THE DESIGN OF COLUMN BASE ANCHORAGES FOR SHEAR AND TENSION

by

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Project submitted to the Faculty of the
Virginia Polytechnic Institute and State University

in partial fulfillment of the requirements for the degree of

MASTER OF ENGINEERING

in

Civil Engineering

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July, 1991

Blacksburg, Virginia
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(ABSTRACT)  

A unified and consistent design procedure is proposed for column base anchorages loaded in shear and tension. A literature review of previous work was done to identify discrepancies. A design procedure for anchorages loaded in shear, tension and combined shear and tension was developed which attempted to coordinate and resolve the discrepancies in previous work. A design methodology utilizing shear lugs was developed. The overall design procedure is for column bases loaded in shear and tension and uses two design methods:  

Method 1: Headed anchor bolts are used to resist both shear and tension loads.  
Method 2: A shear lug welded to the bottom of the base plate resists shear loads and the headed anchor bolts resist only tension loads.
The proposed design method differs from the design method used by Shipp and Haninger (Reference 23) as follows:

1. The proposed procedure incorporates both shear and tension design stress based on the ultimate strength of the anchor bolts times a reduction factor.

2. Separate capacity reduction factors are introduced for shear and tension.

3. The use of shear lugs is incorporated in the proposed design.

4. The incorrect use of the "shear-friction" concept is noted and not used in the design.

5. The safety factor for the required embedment depth is applied to the projected area of the failure cone not the embedment depth of the bolt.

Several design examples are presented using the two methods. A computer program (using Microsoft QuickBasic 4.0) has also been developed using the proposed design procedure.
ACKNOWLEDGEMENT

This paper is dedicated to my wife Mary O'Brien whose love, support and encouragement has been instrumental in completing the project. Special thanks are due to Professor Richard M. Barker who served as the chairman for the project and whose support, technical and otherwise was invaluable. The author would also like to thank Professor Don A. Garst and Professor Yvan J. Beliveau for reviewing the project and serving as members of the author's advisory committee. Lastly, grateful acknowledgement is expressed to my parents who encouraged my education.
# THE DESIGN OF COLUMN BASE ANCHORAGE FOR SHEAR AND TENSION

## TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>ii</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>iv</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>vii</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>viii</td>
</tr>
<tr>
<td><strong>CHAPTER I.</strong></td>
<td></td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>1.1 OVERVIEW</td>
<td>1</td>
</tr>
<tr>
<td>1.2 PURPOSE</td>
<td>4</td>
</tr>
<tr>
<td>1.3 SCOPE</td>
<td>4</td>
</tr>
<tr>
<td><strong>CHAPTER II.</strong></td>
<td></td>
</tr>
<tr>
<td>LITERATURE REVIEW.</td>
<td>5</td>
</tr>
<tr>
<td>2.1 GENERAL</td>
<td>5</td>
</tr>
<tr>
<td>2.2.1 SHEAR</td>
<td>7</td>
</tr>
<tr>
<td>2.2.2 TENSION</td>
<td>14</td>
</tr>
<tr>
<td>2.2.3 COMBINED SHEAR AND TENSION</td>
<td>21</td>
</tr>
<tr>
<td>2.3 SHEAR LUGS</td>
<td>21</td>
</tr>
<tr>
<td><strong>CHAPTER III.</strong></td>
<td></td>
</tr>
<tr>
<td>DESIGN METHODOLOGY</td>
<td>25</td>
</tr>
<tr>
<td>3.1 DESIGN PARAMETERS</td>
<td>25</td>
</tr>
<tr>
<td>3.2 SHEAR AND TENSION</td>
<td>26</td>
</tr>
<tr>
<td>3.3 ANCHORAGE</td>
<td>28</td>
</tr>
</tbody>
</table>
CHAPTER IV. DESIGN EXAMPLES 30
CHAPTER V. CONCLUSIONS 39
REFERENCES 44
APPENDIX A DERIVATION OF MINIMUM SPACING AND EMBEDMENT 46
APPENDIX B NOMENCLATURE 51
APPENDIX C COMPUTER PROGRAM LISTING 53
VITA 86
# LIST OF TABLES

<table>
<thead>
<tr>
<th>TABLE</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Summary of Procedures for Calculating Nominal Shear Capacities.</td>
<td>10</td>
</tr>
<tr>
<td>2.2</td>
<td>Pullout Surface Areas for Stud Groups.</td>
<td>20</td>
</tr>
<tr>
<td>A.1</td>
<td>Summary of Required Embedment Lengths of Anchor Bolts to Develop Steel Tensile Capacity.</td>
<td>48</td>
</tr>
</tbody>
</table>
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>FIGURE</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Column Base Detail (Small Lateral or Uplift Loads).</td>
<td>2</td>
</tr>
<tr>
<td>1.2</td>
<td>Column Base detail (Large Lateral or Uplift Loads).</td>
<td>3</td>
</tr>
<tr>
<td>2.1</td>
<td>Typical Concrete Wedge Development at Anchor Bolts.</td>
<td>8</td>
</tr>
<tr>
<td>2.2</td>
<td>Base Plate-Foundation interface Conditions.</td>
<td>11</td>
</tr>
<tr>
<td>2.3</td>
<td>Typical Concrete Failure Cone at Headed Anchor Bolt.</td>
<td>13</td>
</tr>
<tr>
<td>2.4</td>
<td>Shear Reinforcement (Ref. 23).</td>
<td>15</td>
</tr>
<tr>
<td>2.5</td>
<td>Typical Concrete Failure Cone at Headed Anchor Bolt.</td>
<td>16</td>
</tr>
<tr>
<td>2.6</td>
<td>Various Proposed Models of Concrete Failure Surfaces.</td>
<td>19</td>
</tr>
<tr>
<td>2.7</td>
<td>Wind Loads, 3/4&quot; Diameter A307 Bolts.</td>
<td>23</td>
</tr>
<tr>
<td>2.8</td>
<td>Wind Loads, 3/4&quot; Diameter A325 Bolts.</td>
<td>24</td>
</tr>
<tr>
<td>A.1</td>
<td>Projected Shear Cone Development.</td>
<td>47</td>
</tr>
<tr>
<td>A.2</td>
<td>Nomenclature at Headed Anchor Connections.</td>
<td>50</td>
</tr>
</tbody>
</table>
1.1 OVERVIEW

Anchor bolts and other devices have been used for many years to anchor steel frames to a concrete foundation. The majority of these base connections are expected to receive nominal loads (i.e., loads due to erection). Figure 1.1 shows a column base detail with erection bolts which receive relatively small loads. These same anchorage devices are also used in critical applications within a building (i.e., anchorage of braced frames).

These connections may receive considerably larger loads and are responsible for the overall stability of the structure. Figure 1.2 shows a column base detail for a braced frame which may resist relatively large shear and tension forces. The loads applied to these same braced frames have increased due to larger wind and seismic design forces mandated by recent code revisions (i.e., 1990 BOCA).

Previous researchers (7, 9, 22, 23) have proposed various design procedures for the anchorage of steel frame bases to concrete. These procedures vary
FIG. 1.1 Column Base Detail (Small Lateral or Uplift Loads).
FIG. 1.2  Column Base detail (Large Lateral or Uplift Loads).
widely; therefore, there is a need for a unified and consistent design approach to transfer the loads from a steel frame to the concrete foundation.

1.2 Purpose

The purpose of this project is to assimilate the design recommendations of previous work and to develop a practical and consistent design approach for column base anchorages loaded in shear and tension.

1.3 Scope

The paper includes a literature review, the development of a design methodology and a conclusion that summarizes the principal elements of the paper. In addition, several design examples including an example of the design of shear lugs, the derivation of minimum spacing and embedments, a glossary of the nomenclature used, and a list of references are included as Appendices.
CHAPTER II.

LITERATURE REVIEW

2.1 General

The transfer of shear and tension forces from steel to concrete has received considerable attention from a variety of scientists, researchers, instructors, and engineers. Even though various authors differ on the interpretation of test data and on design methodology, there is widespread agreement of the best type of load transfer mechanism.

Headed anchor bolts, when properly designed and detailed, are recommended as the most efficient mechanisms for anchoring steel to concrete (5, 6, 7, 16, 17, 22, 23, 24). For large shear forces the use of shear lugs on the bottom of the base plate has been proposed as an efficient transfer device (21). Shear lugs may be used as part of an anchorage connection but the ductility of the connection must be insured (5). Other anchorage devices (L-bolts, J-bolts, embedded rods with bearing plates, etc.) have been used but are not recommended (23). The headed anchor bolt, when correctly embedded and confined, will develop the full tensile capacity of even A490 high strength bolts. A tensile failure of the anchor bolt steel (as described in Ref. 5) or the shear lug steel in bending will insure a ductile failure mode for non-cyclic loadings in a normal temperature range for the type of anchorage steel considered.
The design of base plate anchorages loaded in shear and tension is a complex subject. Previous articles have addressed the entire design (7, 9, 22, 23) while others have concentrated on various parts of the design (2, 10, 11, 15). The literature review presented here has been organized based on the potential loading conditions; shear, tension and combined shear and tension. The foundation subjects of edge effects, edge reinforcing, embedment length, base plate configuration, and bolt spacing are addressed within the individual loading conditions. Shear lugs are addressed as a separate topic at the end of the review.

The limit states or failure modes controlling the capacity of a headed anchor bolt are:

1. Tensile strength of the anchor.
2. Shear strength of the anchor.
3. The pullout cone of concrete at the anchor.
4. The failure of the concrete due to various edge conditions.

Shear forces in only one direction are considered in this paper. Moments applied to a base plate are not addressed. Other references (i.e., Design of Welded Structures by Blodgett and Structural Steel Design by Beedle) resolve an applied moment on a base plate into shear and tension forces on the anchorage devices.
2.2.1 Shear

The transfer of shear forces, as stated above, may best be accomplished by either a ductile shear lug or properly embedded and confined headed anchor bolts. The transfer of shear by a headed anchor bolt is through bearing of steel against concrete. It is assumed that the bearing of an anchor bolt causes the concrete ahead of the anchorage device to crush near the surface. Previous articles (5, 16, 23) have detailed the development of a concrete wedge at this bearing condition (see Figure 2.1). The base plate prevents the wedge from moving outward and upward. The restriction of the upward movement of the wedge by the base plate creates a tension force on the anchor bolt. This is the "shear friction" concept.

The design criteria for the transfer of shear forces by headed anchor bolts must respond to the various modes of failure mentioned in Section 2.1. These failure mechanisms have been addressed previously and were compiled and compared in References 10 and 12. The literature review of Reference 10 will be reiterated to an extent in this section. The conclusions and recommendations of References 10 and 12 will be evaluated and new recommendations proposed. A summary of the different methods for determining the capacity of headed anchor bolts loaded in shear is compiled in Table 2.1.

The computation of the shear capacity of headed anchor bolts has been developed in previous articles (5, 7, 9, 12, 16, 17, 18, 22, 23, 24). The failure
**FIG. 2.1** Typical Concrete Wedge Development at Anchor Bolts.
modes, as stated before, are steel yielding, concrete failure due to inadequate embedment, and concrete failure due to edge conditions or overlapping cones. The shear resistance of headed anchor bolts due to steel yielding must be checked by both the ACI and AISC design criteria. The shear resistance of headed anchors based on steel failure has been computed by several authors (7, 17) as the anchor's cross-sectional area times the ultimate tensile strength of the steel. However, Reference 25 suggests that the design of the connection based on this method may not provide a consistently adequate factor of safety. Several articles (5, 16, 23) use the shear-friction concept to describe steel failure. Tests performed in Reference 12 have not substantiated the shear-friction concept. Conversations with one of the authors from each of Reference 5 and Reference 12 verified that the shear-friction concept did not actually occur and that the use of it was "political." However, the method does provide steel failures in shear that agree with test data. It is also interesting to note that the method presented in References 5 and 23 addresses the three base plate-concrete interface conditions shown in Figure 2.2.

The shear resistance computed by References 10, 12, 18 and 19 (3rd Edition) uses the anchor's cross-sectional area times an estimate of the ultimate shear strength. The method proposed in Reference 12 is as follows, with the friction coefficient, C (determined later) incorporated in the design:

\[ V_s = A t (0.675) (F_u)/C \]  \hspace{1cm} (2.1)

Where,

\[ V_s = \text{Ultimate shear strength of anchor.} \]
<table>
<thead>
<tr>
<th>REFERENCE</th>
<th>STEEL FAILURE</th>
<th>CONCRETE FAILURE</th>
<th>CONCRETE FAILURE CLOSER TO EDGE</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>$V_s = A_t (H F_y)$</td>
<td>——</td>
<td>$V_c' = 2\pi (m)^2 \sqrt{f_c}$</td>
<td>$\phi_s = 0.9$, $\phi_c = 0.65$</td>
</tr>
<tr>
<td>7</td>
<td>$V_s = A_t (F_u)$</td>
<td>$V_c = 0.0666(A_t f_c)^{0.33} (E_c)^{0.44}$</td>
<td>$V_c' = V_c \left(\frac{m-1}{8d}\right)$</td>
<td>$\phi_s = 0.9$, $\phi_c = 0.65$</td>
</tr>
<tr>
<td>10</td>
<td>$V_s = A_t (0.675 F_u)$</td>
<td>——</td>
<td>$V_c' = 2\pi (m)^2 \sqrt{f_c}$</td>
<td>$\phi_s = 0.9$, $\phi_c = 0.65$</td>
</tr>
<tr>
<td>14</td>
<td>——</td>
<td>$V_c = 0.5 (A_t) \sqrt{f_c} E_c$</td>
<td>$m-1 \geq 8d$</td>
<td>——</td>
</tr>
<tr>
<td>17</td>
<td>$V_s = A_t (F_u)$</td>
<td>$V_c = 1.106 A_t (f_c)^{0.33} (E_c)^{0.44}$</td>
<td>$V_c' = V_c \left(\frac{m-1}{8d}\right)$</td>
<td>$\phi_s = \phi_c = 0.85$</td>
</tr>
<tr>
<td>19</td>
<td>$V_s = A_t (0.75 F_u)$</td>
<td>$V_c = 800 A_t \sqrt{f_c}$</td>
<td>$V_c' = 2\pi (m)^2 \sqrt{f_c}$</td>
<td>$\phi_s = 1.0$, $\phi_c = 0.85$</td>
</tr>
<tr>
<td>20</td>
<td>$V_s = A_t (0.75 F_u)$</td>
<td>$V_c = 1.106 A_t (f_c)^{0.33} (E_c)^{0.44}$</td>
<td>$V_c' = V_c \left(\frac{m-1}{8d}\right)$</td>
<td>$\phi_s = 1.0$, $\phi_c = 0.85$</td>
</tr>
<tr>
<td>PROPOSED</td>
<td>$V_s = A_t (0.655 F_u)$</td>
<td>——</td>
<td>$V_c' = 2\pi (m)^2 \sqrt{f_c}$</td>
<td>$C = 1.82$ (GROUP), $1.43$ (FLUSH), $1.11$ (EMBED), $\phi_s = 0.85$, $\phi_c = 0.65$</td>
</tr>
</tbody>
</table>
a) Base plate mounted on grout pad.
(\(\mu = 0.55\), \(c = 1.82\))

b) Base plate mounted on concrete.
(\(\mu = 0.70\), \(c = 1.43\))

c) Base plate embedded in concrete.
(\(\mu = 0.90\), \(c = 1.11\))

FIG. 2.2 Base Plate-Foundation Interface Conditions.
\[ A_t = \text{Tensile stress area.} \]
\[ F_U = \text{Minimum specified tensile strength.} \]
\[ C = \text{Friction coefficient.} \]

Definitions of terms used throughout this paper are given in Appendix B, Nomenclature.

