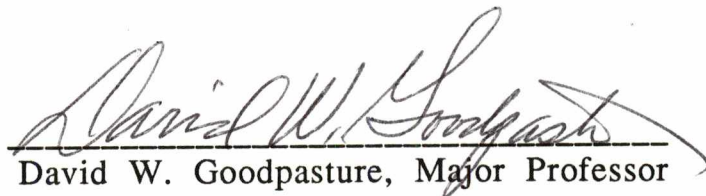
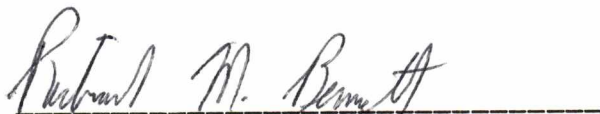


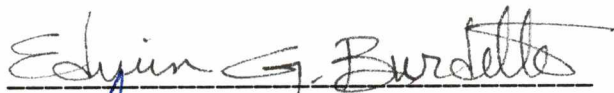
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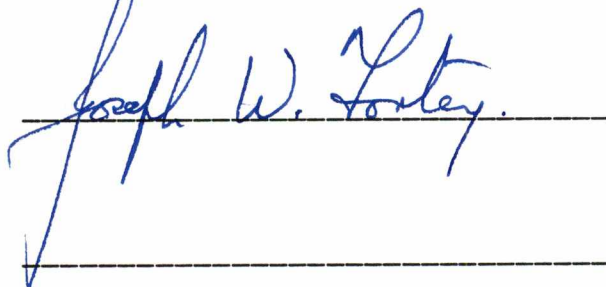
I am submitting herewith a dissertation written by Eng-Kian Koh entitled "Prototype Expert System in Partially Restrained Steel Connection Design." I have examined the final copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Civil Engineering.


David W. Goodpasture, Major Professor

We have read this dissertation
and recommend its acceptance:







Accepted for the Council:


Associate Vice Chancellor
and Dean of The Graduate School

Prototype Expert System
in Partially Restrained Steel Connection Design

A Dissertation
Presented for the
Doctor of Philosophy
Degree

The University of Tennessee, Knoxville

Eng-Kian Koh
December 1993

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ABSTRACT

The suitability of an expert system to design steel connections is investigated. The design is based on the American Institute of Steel Construction's Load and Resistance Factor Design manual. The prototype expert system designs welded seated beam connections and standard bolted framed connections.

The expert system shell used was PC Plus, a backward chaining system. Design knowledge is used in the rules; design tables and property tables are stored in database files for interaction with PC Plus.

A number of example connections are designed using CONDSIGN, the expert system developed in this dissertation. These designs were compared to similar designs performed by a commercially available expert system called CONXPRT; the two systems gave identical results.

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Chapter 1

Introduction

1.1 Historical Background

“Artificial Intelligence” (A.I.) is one of the various areas of study in computer science. The concept of the possibility of artificial intelligence was introduced by Turing in 1950. The term, “Artificial Intelligence,” was first officially used in 1956 during the initial conference on artificial intelligence (Mount and List, 1987). This field of study is concerned with devices which can “think” or function in a fashion similar to human beings. In 1958 Rosenblatt developed an intelligent machine which was modeled after the human brain called the “Perceptron.” Scientists have discovered through the research of artificial intelligence how the human brain works in the areas of analysis, learning, and providing solutions. Machines are made to imitate the functions of the human brain. The area of neural networks is a branch of A.I. that simulates not only the physical appearances aspect of the neurons in the brain but also the operations aspect of the neurons. The physical configuration of the neural network is very similar to the biological structure of the neurons in the brain. The neural networks are actually trained to perform a specific task by feeding them with the required knowledge for those particular areas. The amount of training also corresponds to the level of performance, just like their human counterpart. Robots and expert systems are two related fields of artificial intelligence (Mount and List, 1987).

Expert systems grew out of artificial intelligence research. An expert system is a computer system that can solve problems which normally require the handling of a human expert. In 1947, Samuel developed one of the first expert systems which played checkers. By 1961, it was playing championship checkers. Some of the well known expert systems are DENDRAL, an early expert system which determines the structure of organic compounds developed by Feigenbaum in 1965, and a medical diagnosis system called MYCIN, which was developed by Shortliffe in 1972 (Michie, 1982).

SACON, built by Bennett and Engelmores, is the earliest expert system in structural engineering, which advises engineers in using a structural analysis program called MARC. Ishizuka, Fu, and Yao's SPERIL-I assesses structural damages of existing structures in an earthquake. Ogawa, Fu, and Yao's SPERIL-II determines the safety of existing structures (Waterman, 1986). Carnegie-Mellon University produced a preliminary design system for high rise buildings called HI-RISE, and LOW-RISE for low rise industrial buildings (Maher, 1987).

1.2 Expert System vs. Conventional Program

Programming languages like BASIC or FORTRAN are widely used for scientific programming and in conventional programs. LISP (LISt Processing language) and PROLOG are commonly used programming languages in expert systems. Sometimes, FORTRAN and PASCAL are also used in building expert systems. LISP is considered to be a good computer-aided-design system programming

language (Holtz and Rasdorf, 1983). LISP programs are able to satisfy the requirements of CAD software to be interactive and data directed. The concept of data directed programming is unique to LISP. As opposed to program-governed data organization in conventional programs, data directed programming organizes programs around the data.

Unlike ordinary programs, expert systems manipulate "knowledge" instead of "data" (Waterman, 1986). Solving sets of equations or performing laborious mathematical computations are more suitable for conventional programs. Expert systems use symbols to represent problem concepts or knowledge; then various heuristics and strategies are applied to manipulate the symbols to arrive at a solution. Symbols, in artificial intelligence jargon, mean a string of characters that represent some real-world concepts. This does not mean that expert systems do not do mathematics; it is just that the emphasis is on manipulating knowledge.

During a run (consultation) with an expert system, the user can stop at any point to learn why he or she is being asked a particular question, or how the expert system came to a particular conclusion (Ortolano and Perman, 1987). In conventional programs, persons other than the programmer will probably not understand the code. Structural design is a repetitive process; the design knowledge can be stored in a root frame and other sub-frames in the knowledge base. Root frame is the first frame to be activated during a consultation. Sub-frames are activated after that and subsequently can be

reactivated over and over again; this process is very similar to iterative design work. So the expert system is ideal for this purpose. And a user can stop in the middle of a run to find out in plain English why or how a decision is made (Harmon and King, 1985).

In a BASIC or FORTRAN program, the flow of the program depends on how it is written. The control strategy is embedded in the program code. In an expert system, the control mechanism is a separate entity. "Inference engine" is the name for the control mechanism in expert systems. All the facts, rules-of-thumb, computational procedures, etc. are stored in the knowledge base. Ortolano and Perman (1987) claim that this separation allows the ease of adding, deleting, or changing the items in the knowledge base. Such editing would be quite extensive in a conventional program because other portions of the program would have to be rewritten.

1.3 Ways of Building an Expert System

An expert system developer can build the system from scratch by using A.I. source codes like LISP or PROLOG, which is referred to as symbolic programming. Another way to build a system is to use a development tool like the expert system shell, which provides rapid prototyping. LISP is considered by Holtz an easy language to learn provided it is the first computer language a person is trying to learn (Holtz, 1983). LISP is very different from FORTRAN; one with the previous knowledge of FORTRAN will find learning LISP difficult,

which supports Fortey's (Ref. 19) claim that LISP requires months to master. Other types of development tools are programming environments and rule-induction software. Programming environments are more advanced versions of the expert system shell. Programming environments usually have robust features to enable the creation of a sophisticated expert system. Rule-induction software uses case study examples to identify rules for knowledge acquisition. For a civil engineer who is not familiar with LISP or PROLOG, it takes a long time to learn and master them, but they offer greater flexibility in designing programs. It is ideal if the system builder is a knowledge domain expert as well as a computer scientist who is familiar with artificial intelligence programming languages. However, an engineer with some programming experience can also use an expert system shell and create a reasonable application. Expert system shells are rather economical, and they are not very difficult to learn. Most expert systems built with these shells could be run on widely used microcomputers. Programming environments are more expensive, both in terms of the software and the hardware in which it resides. Rule-induction tools are not very popular with civil engineers.

It has also been suggested that if design standards are tabulated and stored in the database, they can also be used by the expert system for the basis of design (Garrett and Fenves, 1989). The tabulated design standards are called decision tables. This way, different design codes can be stored in different modules making the

system standard-independent, meaning the system does not depend on any particular design code. This method provides flexibility in design, but it takes a group of knowledgeable structural engineers to put it together over several years.

Choosing an appropriate tool to build the expert system is important. Considerations must be given to the problem area's characteristics so that a suitable tool can be used. If time is a constraint, a tool which has built-in explanation or interaction facilities will help (Hayes-Roth, et al., 1983).

1.4 Personal Consultant Plus

In the case described in this dissertation, a commercially available expert system shell named "Personal Consultant Plus" (PC Plus) which was developed at Texas Instruments Corp. (TI), was used (Personal, Vol.1, 1988). This shell is personal-computer-based (p. c. based) either on the TI or IBM machine with hard disks. For an IBM personal computer, developing the expert system requires at least an Intel 80286 microprocessor, 1.5 Megabytes (Mb) of disk storage, 640 Kilobytes (Kb) of Random Access Memory (RAM), and DOS 2.10 or later. 1.5 Mb of additional extended or expanded memory will enhance the system. An IBM PC-AT equivalent called RITA (Revolutionary In Technology Advancement), Model 2610 was used. It had an Intel 80286 microprocessor, a math coprocessor, 638 Kb of RAM, 2 Mb of expanded memory, and Microsoft DOS version is 3.20. The PC Scheme and PC Plus software are both version 3.02. PC

Scheme contains the Scheme compiler for PC Plus and programmers who program with Scheme. Source code Scheme is a dialect of LISP. Scheme or Abbreviated Rule Language (ARL) can be used in this expert system shell. ARL is a language for writing the rules in PC Plus. Being p. c. based has the advantage of portability and low cost of both hardware and software. Most small structural engineering companies cannot afford a mainframe computer. PC Plus has the capability to interface with "dBASE III PLUS" which is an assembly-language relational database management system. Data for steel wide-flange sections, bolt types, and weld electrodes can be stored in the relational database. The data can then be retrieved and manipulated by the expert system. dBASE III PLUS is a popular product; therefore, a lot of users will be able to access its databases. It also provides a standard way to store, manipulate, and retrieve data so that confusion and redundancy are avoided. The other advantage is 'data independence', which a database provides, that allows the user to only specify the data items needed and not how to find them (Schaefer, et al., 1984). The storage and access of data are independent of its usage. No matter which form the user wants the data in, a separate scheme takes care of that. This scheme will, for example, display data in scientific notation if the user wants it that way. Therefore, storage of the same data of different forms can be done just once, hence saving memory space. A relational database stores data like a table in which the rows or columns are related. Data retrieval can be done interactively between the user and the database, or calling the database from a host program. The program

requires the presence of dBASE III PLUS to access the information in the database.

Since building an expert system is sometimes similar to symbolic programming, it does not process complex numerical manipulations very well. To cope with this deficiency, PC Plus has the facility to interface with external programs written in other computer languages to do the tasks of mathematical calculations. This interaction creates a hybrid type of expert system that eliminates the disadvantage of the non-algorithmic heuristic programming (Jones and Saouma, 1988).

1.5 Architecture of an Expert System

A rule-based expert system has two major components (Figure 1), namely the inference engine and the knowledge base (Adeli, 1986). The inference engine is in control of processing rules and information in the knowledge base to make inferences to arrive at specific conclusions. Basically the inference engine controls the direction of the program flow. Backward-chaining is the basic procedure used in PC Plus. It starts with a goal in the knowledge base and traces backward to find the rules and parameter values which satisfies the goal, which is literally what "backward-chaining" means (Grierson and Cameron, 1988). This procedure is more efficient when the user is verifying his design, because the expert system's inference engine searches for evidence to support a selected

design. PC Plus will also do forward-chaining. Both backward and forward chaining are explained in greater detail in section 2.3.

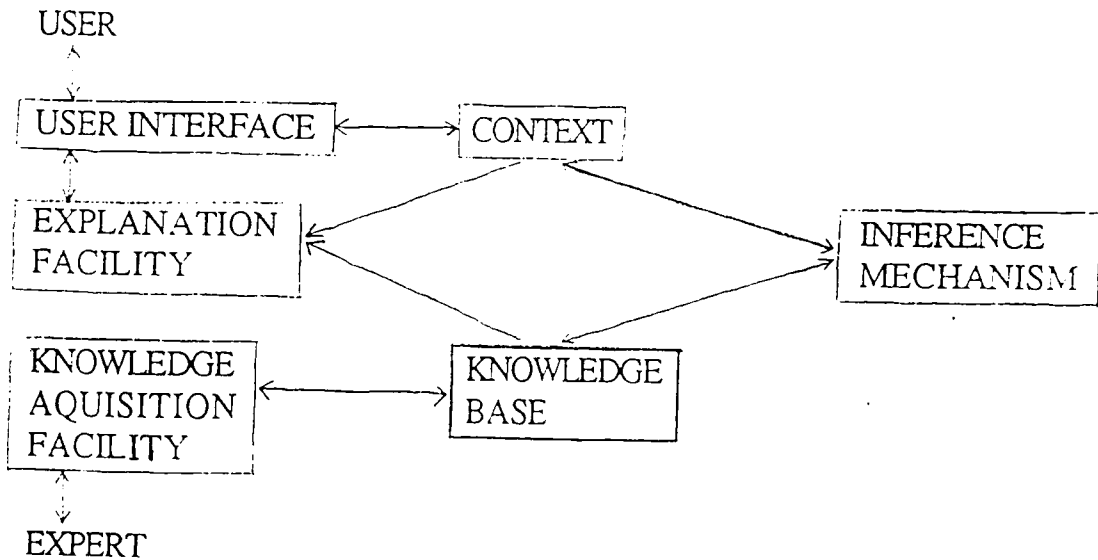


Figure 1: Generalized Expert System Architecture.

The knowledge base of PC Plus is basically composed of three items: frames (root frame and sub-frames), parameters, and rules (Personal, 2, 1988). Frames describe a particular problem area in the knowledge base domain. Rules and parameters which are related to each design problem are grouped by the individual frame. Frames are organized in a hierarchical structure called "frame tree". Within the frame tree there are parent frames and child frames. Child frames have the characteristic of inheriting the use of parameters and rules from their parent frame. An expert system can either have just one frame or multiple frames. For knowledge bases which have only one frame each, that frame is the root frame. Multiple

frame knowledge bases have only one root frame and one or more sub-frames.

If the frames are arranged as shown in Figure 2, the root frame is the parent frame of sub-frame 1; and sub-frame 1 is the parent frame of sub-frame 2. Consequently, sub-frame 1 is the child frame of the root frame, and sub-frame 2 is the child frame of sub-frame 1.

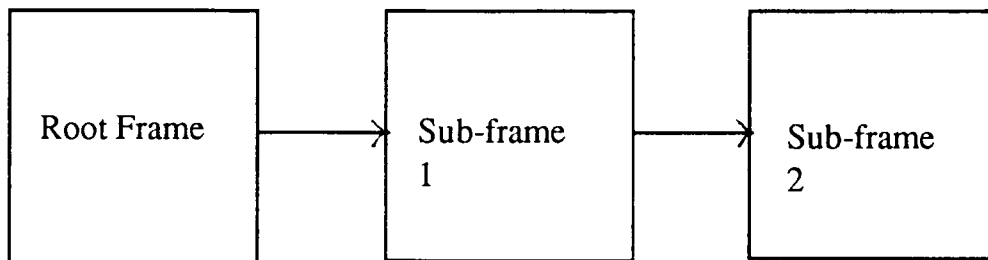


Figure 2: Relationship of frames.

Information or facts which are input by the user or inferred by the system are stored in the parameters. Rules of thumb, code specifications, and textbook procedures are coded in rule forms to determine the solution of a problem. Rules consist of IF and THEN statements that contain antecedent and consequence respectively. After the knowledge base is built, testing is carried out. An expert system with approximately 150 rules can take six man-months to complete; development and testing are a very time consuming processes (Maher, 1987). The final application not only has the potential to help structural engineers in design, but it can also be used as a learning aid for students, because the expert system has an explanation facility that a user can invoke to find out how the system arrived at the conclusion.

