR Scott Cloee DATE 6/8/79 CHECKED [illegible] DATE 6/8/79

PROJECT Civil Staff JOB NO. —

SUBJECT Cinch Anchor Computer Program SHEET NO. 4B

total shear in y direction ; total shear in x direction

$$F_{sy} = \left(\frac{M_Z R_X}{J}\right)_y + F_y/n \qquad F_{sx} = \left(\frac{M_Z R_B}{J}\right)_y + F_x/n$$

total Resultant shear

$$F_{STOT} = \sqrt{F_{sy}^2 + F_{sx}^2}$$

Treatment of Applied Loads

1) FX, FY, FZ and MZ are all treated as absolute values in the computer program.

2) FZ is always taken as tension. If a compressive load is required for FZ, then the user should input a 0. load.

3) For FX, FY, and MZ all shears at all bolts are combined. Therefore maximum bolt force (which occurs @ only one bolt) is printed for several bolts.

JUL 2 '79 106276

CALCULATION SHEET

BECHTEL

CALC. NO. C-1979-3 REV. NO. 1

ORIGINATOR Scott Close DATE 5/14/79 CHECKED Ed Maloney DATE 5/15/79

PROJECT Civil Staff JOB NO. —

SUBJECT Concrete Anchor Computer Program SHEET NO. 5

Program Listing

Included in the following pages is a listing of the BOLTS computer program, also a brief description is included

Lines	Contents
100 to 1030	Main program: Reads input, initializes some Parameters, and calls appropriate subroutine
1040 to 1760	BOLTS4 Subroutine: Does the 4-bolt analysis and calls the print subroutine for output of results. This subroutine, as for the other 2 subroutines is divided into the following five Parts: (1) initialization of Parameters (2) axial bolt loads due to bending (M_x, M_y) (3) axial bolt loads due to tension (F_z) (4) shear bolt loads due to torsion (M_z), and shear (F_x, F_y) (5) Print input and output (calls PRINT)
1770 to 2840	Bolts 6 Subroutine: Does the 6-Bolt analysis and calls the Print subroutine. -refer to Bolts4 Subroutine for description.
2850 to 4130	BOLTS8 Subroutine: Does the 8-Bolt analysis and Calls the PRINT Subroutine. -refer to Bolts4 Subroutine for description.
4140 to 4660	PRINT Subroutine: Prints out input values used for design and prints output from the analysis

JUL 2 '79 106276

CALCULATION SHEET

BECHTEL

CALC. NO. C-1979-3 REV. NO. 2

ORIGINATOR Scott Close DATE 6/8/79 CHECKED ______ DATE ______

PROJECT Civil Staff JOB NO. ______

SUBJECT Cinch Anchors Comp Prog. SHEET NO. 6

Main Program

```
      PROGRAM BOLTS (INPUT,OUTPUT,TAPE5=INPUT)
C     -----------------------------------------------
C
C                VERSION C
C
C     PROGRAM BOLTS DETERMINES THE ANCHOR BOLT FORCES
C     AND INTERACTION VALUES FOR A CENTRALLY LOADED
C     BASE PLATE.  THE FOLLOWING ARE SEVERAL OF THE
C     IMPORTANT VARIABLES USED IN THE PROGRAM:
C
C           THK    =   PLATE THICKNESS (IN)
C            KB    =   BOLT STIFFNESS (K/IN)
C         FTALL    =   ALLOWABLE TENSILE FORCE (K)
C         FSALL    =   ALLOWABLE SHEAR FORCE (K)
C      FX,FY,FZ    =   APPLIED FORCES (K)
C      MX,MY,MZ    =   APPLIED MOMENTS (IN-K)
C
C     -----------------------------------------------
      REAL KB,MX,MY,MZ
      COMMON /FORCES/ FX,FY,FZ,MX,MY,MZ
      COMMON /PARAM1/ THK,KB,FTALL,FSALL
      COMMON /PARAM2/ S(2),T(2),B(2),ALPHA(8),TITLE(1)
C
C     READ INPUT VALUES .
C
      PRINT 1000
    5 PRINT 900
  900 FORMAT(/,5X,35HINPUT TITLE ( UP TO 10 CHARACTERS ))
      READ(5,901) TITLE(1)
  901 FORMAT(A10)
      PRINT 1001
      READ(5,*) NB,ICODE
      PRINT 1002
      READ(5,*) FX,FY,FZ,MX,MY,MZ
      PRINT 1010
      READ(5,*) THK,KB,FTALL,FSALL
      PRINT 1020
      READ(5,*) S(1),S(2),T(1),T(2),B(1),B(2)
C
C     INITIALIZE PARAMETERS
C
      ALPHA(1)=3H  A
      ALPHA(2)=3H  B
      ALPHA(3)=3H  C
      ALPHA(4)=3H  D
      ALPHA(5)=3H  E
      ALPHA(6)=3H  F
      ALPHA(7)=3H  G
      ALPHA(8)=3H  H
```

2 '79 106276

BECHTEL

CALCULATION SHEET

CALC. NO. C-1979-3 REV. NO. 2

ORIGINATOR Scott Close DATE 6/5/79 CHECKED E. Mahoney DATE 6/8/79

PROJECT Civil Staff JOB NO. —

SUBJECT Crack Anchor Comp. Program SHEET NO. 7

```
C
C       CALL CORRECT SUBROUTINE
C
        IF(NB.NE.4) GO TO 10
        PRINT 1130 ,NB,ICODE
        CALL BOLTS4(NB,ICODE)
        GO TO 100
    10  IF(NB.NE.6) GO TO 20
        PRINT  1130 ,NB,ICODE
        CALL BOLTS6(NB,ICODE)
        GO TO 100
    20  IF(NB.NE.8) GO TO 30
        PRINT  1130 ,NB,ICODE
        CALL BOLTS8(NB,ICODE)
        GO TO 100
    30  PRINT 1005
   100  CONTINUE
        PRINT 1120
        READ(5,*) IRUN
        IF(IRUN.GT.0) GO TO 5
C
C          ------------  FORMATS  -------------
C
  1000  FORMAT(//,28X,31HANCHOR BOLT PROGRAM - VERSION C,/,35(2H *),
     +         //,39HINPUT IS FREE FIELD SEPARATED BY COMMAS,
     +         30H, UNITS ARE IN KIPS AND INCHES,//,5X,
     +  60HVERSION C OF BOLTS PROGRAM HAS FOLLOWING REVISIONS (6/5/79),
     +  //,5X,45H1.) EQUATION LIMITING THE MOMENT ARM INCLUDED,/,
     +  //,5X,44HANY QUESTIONS SHOULD BE DIRECTED TO S. CLOSE,
     +  /,5X,19HOF GPD AT EXT 2986 ,//,20X,
     +         26HINTERACTION EQUATION CODE:,/,19X,
     +         29H1=LINEAR INTERACTION EQUATION,/,19X,
     +    36H2=NON-LINEAR INTERACTION EQUATION #1,/,19X,
     +         36H3=NON-LINEAR INTERACTION EQUATION #2,/,35(2H *),/)
  1001  FORMAT(/,37HINPUT THE NUMBER OF BOLTS (4,6,OR 8) ,1X,
     +         33HAND  INTERACTION CODE (1,2 OR 3):)
  1002  FORMAT(/,5X,40HINPUT APPLIED LOADS (FX,FY,FZ,MX,MY,MZ):)
  1005  FORMAT(5X,35HERROR - NUMBER OF BOLTS NOT CORRECT)
  1010  FORMAT(/,5X,45HINPUT DESIGN PARAMETERS (THK,KB,FTALL,FSALL):)
  1020  FORMAT(/,5X,45HINPUT PLATE DIMENSIONS (SX,SY,TBX,TBY,BX,BY):)
  1120  FORMAT(//,5X,32HDO YOU WANT TO RUN BOLTS AGAIN ?,
     +          /,5X,19H(TYPE: 1=YES, 0=NO))
  1130  FORMAT(///,5X,I2,14H - BOLT OPTION,5X,18HINTERACTION CODE =,I2)
        END
```

JUL 2 '79 106276

BECHTEL

CALCULATION SHEET

CALC. NO. C-1979-3 REV. NO. 2

ORIGINATOR Scott Close DATE 6/5/79 CHECKED E Mahoney DATE 6/8/79

PROJECT Civil Staff JOB NO. —

SUBJECT Cinch Anchor Comp. Prog. SHEET NO. 8

4-BOLT SUBROUTINE

```
      SUBROUTINE BOLTS4 (NB,ICODE)
      COMMON /FORCES/ FX,FY,FZ,MX,MY,MZ
      COMMON /PARAM1/ THK,KB,FTALL,FSALL
      COMMON /PARAM2/ S(2),T(2),B(2),ALPHA(8),TITLE(1)
      DIMENSION F(4,4),XYRAY(4,2)
      REAL M(2),KB,MX,MY,MZ
C
C     INITIALIZE PARAMETERS
C
      DO 10 I=1,4
      DO 10 J=1,4
      F(I,J)=0.0
   10 CONTINUE
      M(1)=ABS(MX)
      M(2)=ABS(MY)
      TORJ=S(1)*S(1)+S(2)*S(2)
C
C     DETERMINE BOLT LOADS DUE TO BENDING MOMENTS AND STORE IN
C     APPROPRIATE F(I,J)
C
      DO 100 I=1,2
      D=.5*(T(I)-B(I))
      AL=3.5*D*((THK/D)**.6667)
      AL=AL*((44./KB)**.3333)
      IF(AL.GT.D) AL=D
      FA=M(I)/(S(I)+B(I)+2.*AL)
      IF(I.EQ.2) GO TO 15
      IF(MX.LT.0.0) GO TO 20
      F(1,1)=FA
      F(2,1)=FA
      GO TO 100
   20 CONTINUE
      F(3,1)=FA
      F(4,1)=FA
      GO TO 100
   15 CONTINUE
      IF(MY.LT.0.0) GO TO 25
      F(1,2)=FA
      F(3,2)=FA
      GO TO 100
   25 CONTINUE
      F(2,2)=FA
      F(4,2)=FA
  100 CONTINUE
```

CALCULATION SHEET

BECHTEL

CALC. NO. C-1979-3 REV. NO. 1

ORIGINATOR Scott Close DATE 5/14/79 CHECKED Ed Mahoney DATE 5/15/79

PROJECT Civil Staff JOB NO.

SUBJECT Cinch Anchor Computer Prog. SHEET NO. 9

```
C
C      DETERMINE BOLT LOADS DUE TO AXIAL FORCE
C
       DO 30 I=1,4
       F(I,3)=ABS(FZ)/4
   30  CONTINUE
C
C      DETERMINE BOLT LOADS DUE TO SHEAR AND TORSION
C
       XYRAY(1,1)=-S(2)/2.
       XYRAY(1,2)=S(1)/2.
       XYRAY(2,1)=-XYRAY(1,1)
       XYRAY(2,2)=XYRAY(1,2)
       XYRAY(3,1)=XYRAY(1,1)
       XYRAY(3,2)=-XYRAY(1,2)
       XYRAY(4,1)=-XYRAY(1,1)
       XYRAY(4,2)=-XYRAY(1,2)
       DO 40 I=1,4
       FTX=ABS(MZ*XYRAY(I,2)/TORJ)+ABS(FX/4.)
       FTY=ABS(MZ*XYRAY(I,1)/TORJ)+ABS(FY/4.)
       F(I,4)=SQRT(FTX*FTX+FTY*FTY)
   40  CONTINUE
C
C      PRINT OUT ALL INPUT VALUES AND RESULTS
C
       DO 50 I=1,NB
       CALL PRINT (NB,ICODE,I,F(I,1),F(I,2),F(I,3),F(I,4))
   50  CONTINUE
       RETURN
       END
```

2 79 106276

CALCULATION SHEET

BECHTEL

CALC. NO. C-1979-3 REV. NO. 2

ORIGINATOR Scott Close DATE 6/5/79 CHECKED E. Mahoney DATE 6/8/79

PROJECT Civil Staff JOB NO. –

SUBJECT Cinch Anchor Comp. Prog. SHEET NO. 10

6-BOLT SUBROUTINE

```
      SUBROUTINE BOLTS6(NB,ICODE)
      COMMON /FORCES/ FX,FY,FZ,MX,MY,MZ
      COMMON /PARAM1/ THK,KB,FTALL,FSALL
      COMMON /PARAM2/ S(2),T(2),B(2),ALPHA(8),TITLE(1)
      DIMENSION F(6,4),XYRAY(6,2),EI(2)
      REAL KB,MX,MY,MZ,K1,K2,L1
C
      INITIALIZE PARAMETERS
C
      DO 10 I=1,6
      DO 10 J=1,4
      F(I,J)=0.0
   10 CONTINUE
      TORJ=1.5*S(1)*S(1)+4.*S(2)*S(2)
C
      DETERMINE BOLT LOADS DUE TO BENDING MOMENT AND STORE IN
      APPROPRIATE F(I,J)
C
      EI(1)=2417.*T(2)*(THK**3.)
      D=.5*(T(1)-B(1))
      L1=3.5*((THK/D)**.6667)*((44./KB)**.3333)*D
     IF(L1.GT.D) L1=D
      SA=SQRT(S(1)*S(1)/4.+S(2)*S(2))
      SB=S(1)/2.
      T1=2.*(ABS(MX))/(S(1)+B(1)+2.*L1)
      DFM=((KB*(S(1)/2.+L1+B(1)/2.)**3.)/EI(1))**.25
      DFM=2.*DFM*(SA/(SA+2.*SB))/3.
      IF(DFM.LT..3333) DFM=.3333
      IF(DFM.GE.1.0) DFM=1.0
      FA=((1.-DFM)/2.)*T1
      FB=DFM*T1
      IF(MX.LT.0.0) GO TO 20
      F(1,1)=FA
      F(2,1)=FB
      F(3,1)=FA
      GO TO 30
   20 CONTINUE
      F(4,1)=FA
      F(5,1)=FB
      F(6,1)=FA
   30 CONTINUE
      D=.5*(T(2)-B(2))
      L1=3.5*((THK/D)**.6667)*((44./KB)**.3333)*D
      IF(L1.GT.D) L1=D
      Z=B(2)/2.+L1
      EI(2)=2417.*T(1)*(THK**3.)
      K1=2.*KB
```

JUL 2 '79 106276

CALCULATION SHEET

ORIGINATOR Scott Clee DATE 5/14/79 CALC. NO. C-1979-3 REV. NO. 1

CHECKED Ed Mahoney DATE 5/15/79

PROJECT Civil Staff JOB NO. —

SUBJECT Cinch Anchor Comp. Prog. SHEET NO. 11

```
      K2=2.*KB*(Z/SB)**2.
      IF(K2.GT.K1) K2=K1
      D1=EI(2)*(ABS(MY))*(K1+K2)/(S(2)*S(2)*K1*K2)
      D1=D1*(Z+(K1/(K1+K2))*S(2))
      D2=(ABS(MY))*Z*S(2)/3.
      D3=EI(2)/(S(2)*S(2)*K1*K2)
      D3=D3*(K1*S(2)*S(2)+2.*K1*Z*S(2)+(K1+K2)*Z*Z)
      D4=S(2)*Z*Z-3.*S(2)*(S(2)+Z)**2.+(S(2)+Z)**3.
      D4=(D4+2.*S(2)*S(2)*S(2)+3.*Z*S(2)*S(2))/3.
      C=(D1+D2)/(D3+D4)
      T1=(-Z*C+ABS(MY))/S(2)
      T2=C-T1
      F(2,2)=T2/2.
      F(5,2)=F(2,2)
      IF(MY.LT.0.0) GO TO 40
      F(1,2)=T1/2.
      F(4,2)=F(1,2)
      GO TO 50
 40   CONTINUE
      F(3,2)=T1/2.
      F(6,2)=F(3,2)
 50   CONTINUE
C
C     DETERMINE BOLT LOADS DUE TO AXIAL FORCE
C
      XK=EI(2)/(2.*S(2))
      YK=EI(1)/S(1)
      TX=XK*(ABS(FZ))/(XK+YK)
      TYR=(ABS(FZ)-TX)/2.
      DFMY=.8888*((KB*S(1)*S(1)/YK)**.25)*(SA/(SA+S(1)))
      IF(DFMY.LT.0.571) DFMY=0.571
      IF(DFMY.GE.1.) DFMY=1.0
      F(1,3)=(-2.*DFMY*TYR+ABS(FZ))/4.
      F(2,3)=DFMY*TYR
      IF(F(2,3).LT.F(1,3)) F(1,3)=ABS(FZ)/6.
      IF(F(2,3).LT.F(1,3)) F(2,3)=ABS(FZ)/6.
      F(3,3)=F(1,3)
      F(4,3)=F(1,3)
      F(5,3)=F(2,3)
      F(6,3)=F(1,3)
C
C     DETERMINE BOLT LOADS DUE TO SHEAR AND TORSION
C
      DO 60 I=1,3
      II=I+3
      XYRAY(I,2)=S(1)/2.
      XYRAY(II,2)=-S(1)/2.
 60   CONTINUE
```

(ED-69)

BECHTEL

CALCULATION SHEET

CALC. NO. C-1979-3 REV. NO. 1

ORIGINATOR Scott Close DATE 5/14/79 CHECKED Ed Mahoney DATE 5/15/79

PROJECT Civil Staff JOB NO.