The computation of the concrete capacity of headed anchor bolts loaded in shear away from free edges is based on a conical failure surface (see Figure 2.3b). The equations used by References 7, 17, 19, and 20 to compute shear capacity are all based on the equation derived in Reference 17 (see Table 2.1) which is as follows:

\[ V_c = 1.106 (A_t)(f'_c^{0.3})(E_c^{0.44}) \quad (2.2) \]

The recommendation of References 5, 10 and 23 is to embed the headed anchor far enough into the concrete to ensure that the steel fails before the concrete. This recommendation assures ductility of the anchor connection and is included in the proposed design method.

The computation of concrete capacity of headed anchors loaded in shear near a free edge is based on the failure surface shown in Figure 2.3a. Therefore the edge effects of a free edge begins to affect the anchors performance when the edge distance is less than the depth of embedment. References 5, 10, and 19 use the assumed failure surface and an average tensile stress of \( 4(SQR(f'_c)) \) to derive the shear capacity. The derivation of the equation, used
Fig. 2.3  Typical Concrete Failure Cone at Headed Anchor Bolt.
in References 5, 10, and 19 to compute the shear capacity, is as follows (see Table 1);

\[ Vc' = 4 (Ae) (SQR(f'c)) \]
\[ = 4 (\Pi (m)^2/2) (SQR(f'c)) \]
\[ = 2 (\Pi )(m)^2 (SQR(f'c)) \]
(2.3)

The equations used by References 7, 14, 17, 19 (2nd Edition), and 20 are all based on the equation of Reference 17;

\[ Vc' = Vc \cdot \left( \frac{(m-1)}{8(d)} \right) \]
(2.4)

However, to provide an adequate level of safety in the connection and insure the ductility of the connection, shear reinforcing is provided when the edge distance is less than the embedment length. The shear reinforcing is placed across the shear failure plane as shown in Figure 2.4. The amount of reinforcing steel required is based on the equation from Reference 23;

\[ Asv = \frac{(Fu*At)}{(Fy*cos 45^\circ *C)} \]
(2.5)

2.2.2 Tension

The transfer of tension forces may best be accomplished by a properly embedded headed anchor bolt (see Figure 2.5). The capacity of a headed anchor bolt may be controlled by either the tensile strength of the steel anchor, pullout of a cone of concrete, or local bursting of the concrete due to edge
Fig. 2.4 Shear Reinforcement (Ref. 23).
FIG. 2.5

Typical Concrete Failure Cone at Headed Anchor Bolt.
effects. The tensile strength of the anchor must be checked by both ACI and AISC design criteria. The ACI criteria has been reviewed in Reference 11 and there is widespread agreement that the tensile capacity of a fully embedded steel anchor is equal to the cross-sectional area times a specified minimum tensile strength. As stated in Reference 13, the equation for the actual tensile stress area of bolts or threaded studs is as follows:

\[ At = 0.7854 \left( d - (0.9743/\text{th' ds per inch}) \right) \]  

(2.6)

This definition of tensile stress area shall be used in the proposed design as opposed to using the full cross sectional area of a stud. In regards to the strength of the anchor bolts, Reference 7 uses the ultimate strength of the anchor steel but the remaining design methods all use only the yield strength equal to 90% of the ultimate capacity of the anchor steel. The proposed design equation for the steel strength of an anchor loaded in tension is as follows:

\[ Ts = (0.9) (Fu*At) \]  

(2.7)

Reference 11 states that two methods exist for computing concrete strength when there are no edge conditions. The method used by References 19 (2nd edition) and 20 were non-conservative when compared with test data. A revised design method developed in Reference 22 agrees with the design methods of other references and has been incorporated in Reference 19 (3rd edition). Therefore, a 45 degree conical surface is established as the
appropriate concrete failure surface (Figure 2.6a). The average tensile stress on the projected area at the concrete surface is assumed to be 4(SQR(f'c) ). Therefore, the design equation for the concrete strength of an anchorage device loaded in tension is as follows:

$$T_c = (4) \Pi (le) (le + dh) SQR(f'c)$$ \hspace{1cm} (2.8)

It is important to note the design recommendations of Reference 5 require an adequate embedment depth to preclude a concrete failure mechanism. Therefore, adequate embedment of headed anchors with the required spacing and no edge considerations will insure a ductile failure mode.

The location of headed anchors close to another anchor or a free edge requires a modification to the design procedure (Figure 2.6). Reference 11 notes that many procedures have been developed. The design method from Reference 7 fits the largest full projected cone that will fit in the original projected cone reduced by free edges or overlapping cones. The ratio of edge distance to embedment depth is used in Reference 19. Reference 5, 11, and 20 recommend the use of a projected area reduced by free edge or overlapping cones. Based on the analysis of data in Reference 22, the ratio of edge distance to embedment at a free edge determines the concrete strength of a headed anchor bolt at a free edge. The equation is as follows:

$$T_c = (m/le) (4) \Pi (le) (le + dh) SQR(f'c)$$

$$= (m) (4) \Pi (le + dh) SQR(f'c)$$ \hspace{1cm} (2.9)
Fig. 2.6

Various Proposed Models of Concrete Failure Surfaces.
## Table 2.2

Pullout Surface Areas for Stud Groups. *(Ref. 22)*

<table>
<thead>
<tr>
<th>Case</th>
<th>Not near a free edge*</th>
<th>Free edge on one side</th>
<th>Free edges on 2 opposite sides</th>
<th>Free edges on 2 adjacent sides</th>
<th>Free edges on 3 sides</th>
<th>Free edges on 4 sides</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( h \geq (y + 21L)/2 )</td>
<td>( P_{nc} = \frac{4\sqrt{F_t}}{l} (x + 21L)(y + 21L) )</td>
<td>( h &lt; (x + 21L)/2 )</td>
<td>( P_{nc} = \frac{4\sqrt{F_t}}{l} (x + 1 - e_d)(y + 21L) )</td>
<td>( h &lt; (x + 21L)/2 )</td>
<td>( P_{nc} = \frac{4\sqrt{F_t}}{l} (x + d_e - 1)(y + 21L) - A_R )</td>
</tr>
<tr>
<td></td>
<td>( d_e )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>( d_e2 )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>( d_{e1} )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>( d_{e3} )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Near a free edge implies \( d < l \).

**"z"** is equal to the lesser of the "x" and "y" values.

\[ h_{s1} = (x + 21L - 2h)(y + 21L - 2h) \]

Note. The nominal tension strength \( P_{nc} \) values given in the table are obtained by using stress levels of \( (4/\sqrt{3}) \sqrt{F_t} \) on the sloping sides area and \( 4\sqrt{F_t} \) on the base area of the failure surface, respectively.
The use of an effective projected area as recommended in References 5 and 11 is the basis of the proposed design procedure for overlapping failure cones. Reference 14 and 22 are excellent sources for the mathematical computation of an effective projected area for overlapping failure cones. The equations for computing effective projected area are derived only for the bolt arrangements listed in Table 2.2.

The concrete tensile stress reduction factor used in References 5 and 23 is .85 when the anchor head is beyond the concrete reinforcement and .65 otherwise. A tensile stress reduction factor of .65 is used at all locations in the proposed design as recommended by Reference 11.

2.2.3 Combined Shear and Tension

Reference 7, 17, 19, and 20 recommend the use of interaction equations where the applied load divided by the allowable capacity is raised to a power (5/3 for Reference 7, 17 and 2 for 19,20). References 1 and 5 state that not enough reliable data is available on the effects of combined loading, especially with large shear forces, grouted base conditions and in field installation, to justify a nonlinear interaction equation. Therefore, the straight line or additive form of interaction equation is used, similar to Reference 23. Figures 2.7 and 2.8 show a graph which compares the interaction equations of Reference 23 and 5 versus the proposed equation versus the interaction equation used in steel design (Reference 14).
2.3 Shear Lugs

A shear lug transfers shear forces from the steel column base to the foundation through bearing of the lug against the concrete. An example of a shear lug keyed and grouted into a concrete footing is shown in Figure 1.2. Therefore, the capacity of a shear lug may be controlled by bearing on the concrete, shear on the lug, bending of the lug, or failure of the welding of the lug to the base plate.

As shear lug transfers the shear forces in a base plate to the foundation by bearing against the concrete, the shear force is transmitted to the bearing point of the shear lug by combined shear and bending of the steel lug. A uniform stress distribution (similar to the Whitney stress block used in ultimate strength design) is assumed for the bearing stress on the concrete. The allowable bearing pressure is kept low to prevent a brittle bearing failure. In accordance with the recommendation of References 4 and 5, the assumed bearing pressure is

\[ F_p = 0.85 \times 0.6 \times f_c \]  \hspace{1cm} (2.10)

The use of a shear lug creates a vertical plane in the concrete foundation which may create problems with top steel reinforcing in the footing. In addition, due to the lack of experimental data available on shear lugs, their use is discouraged at free edges loaded in shear unless adequate reinforcement is developed from the shear lug away from the free edge.
Fig. 2.7 Wind Loads, 3/4" Diameter A307 Bolts.
FIG. 2.8  Wind Loads, 3/4" Diameter A325 Bolts.
CHAPTER III.

DESIGN METHODOLOGY

3.1 Design Parameters

The ductility of the design is assured by causing a failure of the anchor bolt steel by yielding rather than a brittle tensile failure of the concrete. This is accomplished by designing the tensile failure strength of the concrete (U_p) such that it exceeds the minimum specified tensile strength of the anchor bolt (F_{u\cdot a_t}) by a factor of 1.5. The concrete failure surface was previously defined in the Literature Review. Appendix A shows the derivation of the required embedment depth, L_d, to accomplish this criteria. The design approach is similar to Reference 23 and is compatible with the requirements of Reference 5 except as modified herein.

The following design parameters are taken from Reference 23 but are applicable for most building applications. They are:

"The design approach presented is generally applicable to any of a number of bolt or concrete strengths. However, the following representative materials are used in developing the design values. Anchor bolt materials used are ASTM A36, A307 (Grade B), A325, A449 and A687. Concrete is assumed to have a minimum compressive strength (f'_c) of 3,000 psi. Anchor bolts are heavy hex bolts or threaded steel bars with one heavy hex nut placed in
concrete. Bolt threads at the embedded end of each threaded steel bar are "staked" at two places below the heavy hex nut. All bolts are brought to a "snug tight" condition as defined by AISC to ensure good contact between attachments. The concrete is at least 14 days old prior to tightening the anchor bolts in order to prevent bolt rotation. Anchor bolts are designed for combined shear and tension loads; the area of steel required for tension and shear is considered additive."

3.2 Shear and Tension

The anchor bolts shall be designed to resist tension if a shear lug is used or combined shear and tension if no shear lug is used. The anchor bolt area of steel required to resist shear and tension is considered additive. Therefore the proposed design equation to determine the size of the headed anchor bolts is as follows:

\[ [V_U \cdot C / \phi_v + T_U \cdot .75 / \phi_z] = A_t \cdot (0.675 \cdot F_u) \]  \hspace{1cm} (3.1)

where:
- \( C \) = Base plate - foundations shear coefficient
  - \( = 1.11 \) embedded plate
  - \( = 1.43 \) flush mounted plate
  - \( = 1.82 \) plate on grout pad
- \( V_U, T_U \) = Ultimate shear and tension loads, respectively
- \( \phi_v, \phi_z \) = Ultimate shear and tension capacity reduction factors, respectively.
- \( A_t \) = Required tensile stress area.
- \( F_u \) = Ultimate strength of anchor steel.
The ultimate loads are based on the design format of Reference 4. Figure 2.2 shows the different base plate-concrete interface conditions. Based on these failure interfaces, distribution coefficients for headed anchor bolts loaded in shear have been empirically developed by several authors (5, 16). The empirical values stated in Reference 5 are rational and are used in the proposed design.

The design of a shear lug to resist the shear forces is based on the procedure presented in Reference 26. In Reference 26 a portion of the shear face is resisted by friction between the base plate and the foundation while the remaining shear load is resisted by a shear lug. The bearing pressure used in Reference 26 is \((.85 \times .6 \times f'c)\). Even though the clamping effect of the anchor bolts may allow a larger value, the proposed design method uses the effective bearing stress stated above. The required area of a shear lug is then determined and after assuming a width; the depth, thickness and required welds can be computed. The procedure for the design of a shear lug is shown as an example in Chapter IV.

3.3 Anchorage

The anchorage of headed anchor bolts in concrete can be classified in four categories. These categories have different classifications than the categories detailed in Reference 23. Figure A.2 defines the nomenclature used to
differentiate the various types of footings. The categories are as follows:

1. Type 'A' Footings:
   Isolated anchor bolts where bolt spacing exceeds $r_m$, the edge distance exceeds $m_v$ and the required embedment depth, $L_d$, is provided.

2. Type 'B' Footings:
   Shear reinforcement anchor bolts where bolt spacing exceeds $r_m$, and the required embedment depth, $L_d$, is provided but the edge distance is between $m_t$ and $m_v$.

3. Type 'C' Footings:
   Overlapping anchor bolts where the required embedment depth, $L_d$, is provided and the edge distance exceeds $m_v$ but the bolt spacing is less than $r_m$.

4. Type 'D' Footings:
   Tension lap anchor bolts where the bolt spacing does not exceed $r_m$, the edge distance may not exceed $m_v$ and the required embedment depth, $L_d$, is provided, but the projected tensile stress area, $A_e$, is not adequate (such as in a concrete pier) and tension reinforcement is provided.

It is important to note that Categories 2 and 3 may occur simultaneously and that Category 4 is a special case of either Category 2 or 3 or both. The minimum depth of embedment is derived in Appendix A and presented with
the values of $m_t$, $m_V$, and $r_m$ in Table A.1. The required depth of embedment is determined by the required value of $A_e$ where $A_e$ is as follows:

$$U_p = [4* \beta * \text{SQR}(f_c)] * A_e > (Fu)(At) \quad (3.2)$$

$$A_e = (Fu * At) / (4 * \beta * \text{SQR}(f_c)) \quad (3.3)$$

The required depth of embedment is then determined based on the required projected tensile area. The special case of Category 4 would require tensile reinforcement to lap with the embedded, headed anchor bolts where the required embedment would be the larger of $l_d$ of the anchor bolts or the $l_{d_h}$ of the tensile reinforcement. The area of tensile reinforcement required is equal to the following equation:

$$A_{st} = (n) (Fu)(At) / F_y \quad (3.4)$$

As stated previously in the Literature Review, the area of reinforcing steel required for Category 2 anchor bolts is:

$$A_{sv} = (Fu * At) / (C * F_y * \cos 45^\circ) \quad (3.5)$$

Refer to Figure 2.4 for placement and reinforcing details.

The application of this criteria is presented in Chapter IV Design Examples.
CHAPTER IV.

DESIGN EXAMPLES

Three examples of column base anchorage design are presented.

Example 1 is the design of an isolated column footing with tension and shear loads applied. The design of the column base anchorages uses the anchor bolts to resist both the tension and shear loads.

Example 2 is the design of an isolated column footing with the same tension and shear loads applied as in Example 1. A shear lug is used in the design of the column base anchorage to resist shear forces while the anchor bolts resist only tension forces.

Example 3 is the design of a column base anchorage to a concrete pier. The design of the column base anchorages is for the same loads as Example 1; however, the tension forces in the headed anchor bolts must be developed into the concrete reinforcement. The concrete reinforcement must also be detailed properly to develop the reinforcement capacity.