1.6 Purpose of this Project

The primary objective of this research was to study the feasibility of using a p. c. based expert system shell to build an application for the design of steel connections. Due to time and manpower constraints, the knowledge base does not contain the heuristics of an expert problem solver. Therefore, the final product was a limited prototype expert system or a knowledge-based system. A prototype is an original or model on which something is patterned. Building the prototype with an expert system shell is an efficient way to learn how to develop an expert system. The prototype's knowledge base can be added on to later to become a larger expert system. Observations were made in the process of the construction of the prototype expert system, and they can be useful to other builders who are thinking of using the shell.

Structural steel can be designed using either Allowable Stress Design (ASD) or Load and Resistance Factor Design (LRFD). This study is based on LRFD.

The prototype expert system can also be used as a learning aid. The 'HOW' and 'WHY' features which are built into PC Plus can show a user of the program how the conclusions are reached, and why some decisions are made.

Database interaction of PC Plus is also part of the study here. There are commercial databases available, and successful interface between them and PC Plus is valuable.

Chapter 2

Building of the Knowledge Base

2.1 Knowledge Acquisition

Knowledge acquisition is viewed as the most important task in the process of building an expert system. Knowledge can be classified into two types: public and private. Public knowledge may also be considered as static knowledge; it can be found in textbooks, journals, and reference materials. Private knowledge, such as rules of thumb, are usually not published. Knowledge is also known as heuristics, something found in human experts (Cohn, 1988).

Sources of public and private knowledge must be thoroughly identified. Up to date information from literature and human expertise must be included in the knowledge base in order for the program to be called an expert system. In this prototype expert system, the collection of knowledge will not be so elaborate, because the main objective here is to explore the PC Plus's ability of doing certain structural design.

Extracting static knowledge from written material and heuristic knowledge from domain experts is the next logical step in knowledge acquisition. Interviews conducted by the knowledge engineer with various domain experts will be documented for later inclusion in the knowledge base. Static knowledge has to be thoroughly understood in order to assemble the necessary knowledge for the expert system so that it will work properly.

After all the knowledge has been gathered, the evaluation has to be done by all who are involved in the project. This is to avoid any bias, and to check for completeness of the knowledge. In the case of any conflicts, they must be resolved through discussion.

2.2 Structuring the Design Knowledge

The design knowledge should be structured in such a way in the knowledge base that the expert system would simulate the chronological order of decision making of an expert. The knowledge base must be relatively easy to understand, and thus simplify the process of future refinement.

The knowledge in the expert system described herein is based on the American Institute of Steel Construction's (AISC) Load and Resistance Factor Design (LRFD) Specification (Manual, 1986), Structural Steel Design-LRFD method (McCormac, 1989), Steel Structures: Design and Behavior: Emphasizing Load and Resistance Factor Design (Salmon and Johnson, 1990), Structural Engineering Handbook (Gaylord and Gaylord, 1990), Guide to Design Criteria for Bolted and Riveted Joints (Kulak, et al., 1987), and the personal design experiences of Professor Harry L. Johnson (Ref. 20). The knowledge base contains two types of connection design information: standard bolted framed connections and welded seated beam connections. Design data like assembling clearances for bolted connections reside in the database to be easily transferred to PC Plus. Design specifications and procedures were transformed into rules to

guide the inference process. The expert system is capable of performing designs for commonly used beam-to-beam and beam-to-column connections in steel structures.

The LRFD manual specifies four types of fasteners: welds, unfinished bolts, high-strength bolts, and rivets. In the prototype, the selection of the type of fastener to be used is limited to welds and high-strength bolts, because unfinished bolts are limited to lightweight structures under small static loads; and riveting is almost extinct in the field.

Simple connections and semirigid connections are classified as partially restrained (Type P. R.). The area of design in the expert system is restricted to this type of connection ignoring the moment, because it is very small. In reality, simple connections are actually semirigid. It is impossible to achieve complete flexibility or complete rigidity. Therefore, the percentage of the moment developed in rigid or continuous frame connections (Type F. R., fully restrained) are considered as only 90 percent or more of the total moment resistance. To simplify structural analysis, a typical designer usually assumes that the joints are either simple or rigid. On a simple beam, if semirigid connections are assumed on both ends, the maximum moment of the beam can be reduced below that maximum moment at the midspan of the simple beam. The standard bolted beam connections are usually designed as simple connections which only resist shear. Therefore these simple connections use angles that are

light and flexible so that they will deform while the beam rotates so as to provide minimum moment resistance.

Some knowledge of preliminary design is in the root frame. When a decision is made about which type of connection is to be designed, the sub-frame which contains the standard bolted framed connection design knowledge or the other sub-frame that holds the welded seated beam connection design knowledge will be accessed. The structure of the knowledge base is shown in Figure 3. Certain design parameters are shared between the two sub-frames, so a big parameter group shared by both sub-frames was made (Personal, Vol. 2, 1988). The parameter group is a group of parameters including goal parameters.

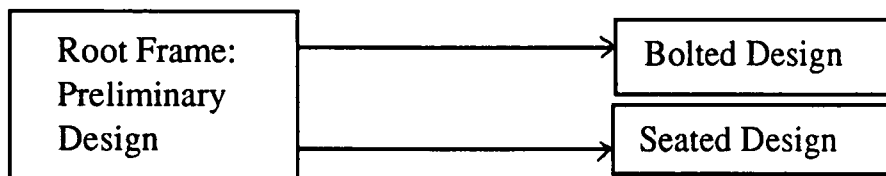


Figure 3: Hierarchy of frames.

Figure 4 is a flow chart which shows the preliminary design process of the prototype expert system's root frame. If the user knows exactly what kind of connection he or she wants to design, one can skip the questions about preliminary design. Otherwise, the person can answer five questions or less, and the expert system will suggest a type of connection for design. When the system cannot come to a conclusion about the bolted double angle or welded seat angle design, the program will ask him to choose one of the designs.

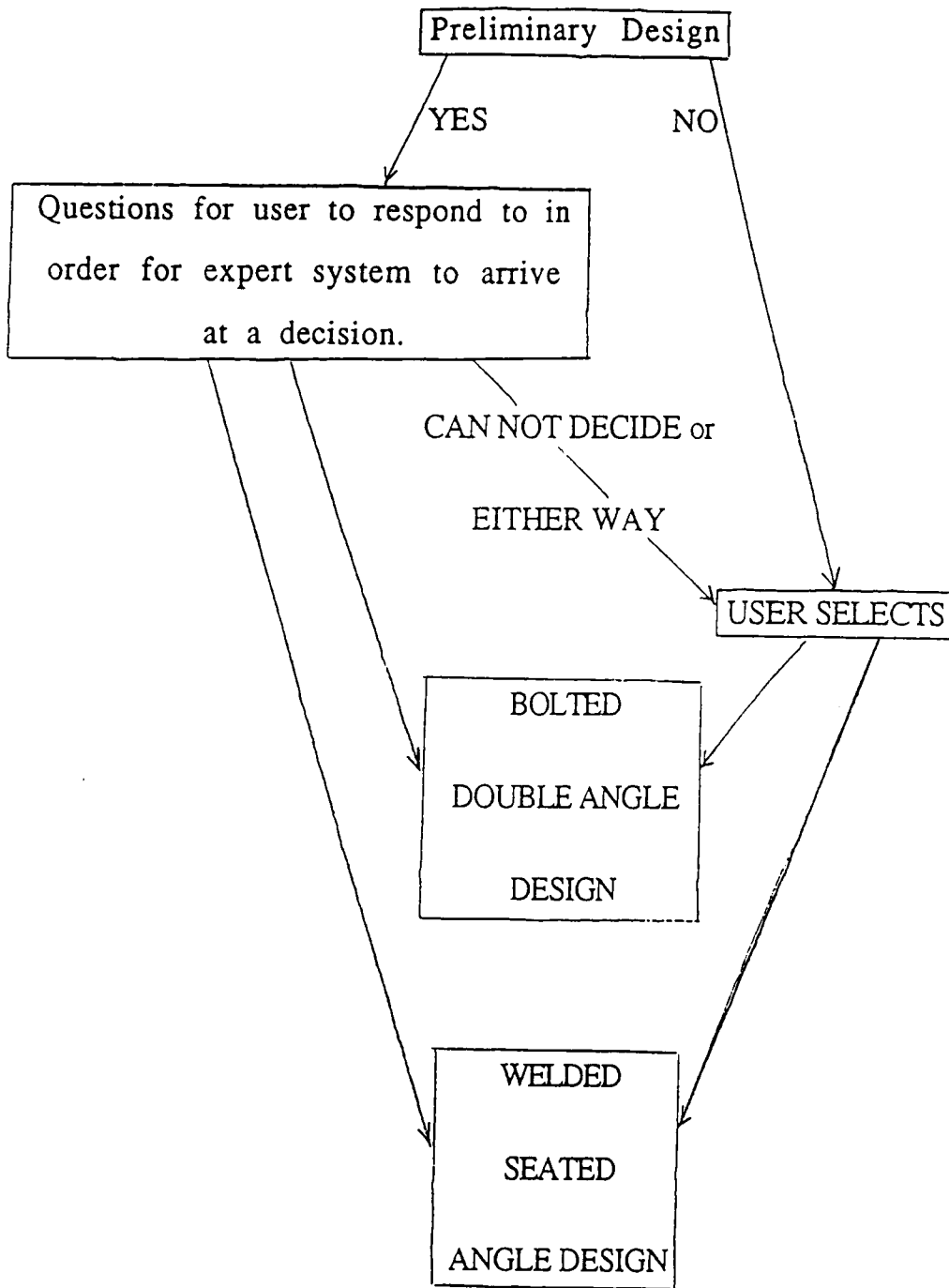


Figure 4: Flow chart for the root frame.

Qualified welders are skilled workers who are not necessarily available everywhere. As high as the cost of labor is, transplanting welders to a far away site will not be wise. So, when welders are not available, bolted connections should be used. Bolting is faster than welding; if time is very critical, the bolted double angle connection is more suitable. For temporary structures, bolted design is definitely the choice. Because these connections can be disassembled, the members can be reused. Welded connections generally weigh slightly less than the bolted ones. If weight is a concern, then welded design is preferred. Bolted connections have protruding bolt heads, shafts and nuts. Aesthetically, these types of connections are considered unpleasant. To solve this problem, the welded connections are suggested.

To design a standard bolted framed connection, the tables in part 5 of the LRFD manual may be used. These tables reside in the database while providing the expert system with shearing and bearing capacities of the bolts and connection angles. Figure 5 illustrates the steps taken by the program for this design. Table II-A in Appendix A is used to find the number of bolts needed to provide enough shearing strength. When the angle length is known, stability check is done to make sure that it is at least half the height of the beam web. The program will also make sure that clearance is sufficient for the angles. Then table II-C is used to check if the shear capacity provided by the angles are adequate. Bearing capacities of the beam web and angles are taken from tables I-E and I-F

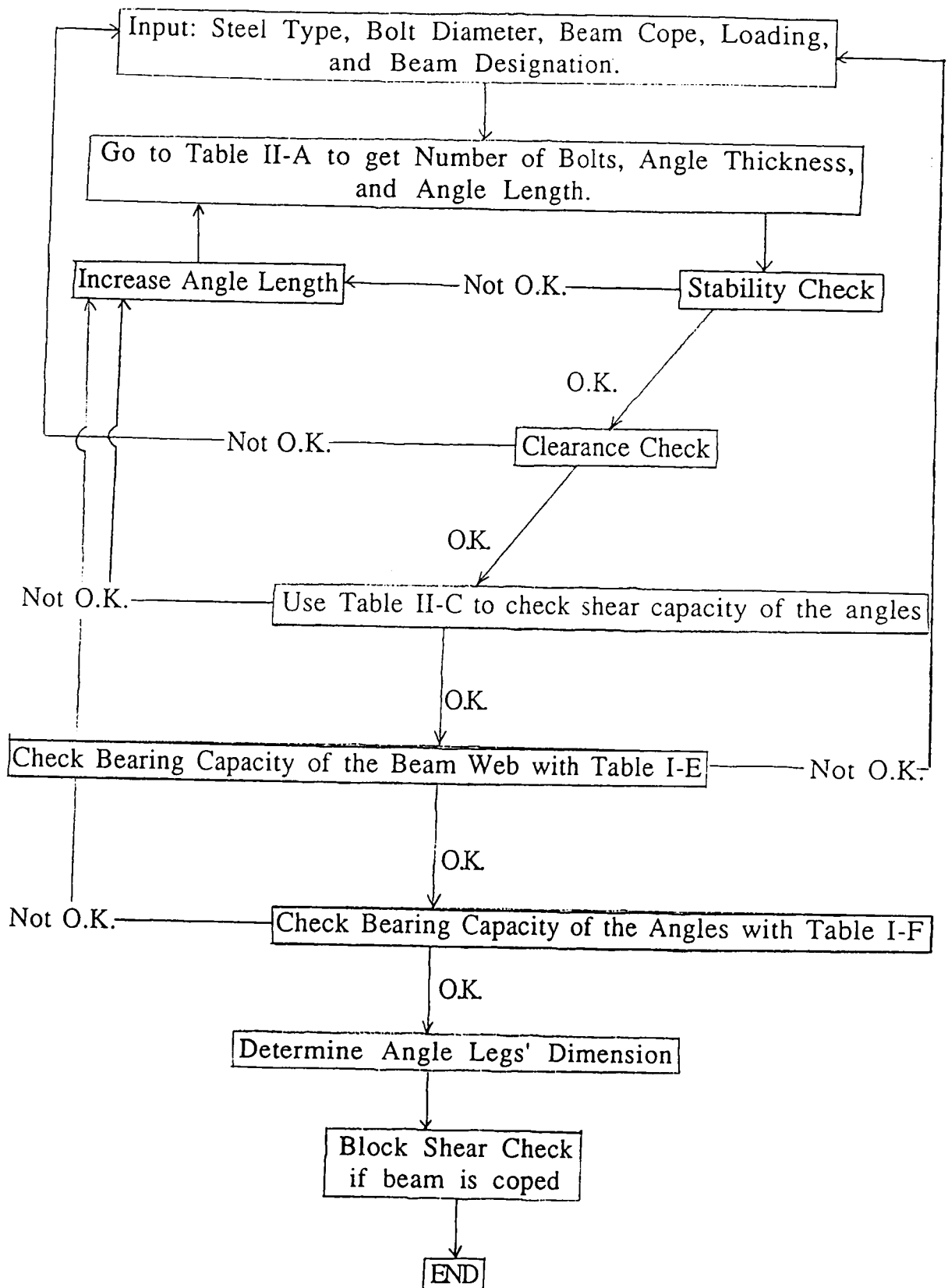


Figure 5: Flow chart for subframe 'BOLTED.'

respectively. The table of "Assembling Clearances" helps to determine the length of the angle legs. If the beam is coped, block shear checks with tables I-G.1 and I-G.2 on pages 5-10 and 5-11 respectively are performed by determining values of coefficients C_1 and C_2 . Design tables were used instead of equations, because PC Plus had the capability of interacting with databases. As explained earlier, expert systems are not very good at making numerical calculations. In addition, interfacing with databases makes the expert system modular. Future changes will be very simple, just replace, delete from, or add to the databases concern and maybe make some minor corrections to the knowledge base.