SUBJECT Cinch Anchor Comp. Prog. SHEET NO. 12

```
      XYRAY(1,1)=-S(2)
      XYRAY(2,1)=0.0
      XYRAY(3,1)=S(2)
      XYRAY(4,1)=-S(2)
      XYRAY(5,1)=0.0
      XYRAY(6,1)=S(2)
      DO 70 I=1,6
      FTX=ABS(MZ*XYRAY(I,2)/TORJ)+ABS(FX/6.)
      FTY=ABS(MZ*XYRAY(I,1)/TORJ)+ABS(FY/6.)
      F(I,4)=SQRT(FTX*FTX+FTY*FTY)
   70 CONTINUE
C
C     PRINT OUT ALL INPUT VALUES AND RESULTS
C
      DO 80 I=1,NB
      CALL PRINT (NB,ICODE,I,F(I,1),F(I,2),F(I,3),F(I,4))
   80 CONTINUE
      RETURN
      END
```

(FI-69)

BECHTEL

CALCULATION SHEET

CALC. NO. C-1979-3 REV. NO. 2

ORIGINATOR Scott Close DATE 6/5/79 CHECKED Ed Mahoney DATE 6/8/79

PROJECT Civil Staff JOB NO. —

SUBJECT Cinch Anchor Comp. Prog. SHEET NO. 13

8-BOLT SUBROUTINE

```
      SUBROUTINE BOLTS8 (NB,ICODE)
      COMMON /FORCES/ FX,FY,FZ,MX,MY,MZ
      COMMON /PARAM1/ THK,KB,FTALL,FSALL
      COMMON /PARAM2/ S(2),T(2),B(2),ALPHA(8),TITLE(1)
      DIMENSION F(8,4),XYRAY(8,2),EI(2)
      REAL M(2),KB,L1,MX,MY,MZ,K1,K2
C
C     INITIALIZE PARAMETERS
C
      M(1)=ABS(MX)
      M(2)=ABS(MY)
      SA=SQRT(S(1)*S(1)+S(2)*S(2))
      DO 5 I=1,8
      DO 5 J=1,4
      F(I,J)=0.0
    5 CONTINUE
      TORJ=6.*(S(1)*S(1)+S(2)*S(2))
      EI(1)=2417.*T(2)*(THK**3.)
      EI(2)=2417.*T(1)*(THK**3.)
C
C     DETERMINE BOLT LOADS DUE TO BENDING MOMENTS
C
      DO 10 I=1,2
      K1=3.*KB
      K2=2.*KB
      SS=S(2)
      IF(I.EQ.2) SS=S(1)
      D=.5*(T(I)-B(I))
      L1=3.5*D*((THK/D)**.6667)*((44./KB)**.3333)
      IF(L1.GT.D) L1=D
      Z=.5*B(I)+L1
      AKCHK=2.*KB*Z*Z/(SS*SS)
      IF(AKCHK.LT.K2) K2=AKCHK
      D1=(EI(I)*M(I)*(K1+K2)/(S(I)*S(I)*K1*K2))*(Z+(K1/(K1+K2))*S
     D2=EI(I)*(K1*S(I)*S(I)+2.*S(I)*Z*K1+(K1+K2)*Z*Z)
      D2=D2/(S(I)*S(I)*K1*K2)
      D3=M(I)*Z*S(I)/3.
      D4=S(I)*Z*Z+(Z+S(I))**3.+2.*S(I)*S(I)*S(I)
      D4=(D4+3.*S(I)*S(I)*Z-3.*S(I)*(Z+S(I))**2.)/3.
      C=(D3+D1)/(D4+D2)
      T1=(-Z*C+M(I))/S(I)
      DFM=((KB*(S(I)+Z)**3.)/EI(I))**.25
      DFM=2.*DFM*(SA/(2.*S(I)+SA))/3.
      IF(DFM.LT..3333) DFM=.3333
      IF(DFM.GE.1.0) DFM=1.0
      FA=(1.-DFM)*T1/2.
      FB=DFM*T1
      IF(I.EQ.2) FB=(C-T1)/2.
      FD=(C-T1)/2.
      IF(I.EQ.2) FD=DFM*T1
```

8'76 (ED-69)

JUL 2 79 106276

BECHTEL

CALCULATION SHEET

CALC. NO. C-1979-3 REV. NO. 1

ORIGINATOR Scott Close DATE 5/14/79 CHECKED Ed Mahoney DATE 5/15/79

PROJECT Civil Staff JOB NO. —

SUBJECT Cinch Anchor Computer Prog SHEET NO. 14

```
03320C
03330C        STORE BENDING MOMENT IN APPROPRIATE F(I,J)
03340C
03350         IF(I.EQ.2) GO TO 20
03360         F(4,1)=FD
03370         F(5,1)=FD
03380         IF(MX.LT.0.) GO TO 30
03390         F(1,1)=FA
03400         F(2,1)=FB
03410         F(3,1)=FA
03420         GO TO 10
03430    30   CONTINUE
03440         F(6,1)=FA
03450         F(7,1)=FB
03460         F(8,1)=FA
03470         GO TO 10
03480    20   CONTINUE
03490         F(2,2)=FB
03500         F(7,2)=FB
03510         IF(MY.LT.0.) GO TO 40
03520         F(1,2)=FA
03530         F(4,2)=FD
03540         F(6,2)=FA
03550         GO TO 10
03560    40   CONTINUE
03570         F(3,2)=FA
03580         F(5,2)=FD
03590         F(8,2)=FA
03600    10   CONTINUE
03610C
03620C        DETERMINE BOLT LOADS DUE TO AXIAL FORCE
03630C
03640         XK=EI(2)/(2.*S(2))
03650         YK=EI(1)/(2.*S(1))
03660         TX=XK*(ABS(FZ))/(XK+YK)
03670         TXR=TX/2.
03680         TYR=(ABS(FZ)-TX)/2.
03690         DFMX=.8888*((KB*4.*S(2)*S(2)/XK)**.25)*(SA/(SA+2.*S(2)))
03700         DFMY=.8888*((KB*4.*S(1)*S(1)/YK)**.25)*(SA/(SA+2.*S(1)))
03710         IF(DFMX.LT.0.571) DFMX=0.571
03720         IF(DFMY.LT.0.571) DFMY=0.571
03730        IF(DFMX.GE.1.) DFMX=1.0
03740        IF(DFMY.GE.1.) DFMY=1.0
03750         F(1,3)=(-2.*(DFMY*TYR+DFMX*TXR)+ABS(FZ))/4.
03760         F(2,3)=DFMY*TYR
03780         F(4,3)=DFMX*TXR
03781         IF(F(2,3).GE.F(1,3).AND.F(4,3).GE.F(1,3)) GO TO 50
03782         F(1,3)=ABS(FZ)/8.
03783         F(2,3)=F(1,3)
03784         F(4,3)=F(1,3)
03785    50   CONTINUE
```

JUL 2 79 - 106276

BECHTEL

CALCULATION SHEET

CALC. NO. C-1979-3 REV. NO. 1

ORIGINATOR Scott Close DATE 5/14/79 CHECKED Ed Meloney DATE 5/15/79

PROJECT Civil Staff JOB NO.

SUBJECT Cinch Anchor Comp. Prog. SHEET NO. 15

```
03786            F(3,3)=F(1,3)
03790            F(5,3)=F(4,3)
03800            F(6,3)=F(1,3)
03810            F(7,3)=F(2,3)
03820            F(8,3)=F(1,3)
03830C
03840C           DETERMINE BOLT LOADS DUE TO SHEAR AND TORSION
03850C
03860            DO 55 I=1,8
03870            DO 55 J=1,2
03880            XYRAY(I,J)=0.
03890      55    CONTINUE
03900            DO 60 I=1,3
03910            J=I+5
03920            XYRAY(I,2)=S(1)
03930            XYRAY(J,2)=-S(1)
03940      60    CONTINUE
03950            XYRAY(1,1)=-S(2)
03960            XYRAY(3,1)=S(2)
03970            XYRAY(4,1)=-S(2)
03980            XYRAY(5,1)=S(2)
03990            XYRAY(6,1)=-S(2)
04000            XYRAY(8,1)=S(2)
04010            DO 70 I=1,8
04020            FTX=ABS(MZ*XYRAY(I,2)/TORJ)+ABS(FX/8.)
04030            FTY=ABS(MZ*XYRAY(I,1)/TORJ)+ABS(FY/8.)
04040            F(I,4)=SQRT(FTX*FTX+FTY*FTY)
04050      70    CONTINUE
04060C
04070C           PRINT OUT ALL INPUT VALUES AND RESULTS
04080C
04090            DO 80 I=1,NB
04100            CALL PRINT (NB,ICODE,I,F(I,1),F(I,2),F(I,3),F(I,4))
04110      80    CONTINUE
04120            RETURN
04130            END
```

JUL 2 '79 106276

BECHTEL

CALCULATION SHEET

ORIGINATOR Scott Close DATE 5/14/79 CALC. NO. C-1979-3 REV. NO. 1

PROJECT Civil Staff JOB NO. CHECKED [illegible] DATE 5/15/79

SUBJECT Cinch Anchor Comp. Prog. SHEET NO. 16

PRINT SUBROUTINE

```
      SUBROUTINE PRINT(NB,ICODE,I,F1,F2,F3,F4)
      COMMON /FORCES/ FX,FY,FZ,MX,MY,MZ
      COMMON /PARAM1/ THK,KB,FTALL,FSALL
      COMMON /PARAM2/ S(2),T(2),B(2),ALPHA(8),TITLE(1)
      IF(I.GT.1) GO TO 10
      PRINT 1030
     PRINT(5,1036) TITLE(1)
1036 FORMAT(//,5X,13H * * PROBLEM ,A10,4H * *)
      PRINT 1040 ,FX,FY,FZ,MX,MY,MZ
      PRINT 1050 ,THK,KB,FTALL,FSALL
      PRINT 1060 ,S(1),S(2),T(1),T(2),B(1),B(2)
C
C     CALCULATE TOTAL LOADS ON BOLTS, INTERACTION VALUES AND
C     PRINT OUT RESULTS.
C
      PRINT 1070
      PRINT 1080
      PRINT 1090
   10 CONTINUE
      FLG=3H
      TOTF=F1+F2+F3
      VINT=ABS(TOTF/FTALL)+ABS(F4/FSALL)
      IF(ICODE.EQ.2)VINT=(ABS(TOTF/FTALL))**1.667+(ABS(F4/FSALL))**1.667

      IF(ICODE.EQ.3)VINT=(ABS(TOTF/FTALL))**2.+(ABS(F4/FSALL))**2.
      IF(VINT.GT.1.0) FLG=3H *
      PRINT 1100 ,ALPHA(I),FLG,F1,F2,F3,TOTF,F4,VINT
      IF(I.NE.NB) GO TO 20
      PRINT 1110
      IF(ICODE.EQ.1) PRINT 1114
      IF(ICODE.GE.2) PRINT 1115
   20 CONTINUE
      RETURN
```

BECHTEL

CALCULATION SHEET

ORIGINATOR Scott Ana DATE 5/14/79 CALC. NO. C-1979-3 REV. NO. 1

PROJECT Civil Staff CHECKED [illegible] DATE 5/15/79

SUBJECT Cinch Anchor Comp. Prog. JOB NO. — SHEET NO. 17

JUL 2 79 106276

```
C
C      ------------  FORMATS  -------------
C
 1030  FORMAT(//,5X,40HRE-PRINT OF INPUT VALUES USED IN DESIGN:)
 1040  FORMAT(/,5X,3HFX=,F10.3,5X,3HFY=,F10.3,5X,3HFZ=,F10.3,
              /,5X,3HMX=,F10.3,5X,3HMY=,F10.3,5X,3HMZ=,F10.3)
 1050  FORMAT(/,4X,4HTHK=,F10.3,5X,3HKB=,F10.3,
              2X,6HFTALL=,F10.3,2X,6HFSALL=,F10.3)
 1060  FORMAT(/,5X,3HSX=,F10.3,5X,3HSY=,F10.3,/,4X,4HTBX=,F10.3,
              4X,4HTBY=,F10.3,/,5X,3HBX=,F10.3,5X,3HBY=,
               F10.3)
 1070  FORMAT(////,21X,19H* * * RESULTS * * *)
 1080  FORMAT(//,15X,24HAXIAL FORCE DUE TO LOADS,9X,
              16HTOTAL BOLT LOADS,4X,6HINTER.)
 1090  FORMAT(2X,4HBOLT,8X,4H(MX),8X,4H(MY),8X,4H(FZ),6X,
              7HTENSION,7X,5HSHEAR,2X,5HVALUE,/)
 1100  FORMAT(A3,A3,5(3X,F9.4),2X,F5.2)
 1110  FORMAT(5X,35HNOTE: * INDICATES OVERSTRESSED BOLT)
 1114  FORMAT(5X,33HNOTE: LINEAR INTERACTION WAS USED)
 1115  FORMAT(5X,37HNOTE: NON-LINEAR INTERACTION WAS USED)
       END
READY.
```

CALCULATION SHEET

BECHTEL

CALC. NO. C-1979-3 REV. NO. 2

ORIGINATOR Scott Crose DATE 6/8/79 CHECKED Ed Malony DATE 6/8/79

PROJECT Civil Staff JOB NO. —

SUBJECT Cinch Anchor Computer Program Verif. SHEET NO. 18

Computer Program Verification:

The Bolts computer program was verified by executing a series of seven test cases with the Bolts code and checking the computer results with hand calculations. The six test cases are included in the following pages with the hand solution and program output. It can be seen that the programs agrees well in all cases with the hand calculations.

The table on the next page is a summary of the required input to the verification problems.

Run #1 and #2 are for the 4 bolt pattern,

Run #3 and #4 are for the 6 Bolt pattern, and

Run #5, #6 and #7 are for the 8 Bolt pattern.

Theoretical development: details of theory are available in Calculation Number C-1979-2

BECHTEL

CALCULATION SHEET

ORIGINATOR Scott Close DATE 6/8/79 CALC. NO. C-1979-3 REV. NO. 2

PROJECT Civil Staff CHECKED Ed Mahoney DATE 6/8/79 JOB NO.