30.
DESIGN EXAMPLE - P. 1.

DESIGN DATA

Width 60 in. L/W 16" x 16" B.P. (A36)
(4) A.B. spaced 13" OC. (F_u = 50 ksi)

1/2" GROUT PAD NO SHEAR LUG.
(c = 1.02) (\psi_1 = 0.65) (\phi_2 = 0.9)
B = 0.08 ft^2 P = 10.7 k (S = 3.25)

PDL = 70 k, PLL = 120 k, PWL = 84.8 + 12 = 96 k
VWL = 84.8/12 = 7 k

1. BASED ON VERTICAL LOADS AND THE DESIGN PROCEDURE
OF REF. 13 THE BASE PLATE NEEDS TO BE 1/8" THICK.

2. ANCHOR BOLT DESIGN:

\[
\frac{V_{\text{UMAX}}}{1.3} = 78 k \\
\frac{V_{\text{UMAX/EBT}}}{19.5 k} = 3.5 k
\]
\[
F_{\text{UMAX}} = 0.9(70 k) + 1.2(-60 k) \\
F_{\text{UMAX/EBT}} = -3.75 k
\]

\[
\frac{V_c + T_u(0.75)}{\phi} = A_t \left( \frac{675}{F_u} \right)
\]

\[
\frac{19.5(1.25) + 3.75(0.75)}{0.85} \left( \frac{675}{58 \text{ ksi}} \right) = A_t \\
\frac{41.75 + 3.125}{39.15} = A_t
\]

\[1.14 \text{ in}^2 = A_t \]

SELECT 1 1/2" A.B.

\[A_t = 1.16 \text{ in}^2 \]

\[r = 22.27 \text{ in.} \]

3. SINCE \( r = 15" < r_m = 22.27" \) TYPE "C" FTG.
DESIGN EXAMPLE #1 (CONT.)

4. TO DEVELOP A.B. COMPUTE REQUIRED EMBEDMENT.

F.S.F.

\[ U_p = 4 \left( \frac{p}{13.2} \times A_c \right) < F \left( A + \text{total} \right) \]

\[ A_c \text{ req'd} = \frac{58(0.016) \times 4}{4(0.65) \times \sqrt{3000}} \]

\[ = 1882 \text{ in}^2 \]

TRY EMBEDMENT OF 17 in.

\[ A_1 = 12^2, A_2 = 13^2, A_3 = \pi(17)^2 \]

\[ A_c = 169 + 884 + 905 \]

\[ = 2058 \text{ in}^2 \]

\[ A_c \text{ req'd} = 1882 \text{ in}^2 \]

5. SELECT (4) 1 3/8 in. HEADED A307 A.B. EMBEDDED 1-5 into footing.

6. SEE ENCLOSED PRINTOUT FROM COMPUTER PROGRAM WHICH CONVNETS RESULTS.
### DESIGN EXAMPLE #1 (cont.)

#### COLUMN BASE PLATE RESULTS

<table>
<thead>
<tr>
<th>Bolt</th>
<th>Ft. type</th>
<th>Reason</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.125</td>
<td>1.375</td>
<td>C</td>
<td>Rx,Ry &lt; r, de &gt; av</td>
</tr>
</tbody>
</table>

#### CONFIGURATION INPUT

**NO SHEAR LUG**

<table>
<thead>
<tr>
<th>C1. Base plate length, L, in.</th>
<th>16.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>C2. Base plate width, B, in.</td>
<td>16.00</td>
</tr>
<tr>
<td>C3. Column length, Lx, in.</td>
<td>10.00</td>
</tr>
<tr>
<td>C4. Column width, Dy, in.</td>
<td>16.00</td>
</tr>
<tr>
<td>C5. Number of headed anchors.</td>
<td>4</td>
</tr>
<tr>
<td>C6. Bolt spacing, Rx, in.</td>
<td>13.00</td>
</tr>
<tr>
<td>C7. Bolt spacing, Ry, in.</td>
<td>13.00</td>
</tr>
<tr>
<td>C8. Base plate pad type, C.</td>
<td>1.82</td>
</tr>
<tr>
<td>C9. Bolt strength, Fy, ksi.</td>
<td>58</td>
</tr>
<tr>
<td>C10. Concrete, fc, ksi.</td>
<td>3.00</td>
</tr>
<tr>
<td>C11. Conc. area, A2, in**2.</td>
<td>9612.0</td>
</tr>
<tr>
<td>C12. Edge distance, de, in.</td>
<td>48.00</td>
</tr>
</tbody>
</table>

#### LOAD INPUT

**UNFACTORED**

| L1. Vertical dead loads, kip. | 70.00 |
| L2. Vertical live loads, kip. | 130.00|
| L3. Vertical wind loads, kip. | -60.00|
| L4. Lateral dead loads, kip.  | 0.00  |
| L5. Lateral live loads, kip.  | 0.00  |
| L6. Lateral wind loads, kip.  | 66.00 |
| L7. Dead load moment, in-k.   | 0.00  |
| L8. Live load moment, in-k.   | 0.00  |
| L9. Wind load moment, in-k.   | 0.00  |

#### BASE PLATE RESULTS

<table>
<thead>
<tr>
<th>tpl(vert)</th>
<th>tpl(bend)</th>
<th>tpl(tens)</th>
<th>tpl(used)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.081</td>
<td>0.000</td>
<td>0.353</td>
<td>1.125</td>
</tr>
</tbody>
</table>

controls

#### ANCHOR BOLT RESULTS

<table>
<thead>
<tr>
<th>Bolt</th>
<th>Length</th>
<th>Spacing</th>
<th>Edge(min)</th>
<th>Edge(v)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.33</td>
<td>13.64</td>
<td>22.27</td>
<td>5.99</td>
<td>16.34</td>
</tr>
</tbody>
</table>

#### FOUNDATION RESULTS

<table>
<thead>
<tr>
<th>Ftg type</th>
<th>Reason</th>
<th>Fig. stl.(Av)</th>
<th>Area_xd</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>Rx,Ry &lt; r, de &gt; av</td>
<td>0.000</td>
<td>1882.</td>
</tr>
</tbody>
</table>
Design Example #2

Design Data:
Repeat of Example #1
(use 1" GROUT PAD and SHEAR LUG)

Design:
1. As in Example #1
   Base Plate is 1 1/2" thick.
2. Shear Lug Design
   \( v_{\text{max}} = 78^k \quad P_{\text{min}} = -15^k \) (no friction on B.P.).

   \( v_{\text{lug}} = 78^k - (55)(P_{\text{min}}) = 78^k \)

   \( A_{\text{lug}} = 78^k / (0.85 \times 0.6 \times 3^k) = 50.98\text{ in}^2 \)

   \( P_{\text{lug}} = \frac{50.98\text{ in}^2}{12"} \)

   \( M_{\text{lug}} = \left( \frac{78^k}{12"} \right) \times \left( \frac{5.25" - 1"}{2} + 1 \right) = 20.31\text{ in} \times \text{lb} \)

   \( T_{\text{lug}} = \sqrt{4(20.31)} = 1.583 \text{ in} \quad \text{use 1 3/4" thick \times 12" long} \quad \times 5 1/4" \text{ deep shear lug.} \)

   \( S_{\text{weld}} = \sqrt{\left( \frac{78^k}{2(12\text{ in})} \right)^2 + \left( \frac{20.31\text{ in} \times \text{lb}}{1.75\text{ in}} \right)^2} = 12.05\text{ in} \quad 1.392 \text{ in} = 8.06 \text{ sixteenths weld} \quad \text{use 9/16" fillet weld} \)

Anchor Bolt Design:
\[
T_w (0.75) = \frac{A_t (0.675)(F_u)}{\phi_e} \quad A_t = \left[ \frac{3.75^k (0.75)}{0.9} \right] (0.675)(58) = 0.08\text{ in}^2
\]

Use 1/2" head A327 A8.
DESIGN EXAMPLE 42 (CONT.)

3. Since $r = 13" > \text{r}_m = 4.72"$, TYPE 'A' FIG.

4. EMBED A.B. 5" HILL. TO DEVELOP EDGES.

5. SELECT (4) ½" Ø HEADED A307 A.B. EMBEDDED 5"
   INTO FOOTING WITH 12" LONG x 1¾" THICK x 3.25" DEEP
   SHEAR LG., WELD TO B.P. WITH 9½" PILLET.

6. SEE ENCLOSED PRINTOUT FROM COMPUTER PROGRAM
   WHICH CONFIRMS RESULTS.
### DESIGN EXAMPLE #2 (CONT.)

<table>
<thead>
<tr>
<th>Column Base Plate Results</th>
<th>Project ID</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>tbp (used)</strong></td>
<td><strong>Bolt</strong></td>
</tr>
<tr>
<td>1.125</td>
<td>0.500</td>
</tr>
</tbody>
</table>

**Configuration Input**

<table>
<thead>
<tr>
<th>Shear Lug</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1. Base plate length, L, in.</td>
</tr>
<tr>
<td>C2. Base plate width, B, in.</td>
</tr>
<tr>
<td>C3. Column length, z, in.</td>
</tr>
<tr>
<td>C4. Column width, D, in.</td>
</tr>
<tr>
<td>C5. Number of headed anchors</td>
</tr>
<tr>
<td>C6. Bolt spacing, Rx, in.</td>
</tr>
<tr>
<td>C7. Bolt spacing, Ry, in.</td>
</tr>
<tr>
<td>C9. Base plate gage type</td>
</tr>
<tr>
<td>C10. Concrete, ft. ksi.</td>
</tr>
<tr>
<td>C11. Conc. area, A2, in**2</td>
</tr>
<tr>
<td>C12. Edge distance, de, in.</td>
</tr>
<tr>
<td>C13. Lug width, Liug, in.</td>
</tr>
<tr>
<td>C14. Grout thickness, in.</td>
</tr>
</tbody>
</table>

**LDAO Input**

<table>
<thead>
<tr>
<th>Unfactored</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1. Vertical dead loads, kip.</td>
</tr>
<tr>
<td>L2. Vertical live loads, kip.</td>
</tr>
<tr>
<td>L3. Vertical wind loads, kip.</td>
</tr>
<tr>
<td>L4. Lateral dead loads, kip.</td>
</tr>
<tr>
<td>L5. Lateral live loads, kip.</td>
</tr>
<tr>
<td>L6. Lateral wind loads, kip.</td>
</tr>
<tr>
<td>L7. Dead load moment, in-k.</td>
</tr>
<tr>
<td>L8. Live load moment, in-k.</td>
</tr>
<tr>
<td>L9. Wind load moment, in-k.</td>
</tr>
</tbody>
</table>

**Base Plate Results**

<table>
<thead>
<tr>
<th>Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>tbp (vert)</strong></td>
</tr>
<tr>
<td>1.061</td>
</tr>
</tbody>
</table>

**Anchor Bolt Results**

<table>
<thead>
<tr>
<th>Bolt</th>
<th>Length</th>
<th>Spacing</th>
<th>Edge(min)</th>
<th>Edge(v)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.50</td>
<td>4.72</td>
<td>7.71</td>
<td>4.00</td>
<td>5.94</td>
</tr>
</tbody>
</table>

**Foundation Results**

<table>
<thead>
<tr>
<th>Ftg. type</th>
<th>Reason</th>
<th>Ftg. stl. (Av)</th>
<th>Aedere</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Rx, Ry &gt; r, de &gt; sv</td>
<td>0.000</td>
<td>251.</td>
</tr>
</tbody>
</table>

**Shear Lug Results**

<table>
<thead>
<tr>
<th>Length</th>
<th>Depth</th>
<th>Thickness</th>
<th>Size of weld</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.00</td>
<td>5.25</td>
<td>1.75</td>
<td>0.66</td>
</tr>
</tbody>
</table>
**DESIGN EXAMPLE #3**

**DESIGN DATA**

**REPEAT OF EXAMPLE #1, 30" X 30" CONC. PIER BELOW**

**CONC. PIER. \(A_z = 900 \text{ in}^2, c = 8.5"\)**

**DESIGN**

1. AS IN EXAMPLE #1, BASE PLATE IS 1/4" THICK.

2. ANCHER BOLT DESIGN.

   AS IN EXAMPLE #1, SELECT (4) \(\frac{3}{4}"\) HEADED ASM T. A. B. \(A_b = 1.16 \text{ in}^2\).

3. SINCE \(\sum = 13" < \sum_m = 22.27"\)

   \[d_e = 8.5" < \sum_m = 16.34"\]

   \[A_2 = 100 \text{ in}^2 < A_2 = 1862 \text{ in}^2\] (SEE EXAMPLE #1)

   **TYPE 'D' FIG.**

4. TO DEVELOP A.B., LAP WITH VERT. REINF. AND SINCE \(d_e < \sum_m, A_v = 868 \text{ in}^2\)

   **EMBEDMENT OF BOLTS IS LARGER OF \(\frac{1}{4}h\) OR \(d_e\)**

   \[d_e = 13.6"\]

   \[20 = 29" \text{ CONTROLS (14" WITH END HOOKS).}\]

   \[h = 13.6"\]

   USE \(14" + 2" = 16"

   **EMBED BOLTS 16" INTO PIER.**

   TIE BARS AT TOP OF PIER

   \[A_v = .868 \text{ in}^2\]

   \[A_v = (6 \times .20) = 1.2 \text{ in}^2\]

   \[\therefore \text{ USE (3) #4 CLOSED TIES.}\]
DESIGN EXAMPLE #3 (cont.)

4. (cont.)
   TO DEVELOP REINFORCEMENT ACROSS
   FAILURE PLANE, USE #7
   U-BARS WITH 29" + 14" = 43"
   LEGS.

5. SELECT (4) 1/2" #4 HEADED A307
   A.B., EMBEDDED 16" INTO FIG.
CHAPTER V.

CONCLUSIONS

Headed anchor bolts are an effective method for the anchorage of steel base plates to concrete foundations. References 5, 7, 9, 19, 22, 23 and 26 address the entire design of headed anchor bolts. References 5, 19, 22 23 and 26 are prepared as design guides for the practicing engineer.

The design method of the PCI (Reference 19) has presented guidelines for the installation of headed anchors under plant conditions. Therefore, the use of higher values for shear, tension and the use of an equation raised to a power to represent the combined shear and tension interaction is accurate and appears to correlate with test data. The ACI design guide in Reference 5 and the AISC design guide in Reference 26 have both offered practical design guidelines for field installed base plates and headed anchor bolts. The analysis of the design guidelines for field installed headed anchors is the objective of this paper; therefore, concentrated efforts have been made on these two design guides and their practical applications in References 23 (Shipp and Haninger).

In response to shear forces, the use of either headed anchor bolts or shear lugs and column base friction to resist the shear forces are both satisfactory. The designer must weigh the cost of using heavier anchor bolts and their difficulty in setting in place versus the additional cost of a shear lug and the
grouted keyway it requires. The design equation proposed for shear agrees with Klingner et al (Reference 12) and is as follows:

\[ V_s = A_t (0.675 F_u/C) \]  \hspace{1cm} (5.1)

The design equation is similar to that given by Shipp and Haninger (23) which is modified to incorporate the base plate factor for shear. The C factor (column base to foundation coefficient) is accepted with the following values:

\[ C = 1.82 \text{ with grout pads} \]
\[ = 1.43 \text{ with flush mounted base plate} \]  \hspace{1cm} (5.2)
\[ = 1.11 \text{ with an embedded base plate} \]

The shear lug design methodology proposed by AISC (26) is accepted in the proposed design. Therefore, when the shear lug design method is used the tension capacity is not reduced by the presence of shear. An allowable bearing stress greater than the unconfined allowable bearing stress used by AISC (26) may be used if headed anchor bolts are used as erection bolts in conjunction with the shear lug. The headed anchor bolts are assumed to act as a clamping force thus permitting the use of the higher bearing stress.