For welded seated beam connections, the seat angle is usually welded to the supporting member in the shop and field-welded to the supported beam. An angle either on the top of the beam or the side of the beam web is necessary to give lateral support to the beam. Typically, this angle is not considered to resist any loading, and the selection is based on engineering judgment; a common size is L4x4x1/4. The welded seated beam connection supports a rather light load. The seat angle is usually only welded vertically on the ends, and the top angle is only welded on its toes to enable the angle to stretch while the beam end is rotating downwards. Figure 6 shows how the design is done. Tables VI-A and VI-B are used to obtain maximum design loads for the horizontal outstanding leg of the seat angle. These tables can only accept angle lengths of 6 and 8 inches. Here, the angle thickness is determined. Table VI-C has the

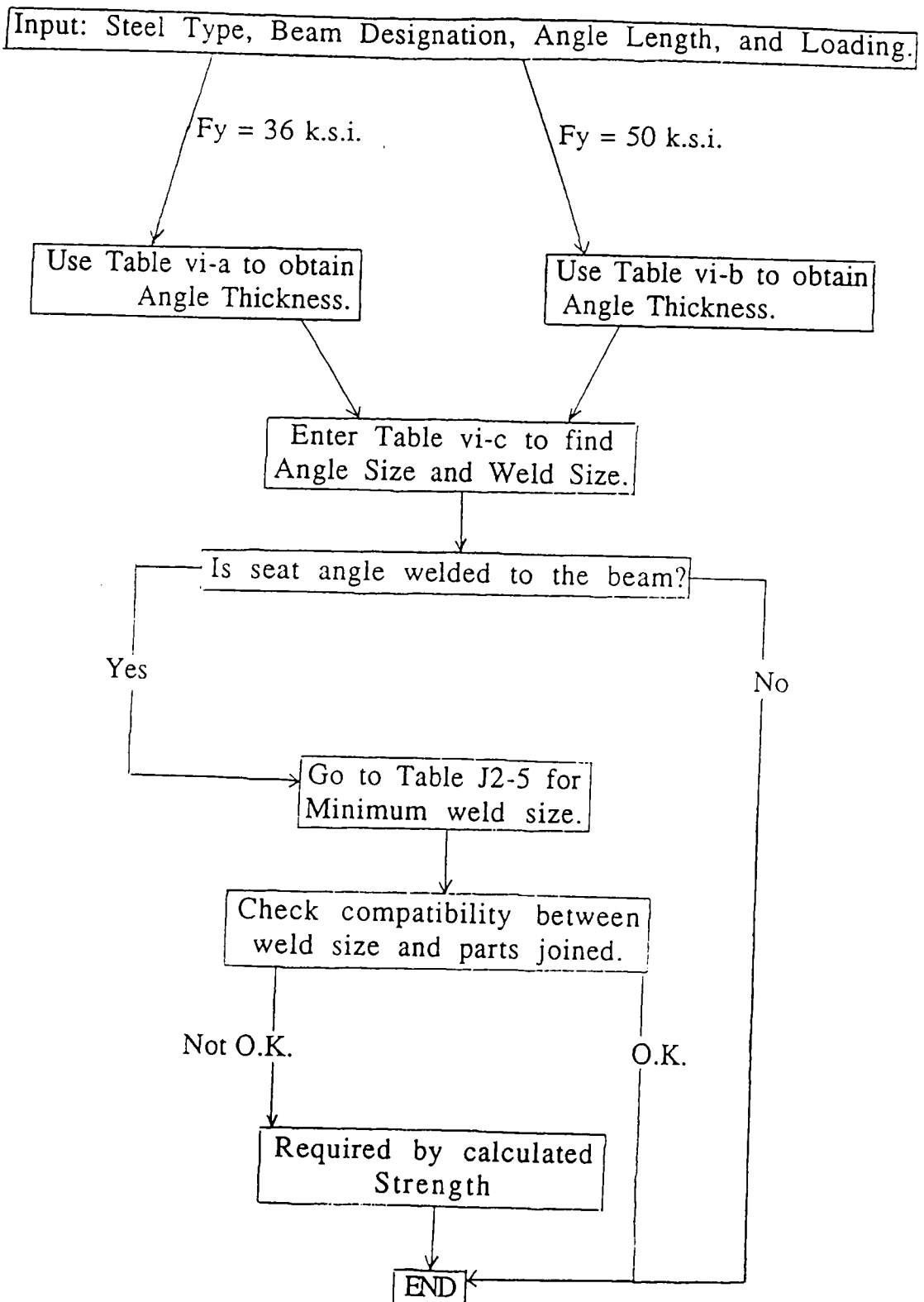


Figure 6: Flow chart for subframe 'SEATED.'

design strengths of the seat angle welds whose values are calculated by using the elastic method. The angle legs' lengths and weld size are selected at this stage. If the seat angle is welded to the beam, table J2-5 will be used to find the minimum weld size. At last, the weld size is checked to make sure that it is smaller than the thinner part joined. If calculations can justify the need for a weld size which is bigger, it will be permitted.

2.3 Creating the Production Rules

Knowledge assembled has to be coded into a format consistent with the selected shell. PC Plus must have at least one goal or goal parameter. The goal or goals are part of the parameter group. At the conclusion of a consultation, the value which PC Plus has reached for the goal is presented. Within a rule group, there must also be at least one rule which assigns a value to the goal.

The order in which the rules are created is different from the order in which the rules are tried. A "UTILITY" property can be used to specify the order which one wants the rules to be traced. The default inference procedure, which is backward chaining, will first locate the rule or rules that will provide a value for the goal. During a check of the rule's premise, the inference engine might have to look into the consequence part of the other rules for a possible value to assign to the parameter in the premise so that a fire or not to fire decision can be made. Forward chaining can also be done in PC Plus by giving a rule property value, antecedent, to the rule. In this case,

the inference engine will do the search in the reverse direction of backward chaining. It looks into the premise of a rule for the parameter which has just received a value. If the condition in the IF statement is satisfied, then the rule will fire; otherwise it will not. This way of searching is quite different from the search pattern of backward chaining. Everytime a parameter which is contained in the premise of an antecedent rule is assigned a value in the THEN statement of the other rules, PC Plus will test this antecedent rule. The following is an example to demonstrate the mechanics of backward and forward chaining.

In the "BOLTED" sub-frame, there is a goal named "STABLE". There is one rule that will conclude with a value for "STABLE", rule 55. A listing of the rule in the knowledge base "CONDSIGN" is given in Appendix A (page 89). When the sub-frame "BOLTED" is activated, the goal "STABLE" is traced among others. The inference engine found "STABLE" in the THEN statements of rule 55. It investigates the IF statement of rule 55, and realizes that the values of L and TH are required. So it finds that rules 6 and 36 will assign a value to each one of them. PC Plus then checks the value of "COPED" which is contained in the IF statements of rules 6 and 36; if it is greater than 0, it will fire rule 36, and get a value for L from a database file called "ii-a.dbf". The value of "TH" is calculated using an expression: $DEPTH - (2 * XK)$. The antecedent rule 27 will then be checked for compliance, since it has L and TH in its premise. After evaluating $0.5 * TH$, if L is less than that, PC Plus will conclude that stability

during the construction of the steel connection is not sufficient as in rule 56. It will advise that the length of the angle must be increased to at least one-half of the height of the beam's web.

The PC Plus's functions DBASE-RETRIEVE and DBASE-MRETRIEVE are used in the expert system to search for data in the database files in the dBASE environment. The following is one of the ways DBASE-RETRIEVE can be used. In a THEN statement of RULE004 in the expert system's sub-frame: "SEATED" (p.81), it appears as follows; T = (DBASE-RETRIEVE "vi-a" (QUAL L = L AND OSL_CAPACI = OSL-CAPACI AND WEB_THICKN = WEB-THICKN) T). The left most T is a parameter in "SEATED", the right most T is a field name in the database file call "vi-a". QUAL is a qualifier which specifies the criteria for the database record search. Within the brackets that enclosed the qualifier, on the left of the = signs are field names, and the parameter names are on the right of the = signs. It was desired to use different names for the same item in the knowledge base and the database initially so that one can know whether it is a parameter or a field. But that will create too many names, and that can be confusing. dBASE does not take the - symbol for its field names, therefore _ is used instead. So it is clear that OSL_CAPACI is a field name, and OSL-CAPACI is a parameter name. In the same rule, DBASE-MRETRIEVE is used in the following way: DBASE-MRETRIEVE ANGLE-SIZE "vi-c" (QUAL CAPACITY >= RU AND MAX_THICK >= T AND MIN_THICK <= T AND WELD_SIZE <= 0.3125) ANGLE_SIZE WELD-SIZE "vi-c" (QUAL CAPACITY >= RU AND

MAX_THICK >= T AND MIN_THICK <= T AND WELD_SIZE <= 0.3125) WELD_SIZE). The term ANGLE-SIZE right after DBASE-MRETRIEVE is a parameter name, the rest is in the same order as above. DBASE-MRETRIEVE can have more than one parameter's value to retrieve for by using AND to connect them. DBASE-RETRIEVE temporarily suspends the execution of the expert system to activate dBASE, looks for the desired data, and passes it back to the expert system. DBASE-RETRIEVE can only assign a value or a set of values to one parameter in the expert system, whereas DBASE-MRETRIEVE can make multiple retrieves with a single activation of dBASE. Calling up dBASE takes about 10 seconds, which is quite a long time for computer execution. Therefore DBASE-MRETRIEVE should be used rather than DBASE-RETRIEVE as much as possible.

Chapter 3

dBASE III PLUS

3.1 Design Tables in Database Files

PC Plus has the capability of interacting with the database files created by dBASE II, dBASE III, and dBASE III PLUS (Learning, 1985). Design tables in the LRFD manual were transformed into a database file.

In the design of standard bolted framed connections, the design tables that are needed are given in Table 1. These tables were created as database files so that the prototype expert system can find the appropriate values for design. All the fields' names and their corresponding names in the LRFD manual tables can be found in the appendix following each listing of a database file. The design of a welded seated beam connection requires the design tables given in Table 2.

3.2 Properties Tables in Database Files

The dimensions and properties tables of various shapes in the LRFD manual are available in the form of a database in ASCII (American Standard Code for Information Interchange) text format from the American Institute of Steel Construction (AISC) and ECOM Associates. Because the text is in ASCII format, it can be accessed by almost any programming language. The ASCII database of shapes was converted into a dBASE III PLUS database.

Table 1: Design Tables for Bolted Framed Connections.

Table	Title	Page (LRFD, 1986)
II-A	Bolt Shear	5-28
II-C	Design Shear in Connection Angles for A36 Material	5-30
I-E	"BEARING" Slip-critical and Bearing-type Connections	5-7
I-F	"EDGE DISTANCE"	5-9
---	"THREADED FASTENERS" Assembling clearances: A325 AND A490 HIGH-STRENGTH BOLTS ENTERING AND TIGHTENING CLEARANCES	5-164
J3.7	Minimum Edge Distance	6-72
I-G.1	COEFFICIENTS FOR WEB TEAR-OUT (BLOCK SHEAR) 'Based on standard holes and 3" fastener spacing' 'Shear yield, Tension fracture'	5-10
I-G.2	COEFFICIENTS FOR WEB TEAR-OUT (BLOCK SHEAR) 'Tension yield, Shear fracture'	5-11

Table 2: Design Tables for Welded Seat Angle Connections.

Table	Title	Page (LRFD, 1986)
VI-A	Outstanding Leg Capacity ($F_y = 36$ k.s.i.)	5-45
VI-B	Outstanding Leg Capacity ($F_y = 50$ k.s.i.)	5-45
VI-C	Weld Capacity	5-45
J2.5	Minimum Size of Fillet Welds	6-62

The advantage of having tables in database files is that changes can be done by plugging new databases into the expert system without having to modify the source code at all. dBASE itself has many useful features to work with data. For example, when a new code is published, improved design tables can be used in place of the old version. A lot of time will be saved, especially if a programmer other than the software's creator has to first understand the program and then modify the necessary parts.

Chapter 4

External Access

4.1 Interaction of PC Plus and dBASE III PLUS

There are two types of systems in which dBASE III PLUS interacts with PC Plus; they are called front end and back end systems. An expert system that is a front end to the database collects information for the database. A back end system uses information from the database for its consultation. In both systems PC Plus can store and retrieve information to and from the database. PC Plus's dBASE functions like DBASE-APPEND can add information to the database; and DBASE-RETRIEVE can get information from the database.

This prototype expert system is a back end system, because it receives member dimensions or design values from tables which were converted into databases. Basically, data received from the databases were used to set parameter values in the knowledge base. Parameter values can be set by putting a DBASE function in a parameter's EXPECT list, using the METHOD property of a parameter to retrieve information from a database, including a DBASE function in the ACTIVE-VALUE property of a parameter, and using any DBASE functions in the THEN statement of a rule. PC Plus functions were used together with the DBASE functions in most cases.

Although dBASE III PLUS supports five data types, character, logical, numeric, dates, and memo, PC Plus's DBASE functions only

recognize the character and numeric data types. dBASE must reside in the PCPLUS directory, this also facilitates the activation of dBASE. 272 Kb of free disk space is required to use dBASE III PLUS. When executing a DBASE function, the dBASE screen will override the PC Plus screen, and the PC Plus screen will return at the end of the DBASE call.

All dBASE III PLUS database files have the .DBF extension. But when the filenames are used in the PC Plus rules or parameter properties, the extension is left out. The filename without the extension can not be longer than eight characters, and it has to be enclosed with double quotation marks. A parameter can be used instead of a filename; in this case the double quotation marks are not necessary. The parameter must be defined as an existing filename.

Values which consist of character strings have to be enclosed with double quotation marks, or a parameter.

For DBASE functions which require a qualifier, the qualifier looks like this: (QUAL field operator value). The qualifier is enclosed by parentheses, and starts with the word QUAL. "field" is the field name in a database; "operator" is the DBASE operators which are listed as follow: AND, OR, NOT, =, >, <, >=, <=, and <>. "value" can be a number, character string, or parameter which has a value. AND and OR can be used to link more than one "field operator value" groups in a qualifier. No arithmetic functions or parentheses are allowed within the qualifier. If all the records in a database are to be

included in a qualifier, use the <> operator and a dummy value. There are only twelve PC Plus's DBASE functions available in this version, if other functions in dBASE are needed DBASE-EXECUTE-FILE can provide access to them. The PC Plus function DBASE-EXECUTE-FILE can be used to execute a command file of dBASE functions to allow flexibility in expressing a qualifier. When DBASE-EXECUTE-FILE or DBASE-RETRIEVE function is used in the THEN statement, the = function must assign the parameter's value to the field's value picked up from the database search.

4.2 Search Procedures of Database Files

When PC Plus is searching for a record or records with the DBASE-RETRIEVE or DBASE-MRETRIEVE command, it starts from the bottom of the database file, and works its way up. If one is searching for the smallest weld capacity in the database of Table VI-C to satisfy a certain loading condition, the data in the database file should be sorted in ascending order. The database search will continue until it finds the last record which fulfills the conditions set forth in the qualifier.

Chapter 5

Faulty Areas and Observations

Like all the other software, PC Plus has its shortcomings and errors. The following paragraphs describe some observations made during the course of building the prototype expert system.

In the file named CONDSIGN.LKB, which can be found on page 68 in the appendix, under the heading: "Global KB data", the number of rules and the number of meta-rules are incorrect. The expert system shell generates rule numbers automatically in sequence as the developer adds rules to the knowledge base. When an existing rule's entire contents in the IF and THEN statements are erased, the rule number remains. If the rule being erased happens to be at the beginning or in the middle of the rule group, the rest of the rule numbers are not renumbered. The total numbers of rules and meta-rules reported by the expert system shell reflect the last rule and meta-rule numbers, not the actual counts. The correct number of rules is 61, and the number of meta-rules is 2.

PC Plus's Reference Guide states that if the IF statement of a rule is left blank, the rule will be fired by the inference engine regardless, and the THEN statement will be executed. This method is used to apply actions in the THEN statements which are contained in the rules that must be fired. During the testing process, this did not work. Other methods have to be employed to make sure that such a rule is being fired. One way to do this is to write an IF statement

that will always test positive. In the knowledge base's BOLTED frame, under BOLTED-RULES, antecedent rule #58 (p.91) has an IF statement which says: LEG IS KNOWN AND OSL IS KNOWN. OSL and LEG are goal parameters which stand for the lengths of the legs of an angle in inches. During the trace of the goals in sub-frame BOLTED, the last values for LEG and OSL will be obtained by PC Plus from a database. The THEN statement of this rule contains a conclusion for LEG and OSL, which reads: DBASE-MRETRIEVE OSL "AISCL" (QUAL T = T AND VL >= LEG AND HL >= OSL) HL LEG "AISCL" (QUAL T = T AND VL >= LEG AND HL >= OSL) VL. Before the trace arrived at rule #58, values for LEG and OSL would have been assigned by either rule #33 or #37. So, as long as LEG and OSL has numbers, rule #58 is always true, therefore the final values for LEG and OSL will always be retrieved from database file "AISCL."