SUBJECT Cinch Anchor Computer Program Ver. SHEET NO. 19

Summary of Verification Problems

- units of force are kips, moment kip-in
- units of Length are in inches
- units of Stiffness are in kips/in

RUN NO.	INTER CODE	Applied Load						DESIGN PARAM.				PLATE DIMENSIONS					
		FX	FY	FZ	MX	MY	MZ	THK	KB	FTALL	FSALL	SX	SY	TBX	TBY	BX	BY
1	2	4.	4.	4.	18.	36.	10.	.75	150.	5.	5.	12.	12.	16.	16.	4.	4.
2	1	-8.	-6.	4.	-20.	-32.	-50.	.5	44.	5.	5.	10.	12.	14.	16.	4.	5.
3	1	-12.	-6.	10.	36.	-50.	100.	.5	44.	6.	4.	12.	8.	16.	20.	4.	4.
4	1	6.	12.	12.	-72.	100.	-200.	1.0	940.	6.	4.	14.	12.	18.	28.	5.	5.
5	1	8.	16.	20.	180.	90.	200.	1.25	440.	10.	10.	12.	12.	28.	28.	6.	6.
6	1	-16.	-8.	15.	-100.	-120.	-150.	1.0	300.	10.	10.	8.	12.	20.	28.	5.	6.
7	1	0	7.6	0	319.2	0.	0.	2.0	138.	9.2	8.9	6.	6.	16.	16.	8.	8.

NOTE: Interaction code 2 is for nonlinear equation and code 1 is for the linear equation

CALCULATION SHEET

BECHTEL

CALC. NO. G-1979-3 REV. NO. 0

ORIGINATOR ED MAHONEY DATE 4/14/79 CHECKED [signature] DATE 4/18/79

PROJECT Civil Staff JOB NO. —

SUBJECT CINCH ANCHOR COMPUTER PROG. VERIFICATION SHEET NO. 1 20

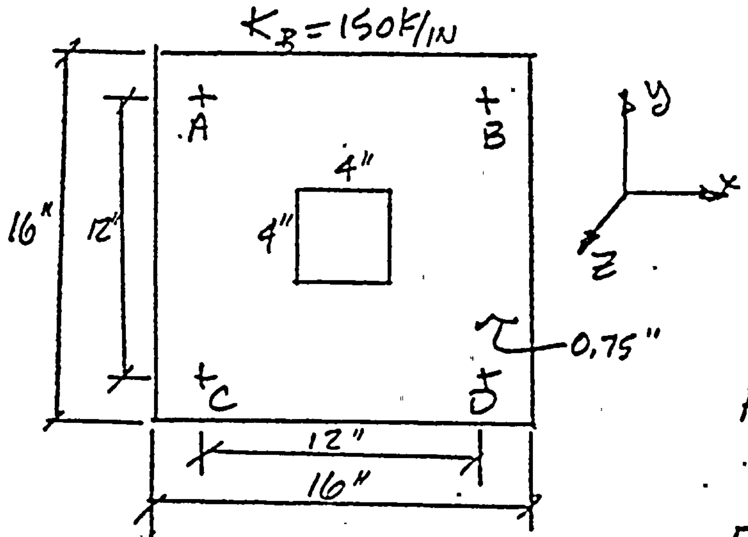
RUN # 1

4-BOLT PATTERN, NON-LINEAR INTERACTION

$F_x = +4^k$ $M_x = +18 k''$ $F_{TALL} = 5^k$

$F_y = +4^k$ $M_y = +36 k''$

$F_z = +4^k$ $M_z = +10 k''$ $F_{SALL} = 5^k$



TENSION:

FOR M_x

$$\ell = 3.5\left(\frac{0.75}{6}\right)^{2/3}\left(\frac{44}{150}\right)^{1/3}(6)$$

$$\ell = 3.49'$$

$$F_{Tx} = \frac{18}{12+4+2(3.49)} = \underline{0.78^K}$$

FOR M_y, $F_{Ty} = 2(0.78) = \underline{1.56^K}$

FOR F_z

$$F_{Tz} = \frac{4^k}{4} = \underline{1^k/_{BOLT}}$$

SHEAR:

FOR F_x

$$F_{Sx} = \frac{4^k}{4} = \underline{1^k/_{BOLT}} \quad ; \quad F_{Sy} = \frac{4^k}{4} = \underline{1^k/_{BOLT}}$$

CALCULATION SHEET

BECHTEL

CALC. NO. C-1979-3 REV. NO. 0

ORIGINATOR ED MAHONEY DATE 4/14/79 CHECKED S. Clore DATE 4/18/79

PROJECT Civil Staff JOB NO. –

SUBJECT CINCH ANCHOR COMPUTER PROG VERIFICATION SHEET NO. 21

FOR M_Z

$J = 2\left[4(6)^2\right] = 288$ $\qquad F_S = \frac{M_Z r}{J}$

∴ y COMPONENT = X COMPONENT

$F_{SZy} = F_{SZx} = \frac{(10\text{K-IN})(6'')}{288} = 0.208^{K}/\text{BOLT}$

SUM. @ EACH BOLT:

$F_{SZ} = \left[(1+0.208)^2 + (1+0.208)^2\right]^{1/2} = 1.71^{K}/\text{BOLT}$ (TOTAL SHEAR)

SUM FOR TOTAL TENSION:

$F_{TA} = 0.78 + 1.56 + 1 = 3.34^{K}$ N.G.

$F_{TB} = 0.78 + 0 + 1 = 1.78^{K}$ N.G.

$F_{TC} = 0 + 1.56 + 1 = 2.56^{K}$ N.G.

$F_{TD} = 0 + 0 + 1 = 1.00^{K}$ O.K.

INTERACTION: (USE COMP VALUES)

BOLT A – $\left(\frac{1.71}{5}\right)^{5/3} + \left(\frac{3.34}{5}\right)^{5/3} = 0.68$

BOLT B – $\left(\frac{1.71}{5}\right)^{5/3} + \left(1.78/5\right)^{5/3} = 0.35$

BOLT C – $\left(\frac{1.71}{5}\right)^{5/3} + \left(2.56/5\right)^{5/3} = 0.49$

BOLT D – $\left(\frac{1.71}{5}\right)^{5/3} + \left(\frac{1.00}{5}\right)^{5/3} = 0.24$

CALCULATION SHEET

BECHTEL

CALC. NO. C-1979-3 REV. NO. 1

ORIGINATOR Scott Close DATE 5/14/79 CHECKED Ed Maloney DATE 5/15/79

PROJECT Civil Staff JOB NO. —

SUBJECT Cinch anchor Computer Program: Ver SHEET NO. 22

```
INPUT TITLE ( UP TO 10 CHARACTERS )
>1234567890

INPUT THE NUMBER OF BOLTS (4,6,OR 8)  AND  INTERACTION CODE (1,2 OR 3):
>4,2

INPUT APPLIED LOADS (FX,FY,FZ,MX,MY,MZ):
>4.,4.,4.,18.,36.,10.

INPUT DESIGN PARAMETERS (THK,KB,FTALL,FSALL):
>.75,150.,5.,5.

INPUT PLATE DIMENSIONS (SX,SY,TBX,TBY,BX,BY):
>12.,12.,16.,16.,4.,4.


4 - BOLT OPTION      INTERACTION CODE = 2

RE-PRINT OF INPUT VALUES USED IN DESIGN:

◆ ◆ PROBLEM 1234567890 ◆ ◆

FX=      4.000     FY=      4.000     FZ=      4.000
MX=     18.000     MY=     36.000     MZ=     10.000

THK=      .750     KB=    150.000   FTALL=      5.000  FSALL=      5.000

SX=     12.000     SY=     12.000
TBX=    16.000     TBY=    16.000
BX=      4.000     BY=      4.000
```

◆ ◆ ◆ RESULTS ◆ ◆ ◆

BOLT	AXIAL FORCE DUE TO LOADS (MX)	(MY)	(FZ)	TOTAL BOLT LOADS TENSION	SHEAR	INTER. VALUE
A	.7834	1.5668	1.0000	3.3502	1.7088	.68
B	.7834	.0000	1.0000	1.7834	1.7088	.35
C	.0000	1.5668	1.0000	2.5668	1.7088	.59
D	.0000	.0000	1.0000	1.0000	1.7088	.24

NOTE: ◆ INDICATES OVERSTRESSED BOLT
NOTE: NON-LINEAR INTERACTION WAS USED

JUL - 2 '79 106276

CALCULATION SHEET

CALC. NO. C-1979-3 REV. NO. 0

ORIGINATOR ED MALONEY DATE 4/14/79 CHECKED I. Clare DATE 4/18/79

PROJECT Civil Staff JOB NO. –

SUBJECT CINCH ANCHOR COMPUTER PROG VERIFICATION SHEET NO. 23

RUN # 2

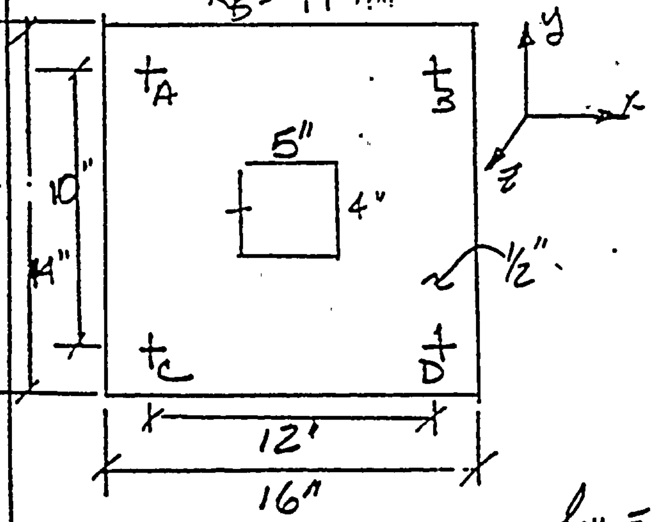
4-BOLT PATTERN, LINEAR INTERACTION

$F_x = -8^k$ $M_x = -20^{k''}$ $F_{T\,ALL} = 5^k$

$F_y = -6^k$ $M_y = -32^{k''}$ $F_{S\,ALL} = 5^k$

$F_z = 4^k$ $M_z = -50^{k''}$

$K_B = 44^{k}/in$



TENSION:

FOR M_x

$$l_x = 3.5\left(\frac{1/2}{5}\right)^{2/3}\left(\frac{44}{4}\right)^{1/3}(5) = 3.77''$$

$$F_{Tx} = \frac{20}{10+4+2(3.77)} = 0.93^k \text{ @ C \& D}$$

FOR M_y

$$l_y = 3.5\left(\frac{1/2}{5.5}\right)^{2/3}(1)^{1/3}(5.5) = 3.89''$$

$$F_{Ty} = \frac{32}{12+5+2(3.89)} = 1.29^k \text{ @ B \& D}$$

FOR F_z

$$F_{Tz} = \frac{4^k}{4} = 1^k/\text{BOLT}$$

CALCULATION SHEET

BECHTEL

CALC. NO. C-1979-3 REV. NO. 0

ORIGINATOR ED MAHONEY DATE 4/14/79 CHECKED S. Ure DATE 4/18/79

PROJECT Civil Staff JOB NO. —

SUBJECT CINCH ANCHOR COMPUTER PROG VERIFICATION SHEET NO. 24

SHEAR:

FOR F_x

$F_{Sx} = \frac{8^k}{4} = 2^k/\text{BOLT}$

FOR F_y

$F_{Sy} = \frac{6^k}{4} = 1.5^k/\text{BOLT}$

FOR M_z

$J = 4(5)^2 + 4(6)^2 = 244$

$f_s = \frac{Tr}{J}$

$F_{Szx} = \frac{50(5)}{244} = 1.02^k$

$F_{Szy} = \frac{50(6)}{244} = 1.23^k$

Σ SHEARS

$F_S = \left[(2+1.02)^2 + (1.5+1.23)^2\right]^{1/2} = 4.07^k/\text{BOLT}$

Σ TENSIONS

$F_{TA} = 0 + 0 + 1 = 1.00^k$

$F_{TB} = 0 + 1.29 + 1 = 2.29^k$

$F_{TC} = 0.93 + 0 + 1 = 1.93^k$

$F_{TD} = 0.93 + 1.29 + 1 = 3.22^k$

INTERACTION

@ A — $(1+4.07)/5 = 1.01$

@ B — $(2.29+4.07)/5 = 1.27$

@ C — $(1.93+4.07)/5 = 1.20$

@ D — $(3.22+4.07)/5 = 1.46$

} ALL OVERSTRESSED

JUL 2 '79 106276

CALCULATION SHEET

BECHTEL

CALC. NO. C-1979-3 REV. NO. 1

ORIGINATOR Scott Close DATE 5/14/79 CHECKED Ed Meloney DATE 5/15/79

PROJECT Civil Staff JOB NO. —

SUBJECT Conc. Anchor Computer Prog. Verification SHEET NO. 25

```
      INPUT TITLE ( UP TO 10 CHARACTERS )
>123456ABCD

 INPUT THE NUMBER OF BOLTS (4,6,OR 8)  AND  INTERACTION CODE (1,2 OR 3):
>4,1

      INPUT APPLIED LOADS (FX,FY,FZ,MX,MY,MZ):
>-8.,-6.,4.,-20.,-32.,-50.

      INPUT DESIGN PARAMETERS (THK,KB,FTALL,FSALL):
>.5,44.,5.,5.

      INPUT PLATE DIMENSIONS (SX,SY,TBX,TBY,BX,BY):
>10.,12.,14.,16.,4.,5.


       4 - BOLT OPTION       INTERACTION CODE = 1

      RE-PRINT OF INPUT VALUES USED IN DESIGN:

       * * PROBLEM 123456ABCD * *

      FX=     -8.000      FY=     -6.000      FZ=      4.000
      MX=    -20.000      MY=    -32.000      MZ=    -50.000

     THK=       .500      KB=     44.000   FTALL=      5.000  FSALL=      5.000

      SX=     10.000      SY=     12.000
     TBX=     14.000     TBY=     16.000
      BX=      4.000      BY=      5.000


                         * * * RESULTS * * *

                AXIAL FORCE DUE TO LOADS          TOTAL BOLT LOADS        INTER.
 BOLT           (MX)         (MY)        (FZ)     TENSION        SHEAR    VALUE

 A *          .0000        .0000       1.0000     1.0000        4.0741    1.01
 B *          .0000       1.2912       1.0000     2.2912        4.0741    1.27
 C *          .9285        .0000       1.0000     1.9285        4.0741    1.20
 D *          .9285       1.2912       1.0000     3.2197        4.0741    1.46
    NOTE: * INDICATES OVERSTRESSED BOLT
    NOTE: LINEAR INTERACTION WAS USED
```