The concept of shear-friction embraced by both ACI (5) and AISC (26) is a flawed one. Klingner in Reference 12 stated this and Cannon of Reference 5 agreed. Both authors stated that the model is used because it agrees with test
data and that the process to change it is arduous. Therefore, the "shear-friction" concept is not incorporated in the proposed design method.

The ability of headed anchor bolts to resist tension forces is well documented. Both ACI (5) and AISC (26) recommend their use and give a minimum embedment length to insure ductility. The design procedure developed by Shipp and Haninger (23) is conservative in that the allowable tensile strength of the anchors is less than what is used by AISC (26). As long as the embedment is adequate to fully develop an anchor bolt for steel failure the full tensile strength (Reference 26) of the bolts should be used. Reference 23 multiplies the embedment depth by 4/3 as a precaution to insure ductility. The effect of this is to increase the projected area at the surface by 16/9. The writer recommends that the projected area be increased by 1.5 to insure ductility.

The use of a straight line interaction equation for combined shear and tension is supported by References 5 and 23. The use of this type of equation as opposed to the ratio of actual to allowable raised to a power (i.e., the PCI method) appears logical due to field conditions. The interaction equation proposed in this paper is as follows:

\[
[V_u \cdot C/\phi + T_u \cdot .75/\phi] = A_t \cdot (.675 \cdot F_u)
\]  

(5.3)

Graphs of the interaction equations for References 23, the AISC steel manual ninth edition (14) and the proposed method are shown in Figures 2.7 and 2.8.
for A307 bolts and A325 bolts. Design examples utilizing the proposed equation have been presented in Chapter IV.

The proposed design method differs from the design method used by Shipp and Haninger (23) as follows:

1. The proposed procedure incorporates both shear and tension design stress based on the ultimate strength of the anchor bolts times a reduction factor.
2. Separate capacity reduction factors are introduced for shear and tension.
3. The use of shear lugs is incorporated in the proposed design.
4. The incorrect use of the "shear-friction" concept is noted and not used in the proposed design method.
5. The safety factor for the required embedment depth is applied to the projected area of the concrete failure cone not the embedment depth of the bolt.

The subject of foundation conditions has been addressed as four independent conditions. It is noted that Type 'B' and Type 'C' footings may occur simultaneously and that Type 'D' footings are actually a special case of Type 'B' or Type 'C' where the effective area $A_e$, is less than, $A_2$, the footing area. They are as follows:

1. **Type 'A' Footings:**
   - Isolated anchor bolts where bolt spacing exceeds $r_m$, the minimum bolt
spacing to insure independent failure cones. The edge distance exceeds mv, the minimum edge distance without shear reinforcement, and the required embedment depth, Ld, is provided.

2. Type 'B' Footings:
Shear reinforcement anchor bolts where bolt spacing exceeds rm, and the required embedment depth, Ld, is provided but the edge distance is between mt and mv.

3. Type 'C' Footings:
Overlapping anchor bolts where the required embedment depth, Ld, is provided and the edge distance exceeds mv but the bolt spacing is less than rm.

4. Type 'D' Footings:
Tension lap anchor bolts where the bolt spacing does not exceed rm, the edge distance may not exceed mv and the required embedment depth, Ld, is provided, but the projected tensile stress area, Ae, is not adequate (such as in a concrete pier) and tension reinforcement is provided.

Therefore, a consistent design procedure has been proposed for the design of field installed headed anchor bolts at column bases to resist shear and tension forces. The procedure has incorporated the option of a shear lug design and the anchorage conditions for the anchor bolts has been clarified.
REFERENCES


4. "Building Code Requirements for Reinforced Concrete (ACI 348-83), "American Concrete Institute, Detroit, 1983.


6. "Code Requirements for Nuclear Safety Related Concrete Structures (ACI 349-80), " and "Commentary on Code Requirements for Nuclear Safety Related Structures (ACI 349-80), "ACI Committee 349, American Concrete Institute, Detroit, 1980, 90 pp. and 30 pp.


APPENDIX A
MINIMUM SPACING AND EMBEDMENT

An equivalent circle is assumed equal to the projected area of a heavy hexagonal head (see Figure A.1).

\[ A_{\text{hex}} = (SQR\ (3/2)\ (F^2) = 0.866\ (F^2) \]

\[ A_{\text{circle}} = \pi\ (C^2)/4 \]

\[ 0.866\ (F^2) = \pi\ (C^2)/4 \]

\[ C = 1.05F \]

Tensile stress area, \( A_e = A_1 - A_2 \)

\[ A_e = \pi\ [((L + C/2)^2) - (C/2)^2)] \]

\[ = \pi\ [(L^2) + (C)(L) + (C^2/4) - (C^2/4)] \]

\[ = \pi\ [(L^2) + (C)(L)] \]

\[ U_p = A_e [(4) (.5) (SQR\ (f'c))] \]

Assume \( \beta = .65 \) and \( f'c = 3000 \) psi

\[ = \pi\ [(L^2) + (C)(L)] (4) (.65) (SQR(3000)) \]

\[ = 477\ [(L^2) + (C)(L)] \]
Fig. A.1  Projected Shear Cone Development.
**TABLE. A.1**

Summary of Required Embedment Lengths of Anchor Bolts to Develop Steel Tensile Capacity.

<table>
<thead>
<tr>
<th>Bolt Diameter $d$ (in.)</th>
<th>Tensile Stress Area $A_t$ (in.$^2$)</th>
<th>Heavy Hex Width Across Flats $F$ (in.)</th>
<th>Eff. Dia. $C$ (in.)</th>
<th>$L_{A36, A307}$ (in.)</th>
<th>$L_{A325, A449}$ (in.)</th>
<th>$L_{A687}$ (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5/8</td>
<td>0.142</td>
<td>0.875</td>
<td>0.92</td>
<td>3.9</td>
<td>5.8</td>
<td>6.5</td>
</tr>
<tr>
<td>7/8</td>
<td>0.226</td>
<td>1.25</td>
<td>1.32</td>
<td>6.0</td>
<td>8.9</td>
<td>10.0</td>
</tr>
<tr>
<td>9/8</td>
<td>0.334</td>
<td>1.625</td>
<td>1.71</td>
<td>8.1</td>
<td>12.0</td>
<td>13.4</td>
</tr>
<tr>
<td>1</td>
<td>0.462</td>
<td>2.056</td>
<td>2.11</td>
<td>10.4</td>
<td>17.0</td>
<td>20.5</td>
</tr>
<tr>
<td>1 1/8</td>
<td>0.616</td>
<td>2.757</td>
<td>2.50</td>
<td>12.4</td>
<td>19.0</td>
<td>23.2</td>
</tr>
<tr>
<td>1 1/4</td>
<td>0.906</td>
<td>3.625</td>
<td>3.28</td>
<td>16.5</td>
<td>22.7</td>
<td>27.3</td>
</tr>
<tr>
<td>2</td>
<td>1.41</td>
<td>4.625</td>
<td>4.07</td>
<td>20.9</td>
<td>28.7</td>
<td>34.6</td>
</tr>
<tr>
<td>2 1/8</td>
<td>2.50</td>
<td>5.97</td>
<td>4.66</td>
<td>25.5</td>
<td>35.1</td>
<td>42.3</td>
</tr>
<tr>
<td>2 3/4</td>
<td>3.25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>4.93</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Also, $U_p = (f_u) (A_t)$, in pounds. Therefore,

$$0 = 447.4 (L^2) + 447.4 (C) (L) - (F_u) (A_t)$$

$$0 = (L^2) + (C) (L) - (F_u) (A_t)/447.4$$

$$L = \sqrt{[ (C^2) + ( (F_u) (A_t)/112)]/2} - C/2$$

See Table A.1 for tabulated values. The design criteria are as follows.

1. Minimum spacing of bolts ($f_m$):
   - A307: $2 \times 8.0d = 16d$
   - A325/A449: $2 \times 12.0d = 24d$
   - A687: $2 \times 14.0d = 28d$

2. Embedment length ($L_d$) to provide 1.5 safety factor on the projected area:
   - A307: $8.3d^* (1.225 \text{ S.F.}) = 10.4d$, use 11d
   - A325/A449: $12.0d (1.225 \text{ S.F.}) = 14.7d$, use 15d
   - A687: $14.1d (1.225 \text{ S.F.}) = 17.3d$, use 18d
Nomenclature at Headed Anchor Connections.
APPENDIX B
NOMENCLATURE

Ae = Effective projected stress area at the surface of the concrete foundation.
Ast = Total area of reinforcing steel across a potential tension failure plane(s).
Asv = Total area of reinforcing steel across a potential shear failure plane(s).
At = Tensile stress area of anchorage (Ref. 13).
C = Shear coefficient applied to standard anchors which accounts for the effects of shear stresses on various base plate configurations.
    = 1.11 when base plates are embedded with exposed surface flush with concrete surface.
    = 1.43 when base plates are recessed in grout with bottom of plate in concrete surface.
    = 1.82 when base plates are supported on grout mortar with exposed surface exterior to concrete surface.
c = Equivalent circle for hex head.
d = Nominal diameter of a bolt or plain bar.
f’c = Specified compressive strength of concrete.
Fy = Minimum specified yield strength of steel or rebar as tabulated below:

<table>
<thead>
<tr>
<th>Fy (ksi)</th>
<th>ASTM</th>
<th>Bolt Diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>36</td>
<td>A307</td>
<td>All</td>
</tr>
<tr>
<td>32</td>
<td>A325</td>
<td>1/2 to 1, incl.</td>
</tr>
<tr>
<td>81</td>
<td>A325</td>
<td>Over 1 to 1 1/2, incl.</td>
</tr>
<tr>
<td>92</td>
<td>A449</td>
<td>1/2 to 1, incl.</td>
</tr>
<tr>
<td>81</td>
<td>A449</td>
<td>Over 1 to 1 1/2, incl.</td>
</tr>
<tr>
<td>58</td>
<td>A449</td>
<td>Over 1 1/2 to 3, incl.</td>
</tr>
<tr>
<td>105</td>
<td>A587</td>
<td>5/8 to 3, incl.</td>
</tr>
<tr>
<td>60</td>
<td>A615</td>
<td>Type S, Grade 60 Rebar</td>
</tr>
<tr>
<td>40</td>
<td>A615</td>
<td>Grade 40, Rebar</td>
</tr>
</tbody>
</table>

Fu = Minimum specified tensile strength of steel or rebar as tabulated below:

<table>
<thead>
<tr>
<th>Fy (ksi)</th>
<th>ASTM</th>
<th>Bolt Diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>58</td>
<td>A307</td>
<td>All</td>
</tr>
<tr>
<td>120</td>
<td>A325</td>
<td>1/2 to 1, incl.</td>
</tr>
<tr>
<td>105</td>
<td>A325</td>
<td>Over 1 to 1 1/2, incl.</td>
</tr>
<tr>
<td>120</td>
<td>A449</td>
<td>1/2 to 1, incl.</td>
</tr>
<tr>
<td>105</td>
<td>A449</td>
<td>Over to 1 to 1 1/2, incl.</td>
</tr>
<tr>
<td>90</td>
<td>A449</td>
<td>Over 1 1/2 to 3, incl.</td>
</tr>
<tr>
<td>150</td>
<td>A687</td>
<td>5/8 to 3, incl.</td>
</tr>
</tbody>
</table>
h = Thickness of a concrete slab or wall.
hd = Diameter of anchor bolt head.
Ld = Minimum embedded length required to fully develop the tensile strength of an anchor bolt.
ld = Basic development length of reinforcement.
ldh = Basic development length of reinforcement with a standard hook.
le = Depth of embedment of headed anchor bolt from top of concrete to top of anchor bolt head.
m = Edge distance from the center of an anchor to the free edge of concrete.
mt = Minimum edge distance to prevent failure due to lateral bursting forces at a standard anchor bolt head.
mv = Minimum edge distance (when properly reinforced) to develop the full tensile capacity of an anchor bolt loaded in shear towards a free edge.
n = Edge distance from the center of an anchor to a side edge of concrete.
nbx = Number of rows of bolts parallel to shear loading.
nby = Number of rows of bolts perpendicular to shear loading.
PF = Probability Factor.
r_m = Minimum spacing of multiple anchor bolts to prevent overlapping cones.
r_x = Spacing of multiple anchors parallel to loading.
r_y = Spacing of multiple anchors perpendicular to loading.
SIF = Stress Increase Factor or reciprocal of the Probability Factor (1/PF).
t = Thickness of concrete foundation.
T_c = Ultimate tensile strength of concrete element.
Tdl = Actual dead load tension force applied to base plate anchorage devices.
Tll = Actual live load tension force applied to base plate anchorage devices.
Ts = Ultimate tensile strength of embedded steel element.
Tx = Design (factored) tension load used to determine required anchor bolt size.
Twl = Actual wind load tension force applied to base plate anchorage devices.
Up = Pullout strength of concrete equal to the tensile capacity of the concrete failure cone.
Vc = Ultimate shear strength of concrete element.
Vc' = Ultimate shear strength of concrete element near a free edge.
Vdl = Actual dead load shear force applied to base plate anchorage devices.
Vll = Actual live load shear force applied to base plate anchorage devices.
Vs = Ultimate shear strength of embedded steel element.
Vu = Design (factored) shear load used to determine required anchor bolt size.
Vwl = Actual wind load shear force applied to base plate anchorage devices.
\( \phi \) = Capacity reduction factor.
Ultimate Strength Design (USD); 0.90 tension, 0.85 shear, and 0.65 bearing.
\( \mu \) = Coefficient of friction or reciprocal of C factor (1/C).
\( \beta \) = Concrete tensile stress reduction factor.
0.65 for all conditions.
APPENDIX C

COMPUTER PROGRAM LISTING
TYPE windowtype
  row AS INTEGER
  col AS INTEGER
  action AS INTEGER
END TYPE

TYPE regtype
  ax AS INTEGER
  bx AS INTEGER
  cx AS INTEGER
  dx AS INTEGER
  sp AS INTEGER
  bp AS INTEGER
  si AS INTEGER
  di AS INTEGER
  flags AS INTEGER
END TYPE

TYPE bolttype
  size AS SINGLE
  area AS SINGLE
  head AS SINGLE
END TYPE

TYPE idtype
  proj AS STRING * 10
  clcc AS STRING * 10
  yname AS STRING * 3
END TYPE

TYPE bctype
  lth AS SINGLE
  wth AS SINGLE
  coll AS SINGLE
  colw AS SINGLE
  vspace AS SINGLE
  yspace AS SINGLE
  boltnum AS INTEGER
  fult AS SINGLE
END TYPE

TYPE ftgtype
  cbc AS SINGLE
  fcnc AS SINGLE
  cedge AS SINGLE
  area2 AS SINGLE
  tp AS SINGLE
  lsql AS SINGLE
END TYPE