During the testing of rules, PC Plus does not follow the sequence of the rule numbers. The inference engine tries rules in the order that they are put in. Editing the rules will change the order. For example, rule #1 is typed in first, then #2, followed by #3. PC Plus will start to try with rule #1 first, followed by #2 and #3. Later, if editing was done to rule #2, the order of the rule group will become: #1, #3, #2. Editing of rule #2 made it go to the end of the line. Now the inference engine will start testing from #1, then #3, and #2 last. This rule trying sequence was not spelled out in the reference manual. It was discovered by the author using trial and error process with the prototype expert system. The realization of

this inferencing procedure is very important, because it helps the expert system developer control the way he wants the rules to be tried. It provides an extra method to structure the knowledge base.

One disadvantage of PC Plus's inference process is the inability to test all the rules that will provide a possible solution to a particular problem. Suppose there are three rules #1, #2, and #3 to be traced in sequence, because they are detected to have possible answers to a question. The inference engine will try rule #1 first; if the premise of the IF statement of the first rule is found to be true, then the conclusion in the THEN statement of the rule will be fired, and the second rule as well as the third will be ignored even though the conditions of their IF statements will be fulfilled. As soon as the expert system can find a solution for its parameter or goal parameter, it will not test the rest of the rules in the knowledge base. Therefore, this leaves possible answers not explored. The expert system then continues to trace other goal parameters, if there are more than one, until all are exhausted. Therefore the builder of the expert system has to be careful while writing rules, and make sure that all the rules that need to be fired are actually fired, and no reasonable solutions are ignored.

Antecedent rules will be tried as many times as required, so long as the rules have not been fired yet. When a parameter receives a value, the antecedent rules which contain this parameter in their IF statements will be marked for testing.

The rules, either antecedent or consequent, in any particular frame can only be fired once. In FORTRAN, commands in the statements can be executed more than once if they are situated within a DO loop. To simulate an algorithmic strategy as realistically as possible, one can either use multiple similar rules with different parameter names, or wait until the end of the consultation to start all over again. PC Plus has a PROMPT2ND feature in the sub-frames so that a client can start over when he comes to the end of the frame. In CONDSIGN's sub-frames SEATED and BOLTED, they will ask if the client wants to design another connection. At the root frame, when all the goals are traced, a client has the option to continue the consultation if he wants to without having to reload the whole knowledge base again.

When CONDSIGN is run on an IBM PS/2 model 56 SLC with an 80486SLC/25 MHz processor, about three consultations can be done consecutively before the machine runs out of memory. Due to the size of the knowledge base, interaction with databases, and the age of PC Plus, the new IBM computer does not work well. The larger the amount of rules, the slower the program runs. When it gets too big, it requires a bigger machine to run on. This version of PC Plus was developed under an older version of DOS, therefore it is not quite compatible with the new one. When the 'out of memory' message appears on the screen, follow the instructions to get out of the situation. Then quit PC Plus and reload it to clear the memory so that consultations can be resumed. During development, the same

problem arises. Getting out of the development environment and into the consultation mode and vice versa are very taxing to the memory. Special efforts have to be made to execute 'save kb' very often to prevent losing information when the software crashes. Using two machines, one for development and one for consultation will help ease the problem a bit.

Instantiation is the activation of a frame during consultation with an expert system. The process of tracing a solution for the problem causes the inference engine to enter a frame which contains possible answers. Frames, where rules and parameters are stored, are instantiated the way the knowledge base is designed. Instantiations do not happen automatically. During a consultation, the root frame is the first frame to be instantiated. A single frame knowledge base is one which only has a root frame and no sub-frames. For a multiple frame knowledge base, there can be as many sub-frames as the memory capacity of the computer can hold, but there is only one root frame.

During a consultation of the expert system, the author discovered that the parameters do not have a default numerical value of zero. Therefore, the programmer has to assign an appropriate value to the parameter if all the other ways of giving it a value failed.

When the program is running, parameters within a frame sometimes do not have the latest or most current value. To illustrate

this, a double-angle bolted connection design example 15-2 from McCormac on page 372 was used to test the knowledge base ANTECEDE (p.93). References are made to the files in the appendix named ANTECEDE.LKB (This file might look like parts of CONDSIGN.LKB, but it is not. It is an earlier version.) which contained the rule group in the "BOLTED" sub-frame, the computer printout ANTECEDE.TRC (p.106) of the activated "TRACE ON" feature during the consultation, and all the related database files. All can be found in the appendix.

Referring to the file named ANTECEDE.TRC, the creation of the root frame CONNECTION-1 signals the start of the consultation. The reader also has to have the knowledge base and design example side by side in front of him to be able to follow the explanation of the way logic flows during a consultation. The first thing that the inference engine does when a frame is instantiated is to look for the goal or the first goal, if there are more than one, to trace. In this case the goal is TYPECONN, p.105. Since none of the consequence rules in this frame has TYPECONN concluding with a value in their THEN statements, PC Plus goes to the CONNECTION-PARMS group (p.93) which is a parameter group for the root frame to look for a prompt so that it can ask the client for an answer. When it is found, there will be a prompt on the computer screen to ask the user to input the appropriate type of connection design. When the user entered BOLT, this value is assigned to TYPECONN. The ANTECEDENT-IN property of the goal parameter TYPECONN tells the inference engine that both

rules #20 and 21 have TYPECONN in their IF statements. Therefore both rules are tested, and rule #21 is determined to satisfy the condition. So the action in the THEN statement is applied, and the sub-frame BOLTED is instantiated.

Again, PC Plus immediately searches for the first goal parameter to be traced. N, the number of bolts, is the first in this case. Consequence rule #6 happens to provide a value for N by retrieving it from a database file named "ii-a.dbf". Actually, it is the dummy value DATA-FROM-TABLE that is equated to N which attracted the inference engine to test this rule. The previous N mentioned above is hidden inside the DBASE-MRETRIEVE statement, and PC Plus will not be able to trace N to this rule. So this rule is tried, and it is found that the IF statement matches with the TYPECONN's value of BOLT. Now the inference engine fires rule #6. After N is assigned the value of DATA-FROM-TABLE, DBASE-MRETRIEVE is executed. "cf" stands for certainty factor in percentage value. To get the value for BOLTSHEAR from database file "ii-a", values for the parameters in the qualifiers, like BOLTTYPE, D, and RU, have to be obtained. Since BOLTTYPE is a user entry value, a prompt will show up on the screen to signal the client for input. Because BOLTTYPE is contained in the antecedent rule #28, this rule is marked for testing. The premise of this rule has numbers for D and T, which have not yet been determined, so the test fails. Now the trace is on the parameter D so as to give a value to the qualifier's database field named D. Value for parameter D is another one that

requires user entry. Rule #28 is checked again, because D is in the premise. It fails again, because T does not have a number yet. Subsequently, RU is traced in the same manner. And rules #29 and 30 fail, because S does not have a value yet. The self-referencing rules #23, 25, 24, 22 fail too, because BC and BCA are not known. These are called self-referencing rules, because the parameter which is tested in the premise also sets a new value in the conclusion. Inside the brackets for the qualifiers in the DBASE-MRETRIEVE statement, the BOLTTYPE on the left of the equal sign is a field, and the BOLTTYPE on the right is a parameter. The author purposely does not want to use a different name for the field in the qualifier, because too much nomenclature is confusing, and the author wants a clear connection of which parameter in the knowledge base matches up with which field in the database. Now that all the qualifiers are satisfied, PC Plus calls up dBASE with the DBASE-MRETRIEVE function. Using the qualifiers as guide lines, numbers for BOLTSHEAR, N, T, and L are retrieved from database "ii-a". During the retrieval, many numbers are assigned to each parameter. This is because all those numbers fall within the guide lines. For example, BOLTSHEAR is assigned with 422, 380, 338, 295, 253, then 211. But, only the last number which is assigned to the parameter is good. All the previous numbers have been replaced by the subsequent numbers. As values for T and L are realized, rules #28 and 27 are marked for testing respectively. Just when the inference engine is about to trace the value for parameter T in the qualifiers for the next DBASE-MRETRIEVE, it is interrupted by the testing of rules #28 and

27. Since all the conditions are satisfied in the premise of rule #28, it prints the text in the THEN statement. Rule #27 fails, because TH is not known. Then, the trace of T continued, followed by L and N. At this point of time, the inference engine is still working on the trail created during the pursuit of the goal parameter N. N, T and L have just received values from the previous DBASE-MRETRIEVE. Therefore, as soon as the trace of each parameter starts, it ends immediately. But for N, instead of displaying: 'End tracing parameter: BOLTED-1 N, ' it is 'Special processing for parameter N already being traced. This is because N is the current goal which is being traced. FU in the next set of qualifiers is now being traced; DSG, DN, WGT, and LV followed. As soon as all the parameters are traced, DBASE-MRETRIEVE can then be carried out. Then S, B, TW, DEPTH, XK, BD, H2, and C1 will have values from the respective databases. Notice that DBASE-MRETRIEVE can get multiple values for various parameters, it can also get into different database files to do that.

One might wonder why two DBASE-MRETRIEVE functions are necessary to do the job in rule #6 (p.104) This is because parameters like N, T, and L need their values from the first multiple retrieve to aid the second multiple retrieve. In one DBASE-MRETRIEVE statement, PC Plus does not find the values for the parameters within a pair of the qualifiers' parenthesis, and then go to that particular database to search. Instead, all the parameters for

the qualifiers are traced first before going to the database or databases.

When parameter S received its value (p.108), antecedent rules #29 and 30 (p.105) are marked for testing. After the tracing of parameter N, which still has a value of 5; and during the tracing of parameter B, which is interrupted by the testing of rules #29 and 30, Rule #29 fails and 30 is fired. Therefore the N on the right hand side of the equation $N=(N+1)$ is traced, and has a value of 5. And N on the left hand side of the equation has a new value of 6. PC Plus goes on to trace N twice, because it appears once in the qualifiers for the retrieval of S, and a second time in the qualifier for L. Then database "II-C" is searched, and 232 is equated to S. Since S is assigned a new value, this triggers the testing of rules #29 and 30 again. Before the tests are carried out, L has been assigned the new values taken from "II-C". And antecedent rule #27 is marked for testing. When N has been set a new value of 6, and S a value of 232, there are no warning signs; because N is the present goal parameter being traced, and S only receives one value from the retrieval. But, when L has a new value, a warning is given about the change in the parameter value that may cause logical inconsistency. Since there are 14 retrievals of the value 17.5 from the database, there are 14 warnings and 14 assignments of the new value. Now the trace is on N, B, and TW of the equation $BC = ((N * B) * TW)$ in rule #30. Using $N = 6$ from rule #30, $B = 91.3$ and $TW = 0.49$ from rule #6, BC in rule #30 is calculated to be 268.422. Rules #23 and 22 are now marked for

testing, because BC has received a value. Rule #29 which has been marked earlier is now tested and fired. Rule #30 has been fired before, so it will not be tested again. Rule #27 and 23 are tested and failed. Rule #22's premise is true, so BC is traced and printed. When BC is assigned a new value, a warning appeared. Since BC has a new value, rules #23 and 22 are marked for testing again. Rule #23 failed again, and rule #22 has just been fired.

As of now, all the antecedent rules have been tested. And the trace of parameter B in equation $BC = ((N * B) * TW)$ of rule #6 is completed. The mathematical expression can be found in the third line from the end of the THEN statement for rule #6. In this rule, the value of N is previously retrieved from database "ii-a" to be 5. And the number can be found on line 72 of ANTECEDE.TRC which reads: Setting parameter : BOLTED-1 N = 5 cf 100.

Previously, when control was passed on to rule #30, and the value of N was changed to 6. But now when control is passed back to rule #6, the value of BC is calculated using the original value for N which is 5. During the tracing of each parameter's value in the arithmetic expression $BC = ((N * B) * TW)$, after a numerical value is being traced, its value does not change until it is retraced again within the equation. In this case, BC has the wrong number. The expression for BC was moved to rule #29 in order to get a right answer.

The preceding description shows how useful the "TRACE ON" feature is to finding bugs in the programs. The builder of an expert system should keep all the above strategies mentioned in mind while constructing a knowledge base so that logical errors can be avoided.

Chapter 6

Testing of the Prototype Expert System

Testing of the prototype expert system was carried out at different stages of the development. The TRACE ON command was used during the consultations to aid in the testing. After the initial consultation, the SAVE PLAYBACK FILE command is used to save client responses so that the values can be recovered automatically during the subsequent consultations by using the GET PLAYBACK FILE command. This is a very effective and time saving way to test knowledge bases, because values which are input via the keyboard will not have to be typed everytime the same questions are asked. The SAVE PLAYBACK FILE command can be used at any prompt during the consultation and at the end of a consultation. The GET PLAYBACK FILE command is only available at the title screen and the Current Objective screen, which occur during the beginning of the consultation. After the previous consultation input has been recovered by the GET PLAYBACK FILE command, modifications can be made to the previous consultation input to test the logic of the knowledge base. The previous consultation input may also be kept constant so that corrections and modifications of the knowledge base can be checked with a standard set of client responses. Using the PRINT function, in the THEN statements, which is one of the system functions to display intermediate results is an excellent way to check the accuracy and logic of the knowledge base. The robustness depends on the degree of testing the expert system is subjected to.

Design examples in textbook and codebook were used to measure the accuracy of the output. Dr. Fortey tried out the prototype and his feedback was noted so that the developer can make the necessary corrections to improve the performance of the system. This is included on page 112 in Appendix A. Testing of the prototype is an iterative process.

During the testing of the knowledge base, precautions were made to select examples which were within the scope of the knowledge base. Examples 15-1 and 15-2 in Jack C. McCormac's "STRUCTURAL STEEL DESIGN, LRFD Method" together with example 1 on page 5-18 of the MANUAL OF STEEL CONSTRUCTION's "LOAD & RESISTANCE FACTOR DESIGN" were used to test the prototype's ability to design standard bolted framed connections. McCormac's example 15-5 and LRFD's example on page 5-44 were used to test the design of welded seated beam connection.

The following are three examples to illustrate 1: bolted double angle design (example 15-1), 2: welded seat angle design (example 15-5), and 3: bolted double angle design which failed during the checking of the shear capacity of the angles (example 15-2).

Example 1

Given: Simple framed end connection for a W30x108 beam.

Factored end reaction R_u equals 160k. Material: A36 Steel.

3/4 in. A325-N bolts with standard-size holes.

Required: Design a double angle bolted connection.

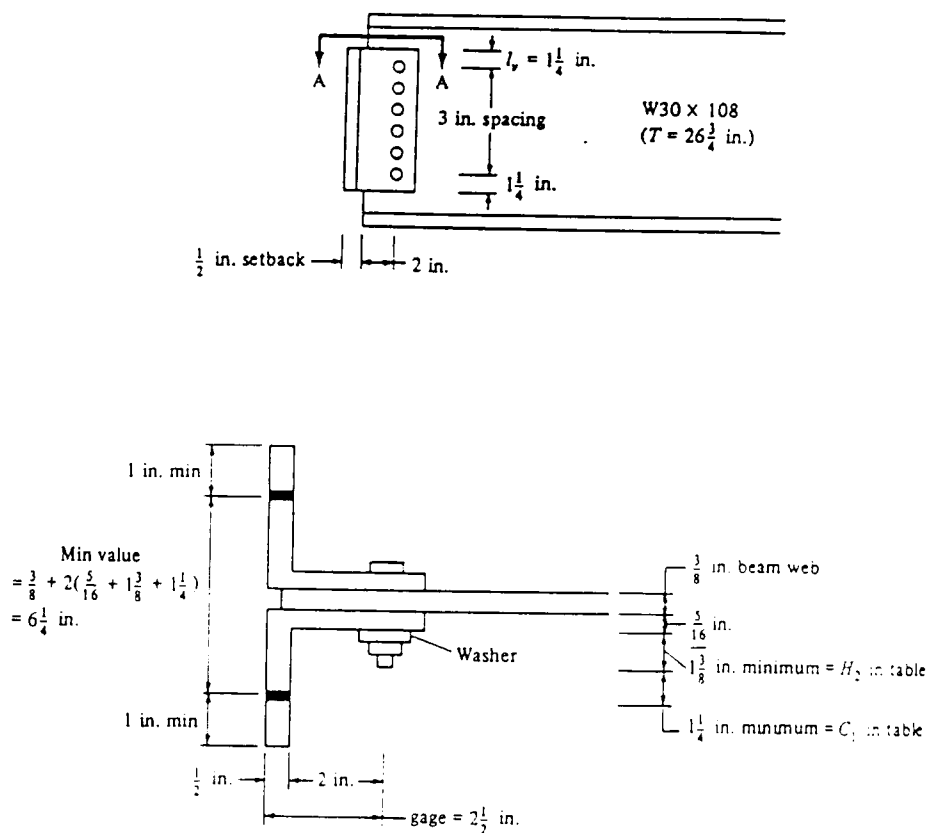


Figure 7: Bolted frame connection. (Diagrams taken from McCormac)

Solution: Questions asked by the program are in bold print, and user responses are in italics. Echos of checks or statements are underlined.