JUL . 2 '79 106276

CALCULATION SHEET

BECHTEL

CALC. NO. C-1979-3 REV. NO. 0

ORIGINATOR Ed Mahoney DATE 4/14/79 CHECKED S. Clore DATE 4/18/79

PROJECT Civil Staff JOB NO. –

SUBJECT CINCH ANCHOR COMPUTER PROG VERIFICATION SHEET NO. 26

RUN # 3

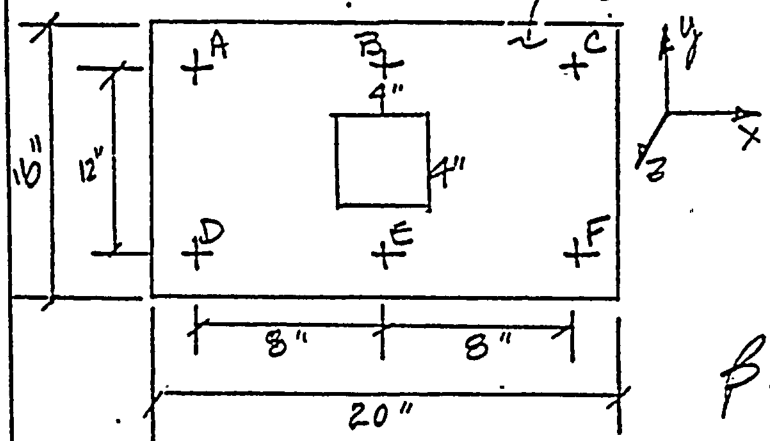
6-BOLT PATTERN, LINEAR INTERACTION

$F_x = -12^k$ $M_x = 36^{k''}$ $F_{TALL} = 6^k$

$F_y = -6^k$ $M_y = -50^{k''}$

$F_z = 10^k$ $M_z = 100^{k''}$ $F_{SALL} = 4^k$

$K_B = 44^k/_{IN}$



FOR M_X

$$l_x = 3.5\left(\frac{1/2}{6}\right)^{2/3}(.1)^{1/3}(6) = 4.00$$

$$T = \frac{36}{6+2+4.00} = \underline{\underline{3.00^k}}$$

$$\beta = \frac{2}{3}\left[\frac{44\,(l_1)^3}{EI}\right]^{1/4}$$

$EI_y = 29{,}000\left(\frac{20}{12}\right)(1/2)^3 = \underline{\underline{6042}}$; $l_1 = 4.00 + 8 \quad \underline{\underline{12''}}$

$\beta = \underline{\underline{1.26}}$ $DF_M = 1.26\left[\frac{1/6}{1/6 + 2/10}\right] = \underline{\underline{0.573}}$

$F_{TXB} = 0.573(3.00) = \underline{\underline{1.72^k}}$

$F_{TXA} = F_{TXC} = \frac{3 - 1.72}{2} = \underline{\underline{0.64^k}}$

CALCULATION SHEET

JUL 2 '79 106276

BECHTEL

CALC. NO. C-1979-3 REV. NO. 0

ORIGINATOR ED MAHONEY DATE 4/14/79 CHECKED S. Clone DATE 4/18/79

PROJECT Civil Staff JOB NO. —

SUBJECT CINCH ANCHOR COMPUTER PROG. VERIFICATION SHEET NO. 27

FOR M_y

$l_y = 3.5\left(\frac{1/2}{8}\right)^{2/3}(1)^{1/3}\left(\frac{8}{8}\right) = 4.41''$; $z = 6.41''$

$EI = 29{,}000\left(\frac{16}{12}\right)(1/2)^3 = 4833.3$; $x = 6''$

$K_1 = 2(44) = 88$ k/in ; $K_2 = 2(44)\left(\frac{6.41}{6}\right)^2 = 100.4$ k/in

USE 88 k/in

$EI\delta_{C0} = 1748.04$; $EI\delta_{CC} = 213.46 + 197.36 = 410.82$

$X_c = 4.26^k$; $R_A = 2.84^k$, $R_B = 1.42^k$

$F_{TyC} = F_{TyF}$ $\frac{2.84}{2}$ 1.42^k ; $F_{TyB} = F_{TyE}$ $\frac{1.42^k}{2} = 0.71^k$

FOR F_z

$EI_y = 6042$ $EI_x = 4833$

$K_y = \frac{6042}{(12)} = 504$ $K_x = \frac{4833}{16} = 302$

$T_x = \left[\frac{302}{302+504}\right](10^k) = 3.75^k$

$T_y = 6.25^k$

JUL 2 '79 1106276

CALCULATION SHEET

BECHTEL

CALC. NO. C-1979-3 REV. NO. 1

ORIGINATOR ED MAHONEY DATE 4/14/79 CHECKED S. Cline DATE 5/15/79

PROJECT Civil Staff JOB NO.

SUBJECT CINCH ANCHOR COMPUTER PROG VERIFICATION SHEET NO. 28

$$DFM_y = \frac{8}{9}\left[\frac{.44(12)^3}{6042}\right]^{1/4}\left[\frac{1/6}{1/6 + 2/10}\right] = \underline{0.761}$$

$$F_{TZB} = F_{TZE} = \tfrac{1}{2}(6.25)(0.761) = \underline{2.38^k}$$

$$F_{TZA} = F_{TZC} = F_{TZD} = F_{TZF} = \left[10 - (2)(2.38)\right]/4 = \underline{1.31^k}$$

SUM TENSIONS

$FTA = 0.64 + 0 + 1.31 = 1.95^k$

$FTB = 1.72 + 0.71 + 2.38 = 4.81^k$

$FTC = 0.64 + 1.42 + 1.31 = 3.37^k$

$FTD = 0 + 0 + 1.31 = 1.31^k$

$FTE = 0 + 0.71 + 2.38 = 3.09^k$

$FTF = 0 + 1.42 + 1.31 = 2.73^k$

SHEAR:

$$J = 4(8)^2 + 6(6)^2 = \underline{472}$$

$$F_{SA} = \left\{\left[\frac{100(8)}{472} + 1\right]^2 + \left[\frac{100(6)}{472} + 2\right]^2\right\}^{1/2} = \underline{4.24^k}$$

$$F_{SB} = \left\{\left[\frac{100(6)}{472} + 2\right]^2 + (1)^2\right\}^{1/2} = \underline{3.42^k}$$

(F0-69)

JUL 2 '79 106276

BECHTEL

CALCULATION SHEET

CALC. NO. C-1979-3 REV. NO. 1

ORIGINATOR ED MAHONEY DATE 4/17/79 CHECKED S. Close DATE 4/18/79

PROJECT Civil Staff JOB NO. —

SUBJECT CINCH ANCHOR COMPUTER PROG. VERIFICATION SHEET NO. 29

$FSA = 4.24^k$

$FSB = 3.42^k$

$FSC = 4.24^k$

$FSD = 4.24^k$

$FSE = 3.42^k$

$FSF = 4.24^k$

INTERACTION:

BOLT	VALUE
A	1.39
B	1.66
C	1.62
D	1.28
E	1.37
F	1.52

'76 (ED-69)

JUL 2 '79 #106276

BECHTEL

CALCULATION SHEET

CALC. NO. C-1979-3 REV. NO. 1

ORIGINATOR Scott Close DATE 5/14/79 CHECKED El Mahoney DATE 5/15/79

PROJECT Civil Staff JOB NO. —

SUBJECT Cinch Anchor Program Verification SHEET NO. 30

```
     INPUT TITLE < UP TO 10 CHARACTERS >
? 6BOLTS1

INPUT THE NUMBER OF BOLTS (4,6,OR 8)  AND  INTERACTION CODE (1,2 OR 3):
? 6,1

     INPUT APPLIED LOADS (FX,FY,FZ,MX,MY,MZ):
? -12.,-6.,10.,36.,-50.,100.

     INPUT DESIGN PARAMETERS (THK,KB,FTALL,FSALL):
? .5,44.,6.,4.

     INPUT PLATE DIMENSIONS (SX,SY,TBX,TBY,BX,BY):
? 12.,8.,16.,20.,4.,4.


      6 - BOLT OPTION      INTERACTION CODE = 1

     RE-PRINT OF INPUT VALUES USED IN DESIGN:

      ◆ ◆ PROBLEM 6BOLTS1     ◆ ◆

     FX=    -12.000      FY=     -6.000     FZ=     10.000
     MX=     36.000      MY=    -50.000     MZ=    100.000

    THK=       .500      KB=     44.000  FTALL=      6.000  FSALL=      4.000

     SX=     12.000      SY=      8.000
    TBX=     16.000     TBY=     20.000
     BX=      4.000      BY=      4.000


                      ◆ ◆ ◆ RESULTS ◆ ◆ ◆
```

BOLT	AXIAL FORCE DUE TO LOADS (MX)	(MY)	(FZ)	TOTAL BOLT LOADS TENSION	SHEAR	INTER. VALUE
A ◆	.6432	0.0000	1.3111	1.9543	4.2383	1.39
B ◆	1.7120	.7073	2.3778	4.7971	3.4206	1.65
C ◆	.6432	1.4204	1.3111	3.3747	4.2383	1.62
D ◆	0.0000	0.0000	1.3111	1.3111	4.2383	1.28
E ◆	0.0000	.7073	2.3778	3.0851	3.4206	1.37
F ◆	0.0000	1.4204	1.3111	2.7315	4.2383	1.51

NOTE: ◆ INDICATES OVERSTRESSED BOLT

NOTE: LINEAR INTERACTION WAS USED

JUL 2 '79 1106276

CALCULATION SHEET

BECHTEL

CALC. NO. C-1979-3 REV. NO. 0

ORIGINATOR ED MAHONEY DATE 4/17/79 CHECKED S. Cnr DATE 4/18/79

PROJECT Civil Staff JOB NO. —

SUBJECT CINCH ANCHOR COMPUTER PROG. VERIFICATION SHEET NO. 31

RUN # 4

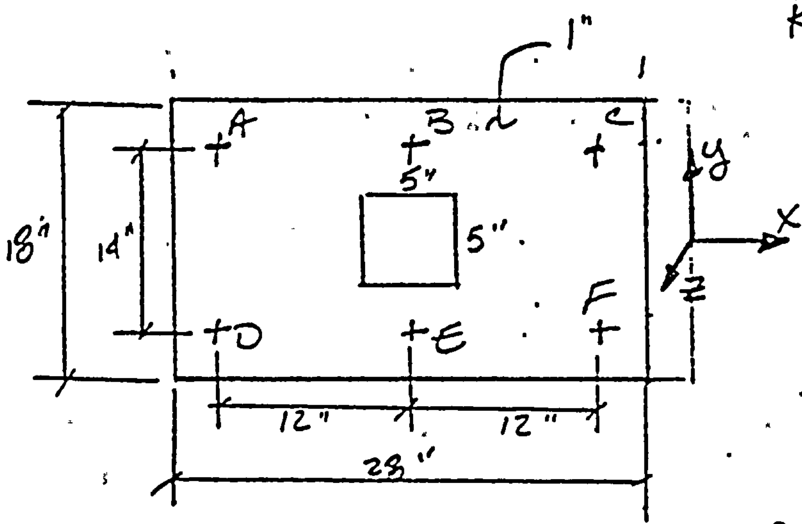
6-BOLT PATTERN, LINEAR INTERACTION

$F_x = 6^k$ $M_x = -72k''$

$F_y = 12^k$ $M_y = +100k''$ $F_{TALL} = 6^k$

$F_z = 12^k$ $M_z = -200k'$ $F_{SALL} = 4^k$

$K_B = 440 \text{ k/in}$



FOR M_y

$\ell_x = 3.5\left(\frac{1}{6.5}\right)^{2/3}\left(\frac{44}{440}\right)^{1/3}(6.5)$

$\ell_x = 3.03^k$

$T = \frac{72}{7+2.5+3.03} = 5.75^k$

$EI_y = 29{,}000\left(\frac{28}{12}\right)(1)^3 = 67{,}700$, $\beta = \frac{2}{3}\left[\frac{440(12.53)^3}{67{,}700}\right]^{1/4} = 1.26$

$DF_m = 1.26\left[\frac{1/7}{1/7 + 2/13.89}\right] = 0.628$

$F_{TXE} = 0.628(5.75^k) = 3.61^k$

$F_{TXD} = \frac{5.75 - 3.61}{2} = 1.07^k$

JUL 2 '79 3106276

CALCULATION SHEET

BECHTEL

CALC. NO. C-1979-3 REV. NO. 1

ORIGINATOR ED MAHONEY DATE 4/17/79 CHECKED [illegible] DATE 4/18/79

PROJECT Civil Staff JOB NO. —

SUBJECT CINCH ANCHOR COMP. PROG. VERIFICATION SHEET NO. 32

FOR M_y

$EI_x = 29{,}000\left(\frac{18}{12}\right)(1)^3 = \underline{43{,}500}$; $l_y = 3.5\left(\frac{1}{11.5}\right)^{2/3}(0.1)^{1/3}(11.5) = \underline{3.67''}$

$z = 3.67 + 2.5 = \underline{6.17''}$; $x = 7$

$K_1 = 2(440) = \underline{880^k/in}$; $K_2 = 2(440)\left(\frac{6.17}{7}\right)^2 = \underline{684^k/in}$

$EI\delta_{co} = \underline{3482.3}$; $EI\delta_{cc} = 158.88 + 230.57 = \underline{389.45}$

$X_c = \underline{8.94^k}$ $\quad R_A = \underline{3.74^k}$ $\quad R_B = \underline{5.20^k}$

$F_{TA} = \underline{1.87^k}$ $\quad F_{TB} = \underline{2.60^k}$

FOR F_z

$K_x = \frac{43{,}500}{(24)} = \underline{1813}$ $\quad K_y = \frac{67{,}700}{(14)} = \underline{4836}$

$T_x = \left[\frac{1813}{1813 + 4836}\right](12^k) = \underline{3.27^k}$, $T_y = 12 - 3.27 = \underline{8.73^k}$

$DFM_y = \frac{8}{9}\left[\frac{440(14)^3}{67{,}700}\right]^{1/4}\left[\frac{1/7}{1/7 + 2/13.89}\right] = \underline{0.910}$

$F_{TB} = 0.91\left(\frac{1}{2}\right)(8.73) = \underline{3.97^k}$

$F_{TA} = \left[12 - (3.97)2\right]/4 = \underline{1.01^k}$

JUL 2 '79 1106276

CALCULATION SHEET

CALC. NO. C-1979-3 REV. NO. 1

ORIGINATOR Ed Mahoney DATE 4/17/79 CHECKED Scott Clone DATE 5/15/79

PROJECT Civil Staff JOB NO. —

SUBJECT CINCH ANCHOR COMP. PROG. VERIFICATION SHEET NO. 33

SUM TENSIONS

FTA = 0 + 1.87 + 1.01 = 2.88^{k}

FTB = 0 + 2.60 + 3.97 = 6.57^{k}

FTC = 0 + 0 + 1.01 = 1.01^{k}

FTD = 1.07 + 1.87 + 1.01 = 3.95^{k}

FTE = 3.61 + 2.60 + 3.97 = 10.18^{k}

FTF = 1.07 + 0 + 1.01 = 2.08^{k}

FOR SHEAR:

$$J = 6(7)^2 + 4(12)^2 = 870$$

$$F_{SA} = \left\{\left[\frac{200(7)}{870} + \frac{6}{6}\right]^2 + \left[\frac{200(12)}{870} + \frac{12}{6}\right]^2\right\}^{1/2} = 5.43^{k}$$

$$F_{SB} = \left\{\left[\frac{200(7)}{870} + \frac{6}{6}\right]^2 + \left[\frac{12}{6}\right]^2\right\}^{1/2} = 3.29^{k}$$

INTERACTION:

BOLT	VALUE
A	1.84
B	1.92
C	1.53
D	2.02
E	2.52
F	1.70

BECHTEL

CALCULATION SHEET

JUL 2 '79 :106276

CALC. NO. C-1979-3 REV. NO. 1

ORIGINATOR Scott Close DATE 5/14/79 CHECKED Ed Mahoney DATE 5/15/79

PROJECT Civil Staff JOB NO. —

SUBJECT Cinch Anchor Program Verif. SHEET NO. 34

```
     INPUT TITLE ( UP TO 10 CHARACTERS )
? 6BOLTS2

INPUT THE NUMBER OF BOLTS (4,6,OR 8)  AND  INTERACTION CODE (1,2 OR 3):
? 6,1

     INPUT APPLIED LOADS (FX,FY,FZ,MX,MY,MZ):
? 6.,12.,12.,-72.,100.,-200.

     INPUT DESIGN PARAMETERS (THK,KB,FTALL,FSALL):
? 1.,440.,6.,4.

     INPUT PLATE DIMENSIONS (SX,SY,TBX,TBY,BX,BY):
? 14.,12.,18.,28.,5.,5.


      6 - BOLT OPTION      INTERACTION CODE = 1

     RE-PRINT OF INPUT VALUES USED IN DESIGN:

      * * PROBLEM 6BOLTS2    * *

     FX=      6.000     FY=     12.000      FZ=     12.000
     MX=    -72.000     MY=    100.000      MZ=   -200.000

    THK=      1.000     KB=    440.000   FTALL=      6.000   FSALL=      4.000

     SX=     14.000     SY=     12.000
    TBX=     18.000    TBY=     28.000
     BX=      5.000     BY=      5.000
```

* * * RESULTS * * *

BOLT	AXIAL FORCE DUE TO LOADS (MX)	(MY)	(FZ)	TOTAL BOLT LOADS TENSION	SHEAR	INTER. VALUE
A *	0.0000	1.8686	1.0150	2.8836	5.4270	1.84
B *	0.0000	2.6031	3.9700	6.5731	3.2875	1.92
C *	0.0000	0.0000	1.0150	1.0150	5.4270	1.53
D *	1.0686	1.8686	1.0150	3.9522	5.4270	2.02
E *	3.6081	2.6031	3.9700	10.1813	3.2875	2.52
F *	1.0686	0.0000	1.0150	2.0836	5.4270	1.70

NOTE: * INDICATES OVERSTRESSED BOLT
NOTE: LINEAR INTERACTION WAS USED

JUL 2 '79 106276

CALCULATION SHEET

BECHTEL

CALC. NO. C-1979-3 REV. NO. 0

ORIGINATOR ED MAHONEY DATE 4/17/79 CHECKED [illegible] DATE 4/18/79

PROJECT Civil Staff JOB NO. —

SUBJECT CINCH ANCHOR COMP. PROG. VERIFICATION SHEET NO. 35

RUN #5

8-BOLTS, LIN. INT.