TYPE loadtype
  pd AS SINGLE
  pl AS SINGLE
  cw AS SINGLE
  vd AS SINGLE
  vl AS SINGLE
  vw AS SINGLE
  ad AS SINGLE
  li AS SINGLE
DECLARE FUNCTION QUADRATIC! (A!, B!, C!)  
DECLARE FUNCTION YSERNDO$ (rowl!, colt!)  
DECLARE SUB SHEARHUG (Vuax!, Vumin!, Pumin!)  
DECLARE SUB TENSTPL (tubolt!, tenstplmax!)  
DECLARE SUB ULTLOADS (Lumax!, Lumin!, Lu!) (deadid!, livedo!, windid!)  
DECLARE SUB VERTTPL (Pumax!, Pumin!, tolvertmax!, Tboltmax!)  
DECLARE SUB MOMENTPL (Moment!, Fxaisl!, tplemdmax!, Tboltmax!)  
DECLARE SUB CHANGECNTRL ()  
DECLARE SUB PRINTSCREEN ()  
DECLARE SUB INTERRUPT (intnum%, inreg AS RegType, cutreg AS RegType)  
DECLARE SUB VALTEST (value!, rowX, colX, lb!, ub!, blank!)  
DECLARE SUB TPAUSE (sec)  
DECLARE SUB WINDOWTEXT (w AS windowtype, wtext$())  
DECLARE SUB SETDATADAT (rexrX, colY)  
DECLARE SUB CONFIGDATAT (rowX, colY)  
DECLARE SUB LOADDATAT (rowX, colY)  
DECLARE SUB IDDATAT (projectid#, locationid#, nameid#)  
DECLARE SUB SIXTITLE (rowX, colX, row2, col2, titles#, TorB#, boxtype#)  
DIM SHARED L1, L2, L3!, L4!, LK!, RK!, RL!, C!, numboltX, Fcl!, Ful!, DE!, Mchoice%  
DIM SHARED PCL!, PCL!, PML!, PVL!, VLL!, VML!, MLL!, NML!  
DIM SHARED PUL!, PUL!, PUL!, PUL!, PUL!, PUL!, PUL!, PUL!  
DIM SHARED Dug!, Lug!, Tgout!, Lg!, Sweld!, test!, changever#, newBLX  
DIM SHARED L1(1 TO 15), r(1 TO 15), n(1 TO 15), av(1 TO 15)  
DIM SHARED bolt!, Av!, m!, n!, sect#, pallback!, A2!, A3!, lugchoice%  
DIM SHARED biganswer AS STRING * 1  
DIM w0 AS windowtype  
DIM w1 AS windowtype  
DIM w2 AS windowtype  
DIM w3 AS windowtype  
DIM SHARED wb1 AS windowtype  
DIM SHARED wb2 AS windowtype  
DIM bolt AS bolttype  
DIM id AS idtype  
DIM bp AS bptype  
DIM ftg AS ftgtype  
DIM load AS lostype  
DIM w0text$#1 TO 10  
DIM w1text$#1 TO 16  
DIM w2text$#1 TO 16  
DIM w3text$#1 TO 16  
DIM SHARED wblendtext#1 TO 16  
DIM SHARED w2blendtext#1 TO 16  
DIM projectid AS STRING * 10  
DIM locationid AS STRING * 10  
DIM nameid AS STRING * 3  

=================================COL BPL BAS================================
applied moment. The anchor bolts are sized to transfer the
shear and tension forces into the foundation. The user has
the option to transfer the lateral forces to the foundation
through a shear lug and the anchor bolts are sized to resist
only tension forces.

ESI = 29300
FIE = 0.14139
bigansw = 1

title0$ = "COLUMN BASE PLATE PROGRAM"
title1# = "PROJECT ID"
title2# = "CONFIGURATION INPUT"
title3# = "LOAD INPUT"
title4# = "COLUMN BASE PLATE RESULTS"
title4a# = "BASE PLATE RESULTS"
title4b# = "ANCHOR BOLT RESULTS"
title4c# = "SHEAR LUG RESULTS"
title4d# = "FOUNDATION RESULTS"

w0.row = 2
w0.col = 7
w0.action = 1

w0text$ = "A small program to determine the required thickness of a"
w0text# = "baseplate to resist vertical loads, lateral loads, and an"
w0text# = "applied moment. The anchor bolts are sized to transfer the"
w0text# = "shear and tension forces into the foundation. The user has"
w0text# = "the option to transfer the lateral forces to the foundation"
w0text# = "through a shear lug and the anchor bolts are sized to resist"
w0text# = "only tension forces."

w0text# = "SPACE(3)"
w0text# = "Select a 1 to continue the program with all new"nw0text# = "data, a 2 to continue the program and edit existing"

w1.row = 8
w1.col = 2
w1.action = 1

w1text$ = "SPACE(15) + "SHEAR LUG" + SPACE(14)"
w1text# = "C1. Base plate length, L, in." + SPACE(9)
w1text# = "C2. Base plate width, B, in." + SPACE(10)
w1text# = "C3. Column length, Du, in." + SPACE(12)
w1text# = "C4. Column width, Dy, in." + SPACE(13)
w1text# = "C5. Number of headed anchors." + SPACE(9)
w1text# = "C6. Bolt spacing, Rv, in." + SPACE(13)
w1text# = "C7. Bolt spacing, Ry, in." + SPACE(11)
w1text# = "C8. Pad plate thickness, C." + SPACE(11)
w1text# = "C9. Bolt strength, Fu, ksi." + SPACE(11)
w1text# = "C10. Concrete, fc, ksi. " + SPACE(12)
w1text# = "C11. Conc. area, A2, in**2." + SPACE(12)
w1text# = "C12. Edge distance, de, in." + SPACE(12)
w1text# = "C13. Lug width, Lluq, in." + SPACE(14)
w1text# = "C14. Grout thickness, in." + SPACE(14)
w1text# = "SPACE(38)"
w2.row = 8
w2.col = 2
w2.action = 1
w2.text$(1) = SPACE$(13) + "NO SHEAR LUG" + SPACE$(10)
w2.text$(2) = "C1. Base plate length, L, in." + SPACE$(9)
w2.text$(3) = "C2. Base plate width, B, in." + SPACE$(10)
w2.text$(4) = "C3. Column length, D, in." + SPACE$(12)
w2.text$(5) = "C4. Column width, Dy, in." + SPACE$(13)
w2.text$(6) = "C5. Number of headed anchors." + SPACE$(9)
w2.text$(7) = "C6. Bolt spacing, Rx, in." + SPACE$(13)
w2.text$(8) = "C7. Bolt spacing, Ry, in." + SPACE$(13)
w2.text$(9) = "C8. Base plate pad type, D, in." + SPACE$(11)
w2.text$(10) = "C9. Bolt strength, Fu, ksi." + SPACE$(11)
w2.text$(11) = "C10. Concrete f', ksi. " + SPACE$(12)
w2.text$(12) = "C11. Conc. area, A2, in.*" + SPACE$(12)
w2.text$(113) = "C12. Edge distance, da, in." + SPACE$(12)
FOR I = 14 TO 16
w2.text$(1) = SPACE$(13)
NEXT I
w3.row = 9
w3.col = 42
w3.action = 1
w3.text$(1) = SPACE$(14) + "UNFACTORED" + SPACE$(14)
w3.text$(2) = "L1. Vertical dead loads, kip." + SPACE$(9)
w3.text$(3) = "L2. Vertical live loads, kip." + SPACE$(9)
w3.text$(4) = "L3. Vertical wind loads, kip." + SPACE$(9)
w3.text$(5) = "L4. Lateral dead loads, kip." + SPACE$(10)
w3.text$(6) = "L5. Lateral live loads, kip." + SPACE$(10)
w3.text$(7) = "L6. Lateral wind loads, kip." + SPACE$(10)
w3.text$(8) = "L7. Dead load moment, in-k." + SPACE$(11)
w3.text$(9) = "L8. Live load moment, in-k." + SPACE$(11)
w3.text$(10) = "L9. Wind load moment, in-k." + SPACE$(11)
FOR I = 11 TO 16
w3.text$(1) = SPACE$(13)
NEXT I
w11.row = 8
w11.col = 2
w11.action = 1
FOR I = 1 TO 16
w11.text$(1) = SPACE$(18)
NEXT I
w21.row = 8
w21.col = 42
w21.action = 1
FOR I = 1 TO 16
w22.text$(1) = SPACE$(13)
NEXT I

"Main loop of program."
CLS
FOR I = 1 TO 25
    PRINT STRING$(80, 177)
NEXT I

'Clear the inside of the first box.
FOR I = 1 TO 14
    LOCATE I, 7
    PRINT SPACE$(67)
NEXT I
CALL B0(TITLE(3, 15, 74, title0$, 1, 1)
CALL WINDOWTEXT2W0, m0text$())
DO
    LOCATE 14, 15
    INPUT "data or a J to exit the program. ", biganswer
LOOP WHILE biganswer <> "1" AND biganswer <> "2" AND biganswer <> "3"
IF biganswer = "3" THEN
    EXIT DO
    'exit biganswer loop
END IF

KEY 15, CHR$(130) + CHR$(131)
KEY$(13) ON
ON KEY(13) GOSUB EntProg

IF biganswer = "1" THEN
    'Clear the inside of the second box.
    FOR I = 17 TO 21
        LOCATE I, 10
        PRINT SPACE$(46)
    NEXT I
    CALL B0(TITLE(16, 9, 22, 71, title1$, 1, 1)
    DALL 1DARRAY(projectid, locationid, nameid)
ELSE
    OPEN "ID.DAT" FOR RANDOM AS #1 LEN = LEN(id)
    OPEN "SP.DAT" FOR RANDOM AS #2 LEN = LEN(bp);
    OPEN "FTG.DAT" FOR RANDOM AS #3 LEN = LEN(ftg)
    OPEN "LD.G.DAT" FOR RANDOM AS #4 LEN = LEN(load)
    GET #1, 1, id
    GET #2, 1, bp
    GET #3, 1, ftg
    GET #4, 1, load
    projectid = id.proj; locationid = id.loc; nameid = id.name
    L1 = bp.lth; B1 = bp.bth; WX = bp.collect; BY = bp.colw; RX = bp.xspace
    RV = bp.yspace; numbol = bp.bolnum; Fu! = bp.full
    CI = ftg.cbp; FC! = ftg.fcnc; DE! = ftg.dedge; A2! = ftg.area2
    Tgoout! = ftg.tg; Ltg! = ftg.ltg
    PDL! = load.pl; PFL! = load.pl; PW! = load.qw; VDL! = load.vt
    VLL! = load.v; VML! = load.vw; MBL! = load.md; MLL! = load.ml
    MHL! = load.ml
CLOSE #1; CLOSE #2; CLOSE #3; CLOSE #4
END IF

SCREEN TWO

CALL BOXTITLE(2, 38, 6, 80, title1$, 1, 1)
CALL BOXTITLE(7, 1, 24, 40, title2$, 1, 1)
CALL BOXTITLE(7, 41, 24, 80, title3$, 1, 1)
LOCATE 1, 59: PRINT "Proj. No.:"; Project
LOCATE 4, 59: PRINT "Location:"; locationID
LOCATE 5, 59: PRINT "Initials:"; nameID
DO
LOCATE 9, 6
PRINT "Enter 1 if you want to design a"
LOCATE 10, 6
PRINT "base plate without shear or"
LOCATE 11, 6
PRINT "moment or 2 to design with"
LOCATE 12, 6
INPUT "shear and moment. ", MChoice$
FOR I = 1 TO 4
LOCATE 9 + I, 6
PRINT SPACE$(I2)
NEXT I
LOOP UNTIL MChoice$ = 1 OR MChoice$ = 2
IF MChoice$ = 1 THEN
LugChoice$ = 1
ELSE
DO
LOCATE 9, 6
PRINT "Enter 1 if you want to design"
LOCATE 10, 6
PRINT "a base plate without a shear"
LOCATE 11, 6
PRINT "lug or 2 to design with a"
LOCATE 12, 6
INPUT "shear lug. ", LugChoice$
FOR I = 1 TO 4
LOCATE 9 + I, 6
PRINT SPACE$(I2)
NEXT I
LOOP UNTIL LugChoice$ = 1 OR LugChoice$ = 2
END IF
CALL CONFIDBATAIN(9, 3)
CALL LOADBATAIN(9, 43)

COMPUTATIONS

DO
COUNT$ = 0
'Compute the ultimate loads.
CALL ULLOADS(Pmax$, Pmin$, Pu$!, Pu!$, PDL$, PLL$, PWL$)
CALL UTLLOADS(Vumax', Vumin', Vud!', Vdl', Vll', Vwl')
CALL UTLLOADS(Vumax', Vumin', Mu!', Mdl', Mll', Mwl')

'Check the base plate for vertical loads.
CALL VERTPL(Vumax', Vumin', tptlvertmax', Tboltmax)
CALL TENSTPL(Tboltmax', tenstplmax')
IF newBL = 1 THEN
  EXIT 20
END IF

'Check for tension in the bolts, determine stresses beneath
'the plate and the required plate thickness.
IF 'Schoice = 2 THEN
  CALL MOMENTPL(Mumin', Pumin', tptlbend1max', Tboltmax)
  CALL TENSTPL(Tboltmax', tenstpl2max')
  IF newBL = 1 THEN
    EXIT 20
  END IF
END IF

CALL MOMENTPL(Mumin', Pumin', tptlbend2max', Tboltmax)
CALL TENSTPL(Tboltmax', tenstpl3max')
IF newBL = 1 THEN
  EXIT 30
END IF

IF tptlbendmax > tptlbend2max THEN
  tptlbendmax = tptlbendmax
ELSE
  tptlbendmax = tptlbend2max
END IF

ELSE
  tptlbendmax = tenstpl2max = tenstpl3max = 0
  T2boltmax = T3boltmax = 0
END IF

'Declare the maximum shear and tension on the anchor bolts or
'the tension in the bolts and the size of shear lug.
IF Tboltmax > T2boltmax AND Tboltmax > T3boltmax THEN
  Tboltmax = Tboltmax
  tenstplmax = tenstplmax
ELSEIF T2boltmax > Tboltmax AND T2boltmax > T3boltmax THEN
  Tboltmax = T2boltmax
  tenstplmax = tenstpl2max
ELSEIF T3boltmax > Tboltmax AND T3boltmax > T2boltmax THEN
  Tboltmax = T3boltmax
  tenstplmax = tenstpl3max
END IF

IF 'Schoice = 2 THEN
  IF 'lugchoice = 2 THEN
    Tmax = (Tboltmax + ,3333)
    CALL SHEARLUG(Vumax', Vumin', Pumin')
  ELSE
    Tmax = 0
    CALL SHEARLUG(Vumax', Vumin', Pumin')
  END IF
ELSE
  Tmax = 0
  CALL SHEARLUG(Vumax', Vumin', Pumin')
END IF
61.

\[ V_{\text{minpart}} = \frac{\text{ABS}(V_{\text{min}})}{C} \times 0.85 \times \text{nubolt} \times \text{C} \]

\[ V_{\text{maxpart}} = \frac{\text{ABS}(V_{\text{max}})}{C} \times 0.85 \times \text{nubolt} \times \text{C} \]

\[ T_1 = (V_{\text{minpart}} + (T_{2\text{boltmax}} + 0.333)) \]

\[ T_2 = (V_{\text{maxpart}} + (T_{3\text{boltmax}} + 0.333)) \]

IF \( T_1 > T_2 \) THEN

\[ T_{\text{max}} = T_1 \]

ELSE

\[ T_{\text{max}} = T_2 \]

END IF

ELSE

\[ T_{\text{max}} = (T_{\text{boltmax}} + 0.333) \]

END IF

Compute the thickness of the base plate in bending, then

compare with the thickness for vert. loads and select final size.