This is a program to design double angle bolted or seat angle welded connections according to the LRFD manual.

Do you wish to consider some preliminary design parameters?

YES

Is the supply of qualified welders adequate in the region where the structure will be erected?

NO

Is rapid erection time critical?

YES

Is there a possibility that the structure will be disassembled in the future?

YES

Do you wish to use the least amount of steel in the design?

NO

Do you want the joint to be pleasing?

NO

The information you have given me suggests that high-strength bolts should be used in a bolted double angle connection design.

Please select the ASTM Structural Steel Specification to be used for the main members. Note: A36 steel is used for detail material.

A36

Please type in the bolt diameter in inches. Use decimal fractions.

.75

A325-N bolt is used. The preferred bolt spacing of 3 inches is used. The bolt spacing is adequate.

Please enter the beam designation as appeared on the structural drawing. Type N.A. if it is not available.

N.A.

What is the depth, in inches, of the cope in the top flange? Use decimal fractions. If the beam is not coped, then type 0. Note: cope in bottom flange is not considered here.

0

Please enter the beam's end reaction in kips obtained from structural analysis with load factor included.

160

W shapes are hot-rolled shapes which have essentially parallel flange surfaces. If the beam which is being connected is a W shape, please enter W. If it is an American Standard, type C.

W

Please enter the nominal depth of the beam or American Standard. Ex.: W21x62, designation is 21.

30

Please enter the unit weight of the beam or American Standard. Ex.: W21x62, 62 is the unit weight.

108

Shearing capacity of the bolts is O.K..

The angle thickness in inches is: 0.3125

Please enter the beam web setback from the face of the angles. Use decimal fractions.

.5

Please enter the distance in inches between the row of bolts' holes in the web and the end of the beam web.

2

Do you want to reduce the angle thickness by 0.0625 in. because the shear capacity is not governed by the net shear on angles?

NO

Shear capacity of connection angles is O.K..

Bearing capacity of the beam web is O.K..

Bearing capacity of angles is O.K..

The following were conclusions which appeared at the end of a consultation:

Edge distance in inches of the top bolt from the top of the angle is as follows: 1.25

Number of bolts is as follows: 6

Angle thickness in inches is as follows: 0.3125

Length of angle in inches is as follows: 17.5

Stability during steel erection is as follows: sufficient

The clearance for the angle to be fitted to the beam web is as follows: O.K.

Shear capacity of bolts in kips is as follows: 186

Design shear in kips for connection angles is as follows: 206

Bearing capacity of the beam web in kips is as follows: 256.041

Bearing capacity in kips of the angles with l_v as the edge distance is as follows: 278.6875

The following value for block shear capacity is the larger of RBS1 or RBS2. RBS1 is the resistance to block shear in kips calculated from

the coefficients from table I-G.1, and RBS2 from I-G.2 is as follows: Calculation of the resistance to block shear is not necessary, because the top flange of the beam is not coped.

Block shear check is as follows: Block shear check is not necessary, because the top flange of the beam is not coped.

The shorter leg of the angle in inches is as follows: 3.5

Length of the other leg in inches is as follows: 4

Minimum flange width or T distance if beam frames into a column is as follows: 8.545

The following were chronological steps taken by the expert system for the design (These are not output during the run of the program):

1. With the diameter and type of bolt, and end reaction; use table II-A to select the number of bolts, angle thickness, and angle length. This table carries the shear strength of the bolt group.
 - 1.1 Compare the angle length to T of the beam to make sure that they fit.
2. With the number and diameter of bolts and the thickness of the angle, table II-C gives the shear capacity of the angles.
3. Check the bearing capacity of the bolt group with table I-E.

4. Use table J3.7 to find minimum edge distances for table I-F and leg size. Check the bearing capacity of the angles with table I-F.
5. Using table of "Assembling Clearances" in Part 5 of the LRFD Manual to obtain values for H_2 and C_1 to come up with the legs' sizes.

Example 2

Given: Factored beam reaction of 60k. The beam is a W24x55.

The seat angle is 8 in. long. Material is A36 Steel.

Weld type is E70 SMAW fillet welds.

Required: Design a welded unstiffened seated beam connection.

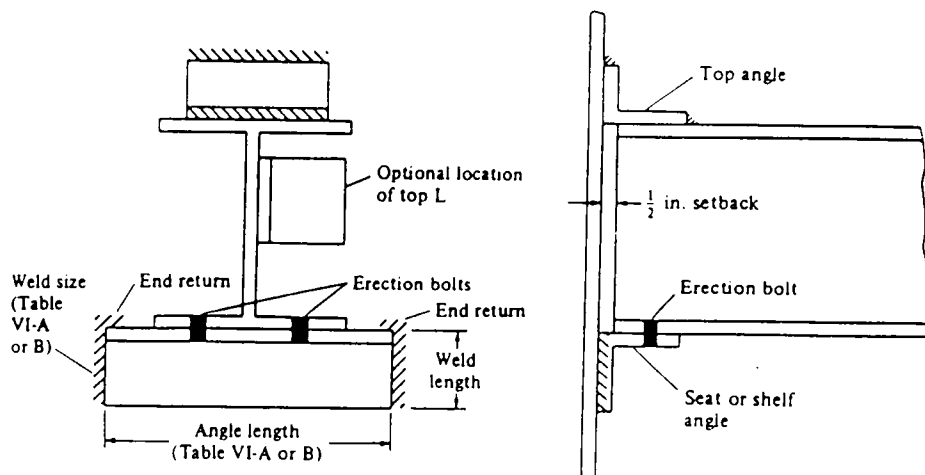


Figure 8: Welded seated beam connection. (Taken from McCormac.)

Solution:

Do you wish to consider some preliminary design parameters?

YES

Is the supply of qualified welders adequate in the region where the structure will be erected?

YES

Is rapid erection time critical?

NO

Is there a possibility that the structure will be disassembled in the future?

NO

Do you wish to use the least amount of steel in the design?

YES

Do you want the joint to be pleasing?

YES

The information you have given me suggests that a welded seated connection design is suitable.

Is the seat angle welded to the beam flange?

NO

Please select the ASTM Structural Steel Specification to be used for the main members. Note: A36 steel is used for detail material.

A36

W shapes are hot-rolled shapes which have essentially parallel flange surfaces. If the beam which is being

connected is a W shape, please enter W. If it is an American Standard, type C.

W

Please enter the designation of the beam or American Standard. Ex.: W21x62, designation is 21.

24

Please enter the unit weight of the beam or American Standard. Ex.: W21x62, 62 is the unit weight.

55

Enter 6 or 8 for the length of the angle in inches. Length of angle perpendicular to beam web

8

Please enter the beam's end reaction in kips obtained from structural analysis with load factor included.

60

When designing a seated connection, top angle must be provided. The LRFD manual suggests that the minimum size be L4x4x1/4. To provide end rotation for the beam, the top angle should be flexible. The electrodes used in this design is E70XX.

Conclusions:

Outstanding leg capacity in kips is as follows: 75

Angle thickness in inches is as follows: 1

The length of the angle legs in inches is as follows: 8x4

Size of the weld in inches is as follows: 0.3125

Steps taken in design:

1. With the beam web thickness and angle length, go to table VI-A to find an angle thickness that will withstand the loading.
2. Use table VI-C to determine the weld size and legs' sizes with given load and angle thickness.

Example 3

Given: Beam simply supported. Beam size: W27x94 Steel: A36
Factored end reaction: 200k Bolts: 7/8 in. A325-N
Holes: 15/16 in. standard

Required: Design a double angle bolted connection.

Figure is similar to example 1.

Solution:

Do you wish to consider some preliminary design parameters?

YES

Is the supply of qualified welders adequate in the region where the structure will be erected?

YES

Is rapid erection time critical?

NO

Is there a possibility that the structure will be disassembled in the future?

NO

Do you wish to use the least amount of steel in the design?

NO

Do you want the joint to be pleasing?

NO

The information you have provided allows you to choose either BOLT or WELD from the following prompt.

Please enter the type of connection design, type WELD for welded seated beam connection, and BOLT for bolted double angle beam connection. Caution: type the words as they appear above, in upper case.

BOLT

Please select the ASTM Structural Steel Specification to be used for the main members. Note: A36 steel is used for detail material.

A36

Please type in the bolt diameter in inches. Use decimal fractions.

.875

A325-N bolt is used. The preferred bolt spacing of 3 inches is used. The bolt spacing is adequate.

What is the depth, in inches, of the cope in the top flange? Use decimal fractions. If the beam is not coped, then type 0. Note: Cope in bottom flange is not considered here.

0

Please enter the beam's end reaction in kips obtained from structural analysis with load factor included.

200

W shapes are hot-rolled shapes which have essentially parallel flange surfaces. If the beam which is being connected is a W shape, please enter W. If it is an American Standard, type C.

W

Please enter the nominal depth of the beam or American Standard. Ex.: W21x62, nominal depth is 21.

27

Please enter the unit weight of the beam or American Standard. Ex.: W21x62, 62 is the unit weight.

94

Shearing capacity of the bolts is O.K.

Capacity is governed by net shear on angles for lengths L. For reduced value see TABLE II-C. (L.R.F.D. manual, p.5-28, TABLE II-A, Note: c)

the angle thickness in inches is: 0.375

Please enter the beam web setback from the face of the angles. Use decimal fractions.

.5

Please enter the distance in inches between the row of bolts' holes in the web and the end of the beam web.

2

The shearing capacity of the connection angles is insufficient. The length of the angle is increased by 3 inches, and one more bolt is added.

Shear capacity of connection angles is O.K.

Bearing capacity of the beam web is O.K.

Bearing capacity of angles is O.K.

Conclusions:

Edge distance in inches of the top bolt from the top of the angle is as follows: 1.25

Number of bolts is as follows: 6

Angle thickness in inches is as follows: 0.375

Length of angle in inches is as follows: 17.5

Stability during steel erection is as follows: sufficient

The clearance for the angle to be fitted to the beam web is as follows: O.K.

Shear capacity of bolts in kips is as follows: 253

Design shear in kips for connection angles is as follows: 232

Bearing capacity in kips of the beam web is as follows: 268.422

Bearing capacity in kips of the angles is as follows: 383.175

The following value for block shear capacity is the larger of RBS1 or RBS2. RBS1 is the resistance to block shear in kips calculated from the coefficients from table I-G.1, and RBS2 from I-G.2 is as follows:

Calculation of the resistance to block shear is not necessary, because the top flange of the beam is not coped.

Block shear check is as follows: Block shear check is not necessary, because the top flange of the beam is not coped.

The shorter leg of the angle in inches is as follows: 5

Length of the other leg in inches is as follows: 5

Minimum flange width or T distance if beam frames into a column is as follows: 10.49

During the consideration of various preliminary design parameters, the expert system will conclude with the following if the user gives conflicting responses: 'I can not reach a conclusion with the conditions you have given me, therefore pick a choice from the following prompt'. Subsequently the program will ask the user to choose between a double angle bolted connection design or welded seat angle connection design.

In Appendix B, there are fifteen more examples. Two of them are taken from the LRFD manual; eleven of them are made up. One of them is from the Structural Engineering Handbook by Gaylord and Gaylord, and the last one is from Steel Structures by Salmon and Johnson.

Chapter 7

Comparison of CONDSIGN with Other Programs

In order to determine the validity of CONDSIGN, several comparisons were made with three sources of problems. The previous chapter dealt with comparison with text book examples. Another expert system program CONXPRT was used on ten examples, and a programmed code for Hewlett Packard 41CX with a card reader written by Emeritus Professor Harry L. Johnson was used to verify CONDSIGN.

CONXPRT is one of the five knowledge bases available for an expert system shell called DESIGN ADVISOR. This particular CONXPRT knowledge base deals with shear connection designs in LRFD; the other two are in ASD. Another knowledge base contains section properties, and the last one designs composite or non-composite beams. These are commercial software programs developed and maintained by Structural Engineers, Inc., Radford, VA, sponsored by AISC and Steel Deck Institute, Canton, OH.

CONXPRT can design framing angles, single plate or shear tab, and shear end-plate. The framing angle design takes into account bolting and welding on the outstanding legs, the other legs, or both. It also needs to know whether the outstanding legs are connected to a column flange, web, or girder web. Single or double beam copes, bolt stagger, and offset beam elevations are featured. The designer can specify a fixed value or maximum number of bolt rows or maximum angle length. Default values can be set for connection dimensions; the user can define a preferred list of angles and

overstress limits. All limit states checks are performed plus block shear and coped beam web strength.

In CONDSIGN, framing angles and seat angles are designed. The framing angles design is only concerned with bolting on both legs. Overall horizontal dimension of the connection is given so that whatever the outstanding legs are connected to can be compatible; and lengths of the angles are checked to make sure that they can fit into the beam's web. The seat angle design is done with the outstanding leg either bolted or welded to the beam flange. The other leg is welded to the supporting member. Top beam cope can be specified, and block shear together with web strength will be checked. The user is allowed to reduce the angle thickness if it is not critical.

Execution speeds of CONXPRT and CONDSIGN cannot be fairly compared because CONDSIGN is not in its faster runtime form. A separate runtime diskette would have to be purchased from TI in order to build a runtime version of CONDSIGN. As they are, CONXPRT is faster since CONDSIGN's dBASE interface takes time. Because it is commercial software, the knowledge base of CONXPRT is not revealed.

CONXPRT has a color graphics feature that facilitates the visualization of the design. While the diagram is not drawn to scale, it is very helpful. CONDSIGN has no picture; but even if it was incorporated, it would just be a generic one with no interactive facilities. Dr. Halo is the graphics editor which is supposed to be connected with PC Plus, but it was not available.

CONXPRT is not as user friendly as CONDSIGN. The user has to read at least part of the manual (User's, 1992) before he knows how to make it work. CONDSIGN puts each question in an easy to understand way on the screen. All the user has to do is follow very clear instructions to key in the required information in order for the program to design. The shell used to develop CONDSIGN was not built specifically for engineering design; therefore, it lacks certain sophistication.

Ten bolted frame connection design examples which were used to test CONDSIGN earlier were verified with CONXPRT for their integrity. The results were tabulated in Appendix C. All examples have exactly the same results as before. The sizes of the angles and the number of bolts which CONXPRT used were the same as those used by CONDSIGN.

In Appendix D, Prof. Johnson's program was used to check all the examples. Every one tested all right except those beams which were coped had lower block shear capacities from Prof. Johnson's program. This difference was due to Johnson's use of the smaller, more conservative number from the two failure modes, although AISC permits the use of the larger. Since the program is run with a calculator, beam depths, web thickness, etc. have to be input. The output provides the minimum angle thickness for the user to pick the angle.

Chapter 8

Conclusions

8.1 General

Expert systems are claimed to be an emerging technology that will improve the less desirable condition of fragmentation in the computer integration area of the architecture, engineering, and construction industries (Howard, et al., 1989). It takes a long time to fully develop an expert system, because testing the program is very lengthy. PC Plus is well suited to the area of structural design of steel connections, because those design tables fit into the databases quite well, and in the work described herein PC Plus interacted with them without many problems.

It generally takes more time to learn how to build an expert system than to write a FORTRAN application. With the help of ARL, development time has been cut tremendously.