$F_x = +8^k$ $M_x = 180\ k''$

$F_y = +16^k$ $M_y = 90\ k''$

$F_z = 20^k$ $M_z = 200k''$

$F_{TALL} = F_{SALL} = 10^k$ $k_B = 440^k/in$ $t = 1\frac{1}{4}''$

$S_x = S_y = 12''$ $TBX = TBY = 28''$ $BX = BY = 6''$

FROM PREVIOUS CALCS:

FOR M_x,

$F_{TXB} = 5.14 \frac{(2/3)}{0.68} = 5.04^k$ $F_{TXA} = 1.63^k$

$F_{TXC} = 1.47^k$

FOR M_y,

$F_{TyD} = \frac{1}{2}(5.04) = 2.52^k$ $F_{TyA} = \frac{1.63}{2} = 0.82^k$

$F_{TyB} = \frac{1}{2}(1.47) = 0.74^k$

(FD 69)

CALCULATION SHEET

BECHTEL

CALC. NO. C-1979-3 REV. NO. 1

ORIGINATOR Ed Mahoney DATE 4/17/79 CHECKED S. Cine DATE 5/15/79

PROJECT Civil Staff JOB NO. —

SUBJECT CINCH ANCHOR COMP. PROG. VERIFICATION SHEET NO. 36

FOR F_z

$$T_x = T_y = \frac{1}{2}(20) = 10^k$$

$$EI_x = EI_y = 29{,}000 \left(\frac{28}{12}\right)(1.25)^3 = 132{,}000$$

$$DFM_x = DFM_y = \frac{8}{9}\left[\frac{440(24)^3}{132{,}000}\right]^{1/4}\left[\frac{1/12}{1/12 + 2/16.97}\right] = 0.959$$

$$F_{TM} = 0.959\left(\frac{10}{2}\right) = 4.79^k \qquad F_{TC} = \left[20 - 4(4.79)\right]/4 = 0.21^k$$

FOR SHEAR $\quad J = 6(12)^2 + 6(12)^2 = 1728$

$$F_{SA} = \left\{\left[\frac{200(12)}{1728} + 1\right]^2 + \left[\frac{200(12)}{1728} + 2\right]^2\right\}^{1/2} = 4.15^k$$

$$F_{SB} = \left\{\left[\frac{200(12)}{1728} + 1\right]^2 + (2)^2\right\}^{1/2} = 3.12^k$$

$$F_{SD} = \left\{\left[\frac{200(12)}{1728} + 2\right]^2 + (1)^2\right\}^{1/2} = 3.53^k$$

(D491)

JUL 2 '79 106276

CALCULATION SHEET

ORIGINATOR: ED MAHONEY DATE: 4/17/78 CALC. NO.: C-1979-3 REV. NO.: 1

CHECKED: [signature] DATE: 5/15/79

PROJECT: Civil Staff JOB NO.: –

SUBJECT: LINCH ANCHOR COMP. PROG VERIFICATION SHEET NO.: 37

Σ TENSIONS

F_{TA} = 1.63 + 0.82 + 0.21 = 2.66^K

F_{TB} = 5.04 + 0.74 + 4.79 = 10.57^K

F_{TC} = 1.63 + 0 + 0.21 = 1.84^K

F_{TD} = 1.47 + 2.52 + 4.79 = 8.78^K

F_{TE} = 1.47 + 0 + 4.79 = 6.26^K

F_{TF} = 0 + 0.82 + 0.21 = 1.03^K

F_{TG} = 0 + 0.74 + 4.79 = 5.53^K

F_{TH} = 0 + 0 + 0.21 = 0.21^K

INTERACTION:

BOLT	VALUE
A	0.68
B	1.37
C	0.60
D	1.23
E	0.98
F	0.52
G	0.87
H	0.44

JUL 2 '79 106276

CALCULATION SHEET

BECHTEL

CALC. NO. C-1979-3 REV. NO. 1

ORIGINATOR Scott Close DATE 5/14/79 CHECKED Ed Mahoney DATE 5/15/79

PROJECT Civil Staff JOB NO. —

SUBJECT Cinch Anchor Program Verification SHEET NO. 38

```
     INPUT TITLE ( UP TO 10 CHARACTERS )
? 8BOLTS1

INPUT THE NUMBER OF BOLTS (4,6,OR 8)  AND  INTERACTION CODE (1,2 OR 3):
? 8,1

     INPUT APPLIED LOADS (FX,FY,FZ,MX,MY,MZ):
? 8.,16.,20.,180.,90.,200.

     INPUT DESIGN PARAMETERS (THK,KB,FTALL,FSALL):
? 1.25,440.,10.,10.

     INPUT PLATE DIMENSIONS (SX,SY,TBX,TBY,BX,BY):
? 12.,12.,28.,28.,6.,6.


     8 - BOLT OPTION      INTERACTION CODE = 1

    RE-PRINT OF INPUT VALUES USED IN DESIGN:

     * * PROBLEM 8BOLTS1     * *

    FX=     8.000      FY=     16.000     FZ=     20.000
    MX=   180.000      MY=     90.000     MZ=    200.000

   THK=     1.250      KB=    440.000  FTALL=     10.000  FSALL=     10.000

    SX=    12.000      SY=     12.000
   TBX=    28.000     TBY=     28.000
    BX=     6.000      BY=      6.000


                    * * * RESULTS * * *
```

BOLT	AXIAL FORCE DUE TO LOADS (MX)	(MY)	(FZ)	TOTAL BOLT LOADS TENSION	SHEAR	INTER. VALUE
A	1.6216	.8108	.2057	2.6381	4.1462	.68
B *	5.0348	.7342	4.7943	10.5634	3.1156	1.37
C	1.6216	0.0000	.2057	1.8273	4.1462	.60
D *	1.4684	2.5174	4.7943	8.7801	3.5334	1.23
E	1.4684	0.0000	4.7943	6.2627	3.5334	.98
F	0.0000	.8108	.2057	1.0165	4.1462	.52
G	0.0000	.7342	4.7943	5.5285	3.1156	.86
H	0.0000	0.0000	.2057	.2057	4.1462	.44

NOTE: * INDICATES OVERSTRESSED BOLT

NOTE: LINEAR INTERACTION WAS USED

CALCULATION SHEET

BECHTEL

CALC. NO. C-1979-3 REV. NO. 0

ORIGINATOR ED MAHONEY DATE 4/17/79 CHECKED S Cin DATE 4/18/79

PROJECT Civil Staff JOB NO. —

SUBJECT CINCH ANCHOR COMP. PROC. VERIFICATION SHEET NO. 39

RUN # 6

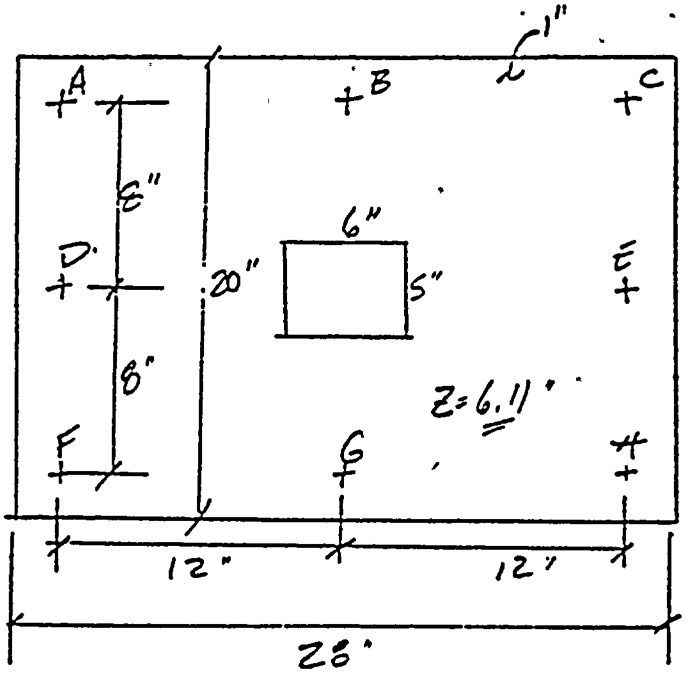
8-BOLTS, LIN. INTERACTION

$F_x = -16^k$ $M_x = -100k''$ $F_{T\,ALL} = 10^k$

$F_y = -8^k$ $M_y = -120k''$

$F_z = 15^k$ $M_z = -150k''$ $F_{S\,ALL} = 10^k$

$K_B = 300^k/in$



FOR M_x

$\lambda_x = 3.5\left(\frac{1}{7.5}\right)^{2/3}\left(\frac{44}{300}\right)^{1/3}(7.5) = 3.61''$

$EI_y = \frac{28(1)^3}{12}(29000) = 67{,}700$

$K_1 = 3(300) = 900^k/in$

$K_2 = 2(300)\left(\frac{6.11}{12}\right)^2 = 156^k/in$

$K_1 + K_2 = 1056$

$EI\delta_{co} = 11{,}915$; $EI\delta_{cc} = 1393.9 + 175.6 = 1569.5$

$X_c = 7.59^k$; $R_A = 6.70^k$; $R_B = 0.89^k$

$\beta = \frac{2}{3}\left[\frac{300(14.11)^3}{67{,}700}\right]^{1/4}\left[\frac{1/8}{1/8 + 2/14.42}\right] = 0.594$

BECHTEL

CALCULATION SHEET

CALC. NO. C-1979-3 REV. NO. 0

ORIGINATOR ED MAHONEY DATE 4/17/79 CHECKED S. Clar[illegible] DATE 4/18/79

PROJECT Civil Staff JOB NO. —

SUBJECT CINCH ANCHOR COMP. PROG VERIFICATION SHEET NO. 40

$F_{TXG} = 0.59^{i}(6.70) = \underline{3.98}^{k}$; $F_{TXF} = \underline{1.36}^{k}$

$F_{TX.D} = \dfrac{0.87}{2} = \underline{0.45}^{k}$

FOR M_y

$\ell_y = 3.5\left(\dfrac{1}{11}\right)^{2/3}\left(\dfrac{44}{300}\right)^{1/3}(11) = \underline{4.10}''$, $Z = \underline{7.10}''$

$EI_x = \dfrac{20(1)^3}{12}(29{,}000) = \underline{48{,}330}$

$K_1 = 3(300) = \underline{900}^{k}/IN$, $K_2 = 2(300)\left(\dfrac{7.10}{8}\right)^2 = 473^{k}/_{IN}$, $k_1 + k_2 = \underline{1373}$

$EI\delta_{CO} = \underline{5352}.1$, $EI\delta_{CC} = 277.66 + 320.94 = \underline{598.60}$

$X_C = \underline{8.94}^{k}$ $R_A = \underline{4.71}^{k}$ $R_B = \underline{4.23}^{k}$

$\beta = \dfrac{2}{3}\left[\dfrac{300(19.1)^3}{48{,}330}\right]^{1/4}\left[\dfrac{1/12}{1/12 + 2/14.12}\right] = \underline{0.642}$

$F_{TYE} = 0.642(4.71^{k}) = \underline{3.02}^{k}$ $F_{TYC} = 0.85$

$F_{TYB} = \dfrac{4.23}{2} = \underline{2.12}^{k}$

JUL 2 '79 106276

CALCULATION SHEET

BECHTEL

CALC. NO. C-1979-3 REV. NO. 1

ORIGINATOR ED MAHONEY DATE 4/17/79 CHECKED S. Cone DATE 5/15/79

PROJECT Civil Staff JOB NO. —

SUBJECT CINCH ANCHOR COMP. PROG. VERIFICATION SHEET NO. 41

FOR F_z

$K_y = \frac{67{,}700}{(16)} = .4231 \qquad K_x = \frac{48{,}330}{(24)} = .2014$

$T_x = \left[\frac{.2014}{.4231+.2014}\right](15) = 4.84^k \; ; \; T_y = 10.16^k$

FOR T_x

$DFM_x = \frac{8}{9}\left[\frac{300(24)^3}{48{,}330}\right]^{1/4}\left[\frac{1/12}{1/12+2/14.42}\right] = 1.02$, USE 1.00

$F_{TDz} = \frac{1(4.84)}{2} = 2.42^k$

FOR T_y

$DFM_y = \frac{8}{9}\left[\frac{300(16)^3}{67{,}700}\right]^{1/4}\left[\frac{1/8}{1/8+2/14.42}\right] = 0.870$

$F_{TBz} = 0.87\left(\frac{10.16}{2}\right) = 4.42^k \qquad F_{TAz} = \left[\frac{15-2(4.42+2.42)}{4}\right] = 0.33^k$

Σ TENSIONS:

$FTA = 0 + 0 + 0.33 = 0.33^k$

$FTB = 0 + 2.12 + 4.42 = 6.54^k$

$FTC = 0 + 0.85 + 0.33 = 1.18^k$

$FTD = 0.45 + 0 + 2.42 = 2.87^k$

$FTE = 0.45 + 3.02 + 2.42 = 5.89^k$

$FTF = 1.36 + 0 + 0.33 = 1.69^k$

$FTG = 3.98 + 2.12 + 4.42 = 10.52^k$

$FTH = 1.36 + 0.85 + 0.33 = 2.54^k$

JUL 2 '79 106276

BECHTEL

CALCULATION SHEET

CALC. NO. C-1979-3 REV. NO. 1

ORIGINATOR Ed Mahoney DATE 4/17/79 CHECKED S. Cox DATE 5/15/79

PROJECT Civil Staff JOB NO. —

SUBJECT Cinch Anchor Conn. Proc. Verification SHEET NO. 42

SHEAR $J = 6(8)^2 + 6(12)^2 = 1248$

$$F_{SA} = \left\{ \left[\frac{150(12)}{1248} + 1 \right]^2 + \left[\frac{150(8)}{1248} + 2 \right]^2 \right\}^{\frac{1}{2}} = 3.34^k$$

$$F_{SB} = \left\{ \left[\frac{150(8)}{1248} + 2 \right]^2 + \left(\ \right)^2 \right\}^{\frac{1}{2}} = 3.5^k$$

$$F_{SC} = \left\{ \left[\frac{150(\ )}{1248} + 1 \right]^2 + \ \right\}^{\frac{1}{2}} = 3.16^k$$

INTERACTION:

BOLT	VALUE
A	0.42
B	0.97
C	0.50
D	0.60
E	0.91
F	0.55
G	1.37
H	0.64

BECHTEL

JUL. 2 '79 106276

CALCULATION SHEET

CALC. NO. C-1979-3 REV. NO. 1

ORIGINATOR Scott Close DATE 5/14/79 CHECKED Ed Mahmer DATE 5/15/79

PROJECT Civil Staff JOB NO. —

SUBJECT Cinch Anchor Prog. Verification SHEET NO. 43

```
     INPUT TITLE ( UP TO 10 CHARACTERS )
? 8BOLTS2

INPUT THE NUMBER OF BOLTS (4,6,OR 8)  AND  INTERACTION CODE (1,2 OR 3):
? 8,1

     INPUT APPLIED LOADS (FX,FY,FZ,MX,MY,MZ):
? -16.,-8.,15.,-100.,-120.,-150.

     INPUT DESIGN PARAMETERS (THK,KB,FTALL,FSALL):
? 1.,300.,10.,10.

     INPUT PLATE DIMENSIONS (SX,SY,TBX,TBY,BX,BY):
? 8.,12.,20.,28.,5.,6.


      8 - BOLT OPTION      INTERACTION CODE = 1

     RE-PRINT OF INPUT VALUES USED IN DESIGN:

      * * PROBLEM 8BOLTS2     * *

     FX=   -16.000      FY=    -8.000      FZ=    15.000
     MX=  -100.000      MY=  -120.000      MZ=  -150.000

    THK=     1.000      KB=   300.000   FTALL=    10.000   FSALL=    10.000

     SX=     8.000      SY=    12.000
    TBX=    20.000     TBY=    28.000
     BX=     5.000      BY=     6.000


                        * * * RESULTS * * *
```

BOLT	AXIAL FORCE DUE TO LOADS (MX)	(MY)	(FZ)	TOTAL BOLT LOADS TENSION	SHEAR	INTER. VALUE
A	0.0000	0.0000	.3308	.3308	3.8387	.42
B	0.0000	2.1135	4.4190	6.5325	3.1258	.97
C	0.0000	.8433	.3308	1.1741	3.8387	.50
D	.4441	0.0000	2.4194	2.8634	3.1567	.60
E	.4441	3.0225	2.4194	5.8859	3.1567	.90
F	1.3610	0.0000	.3308	1.6918	3.8387	.55
G *	3.9790	2.1135	4.4190	10.5115	3.1258	1.36
H	1.3610	.8433	.3308	2.5351	3.8387	.64

NOTE: * INDICATES OVERSTRESSED BOLT
NOTE: LINEAR INTERACTION WAS USED

JUL 2 '79 106276

CALCULATION SHEET

BECHTEL

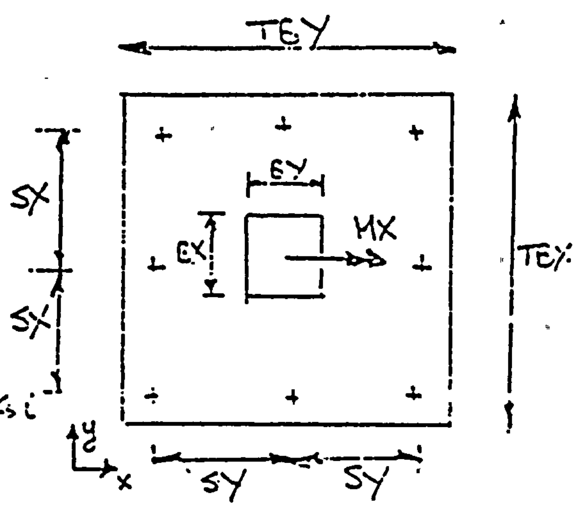
CALC. NO. [illegible] REV. NO. 2

ORIGINATOR [illegible] DATE [illegible] CHECKED [illegible] DATE 6.2.79

PROJECT Civil Staff JOB NO. –

SUBJECT Cinch Anchor Program Verification SHEET NO. 44

Run # 7 – 8 BOLTS



FY = 0^k MX = 319.2^k-in

FX = [illegible] MY = 0^k-in

FZ = 0^k MZ = 0^k-in

t = 2" ; K_E = 13.8 k/in ; F_{TALL} = 9.2 ksi

F_{SALL} = 6.9 ksi

SY = SX = 6"

TEX = TEY = 16"

EX = EY = 8"

$\lambda = 3.5(\ldots)^{?}(\ldots/38)^{?}(4) = 6.03"$ but $\lambda \le d$ ∴ $\lambda = 4$

$EI = 16(2)^3/12\,(29000) = 309333$ in⁴

K_1 = 3(138) = 414

K_2 = 2(13.8) = 276 (Because Z ≥ X) $K_1 + K_2 = 690$

$$EI\,\delta_{co} = \frac{-(309333)M(690)}{6^2(414)(276)}\left[8 + \left(\frac{414}{690}\right)6\right] - \frac{M(68)}{3} = -617.90M$$

$$EI\,\delta_{cc} = \frac{(309333)}{6^2(414)(276)}\left[414(6)^2 + 2(414)(6)(8) + (690)(8)^2\right] + \frac{8^2}{3}[14] = 7729.0$$

$$\left[\frac{1/L_m}{1/L_m + 2/L_c}\right] = .414 \quad \text{where } L_m = .6",\ L_c = 8.49"$$

$$\beta = \frac{2}{3}\left(\frac{(138)(14)^3}{309333}\right)^{1/4} = .7012$$

$$\beta\left[\frac{1/L_m}{(1/L_m + 2/L_c)}\right] = .2903 < 1/3$$

use DFM = .3333

(FD-69)

JUL 2 '79 106276

BECHTEL

CALCULATION SHEET

CALC. NO. C-1070-3 REV. NO. 2

ORIGINATOR [illegible] DATE 6.8.79 CHECKED [illegible] DATE 6.8.79

PROJECT CIVIL STAFF JOB NO.

SUBJECT CINCH ANCHOR PREFAB VERIFICATION SHEET NO. 45

X – DIR
M = 319.[illegible]

R_c = 617(319.[illegible])/[illegible] = 25.52

R_A = [3[illegible].2 – 8(25.52)]/6 = 19.17

R_c = 25.52 – 19.17 = 6.34

[illegible] T_{Te} = $R_E/2$ = 3.17 BOLTS D, E

[illegible] A

M [illegible] = .3333(19.17) = 6.39 [illegible] BOLTS A, B, C

SHEAR
ALL BOLTS = 38/8 = .95 K

BOLT	AXIAL DUE TO M_x	SHEAR DUE TO F_y	INTER	
A	6.39	0.95	$(\frac{6.39}{9.2}) + (\frac{.95}{8.9})$ =	.80
B	6.39	0.95	=	.80
C	6.39	0.95	=	.80
D	3.17	0.95	$(3.17/9.2) + (.95/8.9)$ =	.45
E	3.17	0.95	=	.45
F	0	0.95	$+(.95/8.9)$ =	.11
G	0	0.95	=	.11
H	0	0.95	=	.11

GP 3/76 (ED-69)

BECHTEL

CALCULATION SHEET

JUL 2 '79 106276

CALC. NO. G-1979-3 REV. NO. 2

ORIGINATOR [illegible] DATE 6.8.79 CHECKED [illegible] DATE 6.8.79

PROJECT Civil Staff JOB NO.

SUBJECT Cinch Anchor Program Verification SHEET NO. 46

```
                              ANCHOR BOLT PROGRAM - VERSION C
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

INPUT IS FREE FIELD SEPARATED BY COMMAS, UNITS ARE IN KIPS AND INCHES

     VERSION C OF BOLTS PROGRAM HAS FOLLOWING REVISIONS (6/5/79).

     1.) EQUATION LIMITING THE MOMENT ARM INCLUDED


     ANY QUESTIONS SHOULD BE DIRECTED TO S. CLOSE
    OF GPD AT EXT 2986

                    INTERACTION EQUATION CODE:
                  1=LINEAR INTERACTION EQUATION
                  2=NON-LINEAR INTERACTION EQUATION #1
                  3=NON-LINEAR INTERACTION EQUATION #2
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *


     INPUT TITLE ( UP TO 10 CHARACTERS )
? EXAMPLE 7

INPUT THE NUMBER OF BOLTS (4,6,OR 8)  AND  INTERACTION CODE (1,2 OR 3):
8,1

     INPUT APPLIED LOADS (FX,FY,FZ,MX,MY,MZ):
 0.,7.6,0.,319.2,0.,0.

     INPUT DESIGN PARAMETERS (THK,KE,FTALL,FSALL):
 2.,138.,9.2,8.9

     INPUT PLATE DIMENSIONS (SX,SY,TEX,TEY,EX,EY):
 6.,6.,16.,16.,8.,8.,



      8 - BOLT OPTION     INTERACTION CODE = 1


     RE-PRINT OF INPUT VALUES USED IN DESIGN:


      * * PROBLEM EXAMPLE 7  * *

     FX=      0.000     FY=      7.600     FZ=      0.000
     MX=    319.200     MY=      0.000     MZ=      0.000

    THK=      2.000     KE=    138.000  FTALL=      9.200   FSALL=      8.900

     SX=      6.000     SY=      6.000
    TEX=     16.000    TEY=     16.000
     EX=      8.000     EY=      8.000
```

BECHTEL

CALCULATION SHEET

CALC. NO. C-1979-3 REV. NO. 2

ORIGINATOR [illegible] DATE 6·8·79 CHECKED J. Fi DATE 6·8·79

PROJECT Civil Staff JOB NO.

SUBJECT Cinch. Anch[illegible] Program Verification SHEET NO. 47

* * * RESULTS * * *

	AXIAL FORCE DUE TO LOADS			TOTAL BOLT LOADS		INTER.
BOLT	(FX)	(FY)	(FZ)	TENSION	SHEAR	VALUE
[illegible]	6.3920	0.0000	0.0000	6.3920	.9500	.80
[illegible]	6.3911	0.0000	0.0000	6.3911	.9500	.80
[illegible]	6.3920	0.0000	0.0000	6.3920	.9500	.80
[illegible]	3.1717	0.0000	0.0000	3.1717	.9500	.45
[illegible]	3.1717	0.0000	0.0000	3.1717	.9500	.45
[illegible]	0.0000	0.0000	0.0000	0.0000	.9500	.11
[illegible]	0.0000	0.0000	0.0000	0.0000	.9500	.11
[illegible]	0.0000	0.0000	0.0000	0.0000	.9500	.11

NOTE: * INDICATES OVERSTRESSED BOLT
NOTE: LINEAR INTERACTION WAS USED

DO YOU WANT TO RUN BOLTS AGAIN ?
(TYPE: 1=YES, 0=NO)
0

SRU 5.537 UNTS.

RUN COMPLETE.

BECHTEL

CALCULATION COVER SHEET

ATTACHMENT 4

JUL 2 '79 106276

PROJECT Civil/Structural Staff SFPD JOB NO. N/A DISCIPLINE Civil/Struct

SUBJECT Determination of Expansion Anchor Loads Based on the Strength Method Given in the ACI 318-77 Code

FILE NO. C/S 15.26

CALC. NO. N/A

ORIGINATOR Karel Mandagi DATE 5/30/79

CHECKER N.B. Duchon DATE 6/11/79 NO. OF SHEETS 15

RECORD OF ISSUES

NO.	DESCRIPTION	BY	DATE	CHKD	DATE	APPRD	DATE	DATE FILMED
0	Issued for Use	KM	5/30/79	NBD	6-11-79	EHE	6/29/79	

PRELIMINARY CALC. ☐ COMMITTED PRELIMINARY DESIGN CALC. ☐

SUPERSEDED CALC. ☐ FINAL CALC. ☒

BECHTEL

CALCULATION SHEET

CALC. NO. N/A REV. NO. 0

ORIGINATOR K. Mandagi DATE 5/30/79 CHECKED N.A.D. DATE 6-11-79

PROJECT Civil/Structural Staff - SFPD JOB NO. N/A

SUBJECT Expansion Anchor Loads/Strength Method SHEET NO. 1/15

STRENGTH DESIGN METHOD

Used for complex pipe hanger supports attached to concrete with expansion type fasteners.

This analytical method has been based on information that the development of the strength of fasteners is accompanied by some slippage which is significantly larger than the elongation of steel rods would be under similar loading, also that some tests indicated the insensitivity of the support assemblies at failure to the original contact surface between concrete and base plate, the forces and moments are compared with the capacities of the assemblies instead of computing and comparing stresses with allowable values.

An approach similar to the column design of the ACI 318-77 Building Code is developed, in this case the axial load is usually tensile. The flexibility of the base plates in considered by checking their bending capacities and accordingly reducing the moment and axial force capacities of the assemblies. The shear capacities related to shear forces in plane of the plate or torsional moment are also considered in establishing the bolt tensile capacities.

The safety factor is applied in two parts, by reducing the bolt ultimate capacity by a factor to approximate the yield capacity and by increasing the applied forces and moments.

1. Biaxial bending:

$$\left(\frac{M_x}{M_{ox'}}\right)^n + \left(\frac{M_y}{M_{oy'}}\right)^n \leq 1$$

in which

M_x = applied moment in x - axis

M_y = " " " y - axis

$M_{ox'}$ = uniaxial moment capacity about x

$M_{oy'}$ = " " " " y

$M_{ox'}$ & $M_{oy'}$ are related to a certain normal force P_z.

$$n = \frac{\log .5}{\log \beta}$$

in which β = .65 (assumed as a conservative value taken from Ref. 5)

n = 1.61

ORIGINATOR K. MANDAGE [redacted] DATE 5-30-79 CHECKED [redacted] DATE 6-11-79
PROJECT C/STRUCTURAL STAFF SFPD JOB NO. N/A
SUBJECT EXP. ANCHOR LOADS/STRENGTH METHOD SHEET NO. 2/15 JUL 2 '79 106276
CALC. NO. N/A REV. NO. 0

2. Tensile Capacity

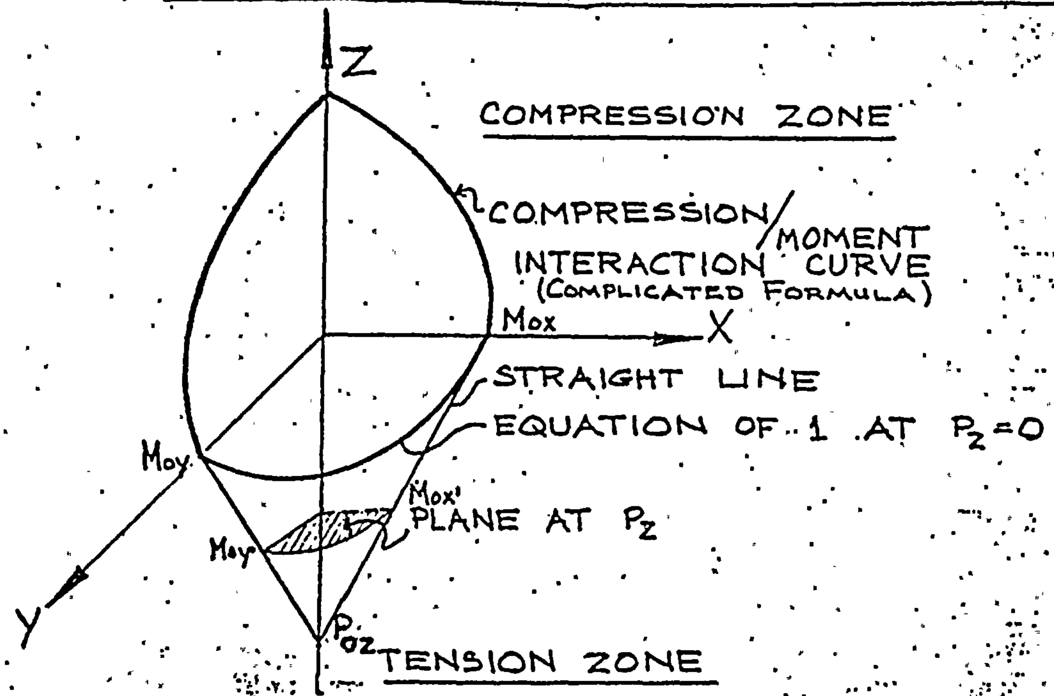
$P_{oz} = m_t \cdot F_{yield}$

m_t = total number of bolts

F_{yield} = C* x ultimate tension based on Ref. 1.