IF \( t_{\text{plvertmax}} > t_{\text{plbendmax}} \) AND \( t_{\text{plvertmax}} > t_{\text{plstplmax}} \) THEN

\[ t_{\text{plmax}} = t_{\text{plvertmax}} \]

\[ \text{pchoice\%} = 1 \]

ELSEIF \( t_{\text{plbendmax}} > t_{\text{plvertmax}} \) AND \( t_{\text{plbendmax}} > t_{\text{plstplmax}} \) THEN

\[ t_{\text{plmax}} = t_{\text{plbendmax}} \]

\[ \text{pchoice\%} = 2 \]

ELSE

\[ t_{\text{plmax}} = t_{\text{plstplmax}} \]

\[ \text{pchoice\%} = 3 \]

END IF

SELECT CASE \( t_{\text{plmax}} \):

CASE IS < 0.375

\[ t_{\text{plused}} = 0.375 \]

CASE IS < 0.5

\[ t_{\text{plused}} = 0.5 \]

CASE IS < 0.625

\[ t_{\text{plused}} = 0.625 \]

CASE IS < 0.75

\[ t_{\text{plused}} = 0.75 \]

CASE IS < 0.875

\[ t_{\text{plused}} = 0.875 \]

CASE IS < 1

\[ t_{\text{plused}} = 1 \]

CASE IS < 1.125

\[ t_{\text{plused}} = 1.125 \]

CASE IS < 1.25

\[ t_{\text{plused}} = 1.25 \]

CASE IS < 1.375

\[ t_{\text{plused}} = 1.375 \]

CASE IS < 1.5

\[ t_{\text{plused}} = 1.5 \]

CASE IS < 1.75

\[ t_{\text{plused}} = 1.75 \]
CASE IS < 2!
  tolused! = 2!
CASE IS < 2.25
  tolused! = 2.25
CASE IS < 2.5
  tolused! = 2.5
CASE IS < 2.75
  tolused! = 2.75
CASE IS < 3!
  tolused! = 3!
CASE ELSE
  EXIT DO
END SELECT

Select the anchorbolt size and compute required spacing, length and edge distances.
OPEN *#1.DAT* FOR RANDOM AS #1 LEN = LEN(bolt)
j = 1
DO
  IF j = 1 THEN
    CLOSE #1
    LOCATE 20, 42
    PRINT "Anchorbolt exceeds 3 in. dia."
    CALL TPAUSE(4)
  30$SUB EndProc
END IF
GET #1, j, bolt
boltok! = Tmax! / (.675 * Fu! * bolt.area)
cd! = 1.05 * bolt.head
x! = cd! * cd! + Fu! * bolt.area / .112
Ltemp! = (GRB(x!)) - cd! / 2!
ep(j) = 2! + Ltemp!
L: L(j) = Ltemp! + 1.2247
mv(j) = bolt.size * SGR(Fu!) * 1000! / (7.5 * SGR(3000!)))
nt1! = bolt.size * SGR(Fu!) * 1000! / (55 * SGR(3000!)))
nt2! = 4!
IF nt1! > nt2! THEN
  nt(j) = nt1!
ELSE
  nt(j) = nt2!
END IF
j = j + 1
LOOP WHILE boltok! > 1!
Lbolt! = L1!(j - 1)
rbolt! = r!(j - 1)
ntbolt! = nt!(j - 1)
mbolt! = mv!(j - 1)

Determine type of ftg and reinj if required.
Ae! = numbolt! * Fu! * 1000! * bolt.area / (2.6 * SGR(Fc! * 1000!))
IF Ae! < numbolt! THEN
PRINT "Program Comments:"
PRINT "Summary of results to"
PRINT "Follow, please wait."
CALL BOXTITLE(2, 1, & 56, title#4$, 1, 1)
LOCATE 5, 2
PRINT " tpi(vert) tpi(bend) tpi(tens) tpi(used)"
LOCATE 4, 2
PRINT USING "#.##$", tpiVertMax!
PRINT USING "#.##$", tpiBendMax!
PRINT USING "#.##$", tpiTensMax!
PRINT USING "#.##$", tpiUsed!
IF p1choice% = 1 THEN
  LOCATE 5, 4
ELSEIF p1choice% = 2 THEN
  LOCATE 5, 17
ELSE
  LOCATE 5, 30
END IF
PRINT "controls"
CALL TIPUSE(5)
CALL BOXTITLE(7, 1, 11, & 56, title#4$, 1, 1)
LOCATE 8, 2
PRINT " Bolt Length Spacing Edge(1)(min) Edge(2)(v)"
LOCATE 9, 2
PRINT USING "### " ; bolt.size.
PRINT USING "##.## " ; Lbolt!
PRINT USING "##.## " ; rbolt!
PRINT USING "##.## " ; mbolt!
PRINT USING "##.## " ; nvbolt!
CALL TPAUSE(5)
CALL BXTITLE(12, 1, 18, 35, title4#, 1, 1)
LOCATE 15, 2
PRINT " Ftg. type Reason Ftg. stl.(Av) Areqd. "
LOCATE 14, 2
PRINT ftgtypes$;
PRINT USING "##.## " ; Av!,
PRINT USING "##.## " ; Ae!
CALL TPAUSE(5)
IF lugchoice$ = 2 THEN
CALL BXTITLE(17, 1, 21, 54, title4#, 1, 1)
LOCATE 18, 2
PRINT " Length Depth Thickness Size of weld "
LOCATE 17, 2
PRINT USING "##.## " ; Lug!,
PRINT USING "##.## " ; Dlug!,
PRINT USING "##.## " ; Tlug!,
PRINT USING "##.## " ; Sweld!
END IF
CALL TPAUSE(5)
'Print out calc. for first output screen.
pagename$ = 1
CLS
CALL BXTITLE(2, 58, 6, 80, title1#, 1, 1)
LOCATE 3, 59: PRINT "Proj. No.:" ; projectid
LOCATE 4, 59: PRINT "Location.:" ; locationid
LOCATE 5, 59: PRINT "Initials.:" ; nameid
CALL BXTITLE(2, 1, 5, 58, title4#, 1, 1)
LOCATE 7, 2
PRINT " tpl(used) Bolt Ftg. type Reason".
LOCATE 4, 2
PRINT USING "### " ; tpluses!,
PRINT USING "### " ; bolt.size,
PRINT ftgtypes$;
CALL BXTITLE(7, 1, 21, 40, title2#, 1, 1)
CALL BXTITLE(7, 41, 24, 80, title3#, 1, 1)
DO 'loop with answer4$
CALL WINDOWTEXT(wbl, wb1text#)
CALL WINDOWTEXT(wbl, wb2text#)
IF lugchoice$ = 2 THEN
   CALL WINDOWTEXT(wl, w1text#)
   CALL WINDOWTEXT(wl, w2text#)
   CALL WINDOWTEXT(wl, w3text#)
ELSE
    CALL WINDOWTEXT(w2, w2text$1)
END IF
CALL WINDOWTEXT(w3, w3text$1)
CALL SETDATAGT(9, 1)
LOCATE 19, 42
PRINT " Program Comments:"
LOCATE 20, 42
PRINT " Do you want to change any"
LOCATE 21, 42
PRINT " of the following variables?"
LOCATE 22, 42
INPUT " Select Y or N.": answer$
FOR I = 1 TO 3
    LOCATE 19 + I, 42
    PRINT SPACE$(10)
NEXT I
answer$ = UCASE$(answer$)
IF answer$ = "Y" THEN
    COUNT% = COUNT% + 1
    CALL CHANGEVALUE
END IF
LOOP UNTIL answer$ = "N"
LOOP WHILE COUNT% > 0 AND answer$ = "N"
PRINTNUM% = 0
KEY 16, CHR$(1H11) + CHR$(1H37)
KEY(16) ON
KEY(2) ON
ON KEY(16) Gosub Printprog
ON KEY(2) Gosub Printprog
DO
    IF printnum% = 1 THEN
        printnum% = 0
    END IF
    DO
        LOCATE 23, 42
        PRINT " Press F2 or Shift + PrtSc"
        LOCATE 21, 42
        PRINT " to print screen contents."
        LOCATE 22, 42
        PRINT " Press any key to continue."
        LOOP WHILE INKEY$ = ""
        LOOP WHILE printnum% = 1
    END DO
PRINT " Printout calc. for second output screen."
    PAGENUMBER = 2
CLS
    CALL BOXTITLE(12, 58, 6, 80, title$, 1, 1)
    LOCATE 3, 59: PRINT " Proj. No.": projectid
LOCATE 4, 59; PRINT "Location: "; locationid
LOCATE 5, 59; PRINT "Initials: "; nameid
CALL BOXTITLE(2, 1, 6, 56, title4$#, 1, 1)
LOCATE 3, 2
PRINT " tptl(vert) tptl(bend) tptl(tens) tptl(used)"
LOCATE 4, 2
PRINT USING "#### "; tptlvertmax!
PRINT USING "#### "; tptlbendmax!
PRINT USING "#### "; tptltensmax!
PRINT USING "#### "; tptlused!
IF plchoice% = 1 THEN
   LOCATE 5, 4
ELSEIF plchoice% = 2 THEN
   LOCATE 5, 17
ELSE
   LOCATE 5, 30
END IF
PRINT "controls"
CALL BOXTITLE(7, 1, 11, 56, title4$#, 1, 1)
LOCATE 8, 2
PRINT " Bolt Length Spacing Edge(min) Edge(max)"
LOCATE 9, 2
PRINT USING "#### "; bolt.size!
PRINT USING "#### "; Lbolt!
PRINT USING "#### "; Rbolt!
PRINT USING "#### "; Etbolt!
PRINT USING "#### "; Avbolt!
CALL BOXTITLE(12, 1, 16, 56, title4$#, 1, 1)
LOCATE 13, 2
PRINT " Ftg type Reason Ftg. stl.(Av) Aeregd "
LOCATE 14, 2
PRINT ftag$#
PRINT USING "##### "; Av!
PRINT USING "##### "; Ae!
IF lugchoice% = 2 THEN
   CALL BOXTITLE(17, 1, 21, 56, title4$#, 1, 1)
   LOCATE 18, 2
   PRINT " Length Depth Thickness Size of weld ",
   LOCATE 19, 2
   PRINT USING "#### "; Llug!
   PRINT USING "#### "; Dlug!
   PRINT USING "#### "; Tlug!
   PRINT USING "#### "; Sweld!
END IF
printnum% = 0
DO
   IF printnum% = 1 THEN
      printnum% = 0
   END IF
   DO
LOCATE 19, 58
PRINT "Press Shift + PrtSc"
LOCATE 20, 58
PRINT "or F2 to print"
LOCATE 21, 58
PRINT "screen contents."
LOCATE 22, 58
PRINT "Press any key"
LOCATE 23, 58
PRINT "to continue."
LOOP WHILE INKEY$ = ""
LOOP WHILE printnumZ = 1
KEY(16) OFF
KEY(2) OFF

Store data incase its used in next run.
OPEN "ID.DAT" FOR RANDOM AS #1 LEN = LEN(id)
OPEN "BP.DAT" FOR RANDOM AS #2 LEN = LEN(bp)
OPEN "FTG.DAT" FOR RANDOM AS #3 LEN = LEN(ftg)
OPEN "LOAD.DAT" FOR RANDOM AS #4 LEN = LEN(load)
loc.x = projectid: loc.cloc = locationid: loc.vname = name:id
bp.w = L: bp.wth = S: bp.call = D!: bp.colw = DY!: bp.xspace = RX!
bp.y = RY!: bp.bolt = numbolt2: bp.Fult = Fu!
fg.cbp = C!: fg.fconc = Fc!: fg.dedge = DE!: fg.area2 = A2!
fg.tg = Tgout!: fg.lag = LLag!
load.ws = PDL!: load.w = PLL!: load.pw = PHL!: load.vd = VDL!
load.xl = VLL!: load.vw = WVL!: load.xd = MDL!: load.xl = ML!
load.ww = MWL!
PUT #1, 1, id
PUT #2, 1, bp
PUT #3, 1, ftg
PUT #4, 1, load
CLOSE #1: CLOSE #2: CLOSE #3: CLOSE #4

LOOP
END

Printprog:
IF pagetext = 1 THEN
LOCATE 19, 42
PRINT SPACE$(50)
LOCATE 20, 42
PRINT SPACE$(30)
LOCATE 21, 42
PRINT SPACE$(30)
LOCATE 22, 42
PRINT SPACE$(30)
CALL BOXTITLE(2, 58, 6, 80, title1#, 1, 0)
CALL BOXTITLE(2, 1, 6, 58, title1#, 1, 0)
CALL BOXTITLE(17, 1, 24, 40, title2#, 1, 0)
CALL BOXTITLE(17, 41, 24, 80, title3#, 1, 0)
CALL PRINTSCREEN
ELSE
   LOCATE 19, 58
   PRINT SPACE$(20)
   LOCATE 20, 58
   PRINT SPACE$(20)
   LOCATE 21, 58
   PRINT SPACE$(20)
   LOCATE 22, 58
   PRINT SPACE$(20)
   LOCATE 23, 58
   PRINT SPACE$(20)
   CALL BOXTITLE(2, 58, 6, 80, title$, 1, 0)
   CALL BOXTITLE(2, 1, 58, title$, 1, 0)
   CALL BOXTITLE(7, 1, 58, title$, 1, 0)
   CALL BOXTITLE(12, 1, 58, title$, 1, 0)
   IF lugchoice = 2 THEN
      CALL BOXTITLE(17, 1, 21, 58, title$, 1, 0)
   END IF
   CALL PRINTSCREEN
END IF
     println = 1
RETURN

EndProg:
   END
RETURN

'==================================================================
SUB BOXTITLE (row1$, col1$, row2$, col2$, title$, Tor$, boxtype$)
'==================================================================
SELECT CASE boxtype$
   CASE 0
      -LEFTX$ = 32; URIGHTX$ = 32; vertical$ = 32; HORIZONTAL$ = 32
      -LEFTX$ = 32; LRIGHTX$ = 32
   CASE 1
      -LEFTX$ = 218; URIGHTX$ = 191; vertical$ = 179; HORIZONTAL$ = 196
      -LEFTX$ = 192; LRIGHTX$ = 217
   CASE 2
      -LEFTX$ = 201; URIGHTX$ = 187; vertical$ = 186; HORIZONTAL$ = 205
      -LEFTX$ = 200; LRIGHTX$ = 188
END SELECT

'Draw top of box starting with the upper left corner.
   LOCATE row1$, col1$: PRINT CHR$(-LEFTX$);
   LOCATE , col1$ + 1: PRINT STRING$(col1$ - col1$, CHR$(HORIZONTAL$));
   LOCATE , col1$: PRINT CHR$(URIGHTX$);

'Draw the body of the box.
   FOR I = row1$ + 1 TO row2$ - 1
'Draw the bottom of the box.
LOCATE row2%, col1%; PRINT CHR$(127);  
LOCATE , col2%; PRINT CHR$(126);  
NEXT I

halftitle% = LEN(title$);
curcol% = ((col1% + col2%) / 2) - (halftitle% / 2)
IF Tor%= 1 THEN
  currow% = row1%
ELSE
  currow% = row2%
END IF
LOCATE currow%, curcol%; PRINT title$

END SUB

'================================================================
SUB CHANGEVALUE
'================================================================
DO
  testvar% = 0
  LOCATE 20, 42
  INPUT " Select an item. ", changevar$
  changevar$ = UCASE$(changevar$)
  SELECT CASE changevar$
    CASE "C1"
      DO
        LOCATE 21, 60
        INPUT " L=", L!
        CALL VALTEST(L!, 21, 68, 1!, 100!, 5)
        LOOP UNTIL test%= 0
      CASE "C2"
      DO
        LOCATE 21, 60
        INPUT " B=", B!
        CALL VALTEST(B!, 21, 68, 1!, 100!, 5)
        LOOP UNTIL test%= 0
      CASE "C3"
      DO
        LOCATE 21, 60
        INPUT " Ox=", DX!
        CALL VALTEST(DX!, 21, 68, 1!, 100!, 5)
        LOOP UNTIL test%= 0
      CASE "C4"
      DO
        LOCATE 21, 60
        INPUT " Ox=", MX!
        CALL VALTEST(MX!, 21, 68, 1!, 100!, 5)
        LOOP UNTIL test%= 0
  END SELECT
END DO
CALL VALTEST(y!, 21, 68, 1!, 100!, 5)
LOOP UNTIL testx = 0
CASE "CS"
DO
   LOCATE 21, 60
   INPUT "* of AB=", numbolt%
   maxnumbolt% = ([11 - 2.5] / 1!) - 1
   SELECT CASE numbolt%
      CASE IS < 2, IS > maxnumbolt%, 3, 5, 7, 9, 11, 13, 15, 17
         LOCATE 22, 45
         PRINT "Input incorrect."
         LOCATE 22, 45
         PRINT SPACE(20)
         LOCATE 21, 68
         PRINT SPACE(5)
         testx = 1
         CASE ELSE
            testx = 0
      END SELECT
   END SELECT
   LOOP UNTIL testx = 0
CASE "Ca"
DO
   LOCATE 21, 60
   INPUT "  Rx=", Rx!
   CALL VALTEST(Rx!, 21, 68, 1!, 100!, 5)
   LOOP UNTIL testx = 0
CASE "Cy"
DO
   LOCATE 21, 60
   INPUT "  Ry=", Ry!
   CALL VALTEST(Ry!, 21, 68, 1!, 100!, 5)
   LOOP UNTIL testx = 0
CASE "CS"
DO
   LOCATE 21, 60
   INPUT "  Ca", Ctype$
   IF Ctype$ = "1" THEN
      C! = 1.82; testx = 0
   ELSEIF Ctype$ = "2" THEN
      C! = 1.43; testx = 0
   ELSEIF Ctype$ = "3" THEN
      C! = 1.11; testx = 0
   ELSE
      LOCATE 22, 45
      PRINT "Input out of range."
      LOCATE 22, 45
      PRINT SPACE(20)
      LOCATE 21, 68
      PRINT SPACE(5)
      testx = 1
71.