One disadvantage of the prototype expert system is the rather lengthy time it takes to accomplish its tasks. Operation is especially slow during interfaces with dBASE; the activation of dBASE takes about five seconds each time a DBASE-RETRIEVE or DBASE-MRETRIEVE is used. When a database is huge, like the one which contains section properties, the retrieval of data can take a significant amount of time.

In the development of CONDSIGN, the knowledge bases became so large that the computer had problems with running out of memory both in the developmental and testing areas. To incorporate more knowledge, either the computer will have to be upgraded, or

the knowledge bases will have to be divided up into smaller independent modules. Investing in a new version of PC Plus would also be a good idea because CONDSIGN will probably run in a much more efficient manner under the newer computer system architecture or central processing unit.

It is evident that expert systems require large amounts of memory space. That is why work in this area only flourished in recent years, coinciding with the advancement of faster machines with bigger memory. However, not having the latest and the most sophisticated computer is not entirely bad, as the situation forces a person to write more efficient programs instead of relying on the machine to execute the software quicker.

Finally, it should be noted that economics should be taken into consideration in any expert system used for design. A number of factors influence the total cost of a structure including, for example, the weights of the various members as well as the availability of materials or of specialized labor needed to perform certain operations. All of these considerations should be included in the development of an expert system used for structural design. These considerations are included in CONDSIGN.

8.2 Future Development

Future development of this project would logically be in the area of self learning, one of the most important features in artificial intelligence. Self learning is what sets artificial intelligence and, in

turn, expert systems apart from conventional computer programs. Just as a design engineer learns from his or her years working in a particular area, an expert system should also evolve and improve. There are basically two types of learned knowledge: successful designs and mistakes. A design engineer keeps previous designs and drawings so that at a later date when he may come across a similar situation, he will be able to save time by relying on the previous design. Similarly, as new information resulting from successful designs or mistakes becomes available, this information can be incorporated into the expert system database so that the ability of the expert system to perform its function is enhanced.

There are different ways to make a program learn. In this particular expert system (CONDSIGN), database files can be used to store both design information and results. Correct designs and errors can be stored in separate files. Then, every time a piece of new information is given by the user, the program will compare it to those in the database files. When a data point is matched up with one in the error file, the program will warn the user that certain designs do not work. If similarity is found with the other database file, then possible solutions will be presented. This is just one illustration of where self learning might be achieved. More research has to be done to find out other possible ways to enhance learning and to identify the most effective means of developing efficient and useful expert systems.

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APPENDICES

APPENDIX A

Knowledge Bases & Databases

CONDSIGN.LKB is a program listing of CONDSIGN. ANTECEDE.LKB is an earlier version of CONDSIGN. ANTECEDE.TRC is the trace of a particular run of ANTECEDE.LKB. Various database files follows and the description of a particular testing session.

File: CONDSIGN.LKB

DOMAIN :: "Design of Partially Restrained Steel Connections"
ROOT FRAME :: CONNECTION

Global KB data

FRAME STRUCTURE ::
CONNECTION
SEATED
BOLTED

KB Files :: (BOLTED CONDSIGN.k1 SEATED CONDSIGN.k2)
Parameter groups :: (SEATED-PARMS CONNECTION-PARMS)
Rule groups :: (BOLTED-RULES SEATED-RULES CONNECTION-RULES META-RULES)
Number of rules :: 77
Number of meta-rules :: 41
Variables :: (DOMAIN)
TEXTAGS :: ()
Functions :: ()

VARIABLES

DOMAIN
VALUE :: "Design of Partially Restrained Steel Connections"

ANTECEDENT-IN :: (SREFMARK RULE020 RULE021)

=====

CONNECTION-RULES

=====

RULE020

=====

SUBJECT :: CONNECTION-RULES
ANTECEDENT :: YES
IF :: (TYPECONN = WELD OR FASTENER = welding)
THEN :: (CONSIDERFRAME SEATED AND TYPECONN = WELD)

RULE021

=====

SUBJECT :: CONNECTION-RULES
ANTECEDENT :: YES
IF :: (TYPECONN = BOLT OR FASTENER = high-strength bolts)
THEN :: (CONSIDERFRAME BOLTED AND TYPECONN = BOLT)

RULE050

=====

SUBJECT :: CONNECTION-RULES
EXPLANATION :: (Although field bolting is very fast, and less skilled
labor is involved compared to welding; the high-strength bolts are expensive.)
IF :: ((! SKILLED AND RAPID AND DISASSEM AND ! LEAST AND ! BEAUTY) OR
(SKILLED AND RAPID AND DISASSEM AND ! LEAST AND ! BEAUTY) OR (! SKILLED
AND RAPID AND ! DISASSEM AND ! LEAST AND ! BEAUTY) OR (SKILLED AND
RAPID AND ! DISASSEM AND ! LEAST AND ! BEAUTY) OR (! SKILLED AND ! RAPID
AND DISASSEM AND ! LEAST AND ! BEAUTY) OR (SKILLED AND ! RAPID AND
DISASSEM AND ! LEAST AND ! BEAUTY) OR (! SKILLED AND ! RAPID AND !
DISASSEM AND ! LEAST AND ! BEAUTY))
THEN :: (FASTENER = "high-strength bolts" AND PRINT "The information you have given
me suggests that high-strength bolts should be used in a bolted double angle connection design.")

RULE051

=====

SUBJECT :: CONNECTION-RULES
IF :: ((SKILLED AND ! RAPID AND ! DISASSEM AND LEAST AND BEAUTY) OR (
SKILLED AND ! RAPID AND ! DISASSEM AND ! LEAST AND BEAUTY) OR
(SKILLED AND ! RAPID AND ! DISASSEM AND LEAST AND ! BEAUTY))
THEN :: (FASTENER = "welding" AND PRINT "The information you have given
me suggests that a welded seated connection design is suitable.")

RULE053

=====

SUBJECT :: CONNECTION-RULES
ANTECEDENT :: YES
IF :: (SKILLED AND ! RAPID AND ! DISASSEM AND ! LEAST AND ! BEAUTY)
THEN :: (PRINT "The information you have provided allows you to choose either BOLT or WELD
from the following prompt." AND FASTENER = "high-strength bolts or welding")

RULE054

=====

SUBJECT :: CONNECTION-RULES

IF :: (FASTENER IS NOTKNOWN)

THEN :: (PRINT "I can not reach a conclusion with the conditions you have given me, therefore pick
a choice from the following prompt." AND FASTENER = "no particular kind")

=====

META-RULES

=====

MRULE040

=====

SUBJECT :: META-RULES

IF :: (PRELIM)

THEN :: (SET-UTILITY FASTENER 0)

MRULE041

=====

SUBJECT :: META-RULES

IF :: (! PRELIM)

THEN :: (FASTENER = "No preliminary design parameters are considered.
therefore either welding or high-strength bolts can be chosen.")

Frame :: SEATED

IDENTIFIER :: "SEATED-"
TRANSLATION :: (welded seated beam connections)
PARENTS :: (CONNECTION)
GOALS :: (OSL-CAPACI T ANGLE-SIZE WELD-SIZE MIN-SIZE COMPATIB)
INITIALDATA :: (SEAT-CONN ASTM)
PROMPT2ND :: (Do you want to design another welded seated beam
connection?)
DISPLAYRESULTS :: YES
PARMGROUP :: SEATED-PARMS
RULEGROUPS :: (SEATED-RULES)
SEATED-PARMS :: (ANGLE-SIZE ASTM B BC BCA BD BOLTSHEAR BSC C1 C11 C12 C21 C22
CLEAR COMPATIB COPE D DBW DEPTH DN DSG FU FY H2 L LEG LV MIN MIN-
SIZE N OSL OSL-CAPACI R RBS RBS1 RBS2 ROLLED RU S SEAT-CONN SETBACK
STABLE T TF TH THICKER THICKEST THIN TW WEB-THICKN WELD-SIZE WGT XK)
SEATED-RULES :: (RULE003 RULE004 RULE007 RULE008 RULE009 RULE010 RULE011
RULE012 RULE013 RULE014 RULE015 RULE016 RULE017 RULE018 RULE019 RULE047
RULE048 RULE049 RULE057 RULE069 RULE070 RULE071 RULE072 RULE073 RULE074
RULE075)

SEATED-PARMS

ANGLE-SIZE

TRANSLATION :: (The length of the angle legs in inches)
TYPE :: SINGLEVALUED
UPDATED-BY :: (RULE073 RULE074 RULE075 RULE069)
CONTAINED-IN :: (RULE073 RULE074 RULE075 RULE069)

ASTM

TRANSLATION :: (ASTM Structural Steel Specifications)
PROMPT :: (Please select the ASTM Structural Steel Specification to be used for the main members.
Note: A36 steel is used for detail material.)
TYPE :: ASK-ALL
EXPECT :: (A36 A529 A441 A572-GRADE42 A572-GRADE50 A572-GRADE60 A572-GRADE65
A242 A588)
USED-BY :: (RULE037 RULE033)
ACTIVE-VALUE :: (DO-ALL (DBASE-MRETRIEVE FY "1" (QUAL ASTM = ASTM) FY
FU "1" (QUAL ASTM = ASTM) FU))

B

=

TRANSLATION :: (Design loads in kips for bearing)
TYPE :: SINGLEVALUED

CONTAINED-IN :: (RULE006 RULE036 RULE060 RULE030 SREFMARK RULE029)

BC

==

TRANSLATION :: (Bearing capacity in kips of the beam web)

TYPE :: SINGLEVALUED

UPDATED-IN :: (RULE030 SREFMARK RULE023 RULE029)

ANTECEDENT-IN :: (RULE022 SREFMARK RULE023)

BCA

==

TRANSLATION :: (Bearing capacity in kips of the angles with lv as the edge distance)

TYPE :: SINGLEVALUED

UPDATED-IN :: (RULE030 SREFMARK RULE025 RULE029)

ANTECEDENT-IN :: (RULE024 SREFMARK RULE025)

BD

==

TRANSLATION :: (bearing design load in kips)

TYPE :: SINGLEVALUED

CONTAINED-IN :: (RULE006 RULE036 RULE060 RULE030 SREFMARK RULE029)

BOLTSHEAR

=====

TRANSLATION :: (shear capacity of bolts in kips)

TYPE :: SINGLEVALUED

UPDATED-IN :: (SREFMARK RULE044 RULE066 RULE056)

ANTECEDENT-IN :: (RULE043 SREFMARK RULE044)

USED-BY :: (RULE037 RULE033)

CONTAINED-IN :: (RULE006 RULE036 RULE060 RULE030)

BSC

==

TRANSLATION :: (block shear check)

TYPE :: SINGLEVALUED

UPDATED-BY :: (RULE006)

UPDATED-IN :: (RULE042 RULE046)

C1

==

TRANSLATION :: (clearance c1 in inches according to the "assembling
clearances" table in L.R.F.D. manual on page 5-164)

TYPE :: SINGLEVALUED

CONTAINED-IN :: (RULE006 RULE036 RULE060 RULE037 RULE033)

C11

==

TRANSLATION :: (COEFFICIENT C1 FROM TABLE I-G.1 IN THE L.R.F.D. MANUAL)

TYPE :: SINGLEVALUED

CONTAINED-IN :: (RULE062)

C12

===

TRANSLATION :: (COEFFICIENT C1 FROM TABLE I-G.2 IN THE L.R.F.D. MANUAL)
TYPE :: SINGLEVALUED
CONTAINED-IN :: (RULE062)

C21

===

TRANSLATION :: (COEFFICIENT C2 FROM TABLE I-G.1 IN THE L.R.F.D. MANUAL)
TYPE :: SINGLEVALUED
CONTAINED-IN :: (RULE062)

C22

===

TRANSLATION :: (COEFFICIENT C2 FROM TABLE I-G.2 IN THE L.R.F.D. MANUAL)
TYPE :: SINGLEVALUED
CONTAINED-IN :: (RULE062)

CLEAR

=====

TRANSLATION :: (the clearance for the angle to be fitted to the beam web)
TYPE :: SINGLEVALUED
UPDATED-BY :: (RULE068)
UPDATED-IN :: (RULE063 RULE027)

COMPATIB

=====

TRANSLATION :: (COMPATIBILITY CHECK OF THE WELD SIZE TO THE THINNER PART
JOINED)
TYPE :: SINGLEVALUED
UPDATED-BY :: (RULE047 RULE049 RULE048)

COPED

=====

TRANSLATION :: (coped top flange in inches)
PROMPT :: (What is the depth, in inches, of the cope in the top flange? Use decimal fractions. If the
beam is not coped, then type 0. Note: Cope in bottom flange is not considered here.)
TYPE :: SINGLEVALUED
EXPECT :: NUMBER
USED-BY :: (RULE038 RULE006 RULE036 RULE060)
RANGE :: (0 2)

D

=

TRANSLATION :: (bolt diameter)
PROMPT :: (Please type in the bolt diameter in inches. Use decimal fractions.)
TYPE :: SINGLEVALUED
EXPECT :: POSITIVE-NUMBER
ANTECEDENT-IN :: (RULE028 RULE064 RULE065)
USED-BY :: (RULE036 RULE060 RULE037 RULE033)
CONTAINED-IN :: (RULE038 RULE006 RULE036 RULE060 RULE030 RULE062
RULE037 RULE033 SREFMARK RULE066 RULE056)
RANGE :: (0.75 1)

ACTIVE-VALUE :: (DO-ALL (DBASE-MRETRIEVE ROLLED "j3_7" (QUAL D = D) ROLLED
LV "j3_7" (QUAL D = D) SHEARED) (MPRINTT "A325-N bolt is used. The
preferred bolt spacing of 3 inches is used."))

DBW

===

TRANSLATION :: (distance in inches between bolts and edge of beam web)

PROMPT :: (Please enter the distance in inches between the row of
bolts' holes in the web and the end of the beam web.)

TYPE :: SINGLEVALUED

EXPECT :: POSITIVE-NUMBER

RANGE :: (2 3)

CONTAINED-IN :: (RULE006 RULE036 RULE060 RULE062)

DEPTH

===

TRANSLATION :: (the d distance in inches from the W shapes dimensions table in the L.R.F.D.
manual)

TYPE :: SINGLEVALUED

CONTAINED-IN :: (RULE006 RULE036 RULE060)

DN

===

TRANSLATION :: (designation)

PROMPT :: (Please enter the nominal depth of the beam or American
Standard. Ex.: W21*62, nominal depth is 21.)

TYPE :: SINGLEVALUED

EXPECT :: INTEGER

CONTAINED-IN :: (RULE006 RULE036 RULE060 RULE070 RULE004)

RANGE :: (4 40)

DSG

===

TRANSLATION :: (designation of beam's shape)

PROMPT :: (W shapes are hot-rolled shapes which have essentially parallel flange surfaces. If the
beam which is being connected is a W shape, please enter W. If it is an American Standard,
type C.)