Note: The yield load is defined as the proportional limit or point at which the load-displacement curve departs from a straight line.

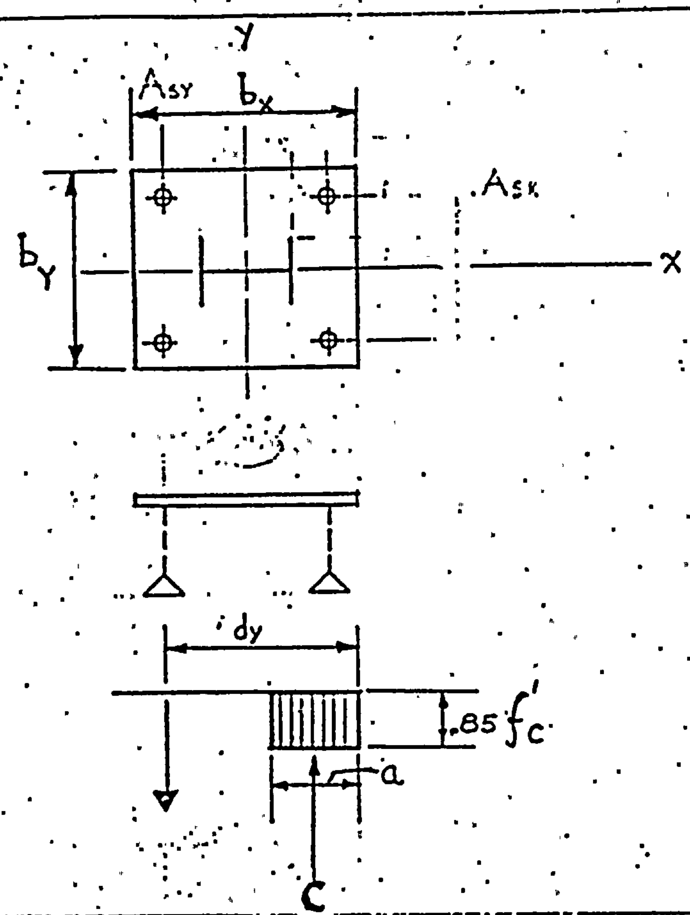
3. Load Contour Surface



We focus our attention on tension zone.
* for C value see page 4.

4. Determination of M_{ox} and M_{oy}.

a) 4 bolts



$$M_{ox} = m_x F_y \left(d_x - .59 \frac{mF_y}{f'_c b_x}\right)$$

$$M_{oy} = m_y F_y \left(d_y - .59 \frac{mF_y}{f'_c b_x}\right)$$

m = number of bolts per row

Fy = C* x ultimate tension in one bolt in tension. (Ref. 1)

f'_c = 3000 psi for conc. (assumed)

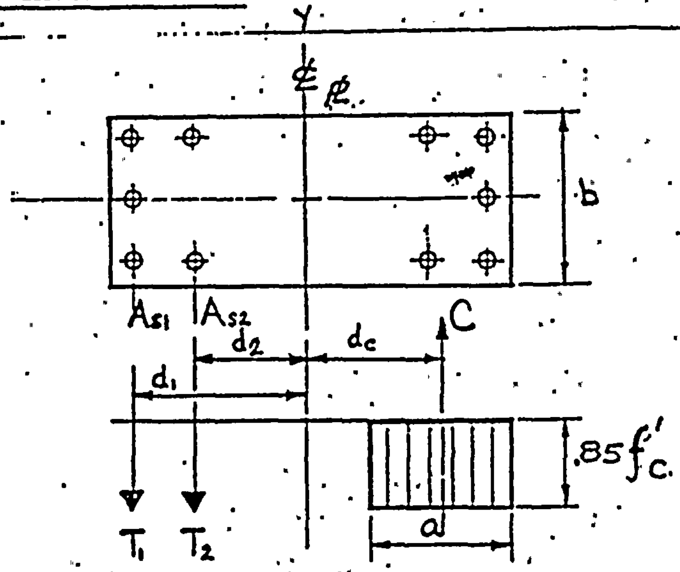
f'_c = 1500 psi for block wall (assumed)

* C = .33 for Phillips Wedge
Wej-It
Hilti Kwik - bolts
in concrete (Ref. 3)

C = .53 for Phillips Snap-off & self-drilling (Ref. 2)
in concrete

C = .65 for Phillips Snap-off & self-drilling in block walls
(Ref. 6)

b) More than 4 bolts



$$a = \frac{T_1 + T_2}{.85\ f'_c\ b}$$

$$T_1 = f_{yield} \times A_{s1}$$

$$T_2 = f_{yield} \times A_{s2}$$

$$C = .85\ f'_c\ b\ a$$

$$M_{oY} = C\ d_c + T_1 d_1 + T_2 d_2 + \text{-----}$$

$$M_{oY} = C\ d_c + \sum T\ d$$

Neglect the bolts in compression side beyond the ℄ PL

ORIGINATOR K. MANDAGI DATE 5-30-79 CHECKED A.O.D. DATE 6-11-79

PROJECT G/STRUCTURAL ST F FPD JOB NO. /A

SUBJECT EXP. ANCHOR LOADS/STRENGTH METHOD SHEET NO. 5/15 JUL 2 79 106276

CALC. NO. N/A REV. NO. 0

5. Shear Force

In case of shear force acting on the pipe support, the tension capacity of bolts should be reduced as follows:

$$\left(\frac{F_y}{P_{yield}}\right)^2 + \left(\frac{V}{V_{yield}}\right)^2 = 1$$

or

$$F_y = P_{yield}\sqrt{1 - \left(\frac{V}{V_{yield}}\right)^2}$$

P_{yield}, V_{yield} } Multiply ultimate values of Ref. 1 by coefficient .33, .53 or .65 shown on page 4.

V = Calculated shear force per bolt

6. Loads from Pipe Support Group

Loads from the pipe support group will be multiplied by the following safety factors according to the type of expansion anchor:

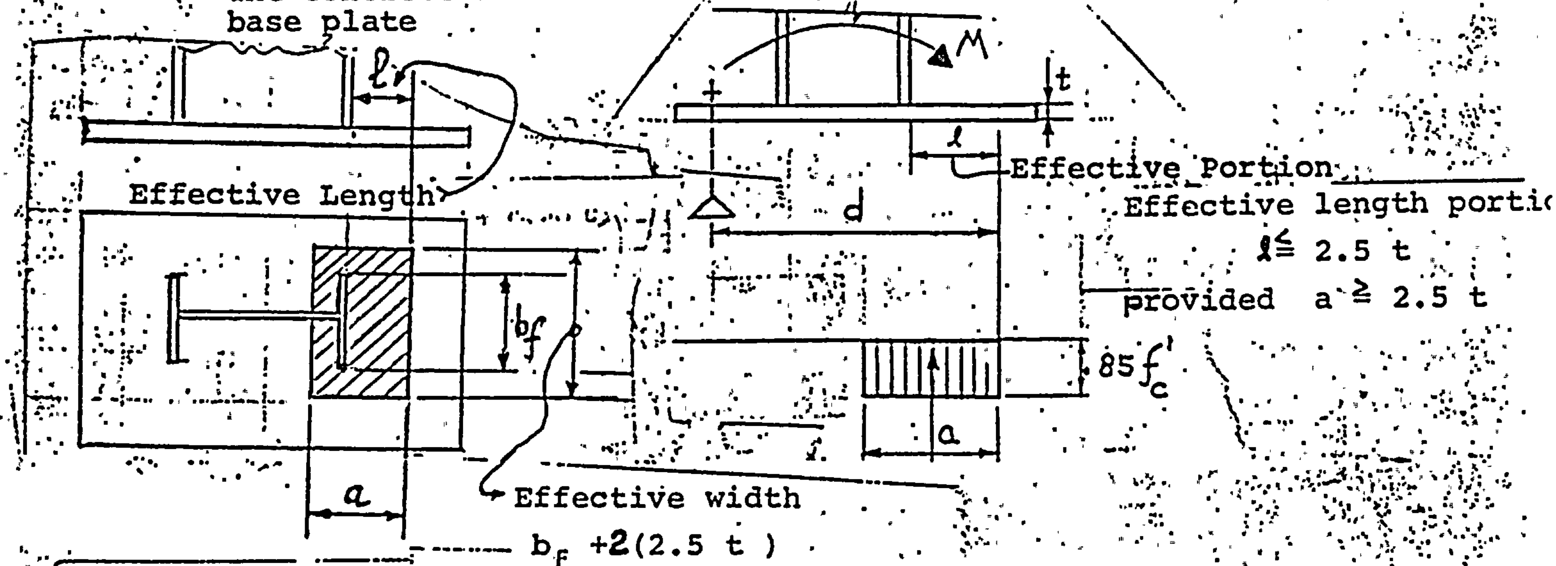
Phillips Wedge, Hilti Kwik & Wej-it ——— 1.33* for concrete
Phillips Snap-Off/Self Drilling ——— 2.65* for concrete
Phillips Snap-Off/Self Drilling ——— 3.25* for concrete block wal

After the application of the safety factors the combination of force: should be within the load contour surface as outlined in 3.

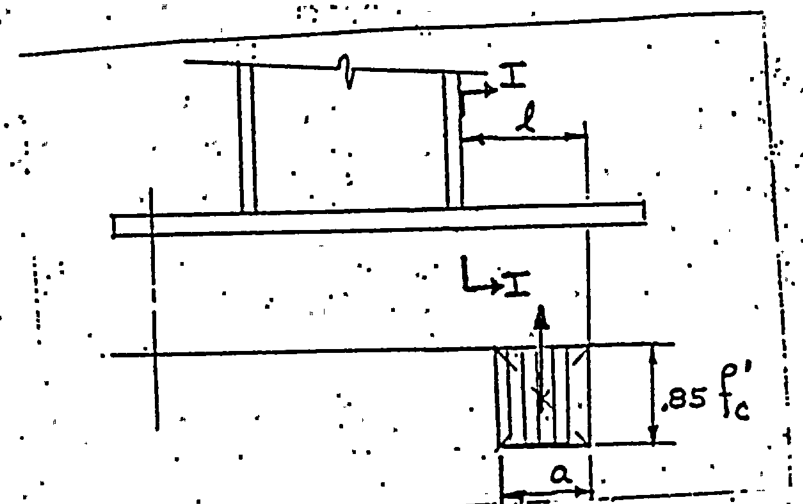
* .33 (SF) = .33 (4) = 1.32 or .387(4) = 1.348 Say 1.33
* .53 (SF) = .53 (5) = 2.65
* .65 (SF) = .65 (5) = 3.25

7. Limitation of Concrete Stress Block

The concrete stress block is a function of the flexibility of the base plate



if a < 2.5 t



*

Effective length $\ell \leq \frac{3.2\ t^2}{a} + \frac{1}{2}a$

For Effective width see page 5

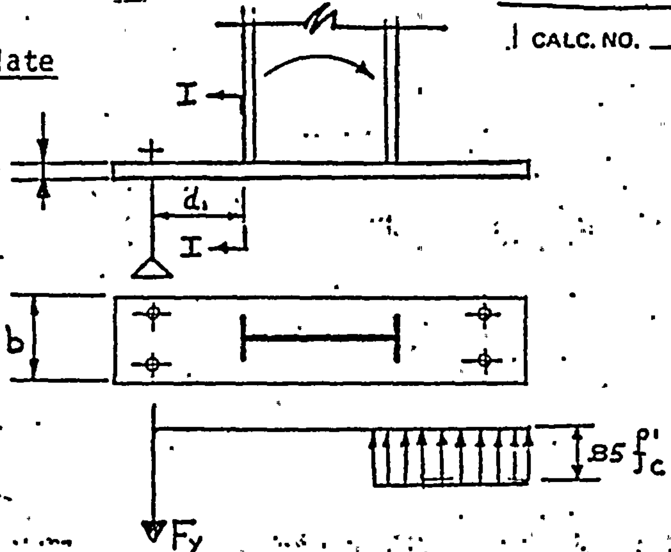
Assuming stress in Section I-I is less than .9 x 36000 psi

* $z = \frac{1}{4}t^2$

$M_{II} = (\ell - \frac{1}{2}a)(.85)(3000)a$

$\frac{M_{II}}{z} = .9 \times 36000 \longrightarrow \ell = \frac{3.2\ t^2}{a} + \frac{1}{2}a$

8. Check Base Plate



mF_y (forces in bolts in that row)

Check stress at I-I of base plate

a) Unstiffened plate

$$M_{II} = mF_y\, d_1$$

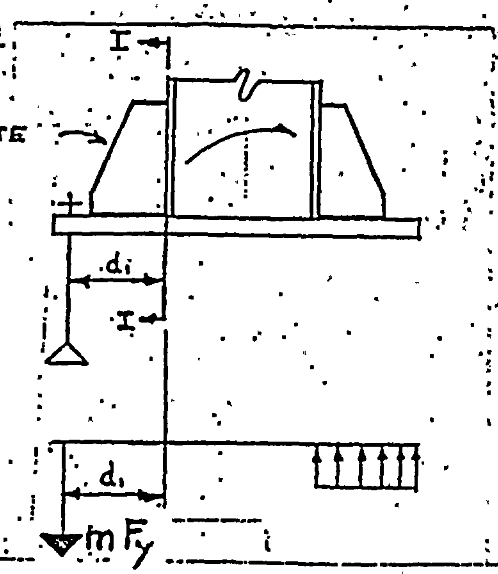
$$= \frac{1}{4}\, b\, t^2 \; (f_{PL})$$

$$f_{pl} = 4\,\frac{mF_y\, d_1}{b\; t^2} \le 36000 \text{ psi}$$

if $f_{pl} > 36000$ psi, then M_{ox} or M_{oy} computed in 4 should be reduced by factor $\frac{36000}{f_{pl}}$. Substitute the new values of M_{ox} and M_{oy} in 1 in order to redetermine the contour surface (see 3) for the criterion of the forces acceptability.

b) Stiffened plate

STIFFENER PLATE



$$M_{I-I} = mF_y\, d_1$$

$$= Z\, f_{PL}$$

in which Z is the plastic section modulus of Section I-I including the stiffener plates.

$f_{pl} = \frac{mFy\ d_1}{Z}$ and should be $\leq$ 36000, if not, then proceed as in a).