END IF
LOOP UNTIL test2 = 0
CASE "C9"
DO
  LOCATE 21, 60
  INPUT " Fu=", Fu!
  CALL VALTEST(Fu!, 21, 68, 58!, 120!, 5)
  LOOP UNTIL test2 = 0
CASE "C10"
DO
  LOCATE 21, 60
  INPUT " fc=", Fc!
  CALL VALTEST(Fc!, 21, 68, 11!, 10!, 4)
  LOOP UNTIL test2 = 0
CASE "C11"
DO
  LOCATE 21, 60
  INPUT " A2=", A2!
  CALL VALTEST(A2!, 21, 68, 11!, 10000!, 7)
  LOOP UNTIL test2 = 0
CASE "C12"
DO
  LOCATE 21, 60
  INPUT " de=", DE!
  CALL VALTEST(DE!, 21, 68, 11!, 100!, 3)
  LOOP UNTIL test2 = 0
CASE "C13"
DO
  IF lugchoice! = 1 THEN
    LOCATE 22, 45
    PRINT "Invalid choice."
    test2 = 1
  ELSE
    LOCATE 21, 60
    INPUT " Lug=", Lug!
    CALL VALTEST(Lug!, 21, 68, 11!, 100!, 5)
  END IF
  LOOP UNTIL test2 = 0
CASE "C14"
DO
  IF lugchoice! = 2 THEN
    LOCATE 22, 45
    PRINT "Invalid choice."
    test2 = 1
  ELSE
    LOCATE 21, 60
    INPUT " Tgrout=", Tgrout!
    CALL VALTEST(Tgrout!, 21, 68, 0!, 10!, 4)
  END IF
  LOOP UNTIL test2 = 0
CASE "C15"
DO
  LOCATE 21, 60
  INPUT " PDL=", PDL!
  CALL VALTEST(PDL!, 21, 6B, .1, 1000!, 4)
  LOOP UNTIL testX = 0
CASE "L2"
  DO
    LOCATE 21, 60
    INPUT " PLL=", PLL!
    CALL VALTEST(PLL!, 21, 6B, -1000!, 1000!, 6)
    LOOP UNTIL testX = 0
CASE "L3"
  DO
    LOCATE 21, 60
    INPUT " PWL=", PWL!
    CALL VALTEST(PWL!, 21, 6B, -1000!, 1000!, 6)
    LOOP UNTIL testX = 0
CASE "L4"
  DO
    LOCATE 21, 60
    INPUT " VDL=", VDL!
    CALL VALTEST(VDL!, 21, 6B, -1000!, 1000!, 6)
    LOOP UNTIL testX = 0
CASE "L5"
  DO
    LOCATE 21, 60
    INPUT " VLL=", VLL!
    CALL VALTEST(VLL!, 21, 6B, -1000!, 1000!, 6)
    LOOP UNTIL testX = 0
CASE "L6"
  DO
    LOCATE 21, 60
    INPUT " VWL=", VWL!
    CALL VALTEST(VWL!, 21, 6B, -1000!, 1000!, 6)
    LOOP UNTIL testX = 0
CASE "L7"
  DO
    LOCATE 21, 60
    INPUT " MDL=", MDL!
    CALL VALTEST(MDL!, 21, 6B, -10000, 10000!, 7)
    LOOP UNTIL testX = 0
CASE "L8"
  DO
    LOCATE 21, 60
    INPUT " MLL=", MLL!
    CALL VALTEST(MLL!, 21, 6B, -10000, 10000!, 7)
    LOOP UNTIL testX = 0
CASE "L9"
  DO
LOCATE 21, 60
INPUT " MWL", MWL!
CALL VALTEST(MWL!, 21, 63, -10000, 10000!, 7)
LOOp untill testX = 0
CASE ELSE
LOCATE 21, 45
PRINT "invalid selection."
testvar% = 1
END SELECT
LOCATE 21, 44
PRINT SPACE(75)
LOOP WHILE testvar% = 1
END SUB

SUB CONFIGURE (rowX, col%) *
============================================================
* SUB CONFIGURE (rowX, col%) *
============================================================
IF biganswer = "1" THEN
LOCATE rowX - 1, col% + 1
IF mChoice% = 2 AND lugChoice% = 2 THEN
PRINT "moment/shear and shear lug"
ELSE IF mChoice% = 2 AND lugChoice% = 1 THEN
PRINT "moment/shear and no shear lug"
ELSE
PRINT "no moment/shear"
END IF
DO
DO
LOCATE rowX, col%
INPUT "base plate length, L, in. ", L!
CALL VALTEST(L!, rowX, col% + 30, 1!, 100!, 5)
LOOP untill testX = 0
DO
LOCATE rowX + 1, col%
INPUT "base plate width, B, in. ", B!
CALL VALTEST(B!, rowX + 1, col% + 30, 1!, 100!, 5)
LOOP untill testX = 0
DO
LOCATE rowX + 2, col%
INPUT "column length, Dx, in. ", Dx!
CALL VALTEST(Dx!, rowX + 2, col% + 30, 1!, 100!, 5)
LOOP untill testX = 0
DO
LOCATE rowX + 3, col%
INPUT "column width, Dy, in. ", Dy!
CALL VALTEST(Dy!, rowX + 3, col% + 30, 1!, 100!, 5)
LOOP untill testX = 0
DO
LOCATE rowX + 4, col%
INPUT "number of headed anchors. ", nutbolt%
maxnumbolt% = ((L! - 2.5) / 3!) + 1
SELECT CASE numbolt$  
    CASE IS < 2, IS > maxnumbolt$, 3, 5, 7, 9, 11, 13, 15, 17  
        LOCATE row% + 5, col% + 10  
        PRINT "Input incorrect."  
        LOCATE row% + 5, col% + 10  
        PRINT SPACE$(20)  
        LOCATE row% + 4, col% + 31  
        PRINT SPACE$(5)  
        test$ = 1  
        CASE ELSE  
            test$ = 0  
        END SELECT  
    END SELECT  
LOOP UNTIL test$ = 0  
DO  
    LOCATE row% + 5, col%  
    INPUT "Bolt spacing, Rx, in. ", RX$  
    CALL VALTEST$(RX$, row% + 5, col% + 30, 1!, 100!, 5)  
LOOP UNTIL test$ = 0  
DO  
    LOCATE row% + 5, col%  
    INPUT "Bolt spacing, Ry, in. ", RY$  
    CALL VALTEST$(RY$, row% + 5, col% + 30, 1!, 100!, 5)  
LOOP UNTIL test$ = 0  
answer2$ = YESORNO$(row% + 7, col%)  
IF answer2$ = "N" THEN  
    CALL WINDOWRITE$(wb1, wbtext$(!))  
END IF  
LOOP UNTIL answer2$ = "Y"  
DO  
    LOCATE row% + 7, col%  
    PRINT "Base plate type, C (1=grout pad,"
    LOCATE row% + 8, col%  
    INPUT " 2=mounted flush, 3=embedded). ", Ctype$  
    IF Ctype$ = "1" THEN  
        C! = 1.82: test$ = 0  
    ELSEIF Ctype$ = "2" THEN  
        C! = 1.43: test$ = 0  
    ELSEIF Ctype$ = "3" THEN  
        C! = 1.11: test$ = 0  
    ELSE  
        LOCATE row% + 9, col% + 10  
        PRINT "Input out of range."
        LOCATE row% + 9, col% + 10  
        PRINT SPACE$(20)  
        LOCATE row% + 8, col% + 31  
        PRINT SPACE$(5)  
        test$ = 1  
    END IF  
LOOP UNTIL test$ = 0  
LOCATE row% + 7, col% + 19
PRINT SPACE$(15)
LOCATE row% + 8, col%
PRINT SPACE$(36)
LOCATE row% + 7, col% + 31
PRINT USING "#.#"; C!
DO
   LOCATE row% + 8, col%
   INPUT "Bolt ult. strength, Fu, ksi. ", Fu!
   CALL VALTEST(Fu!, row% + 9, col% + 30, 3B!, 120!, 5)
LOOP UNTIL test% = 0
DO
   LOCATE row% + 9, col%
   INPUT "Concrete, fc, ksi. ", Fc!
   CALL VALTEST(Fc!, row% + 9, col% + 31, 1!, 10!, 5)
LOOP UNTIL test% = 0
LOCATE row% + 10, col%
PRINT SPACE$(36)
LOCATE row% + 10, col% + 28
PRINT USING "#.# #.## #.## #.## "; A2!
DO
   LOCATE row% + 11, col%
   INPUT "Tcg. edge length, de, in. ", DE!
   CALL VALTEST(DE!, row% + 11, col% + 29, 4!, 10000!, 7)
LOOP UNTIL test% = 0
answer2$ = YESNO$(row% + 12, col%)
IF answer2$ = "N" THEN
   FOR I = 1 TO 5
      LOCATE row% + 6 + I, col%
      PRINT SPACE$(36)
   NEXT I
END IF
LOOP UNTIL answer2$ = "Y"
END IF
IF lugchoice% = 2 THEN
   DO
      LOCATE row% + 12, col%
      INPUT "Shear lug length, Llug, in. ", Llug!
      CALL VALTEST(LLug!, row% + 12, col% + 30, 1!, 100!, 3)
      LOOP UNTIL test% = 0
   DO
      LOCATE row% + 13, col%
      INPUT "Grout pad thickness, in. ", Tgrout!
      CALL VALTEST(Tgrout!, row% + 13, col% + 29, 0!, 10!, 4)
     LOOP UNTIL test% = 0
   answer2$ = YESNO$(row% + 14, col%)
END IF
END IF
PRINT SPACE$(36)
IF answer2$ = "N" THEN
    FOR I = 1 TO 2
        LOCATE row% + 1 + I, col%
        PRINT SPACE$(36)
    NEXT I
END IF
LOOP UNTIL answer2$ = "Y"
END IF
END SUB

SUB GETDATOUT (row%, col%)
    LOCATE row%, col% + 32
    PRINT USING "##.##": L!
    LOCATE row% + 1, col% + 32
    PRINT USING "##.##": B!
    LOCATE row% + 2, col% + 32
    PRINT USING "##.##": 3X!
    LOCATE row% + 3, col% + 32
    PRINT USING "##.##": DY!
    LOCATE row% + 4, col% + 32
    PRINT USING "##.##": numalt%
    LOCATE row% + 5, col% + 32
    PRINT USING "##.##": AX!
    LOCATE row% + 6, col% + 32
    PRINT USING "##.##": BV!
    LOCATE row% + 7, col% + 33
    PRINT USING "##.##": C!
    LOCATE row% + 8, col% + 34
    PRINT USING "##.##": Fu!
    LOCATE row% + 9, col% + 34
    PRINT USING "##.##": Fc!
    LOCATE row% + 10, col% + 39
    PRINT USING "##.##": A2!
    LOCATE row% + 11, col% + 31
    PRINT USING "##.##": 3E!
    SELECT CASE lugchoice
        CASE 2
            LOCATE row% + 12, col% + 32
            PRINT USING "##.##": Llug!
            LOCATE row% + 13, col% + 32
            PRINT USING "##.##": Tgrout!
        CASE ELSE
        END SELECT
    END LOCATE
    LOCATE row%, col% + 71
    PRINT USING "##.##": PDL!
    LOCATE row% + 1, col% + 71
    PRINT USING "##.##": PLL!
    LOCATE row% + 2, col% + 71
PRINT USING "###.###"; PNL!
LOCATE row1 + 5, col1 + 71
PRINT USING "###.###"; VDL!
LOCATE row1 + A, col1 + 71
PRINT USING "###.###"; VLL!
LOCATE row1 + 5, col1 + 71
PRINT USING "###.###"; UML!
LOCATE row1 + 6, col1 + 70
PRINT USING "###.###"; MUL!
LOCATE row1 + 7, col1 + 70
PRINT USING "###.###"; ML!
LOCATE row1 + B, col1 + 70
PRINT USING "###.###"; MLL!
END SUB

'=============================================COL_BPL.BAS=============================================
SUB IDDATAIN (projectid$, locationid$, nameid$)
'=============================================COL_BPL.BAS=============================================
DO
FOR I = 1 TO 5
  LOCATE 18 + I, 10
  PRINT SPACES$(59)
NEXT I
LOCATE 17, 17
PRINT "Input the project identification and location.*
LOCATE 18, 10
INPUT "1. Input the project number, (10) spaces maximum":, projectid$
LOCATE 19, 10
INPUT "2. Input the grid location, (10) spaces maximum":, locationid$
LOCATE 20, 10
INPUT "3. Input your initials :", nameid$
answer$ = YESNO$(121, 17)
LOOP WHILE answer$ <> "Y"
END SUB