TYPE :: SINGLEVALUED

EXPECT :: SINGLE-LINE-INPUT

CONTAINED-IN :: (RULE006 RULE036 RULE060 RULE070 RULE004)

FU

===

TRANSLATION :: (Specified minimum tensile strength in k.s.i. of the type of steel being used)

TYPE :: SINGLEVALUED

EXPECT :: POSITIVE-NUMBER

ANTECEDENT-IN :: (RULE072)

RANGE :: (58 80)

CONTAINED-IN :: (RULE006 RULE036 RULE060)

FY

===

TRANSLATION :: (yield strength of steel)
TYPE :: SINGLEVALUED
EXPECT :: POSITIVE-NUMBER
ANTECEDENT-IN :: (RULE057 RULE072)
USED-BY :: (RULE070 RULE004)
RANGE :: (36 65)

H2

==

TRANSLATION :: (clearance h2 in inches according to the "assembling
clearances" table in the L.R.F.D. manual on page 5-164)
TYPE :: SINGLEVALUED
CONTAINED-IN :: (RULE006 RULE036 RULE060 RULE037 RULE033)

L

=

TRANSLATION :: (length of angle in inches)
PROMPT :: (Enter 6 or 8 for the length of the angle in inches. (Length of angle perpendicular to beam
web))
TYPE :: SINGLEVALUED
EXPECT :: POSITIVE-NUMBER
UPDATED-IN :: (RULE030 SREFMARK RULE066 RULE056)
ANTECEDENT-IN :: (RULE063 RULE055 RULE027 SREFMARK RULE066 RULE056)
USED-BY :: (RULE062 RULE068)
CONTAINED-IN :: (RULE006 RULE036 RULE060 RULE030 RULE070 RULE004
SREFMARK RULE066 RULE056)
RANGE :: (6 8)

LEG

===

TRANSLATION :: (Length of the other leg in inches)
TYPE :: SINGLEVALUED
UPDATED-BY :: (RULE037 RULE033)
ANTECEDENT-IN :: (RULE058)
CONTAINED-IN :: (RULE037 RULE058 RULE033)

LV

==

TRANSLATION :: (Edge distance in inches of the top bolt from the top of the angle)
TYPE :: SINGLEVALUED
EXPECT :: POSITIVE-NUMBER
UPDATED-BY :: (RULE038)
UPDATED-IN :: (SREFMARK RULE039)
ANTECEDENT-IN :: (SREFMARK RULE039)
USED-BY :: (RULE036 RULE060)
RANGE :: (1.25 1.75)
CONTAINED-IN :: (RULE006 RULE036 RULE060 RULE062)

MIN

===

TRANSLATION :: (Minimum flange width or "T" distance if beam frames into a column)
TYPE :: SINGLEVALUED

UPDATED-BY :: (RULE037 RULE033)
PROCEDURE :: PCS-PRIMOP-STD-N2>
PCS*OPCODE :: 99
PCS*PRIMOP-HANDLER :: #<PROCEDURE PCS-PRIMOP-STD-N2>

MIN-SIZE

TRANSLATION :: (Minimum size of the leg dimension of fillet weld will
be used to attach the seat angle to the beam flange, its dimension in inches)
TYPE :: SINGLEVALUED
UPDATED-BY :: (RULE003 RULE047)
USED-BY :: (RULE049 RULE048)

N

=

TRANSLATION :: (number of bolts)
TYPE :: SINGLEVALUED
UPDATED-BY :: (RULE006 RULE036 RULE060)
UPDATED-IN :: (RULE030 SREFMARK RULE066 RULE056)
CONTAINED-IN :: (RULE006 RULE036 RULE060 RULE030 RULE062 RULE037
RULE033 SREFMARK RULE066 RULE056 RULE029)

OSL

==

TRANSLATION :: (The shorter leg of the angle in inches)
TYPE :: SINGLEVALUED
UPDATED-BY :: (RULE006 RULE036 RULE060)
ANTECEDENT-IN :: (RULE058)
USED-BY :: (RULE073 RULE074 RULE075 RULE069)
CONTAINED-IN :: (RULE058 RULE070 RULE004)

OSL-CAPACI

==

TRANSLATION :: (outstanding leg capacity in kips)
TYPE :: SINGLEVALUED
EXPECT :: POSITIVE-NUMBER
UPDATED-BY :: (RULE070 RULE004)
CONTAINED-IN :: (RULE070 RULE004)
RANGE :: (13.6 102)

R

=

TRANSLATION :: (you do want to reduce the angle thickness by 0.0625 in.
because the shear capacity is not governed by the net shear on angles)
PROMPT :: YES
TYPE :: YES/NO
USED-BY :: (RULE037 RULE033)

RBS

TRANSLATION :: (The following value for block shear capacity is the larger of RBS1 or RBS2.
(RBS1 is the resistance to block shear in kips calculated from the coefficients
from table I-G.1, and RBS2 from I-G.2.))

TYPE :: SINGLEVALUED

UPDATED-BY :: (RULE006 RULE040 RULE041)

ANTECEDENT-IN :: (RULE042 RULE046)

RBS1

TRANSLATION :: (RESISTANCE TO BLOCK SHEAR IN KIPS CALCULATED FROM THE
COEFFICIENTS FROM TABLE I-G.1)

TYPE :: SINGLEVALUED

UPDATED-BY :: (RULE062)

USED-BY :: (RULE040 RULE041)

CONTAINED-IN :: (RULE040)

RBS2

TRANSLATION :: (RESISTANCE TO BLOCK SHEAR IN KIPS CALCULATED FROM THE
COEFFICIENTS FROM TABLE I-G.2)

TYPE :: SINGLEVALUED

UPDATED-BY :: (RULE062)

USED-BY :: (RULE040 RULE041)

CONTAINED-IN :: (RULE041)

ROLLED

TRANSLATION :: (MINIMUM EDGE DISTANCE IN INCHES MEASURED FROM THE
LONGITUDINAL EDGE OF THE OUTSTANDING LEG OF THE ANGLE
TO THE CENTER LINE OF THE ROW OF HOLES)

TYPE :: SINGLEVALUED

EXPECT :: POSITIVE-NUMBER

CONTAINED-IN :: (RULE006 RULE036 RULE060 RULE037 RULE033)

RANGE :: (0.75 1.625)

RU

TRANSLATION :: (factored end reaction)

PROMPT :: (Please enter the beam's end reaction in kips obtained from
structural analysis with load factor included.)

TYPE :: SINGLEVALUED

EXPECT :: POSITIVE-NUMBER

ANTECEDENT-IN :: (RULE043 RULE024 RULE057 RULE042 RULE046 RULE030
RULE022 SREFMARK RULE023 RULE044 RULE025 RULE029)

USED-BY :: (RULE037 RULE033)

CONTAINED-IN :: (RULE006 RULE036 RULE060 RULE070 RULE004 RULE073
RULE074 RULE075 RULE069)

RANGE :: (0 551)

S

TRANSLATION :: (Design shear in kips for connection angles)

TYPE :: SINGLEVALUED
UPDATED-BY :: (RULE037 RULE033)
UPDATED-IN :: (SREFMARK RULE029)
ANTECEDENT-IN :: (RULE030 SREFMARK RULE029)
CONTAINED-IN :: (RULE030 SREFMARK RULE029)

SEAT-CONN

TRANSLATION :: (Connection between beam flange and seat angle.)
PROMPT :: (Is the seat angle welded to the beam flange?)
TYPE :: YES/NO
USED-BY :: (RULE003 RULE047)

SETBACK

TRANSLATION :: (the beam web setback from the face of the angles in inches which framing angles extend out from the beam web for easy fitting of members together during steel erection)
PROMPT :: (Please enter the beam web setback from the face of the angles. Use decimal fractions.)
TYPE :: SINGLEVALUED
EXPECT :: POSITIVE-NUMBER
RANGE :: (0.5 1)
CONTAINED-IN :: (RULE006 RULE036 RULE060)

STABLE

TRANSLATION :: (stability during steel erection)
TYPE :: SINGLEVALUED
UPDATED-IN :: (RULE055)

T

=

TRANSLATION :: (angle thickness in inches)
TYPE :: SINGLEVALUED
UPDATED-BY :: (RULE037)
ANTECEDENT-IN :: (RULE028)
USED-BY :: (RULE007 RULE008)
CONTAINED-IN :: (RULE007 RULE008 RULE006 RULE036 RULE060 RULE030 RULE037
RULE058 RULE033 RULE070 RULE004 RULE073 RULE074 RULE075 RULE069
SREFMARK RULE029)

TF

=

TRANSLATION :: (Flange thickness in inches.)
TYPE :: SINGLEVALUED
USED-BY :: (RULE007 RULE008)
CONTAINED-IN :: (RULE007 RULE008 RULE070 RULE004)

TH

=

TRANSLATION :: (The T value in inches in the W SHAPES Dimensions' table of the LRFD manual under the "Distance" column)
TYPE :: SINGLEVALUED

EXPECT :: POSITIVE-NUMBER
UPDATED-BY :: (RULE006 RULE036 RULE060)
ANTECEDENT-IN :: (RULE063 RULE055 RULE027 SREFMARK RULE066 RULE056)
USED-BY :: (RULE062 RULE068)
RANGE :: (2.75 33.75)

THICKER

TRANSLATION :: (Material Thickness of Thicker Part Joined in inches.)
TYPE :: SINGLEVALUED
UPDATED-BY :: (RULE007 RULE008)
USED-BY :: (RULE011 RULE009 RULE010 RULE012)

THICKEST

TRANSLATION :: (Material Thickness of Thicker Part Joined in inches.)
TYPE :: SINGLEVALUED
UPDATED-BY :: (RULE011 RULE009 RULE010 RULE012)
CONTAINED-IN :: (RULE003)

THIN

TRANSLATION :: (THE THICKNESS IN INCHES OF THE THINNER PART JOINED)
TYPE :: SINGLEVALUED
UPDATED-BY :: (RULE007 RULE008)
USED-BY :: (RULE049 RULE048)

TW

TRANSLATION :: (thickness of the beam web in inches)
TYPE :: SINGLEVALUED
EXPECT :: POSITIVE-NUMBER
ANTECEDENT-IN :: (RULE071)
USED-BY :: (RULE013 RULE014 RULE015 RULE016 RULE017 RULE018 RULE019)
RANGE :: (0.1875 0.5625)
CONTAINED-IN :: (RULE006 RULE036 RULE060 RULE030 RULE062 RULE037
RULE033 RULE070 RULE004 SREFMARK RULE029)

WEB-THICKN

TRANSLATION :: (thickness of the beam's web)
TYPE :: SINGLEVALUED
UPDATED-BY :: (RULE013 RULE014 RULE015 RULE016 RULE017 RULE018 RULE019)
CONTAINED-IN :: (RULE070 RULE004)

WELD-SIZE

TRANSLATION :: (size of the weld in inches)
TYPE :: SINGLEVALUED
UPDATED-BY :: (RULE075 RULE069)
CONTAINED-IN :: (RULE073 RULE074 RULE075 RULE069)

WGT

=====

TRANSLATION :: (unit weight in lb. per ft.)

PROMPT :: (Please enter the unit weight of the beam or American Standard. Ex.: W21*62, 62 is the unit weight.)

TYPE :: SINGLEVALUED

EXPECT :: INTEGER

CONTAINED-IN :: (RULE006 RULE036 RULE060 RULE070 RULE004)

RANGE :: (9 848)

XK

=====

TRANSLATION :: (The k distance in inches from the W shapes dimensions table in the L.R.F.D. manual)

TYPE :: SINGLEVALUED

CONTAINED-IN :: (RULE006 RULE036 RULE060)

=====

SEATED-RULES

=====

RULE003

=====

SUBJECT :: SEATED-RULES

IF :: (SEAT-CONN)

THEN :: (MIN-SIZE = (DBASE-RETRIEVE "j2-5" (QUAL THICKNESS = THICKEST)
MIN_SIZE))

RULE004

=====

SUBJECT :: SEATED-RULES

EXPLANATION :: (5/16 in. welds or smaller are single pass welds, they
are more economical than the heavier welds.)

IF :: (FY = 36)

THEN :: (DBASE-MRETRIEVE TW "aisc1" (QUAL DSG = DSG AND DN = DN AND WGT =
WGT) TW TF "aisc1" (QUAL DSG = DSG AND DN = DN AND WGT = WGT) TF AND
OSL-CAPACI = OSL-CAPACI AND DBASE-MRETRIEVE OSL-CAPACI "vi-a" (QUAL L = L
AND OSL_CAPACI >= RU AND WEB_THICKN = WEB-THICKN) OSL_CAPACI T "vi-a"
(QUAL L = L AND OSL_CAPACI >= RU AND WEB_THICKN = WEB-THICKN) T OSL "vi-
a" (QUAL L = L AND OSL_CAPACI >= RU AND WEB_THICKN = WEB-THICKN) OSL
AND PRINT "When designing a seated connection, top angle must be provided. The LRFD
manual suggests that the minimum size be L4x4x1/4. To provide end rotation for the beam, the
top angle should be flexible. The electrodes used in this design is E70XX. The return of the
weld has to be at least twice the size of the weld.")

RULE007

=====

SUBJECT :: SEATED-RULES

IF :: (TF > T)

THEN :: (THICKER = (TF + 0) AND THIN = (T + 0))

RULE008

=====

SUBJECT :: SEATED-RULES

IF :: (TF <= T)

THEN :: (THICKER = (T + 0) AND THIN = (TF + 0))

RULE009

=====

SUBJECT :: SEATED-RULES

IF :: (THICKER <= 0.25)

THEN :: (THICKEST = To 1/4 inclusive)

RULE010

=====

SUBJECT :: SEATED-RULES

IF :: (THICKER > 0.25 AND THICKER <= 0.5)

THEN :: (THICKEST = Over 1/4 to 1/2)

RULE011

=====

SUBJECT :: SEATED-RULES

IF :: (THICKER > 0.5 AND THICKER <= 0.75)

THEN :: (THICKEST = Over 1/2 to 3/4)

RULE012

=====

SUBJECT :: SEATED-RULES

IF :: (THICKER > 0.75)

THEN :: (THICKEST = Over 3/4)

RULE013

=====

SUBJECT :: SEATED-RULES

IF :: (TW >= 0.345 AND TW <= 0.405)

THEN :: (WEB-THICKN = 0.375)

RULE014

=====

SUBJECT :: SEATED-RULES

IF :: (TW >= 0.535 AND TW <= 0.59)

THEN :: (WEB-THICKN = 0.565)

RULE015

=====

SUBJECT :: SEATED-RULES

IF :: (TW >= 0.47 AND TW <= 0.53)

THEN :: (WEB-THICKN = 0.5)

RULE016

=====

SUBJECT :: SEATED-RULES

IF :: (TW >= 0.415 AND TW <= 0.46)

THEN :: (WEB-THICKN = 0.44)

RULE017

=====

SUBJECT :: SEATED-RULES

IF :: (TW >= 0.285 AND TW <= 0.34)

THEN :: (WEB-THICKN = 0.31)

RULE018

=====

SUBJECT :: SEATED-RULES

IF :: (TW >= 0.22 AND TW <= 0.28)

THEN :: (WEB-THICKN = 0.25)

RULE019

=====

SUBJECT :: SEATED-RULES

IF :: (TW >= 0.17 AND TW <= 0.2)

THEN :: (WEB-THICKN = 0.19)

RULE047

=====

SUBJECT :: SEATED-RULES

IF :: (! SEAT-CONN)

THEN :: (MIN-SIZE = "it is not required to determine this value, because the beam flange is bolted to the seat angle." AND COMPATIB = "not necessary, because the beam flange is bolted to the seat angle.")

RULE048

=====

SUBJECT :: SEATED-RULES

IF :: (MIN-SIZE <= THIN)

THEN :: (COMPATIB = 0.K..)

RULE049

=====

SUBJECT :: SEATED-RULES

IF :: (MIN-SIZE > THIN)

THEN :: (COMPATIB = "weld size larger than the thinner part joined; this is permitted if required by calculated strength.")

RULE057

=====

SUBJECT :: SEATED-RULES

ANTECEDENT :: YES

IF :: ((RU > 102 AND FY = 36) OR (RU > 128 AND FY = 50))

THEN :: (PRINT "The tables used in this design can not handle such high factored loading. For $F_y = 36$ k.s.i., maximum Outstanding Leg Capacity is 102 kips. For $F_y = 50$ k.s.i., maximum Outstanding Leg Capacity is 128 kips.")

RULE069

=====

SUBJECT :: SEATED-RULES

IF :: (OSL = 3.5or4)

THEN :: (ANGLE-SIZE = "angle can not be found" AND WELD-SIZE = "weld size can not be found" AND DBASE-MRETRIEVE ANGLE-SIZE "vi-c" (QUAL CAPACITY >= RU AND MAX_THICK >= T AND MIN_THICK <= T) ANGLE_SIZE WELD-SIZE "vi-c" (QUAL CAPACITY >= RU AND MAX_THICK >= T AND MIN_THICK <= T) WELD_SIZE)

RULE070

SUBJECT :: SEATED-RULES

IF :: (FY = 50)

THEN :: (DBASE-MRETRIEVE TW "aiscl" (QUAL DSG = DSG AND DN = DN AND WGT = WGT) TW TF "aiscl" (QUAL DSG = DSG AND DN = DN AND WGT = WGT) TF AND OSL-CAPACI = OSL-CAPACI AND DBASE-MRETRIEVE OSL-CAPACI "vi-b" (QUAL L = L AND OSL_CAPACI >= RU AND WEB_THICKN = WEB-THICKN) OSL_CAPACI T "vi-b" (QUAL L = L AND OSL_CAPACI >= RU AND WEB_THICKN = WEB-THICKN) T OSL "vi-b" (QUAL L = L AND OSL_CAPACI >= RU AND WEB_THICKN = WEB-THICKN) OSL AND PRINT "When designing a seated connection, top angle must be provided. The LRFD manual suggests that the minimum size be L4x4x1/4. To provide end rotation for the beam, the top angle should be flexible. The electrodes used in this design is E70XX. The return of the weld has to be at least twice the size of the weld.")