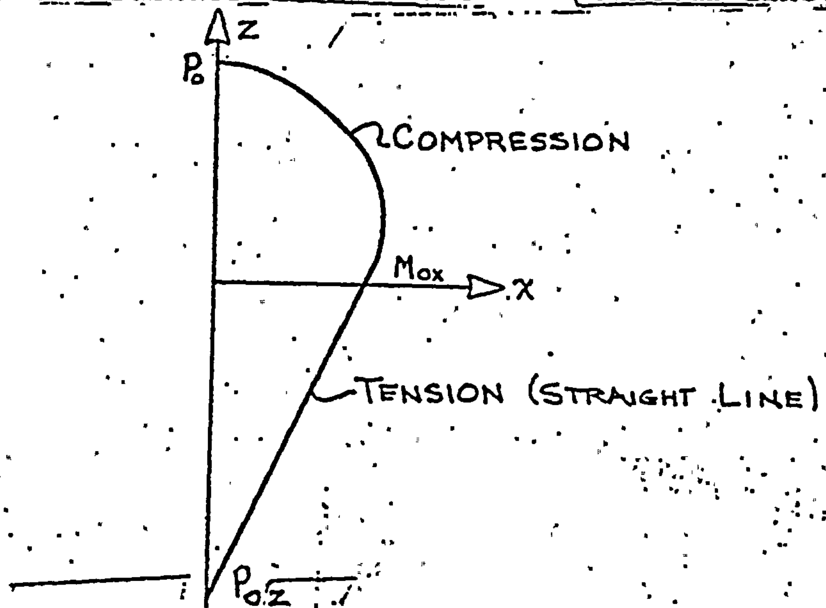
9. For uniaxial bending

formula in 1 still holds.
By substituting $M_y = 0$

$$M_x \leq M_{ox}$$

or if $M_x = 0 \longrightarrow M_y \leq M_{oy}$

for P_{oz} see 2.
The load contour surface becomes the load contour line.



For uniaxial bending combined with small compression force, the compression force can be neglected.

Small compression force is determined as follows:

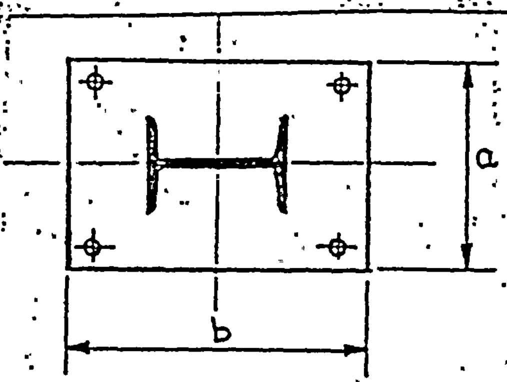


Plate plan

$P_{small} \leq 1/3\ P_o$

$P_o = [.595\ (1-\rho) f'_c + 42\rho]\ a\ b$

in which $\rho = \frac{\Sigma A_s}{ba}$; ΣA_s = Total Area of Bolts.

ORIGINATOR [illegible] DATE [illegible] CHECKED [illegible] DATE [illegible]

PROJECT C/STRUCTURAL ST[illegible]F SFPD JOB NO. N/A

SUBJECT EXP. ANCHOR LOADS/STRENGTH METHOD SHEET NO. 9/15 JUL 2 '79 :106276

CALC. NO. N/A REV. NO. 0

a and b are limited by the limitations outlined in 7.
The small compression criterion holds for the biaxial bending.

For biaxial or uniaxial load, subject to large compression force, follow the interaction formulas outlined in Ref. 4.

REFERENCES:

1. Expansion Anchor Design Capacities for the Review of Operating Plants in response to NRC Bulleting No. 79-02 or specific project criteria.

2. FFTF/PA/SSE 214 Tables 10 and 11 dated 9-20-78 Self-drilling Anchors.

3. FFTF/PA/SSE 203 dated 9-20-78 Wedge Type Anchors.

4. CRSI 1978 edition - page 3-187.

5. ACI Publication SP-17A (78) page 206.

6. FFTF/PA RSE 333 dated 9-20-78.

FFTF/PA/SSE 214
DATED 9-20-78

USE $\frac{F_y}{F_u} = 0.53$

1/3

TABLE 10

CONCRETE EXPANSION ANCHOR TEST DATA

MFG. & TYPE Phillips Drill Co. Self-Drilling (1/2" S-12)

TEST VARIABLE Per Field Insta.

TEST NUMBER	HOLE				TORQUE	TURNS OF NUT	EMBED.	LOADS			DISPLACEMENTS			FAILURE MODE	COMMENTS
	DRILL	DEPTH	$D_{1/4}$	$D_{3/4}$	FT-LBS		IN.	YIELD (F_y)	@ 1/16"	ULT. (F_u)	DESIGN LOAD	YIELD	ULT.		
51	11/16" Twist Bit	2-1/2	.719 .706	.722	NA	NA	NA	1600	1700	2350		~ 0	.500		
52	11/16" Twist Bit	2-1/2	.717	.712	NA	NA	NA	3300	4700	NA		.025	NA		
53	11/16" Twist Bit	2-1/2	.731	.711	NA	NA	NA	3100	5800	NA		.015	NA		
54	11/16" Twist Bit	2-1/2	.723	.715	NA	NA	NA	2300	4100	NA		~ 0	NA		
55	11/16" Twist Bit	2-3/8	.731	.712	NA	NA	NA	2000	3900	NA		.010	NA		
56	11/16" Twist Bit	2-1/4	.756	.712	NA	NA	NA	2000	3700	NA		.005	NA		
57	11/16" Twist Bit	2-1/2	.720	.710	NA	NA	NA	4700	5500	NA		.025	NA		
58	11/16" Twist Bit	2-1/4	.720	.714	NA	NA	NA	3000	4700	NA		.005	NA		
59	11/16" Twist Bit	2-1/2	.716	.713	NA	NA	NA	3000	3900	NA		.015	NA		
60	11/16" Twist Bit	2-1/2	.719	.715	NA	NA	NA	4700	6700	8400		.005	.190		

$$\frac{F_y}{F_u} = \frac{\text{YIELD AVE}}{\text{ULT. AVE}} = 0.5$$

-10- -31- 10/15

FITF/PA/SSE 214
DATED 9-20-78

2/3

TABLE 9

CONCRETE EXPANSION ANCHOR TEST DATA

MFG. & TYPE Phillips Drill Co. Self-Drilling 3/8" S-36

TEST VARIABLE Per Field Instal.

TEST NUMBER	HOLE				TORQUE ft-lbs	TURNS OF NUT	EMBED. IN.	LOADS			DISPLACEMENTS			FAILURE MODE	COMMENTS
	DRILL	DEPTH	$D_{1/4}$	$D_{3/4}$				YIELD (Fy)	@ 1/16"	ULT. (Fu)	DESIGN LOAD	YIELD	ULT.		
41	9/16" Twist Bit	1-3/8	.587	-	NA	NA	NA	2800	3700	NA		.005	NA		
42	9/16" Twist Bit	1-3/4	.588	-	NA	NA	NA	1000	1200	NA		~ 0	NA		
43	9/16" Twist Bit	1-3/4	.582	-	NA	NA	NA	-	-	4400		-	-		Displacement Not Recorded
44	9/16" Twist Bit	1-3/4	.585	-	NA	NA	NA	2800	3800	NA		.015	NA		
45	9/16" Twist Bit	1-3/4	.588	-	NA	NA	NA	2200	4500	5200		.005	.160	Pullout, Concrete Spalling	
46	9/16" Twist Bit	1-3/4	.585	-	NA	NA	NA	3200	4700	NA		~ 0	NA		
47	9/16" Twist Bit	1-3/4	.585	-	NA	NA	NA	2700	5100	NA		.005	NA		
48	9/16" Twist Bit	1-3/4	.578	-	NA	NA	NA	3200	5100	NA		.010	NA		
49	9/16" Twist Bit	1-3/4	.586	-	NA	NA	NA	2600	3400	NA		.005	NA		
50	9/16" Twist Bit	1-3/4	.591	-	NA	NA	NA	2800	3700	3700		~ 0	.065	Concrete Spalling	

$$\frac{F_y}{F_u} = \frac{\text{YIELD AVE.}}{\text{ULT. AVE.}} = 0.58$$

FFTF / HEDL TC-11.16 JUNE - AUGUST 77 3/3

[illegible] EXPANSION ANCHOR TEST DATA

MFG. & TYPE Phillips Drill Co. Self-Drilling 1/4" S-14

TEST VARIABLE Per Field Instal.

TEST NUMBER	HOLE: DRILL	DEPTH (INCH)	$D_{1/4}$ (INCH)	$D_{3/4}$ (INCH)	TORQUE FT-LBS	TURNS OF NUT	EMBED. (INCH)	LOAD (POUNDS): YIELD	@ 1/16"	ULT.	DISPLACEMENT (INCH): DESIGN LOAD	YIELD	ULT.	FAILURE MODE	COMMENTS
								Fy		Fu					
31	7/16" Twist Bit	2-1/2	.462	-	NA	NA	NA			TEST STOPPED					
32	7/16" Twist Bit	1-1/2	.462	-	NA	NA	NA	1400	1800	NA		.005	NA		
33	7/16" Twist Bit	1-1/2	.463	-	NA	NA	NA	600	600	NA		~ 0	NA		
34	7/16" Twist Bit	1-1/2	.463	-	NA	NA	NA	1300	1900	NA		.015	NA		
35	7/16" Twist Bit	1-1/2	.464	-	NA	NA	NA	700	1700	2400		.010	.275	Slippage Conc. Spalling	
36	7/16" Twist Bit	-	.467	-	NA	NA	NA	1000	1200	NA		~ 0	NA		
37	7/16" Twist Bit	1-1/2	.464	-	NA	NA	NA	1000	1700	NA		<.005	NA		
38	7/16" Twist Bit	-	.462	-	NA	NA	NA	1200	1700	NA		.005	NA		
39	7/16" Twist Bit	-	.460	-	NA	NA	NA	1400	1900	NA		.010	NA		
40	7/16" Twist Bit	-	.463	-	NA	NA	NA	2000	2600	2600		.015	.075	Stud Failure	

$$\frac{F_y}{F_u} = \frac{\text{AVE YIELD}}{\text{AVE ULT}} = 0.47$$

E-13

-12-

12/15

1/2

FFTF
PA/RSE 333

USE: $\frac{F_{Y\,AVE}}{F_{U\,AVE}} = 0.65$

TABLE 7

TEST RESULTS
EXPANSION ANCHORS IN CONCRETE BLOCK WALLS
ANCHOR TYPE/SIZE PHILLIPS SELF-DRILLING (S SERIES) 3/8
LENGTH 1 9/16

DRILL: 9/16" TWIST BIT

TEST NUMBER	TEST CONDITION	HOLE DEPTH (INCHES) L	HOLE DIAMETER (INCH) D 1/4	HOLE DIAMETER (INCH) D 3/4	EXPOSED PORTION OF ANCHOR (INCHES)	EMBEDMENT DEPTH (INCHES)	LOADS (POUNDS) YIELD	LOADS (POUNDS) SLIP	LOADS (POUNDS) ULTIMATE	DISPLACEMENT (INCHES) YIELD/SLIP	DISPLACEMENT (INCHES) ULTIMATE	FAILURE MODE/ COMMENTS
42	A	1 1/2	.577	.578	N/A	N/A	1225	450	1525	.18 / .0625	.34	CONCRETE SPALL
43	A	1 1/2	.608	.581	N/A	N/A	850	700	1350	.06 / .0625	.36	
45	A	1 7/16	.602	.598	N/A	N/A	775	775	1325	.06 / .0625	.24	
47	A	1 1/2	.595	.598	N/A	N/A	400	500	1275	.015 / .0625	.505	
50	A	1 1/16	.594	.591	N/A	N/A	1225	950	1650	.1 / .0625	.43	CONCRETE SPALL
102	B	1 7/16	.593	.591	N/A	N/A	850	275	1625	.1 / .0625	.315	CONCRETE SPALL
106	B	1 1/2	.604	.587	N/A	N/A	800	800	1250	.06 / .0625	.19	
107	B	1 1/2	.602	.600	N/A	N/A	800	900	1425	.03 / .0625	.33	PULLOUT
108	B	1 1/2	.630	.587	N/A	N/A	1250	725	1375	.12 / .0625	.175	
112	B	1 7/16	.598	.588	N/A	N/A	950	1050	1450	.05 / .0625	.35	CONCRETE SPALL
41	C	1 1/2	.601	.595	N/A	N/A	1525	1400	2050	.03 / .0625	.26	CONCRETE SPALL
44	C	1 7/16	.597	.591	N/A	N/A	725	350	825	.15 / .0625	.3	
46	C	1 7/16	.602	.597	N/A	N/A	950	500	1200	.1 / .0625	.16	
48	C	1 7/16	.642	.589	N/A	N/A	900	700	1275	.105 / .0625	.43	CONCRETE SPALL
49	C	1 7/16	.595	.571	N/A	N/A	700	150	1175	.2 / .0625	.3	

13/15

FFTF
PA/RSE 333

$\frac{F_{Y AVG}}{F_{U AVG}} = 0.65$

2/2

TABLE 7 (CON'T)

TEST RESULTS

EXPANSION ANCHORS IN CONCRETE BLOCK WALLS

ANCHOR TYPE/SIZE PHILLIPS SELF-DRILLING (S SERIES) 3/8

LENGTH 1 9/16

DRILL: 9/16" TWIST BIT

TEST NUMBER	TEST CONDITION	HOLE DEPTH (INCHES) L	HOLE DIAMETER (INCH) D 1/4	HOLE DIAMETER (INCH) D 3/4	EXPOSED PORTION OF ANCHOR (INCHES)	EMBEDMENT DEPTH (INCHES)	LOADS (POUNDS) YIELD	LOADS (POUNDS) SLIP	LOADS (POUNDS) ULTIMATE	DISPLACEMENT (INCHES) YIELD/SLIP	DISPLACEMENT (INCHES) ULTIMATE	FAILURE MODE/ COMMENTS
99	D	1 7/16	.607	.602	N/A	N/A	600	600	1250	.06/.0625	.455	PULLOUT
103	D	1 1/2	.597	.595	N/A	N/A	450	125	800	.15/.0625	.68	PULLOUT
104	D	1 1/2	.577	.595	N/A	N/A	800	775	1175	.07/.0625	.235	
105	D	1 7/16	.585	.597	N/A	N/A	525	450	1300	.07/.0625	.35	CONCRETE SPALL
109	D	1 1/2	.598	.588	N/A	N/A	850	625	1225	.1/.0625	.30	

14/15

REGULAR AND MAGNETITE CONCRETE

TYPE OF LOAD	ANCHOR SIZE (INCHES)	C-81 MAXIMUM ALLOWABLE LOAD (KIPS)	YIELD			ULTIMATE		
			NUMBER OF TESTS	LOAD (KIPS)	FACTOR OF SAFETY	NUMBER OF TESTS	LOAD (KIPS)	FACTOR OF SAFETY
TENSION	1/4	.30	5	.8	2.8*	4	3.3	11.0
	3/8	.50	7	2.3	4.7*	2	5.8	11.6
	1/2	.75	6	2.9	3.8*	2	6.8	9.1
	5/8	2.00	11	3.8	1.9	4	12.9	6.5
	3/4	3.00	9	6.5	2.2	2	18.8	6.3
SHEAR	1/4	.20	NA	NA	NA	NA	NA	NA
	3/8	.50	NA	NA	NA	NA	NA	NA
	1/2	.75	NA	NA	NA	NA	NA	NA
	5/8	2.00	2	16.4	8.2	2	27.1	13.6
	3/4	3.00	4	24.3	5.4	4	36.7	12.2
COMBINED	1/4	.30	NA	NA	NA	NA	NA	NA
	3/8	.50	NA	NA	NA	NA	NA	NA
	1/2	.75	NA	NA	NA	NA	NA	NA
	5/8	2.00	2	5.0	2.5	2	11.1	5.6
	3/4	3.00	4	3.0	1.0	4	13.2	4.4

NOTES: 1) NA = Test data not available.

2) Yield and ultimate loads are based on averages unless otherwise noted. If a "minimum yield" load is based on $\bar{x}$ - 1.65s (s = standard deviation, $\bar{x}$ = mean), then the safety factor defined as $\frac{\bar{x} - 1.65\,s}{\text{design load}}$ = 2.2 for the 1/4 inch anchor

= 3.6 for the 3/8 inch anchor

= 3.77 for the 1/2 inch anchor

= 1.37 for the 5/8 inch anchor

= 1.63 for the 3/4 inch anchor

3) * Based on the minimum yield load as indicated in Figures 14 thru 16.