'=============================================COL_BPL.BAS=============================================
SUB LOADDATAIN (row%, col%)
'=============================================COL_BPL.BAS=============================================
DO "loop with answer$
  IF Biganswer = "1" THEN
    LOCATE row% - 1, col% + 13
    PRINT "UNFACTORED"
    LOCATE row%, col% + 8
    PRINT "Vertical Loads (+Dn)"
    DO
      LOCATE row% + 1, col%
      INPUT "Input vert. dead loads, kips. ", PDL
      CALL VALTEST(PDL!, row% - 1, col% + 32, 1, 1000!, 5)
      LOOP UNTIL test1 = 0
    DO
    LOCATE row% + 2, col%
INPUT "Input vert. live loads, kips. ", PLL!
CALL VALTEST(PLL!, row% + 2, col% + 32, -1000!, 1000!, 5)
LOOP UNTIL test% = 0
DO
   LOCATE row% + 3, col%
   INPUT "Input vert. wind loads, kips. ", PWL!
   CALL VALTEST(PWL!, row% + 3, col% + 32, -1000!, 1000!, 5)
   LOOP UNTIL test% = 0
   IF MSchoice% = 2 THEN
      LOCATE row% + 4, col% + 5
      PRINT "Lateral Loads (+Rgt)"
      DO
         LOCATE row% + 5, col%
         INPUT "Input lat. dead loads, kips. ", VDL!
         CALL VALTEST(VDL!, row% + 5, col% + 32, -1000!, 1000!, 5)
         LOOP UNTIL test% = 0
      END
      LOCATE row% + 6, col%
      INPUT "Input lat. live loads, kips. ", VLL!
      CALL VALTEST(VLL!, row% + 6, col% + 32, -1000!, 1000!, 5)
      LOOP UNTIL test% = 0
      DO
         LOCATE row% + 7, col%
         INPUT "Input lat. wind loads, kips. ", WWL!
         CALL VALTEST(WWL!, row% + 7, col% + 32, -1000!, 1000!, 5)
         LOOP UNTIL test% = 0
      END
      LOCATE row% + 8, col% + 6
      PRINT "Moment Loads (+)"
      DO
         LOCATE row% + 9, col%
         INPUT "Input dead load mom., in-kips. ", VDL!
         CALL VALTEST(MDL!, row% + 9, col% + 32, -10000!, 10000!, 7)
         LOOP UNTIL test% = 0
      END
      LOCATE row% + 10, col%
      INPUT "Input live load mom., in-kips. ", VLL!
      CALL VALTEST(MLL!, row% + 10, col% + 32, -10000!, 10000!, 7)
      LOOP UNTIL test% = 0
      DO
         LOCATE row% + 11, col%
         INPUT "Input wind load mom., in-kips. ", WWL!
         CALL VALTEST(MWL!, row% + 11, col% + 32, -10000!, 10000!, 7)
         LOOP UNTIL test% = 0
      END
      ELSE
         VDL! = VLL! = WWL! = MDL! = MLL! = MWL! = 0!
         VCL! = 0!
      END IF
   END IF
   IF MSchoice% = 1 THEN
      answer$I$ = YESORNO$(row% + 4, col%)
   ELSE
      answer$I$ = YESORNO$(row% + 12, col%)
   END IF
END IF
ELSE
    answer3$ = "Y"
    IF MSchoice$ = "1" THEN
        VDL! = 0!; VLL! = 0!; WWL! = 0!; MDL! = 0!; MLL! = 0!; MML! = 0!
    END IF
END IF
LOOP UNTIL answer3$ = "Y"
END SUB

==========================COD_5PL_BAS==========================
SUB MOMENTFL (Moment!, Prial!, tlpbendmax!, Tboltax!)  
    newBLX! = 0
    secta! = B! * L! * L! / 6!
    DO
        Momenttemp! = ABB(Moment!)
        ecc! = Momenttemp! / Prial!
        emax! = L! / 3! - RX! / 6!
        IF ecc! > -1! * RX! / 2! AND ecc! < 0! THEN
            Tbolt! = ABB(Prial! / 2!) + Momenttemp! / RX!
            Mpl! = 0!
        ELSEIF ecc! > 0! THEN
            Tbolt! = 0!
            Mpl! = 0!
        ELSEIF ecc! > 0! AND ecc! < (L! / 6) THEN
            tstressax! = (Prial! / A1!) + Momenttemp! / secta!
            tstressax! = (Prial! / A1!) - Momenttemp! / secta!
            IF (tstressax! > Fpallow!) THEN
                LOCATE 22, 42
                PRINT "Base plate size is inadequate."
                LOCATE 23, 42
                PRINT "Input new values for L and B."
                PAUSE (13)
                newBLX! = 1
                EXIT DO
            END IF
            grad! = (tstressax! - tstressmin!) / L!
            unifw! = tstressmax! - (a! * grad!)
            Mpl! = unifw! * (a! ^ 2) / 2! + (a! ^ 3) * grad! / 3!
            Tbolt! = 0!
        ELSEIF ecc! > (L! / 6) AND ecc! < emax! THEN
            tstressax! = (2! * Prial! / (3! * B!) * ((L! / 2!) - ecc!))
            tstressmin! = 0!
            IF tstressax! > Fpallow! THEN
                LOCATE 22, 42
                PRINT "Base plate size is inadequate."
                LOCATE 23, 42

            END IF
        END IF
    END DO
END SUB
PRINT "Input new values for L and B."
FAUSE (3)
newBLX = 1
EXIT DO
END IF
grad' = tstressmax! / (.5 * (L! + RX!))
unifw' = tstressmax! - (m! * grad')
Mpl! = unifw! * (m! ^ 2) / 2! + (m! ^ 3) * grad! / 3!
Tbolt! = 0!
ELSE
first! = B! * Fpallow! / (L! * RX!)
second! = -1! * (B! * Fpallow! / 2!) * ((L! / RX!) + 1!)
third! = Panchor! + (2! / RX!) + Panchor! * acc!
d! = QUADRATIC(first!, second!, third!)
IF newBLX = 1 THEN
LOCATE 22, 42
PRINT "Base plate size is inadequate."
LOCATE 21, 42
PRINT "Input new values for L and B."
FAUSE (3)
EXIT DO
ELSE
grad' = Fpallow! / kd!
IF kd! < m! THEN
Mpl! = (kd! / 2!) * (m! - kd! / 3!)
ELSE
unifw! = Fpallow! - (m! * grad')
Mpl! = unifw! * (m! ^ 2) / 2! + (m! ^ 3) * grad! / 3!
END IF
Tbolt! = 10! * kd! / 2! - Panchor!
END IF
END IF
IF Mpl! > Mplmax! THEN
Mplmax! = Mpl!
END IF
IF Tbolt! > Tboltmax! THEN
Tboltmax! = Tbolt! * 2! / nuxbolt!
END IF
tolbendmax! = SQRT(4! * Mplmax! / 32.4)
LOOP WHILE newBLX = 1
END SUB

'==================================CDL_BPL.SAS=================================='
SUB PRINTSCREEN STATIC
'==================================CDL_BPL.SAS=================================='
DIM reg AS RegType
CALL INTERRUPT(5, reg, reg)
END SUB

'==================================CDL_BPL.SAS=================================='
FUNCTION QUADRATIC (A!, B!, C!)
```plaintext
det! = B! + B! - 4! * A! * C!

IF det! <= 0! THEN
    newALX = 1
    x! = 0!
ELSE
    x! = (-1! + B! - SQR(det!)) / (2! * A!)
END IF
QUADRTIC = x!
END FUNCTION

SUB SHEARLIB (Vmax!, Vumin!, Pumain!)

IF ABS(Vmax!) > ABS(Vumin!) THEN
    Vbp! = ABS(Vみなみ!)
ELSE
    Vbp! = ABS(Vumin!)
END IF
IF Pumin! < 0! THEN
    Pad1! = 0!
ELSE
    Pad1! = Pumin!
END IF
Vlug! = Vbp! - (1! / C!1! * Pad1!
Dlug! = (Vlug! / (.5! * Fc! * Llug!)) + (Grout!)
Mlug! = Vlug! * ((Dlug! + Grout!) / 2!) / Llug!
Tlugtemp! = SQR(4! * Mlug! / 72.4)
SELECT CASE Tlugtemp!
    CASE IS < .375
        Tlug! = .375
    CASE IS < .5
        Tlug! = .5
    CASE IS < .625
        Tlug! = .625
    CASE IS < .75
        Tlug! = .75
    CASE IS < .875
        Tlug! = .875
    CASE IS < 1!
        Tlug! = 1!
    CASE IS < 1.125
        Tlug! = 1.125
    CASE IS < 1.25
        Tlug! = 1.25
    CASE IS < 1.375
        Tlug! = 1.375
    CASE IS < 1.5
        Tlug! = 1.5
    CASE IS < 1.75
        Tlug! = 1.75
    CASE IS < 1.77
        Tlug! = 1.77
END SELECT
```
CASE IS < 2!
   Tlug! = 2!
CASE IS < 2.25
   Tlug! = 2.25
CASE IS < 2.5
   Tlug! = 2.5
CASE IS < 2.75
   Tlug! = 2.75
CASE IS < 3!
   Tlug! = 3!
CASE ELSE
END SELECT
Sweld! = SQR((Mlug! / Tlug!) \(^2 + (Mlug! / (2! + Llug!) \(^2)) / 1.372
END SUB

**==================================CDL_BPL.BAS================================**

SUB T Pendulum (Tboll!, tenstpinax!)
**==================================CDL_BPL.BAS================================**
IF Tboll! <= 0! THEN
   tenstpinax! = 0!
ELSE
   arr! = (RX) - (.75 * 2X)! / 2!
   edge! = (R! - RY)! / 2!
   IF arr! < edge! AND arr! < RY! / 2! THEN
      beff! = 2! + arr!
   ELSEIF arr! > edge! AND arr! < RY! / 2! THEN
      beff! = edge! + arr!
   ELSEIF arr! < edge! AND arr! > RY! / 2! THEN
      beff! = arr! + RY! / 2!
   ELSE
      beff! = 2! * B! / nubcoll!
   END IF
   Mfill! = (2! * Tboll! / nubcoll!) * arr! / beff!
   tenstpinax! = SQR(4! * Mfill! / 32.4)
END IF
END SUB

**==================================CDL_SPL.BAS================================**

SUB T Pause (sec) STATIC
**==================================CDL_SPL.BAS================================**
CONST SecondsInDay = 24h * 60m * 60s
LoopFinish = TIMER + sec
IF LoopFinish > SecondsInDay THEN
   LoopFinish = LoopFinish - SecondsInDay
DO WHILE TIMER > LoopFinish
   LOOP
END IF
DO WHILE TIMER < LoopFinish
   LOOP
END SUB
SUB UTLLOADS (Lumax!, Lumin!, Lu!, (), deadid!, liveld!, windld!)  

   Lumax! = Lumin! = 0!  
   Lu!(1) = 1.4 * deadid!  
   Lu!(2) = 1.2 * deadid! + 1.6 * liveld!  
   Lu!(3) = 1.2 * deadid! + 1.6 * liveld! + .8 * windld!  
   Lu!(4) = 1.2 * deadid! + .5 * liveld! + 1.3 * windld!  
   Lu!(5) = 1.7 * deadid! + 1.3 * windld!  

FOR I = 1 TO 4  
   IF Lu!(I) > Lumax! THEN  
      Lumax! = Lu!(I)  
   END IF  
NEXT I  

Lumin! = Lu!(5)  
END SUB  

SUB VALTEST (value!, rowX, colX, ib!, ub!, blank!)  

   test% = 0  
   IF value! < (ib! OR value! > ub!) THEN  
      LOCATE rowX + 1, colX - 17  
      PRINT "Input out of range"  
      CALL TPAUSE(1.0)  
      LOCATE rowX + 1, colX - 17  
      PRINT SPACE$(120)  
      LOCATE rowX, colX  
      PRINT SPACE$(blank%)  
      LOCATE rowX, colX  
      test% = 1  
   END IF  
END SUB  
END SUB  

SUB VERTPL (Pumax!, Pumin!, tplvertmax!, Tiboltmax!)  

   newBLX = 0  
   DO  
      A1' = L! * B!  
      Fpmax! = 1.02 * Fc!  
      Fpallow! = .51 * Fc! * SOF(A2! / A1!)  
      IF Fpmax! < Fpallow! THEN  
         Fpallow! = Fpmax!  
      END IF  
      IF Pumax! < 0! THEN  
         tplvertmax! = 0!  
         Tibolt! = ABS(Pumax!) / numBLix  
      ELSE  
         Tibolt! = 0!  
   END IF  
   NEWBLX = NEWBLX + 1  
   A1 = NEWBLX  
   Fpmax + 1.02 * Fc  
   Fpallow + .51 * Fc * SOF(A2! / A1!)  
   IF Fpmax < Fpallow THEN  
      Fpallow = Fpmax  
   END IF  
   IF Pumax < 0 THEN  
      tplvertmax = 0  
      Tibolt = ABS(Pumax) / numBLix  
   ELSE  
      Tibolt = 0  
   END IF  
END DO
Fpactual! = Pomax! / Ai!
IF Fpallow < Fpactual! THEN
  LOCATE 22, 42
  PRINT "Base plate size is inadequate."
  LOCATE 23, 42
  PRINT "Input new values for L and B."
  TPAUSE (3)
  newBL% = 1
  EXIT DG
END IF

'Compute the required plate thickness.
.a! = (L! - (.95 * DX!!)) / 2!
.c! = (3! - (.8 * DY!!)) / 2!

Po! = Pumax! * DX! * DY! / Ai!
Aratio! = SQR(A2! / (DX! * DY!!))
IF Aratio! < 2! THEN
  AH! = Po! + .7804 / Fc!
ELSE
  AH! = Po! * 1.9698 / (Aratio! * Fc!)
END IF

.tflg! = .525
.sum! = DX! + DY! - tflg!
.cplate! = .25 * (sum! - SQR((sum! ^ 2) - 4! * (AH! - tflg! * DY!!)))

.X1! = Pumax! * .06173 / Ai!
.X2! = Po! * .06173 / AH!
.tplvert!(1) = X! * SQR(X1!)
.tplvert!(2) = X! * SQR(X1!)
.tplvert!(3) = cplate! * SQR(X2!)
.tplvertmax! = 0!
FOR I = 1 TO J
  IF tplvertmax! < tplvert!(I) THEN
    tplvertmax! = tplvert!(I)
  END IF
NEXT I
IF newBL% = 1 THEN
  tplvertmax! = 0!
END IF

END IF
IF Pmin! < 0! THEN
  Tboltbit! = ABS(Pmin!) / numbolt%
END IF
IF Tboita! > Tboltbit! THEN
  Tboltmax! = Tbolts!
ELSE
  Tboltmax! = Tbolts!
END IF
LOOP WHILE newBL% = 1
END SUB
SUB WINDOWTEXT 'm AS windowtype, wtext*(1) STATIC

' Record current cursor location.
cursorRow% = C3RLIN
cursorCol% = POS(0)

'Determine the array bounds.
ltText% = LBOUND(wtext%)
ubText% = UBOUND(wtext%)

'Determine the longest string array in the text array.
maxLen% = 0
FOR I% = ltText% TO ubText%
    len% = LEN(wtext%(I%))
    IF len% > maxLen% THEN
        maxLen% = len%
    END IF
NEXT I%

'Determine the bottom right corner of the window.
row% = m.row + ubText% - 1
col% = m.col + maxLen%

'Draw the body of the window.
FOR r% = m.row TO row%
    col% = r% - m.row + 1
    LOCATE r%, col%
    PRINT wtext%(r%)
NEXT r%

'Reset the cursor position.
LOCATE cursorRow%, cursorCol%

END SUB

FUNCTION YESORNO# (row%, col%)

LOCATE row%, col%
INPUT "Is this input correct, Y or N. ", n$
n% = UCASE$(n$)
IF n% (=) "Y" AND n% (=) "N" THEN
    LOCATE row%, col%
    PRINT ", Answer must be Y or N."
    CALL TPAUSE(3)
END IF
LOCATE row%, col%: PRINT SPACE$(30)
LOOP UNTIL n% = "Y" OR n% = "N"
YESORNO# = n$
END FUNCTION
VITA

Steven M. Applegate was born in Winston-Salem, North Carolina on May 15, 1957. He graduated from Manchester High School in Richmond, Virginia. He attended Virginia Polytechnic and State Institute from 1975 to 1979 where he earned a Bachelor's degree in Civil Engineering. After graduation he worked from 1979 to 1980 as a project engineer on the construction of a waste treatment plant for Pompano Beach, Florida. From 1980 to 1983, he entered VPI & SU and worked on his Master's degree in Architecture. From 1982 to 1983 he worked on his Master's degree in Civil Engineering also at VPI & SU. In late 1983 he left graduate school to begin work for the firm of Dunbar, Milby & Williams in Richmond, Virginia. In the ensuing 7 1/2 years he has completed incomplete course work, taken a video course from VPI & SU, learned computer programing on an IBM P.C. and completed the enclosed paper and computer program.

The writer lives with his wife of 5 1/2 years with their 2 1/2 year old twin children while being a senior associate with the firm of Dunbar, Milby & Williams.

Steven M. Applegate.