RULE071

SUBJECT :: SEATED-RULES

ANTECEDENT :: YES

IF :: (TW > 0.59)

THEN :: (PRINT " The web thickness of the beam is greater than 0.59 inch. The welded seat angle connections are usually found in light structures, because it can not withstand huge loads. Please press the F2 button and choose NEW START to redesign the connection, and select a smaller section.")

RULE072

SUBJECT :: SEATED-RULES

ANTECEDENT :: YES

IF :: (FY != 36 AND FU != 65)

THEN :: (PRINT "Fy is not 36 or 50 k.s.i., please press the F2 button now and select NEW START to choose an appropriate steel type.")

RULE073

SUBJECT :: SEATED-RULES

IF :: (OSL = 4)

THEN :: (ANGLE-SIZE = "For weld size less than 0.3125 inch, an angle can not be found." AND DBASE-MRETRIEVE ANGLE-SIZE "vi-c" (QUAL CAPACITY >= RU AND MAX_THICK >= T AND MIN_THICK <= T AND WELD_SIZE <= 0.3125 AND ANGLE_SIZE >= "6*4") ANGLE_SIZE WELD-SIZE "vi-c" (QUAL CAPACITY >= RU AND MAX_THICK >= T AND MIN_THICK <= T AND WELD_SIZE <= 0.3125 AND ANGLE_SIZE >= "6*4") WELD_SIZE)

RULE074

SUBJECT :: SEATED-RULES

IF :: (OSL = 3.5or4)

THEN :: (ANGLE-SIZE = "For weld size less than 0.3125 inch, an angle can not be found." AND
DBASE-MRETRIEVE ANGLE-SIZE "vi-c" (QUAL CAPACITY >= RU AND MAX_THICK
>= T AND MIN_THICK <= T AND WELD_SIZE <= 0.3125) ANGLE_SIZE WELD-SIZE "vi-
c" (QUAL CAPACITY >= RU AND MAX_THICK >= T AND MIN_THICK <= T AND
WELD_SIZE <= 0.3125) WELD_SIZE)

RULE075

SUBJECT :: SEATED-RULES

IF :: (OSL = 4)

THEN :: (ANGLE-SIZE = "angle can not be found" AND WELD-SIZE = "weld size can not be
found" AND DBASE-MRETRIEVE ANGLE-SIZE "vi-c" (QUAL CAPACITY >= RU AND
MAX_THICK >= T AND MIN_THICK <= T AND ANGLE_SIZE >= "6*4") ANGLE_SIZE
WELD-SIZE "vi-c" (QUAL CAPACITY >= RU AND MAX_THICK >= T AND MIN_THICK
<= T AND ANGLE_SIZE >= "6*4") WELD_SIZE)

=====
Frame :: BOLTED
=====

IDENTIFIER :: "BOLTED-"
TRANSLATION :: (Design of bolted double angle connection.)
PARENTS :: (CONNECTION)
GOALS :: (LV N T L STABLE CLEAR BOLTSHEAR S BC BCA RBS BSC OSL LEG MIN)
INITIALDATA :: (ASTM D)
PROMPT2ND :: (Do you want to design another bolted double angle connection?)
DISPLAYRESULTS :: YES
PARMGROUP :: SEATED-PARMS
RULEGROUPS :: (BOLTED-RULES)
SEATED-PARMS :: (ANGLE-SIZE ASTM B BC BCA BD BOLTSHEAR BSC C1 C11 C12
C21 C22 CLEAR COMPATIB COPE D DBW DEPTH DN DSG FU FY
H2 L LEG LV MIN MIN-SIZE N OSL OSL-CAPACI R RBS RBS1
RBS2 ROLLED RU S SEAT-CONN SETBACK STABLE T TF TH
THICKER THICKEST THIN TW WEB-THICKN WELD-SIZE WGT XK)
BOLTED-RULES :: (RULE006 RULE022 RULE023 RULE024 RULE025 RULE027 RULE028
RULE029 RULE030 RULE033 RULE036 RULE037 RULE039 RULE040
RULE041 RULE042 RULE043 RULE044 RULE046 RULE055 RULE056
RULE058 RULE060 RULE062 RULE063 RULE064 RULE065 RULE066 RULE068)
=====

BOLTED-RULES
=====

RULE006
=====

SUBJECT :: BOLTED-RULES

IF :: (COPE D = 0)

THEN :: (N = DATA-FROM-TABLE AND DBASE-MRETRIEVE BOLTSHEAR "ii-a" (QUAL
BOLTTYPE = "A325-N" AND D = D AND BOLTSHEAR >= RU) BOLTSHEAR "ii-a" (QUAL
BOLTTYPE = "A325-N" AND D = D AND BOLTSHEAR >= RU) N T "ii-a" (QUAL
BOLTTYPE = A325-N AND D = D) T L "ii-a" (QUAL BOLTTYPE = "A325-N" AND D = D
AND BOLTSHEAR >= RU) L B "I-E" (QUAL FU = FU AND D = D) B TW "AISC1" (QUAL
DSG = DSG AND DN = DN AND WGT = WGT) TW DEPTH "AISC1" (QUAL DSG = DSG
AND DN = DN AND WGT = WGT) D XK "AISC1" (QUAL DSG = DSG AND DN = DN
AND WGT = WGT) XK BD "I-F" (QUAL FU = FU AND LV = LV) BD H2 "assembli" (QUAL
D = D) H2 C1 "assembli" (QUAL D = D) C1 AND TH = (DEPTH - (2 * XK)) AND PRINT "the
angle thickness in inches is:" T AND OSL = ((SETBACK + DBW) + ROLLED) AND RBS =
"calculation of the resistance to block shear is not necessary, because the top flange of the beam is
not coped" AND BSC = "block shear check is not necessary, because the top flange of the beam
is not coped")

RULE022
=====

SUBJECT :: BOLTED-RULES

ANTECEDENT :: YES

IF :: (BC >= RU)

THEN :: (PRINT Bearing capacity of the beam web is O.K.)

RULE023

SUBJECT :: BOLTED-RULES

ANTECEDENT :: YES

IF :: $(BC < RU)$

THEN :: $(BC = \text{"inadequate"})$ AND PRINT "The bearing capacity of the bolt(s) is not adequate for the loading, please press the F2 key and select NEW START to redesign the connection.")

RULE024

SUBJECT :: BOLTED-RULES

ANTECEDENT :: YES

IF :: $(BCA \geq RU)$

THEN :: (PRINT Bearing Capacity of Angles is O.K.)

RULE025

SUBJECT :: BOLTED-RULES

ANTECEDENT :: YES

IF :: $(BCA < RU)$

THEN :: (PRINT "Bearing capacity is inadequate, please press F2 key and select NEW START to redesign the connection." AND $BCA = \text{INADEQUATE}$)

RULE027

SUBJECT :: BOLTED-RULES

ANTECEDENT :: YES

IF :: $(L \leq TH)$

THEN :: (CLEAR = O.K.)

RULE028

SUBJECT :: BOLTED-RULES

ANTECEDENT :: YES

IF :: $(D = 0.875 \text{ AND } T = 0.375)$

THEN :: (PRINT "Capacity is governed by net shear on angles for lengths
L. For reduced value see Table II-C. (L.R.F.D. manual, p.5-28, TABLE II-A, Notes: c)")

RULE029

SUBJECT :: BOLTED-RULES

ANTECEDENT :: YES

DOBEFORE :: (76)

IF :: $(S \geq RU)$ AND $((1.5 * D) < LV \text{ OR } \text{COPED} = 0)$

THEN :: (PRINT "Shear Capacity of Connection angles is O.K." AND $BC = (N * B) * TW$) AND $BCA = ((2 * T) * (((N - 1) * B) + BD))$ AND $S = (S + 0)$)

RULE030

SUBJECT :: BOLTED-RULES

ANTECEDENT :: YES

DOBEFORE :: (77)

IF :: $(S < RU)$ AND $((1.5 * D) < LV \text{ OR } \text{COPED} = 0)$

THEN :: (PRINT "The shearing capacity of the connection angles is insufficient. The length of the angle is increased by 3 inches, and one more bolt is added." AND N = (N + 1) AND DBASE-MRETRIEVE BOLTSHEAR "II-A" (QUAL BOLTTYPE = "A325-N" AND D = D AND N = N) BOLTSHEAR S "II-C" (QUAL D = D AND T = T AND N = N) S AND BC = ((N * B) * TW) AND BCA = ((2 * T) * ((N - 1) * B) + BD)) AND L = (L + 3))

RULE033

SUBJECT :: BOLTED-RULES

DOBEFORE :: (37)

IF :: (((D != 0.875 OR (BOLTSHEAR - RU) > 50) AND ! R) OR (BOLTSHEAR - RU) <= 50) AND ASTM = A36)

THEN :: (S = (DBASE-RETRIEVE ii-c (QUAL D = D AND T = T AND N = N) S) AND LEG = ((T + C1) + H2) + ROLLED) AND MIN = ((LEG * 2) + TW))

RULE036

SUBJECT :: BOLTED-RULES

IF :: (COPEL > 0 AND (1.5 * D) <= LV)

THEN :: (N = DATA-FROM-TABLE AND DBASE-MRETRIEVE BOLTSHEAR "ii-a" (QUAL BOLTTYPE = "A325-N" AND D = D AND BOLTSHEAR >= RU) BOLTSHEAR N "ii-a" (QUAL BOLTTYPE = "A325-N" AND D = D AND BOLTSHEAR >= RU) N T "ii-a" (QUAL BOLTTYPE = A325-N AND D = D) T L "ii-a" (QUAL BOLTTYPE = "A325-N" AND D = D AND BOLTSHEAR >= RU) L B "I-E" (QUAL FU = FU AND D = D) B TW "AISC1" (QUAL DSG = DSG AND DN = DN AND WGT = WGT) TW DEPTH "AISC1" (QUAL DSG = DSG AND DN = DN AND WGT = WGT) D XK "AISC1" (QUAL DSG = DSG AND DN = DN AND WGT = WGT) XK BD "I-F1" (QUAL FU = FU AND D = D AND D1_5 <= LV) BD H2 "assembli" (QUAL D = D) H2 C1 "assembli" (QUAL D = D) C1 AND TH = (DEPTH - (2 * XK)) AND PRINT "the angle thickness in inches is:" T AND OSL = ((SETBACK + DBW) + ROLLED))

RULE037

SUBJECT :: BOLTED-RULES

IF :: ((D != 0.875 OR (BOLTSHEAR - RU) > 50) AND R AND ASTM = A36)

THEN :: (T = (T - 0.0625) AND S = (DBASE-RETRIEVE "ii-c" (QUAL D = D AND T = T AND N = N) S) AND LEG = (((T + C1) + H2) + ROLLED) AND MIN = ((LEG * 2) + TW))

RULE039

SUBJECT :: BOLTED-RULES

ANTECEDENT :: YES

DESCRIPTION :: (For LV = 1.5 and 1.75, in a double angle connection, LV can be 1.25.)

IF :: (LV = 1.5 OR LV = 1.75)

THEN :: (LV = 1.25)

RULE040

SUBJECT :: BOLTED-RULES

IF :: (RBS1 >= RBS2)

THEN :: (RBS = (RBS1 + 0))

RULE041

=====

SUBJECT :: BOLTED-RULES
IF :: (RBS1 < RBS2)
THEN :: (RBS = (RBS2 + 0))

RULE042

=====

SUBJECT :: BOLTED-RULES
ANTECEDENT :: YES
IF :: (RBS >= RU)
THEN :: (BSC = O.K.)

RULE043

=====

SUBJECT :: BOLTED-RULES
ANTECEDENT :: YES
IF :: (BOLTSHEAR >= RU)
THEN :: (PRINT SHEARING CAPACITY OF THE BOLTS IS O.K.)

RULE044

=====

SUBJECT :: BOLTED-RULES
ANTECEDENT :: YES
IF :: (BOLTSHEAR < RU)
THEN :: (PRINT "Shearing capacity of the bolts is not sufficient, please press the F2 key and select
NEW START to redesign the connection." AND BOLTSHEAR = INADEQUATE)

RULE046

=====

SUBJECT :: BOLTED-RULES
ANTECEDENT :: YES
IF :: (RBS < RU)
THEN :: (PRINT "The block shear check had failed, please press the F2
button and select NEW START to redesign the connection " AND BSC = INADEQUATE)

RULE055

=====

SUBJECT :: BOLTED-RULES
ANTECEDENT :: YES
REFERENCE :: "McCormac p.370"
IF :: (L >= (0.5 * TH))
THEN :: (STABLE = SUFFICIENT.)

RULE056

=====

SUBJECT :: BOLTED-RULES
ANTECEDENT :: YES
REFERENCE :: "McCormac p.370"
IF :: (L < (0.5 * TH))
THEN :: (PRINT "Stability during steel erection is not sufficient; the length of the angle has to be
increased to at least one-half of the distance between the web toes of the beam fillets (called the T

distances in part 1 of the L.R.F.D. manual). Length of the angle is increased by 3 inches, and one more bolt is added." AND $N = (N + 1)$ AND $BOLTSHEAR = (DBASE-RETRIEVE \text{"ii-a"} (QUAL D = D \text{ AND } N = N) BOLTSHEAR) \text{ AND } L = (L + 3))$

RULE058

SUBJECT :: BOLTED-RULES

ANTECEDENT :: YES

IF :: (LEG IS KNOWN AND OSL IS KNOWN)

THEN :: (DBASE-MRETRIEVE OSL "AISCL" (QUAL $T = T$ AND $VL \geq LEG$ AND $HL \geq OSL$) $HL \text{ LEG "AISCL" (QUAL } T = T \text{ AND } VL \geq LEG \text{ AND } HL \geq OSL \text{) } VL$)

RULE060

SUBJECT :: BOLTED-RULES

IF :: ($COPEL > 0$ AND $(1.5 * D) > LV$)

THEN :: ($N = DATA-FROM-TABLE$ AND DBASE-MRETRIEVE BOLTSHEAR "ii-a" (QUAL BOLTTYPE = "A325-N" AND $D = D$ AND $BOLTSHEAR \geq RU$) BOLTSHEAR N "ii-a" (QUAL BOLTTYPE = "A325-N" AND $D = D$ AND $BOLTSHEAR \geq RU$) N T "ii-a" (QUAL BOLTTYPE = A325-N AND $D = D$) T L "ii-a" (QUAL BOLTTYPE = "A325-N" AND $D = D$ AND $BOLTSHEAR \geq RU$) L B "I-E" (QUAL $FU = FU$ AND $D = D$) B TW "AISC1" (QUAL DSG = DSG AND $DN = DN$ AND $WGT = WGT$) TW DEPTH "AISC1" (QUAL DSG = DSG AND $DN = DN$ AND $WGT = WGT$) D XK "AISC1" (QUAL DSG = DSG AND $DN = DN$ AND $WGT = WGT$) XK BD "I-F" (QUAL $FU = FU$ AND $LV = LV$) BD H2 "assembli" (QUAL $D = D$) H2 C1 "assembli" (QUAL $D = D$) C1 AND $TH = (DEPTH - (2 * XK))$ AND PRINT "the angle thickness in inches is:" T AND $OSL = ((SETBACK + DBW) + ROLLED)$)

RULE062

SUBJECT :: BOLTED-RULES

IF :: ($L \geq (0.5 * TH)$)

THEN :: (DBASE-MRETRIEVE C11 "i-g11" (QUAL $LV = LV$ AND $LH = DBW$) C1 C12 "i-g21" (QUAL $LV = LV$ AND $LH = DBW$) C1 C21 "i-g12" (QUAL $D = D$ AND $N = N$) C2 C22 "i-g22" (QUAL $D = D$ AND $N = N$) C2 AND $RBS1 = ((C11 + C21) * TW)$ AND $RBS2 = ((C12 + C22) * TW)$)

RULE063

SUBJECT :: BOLTED-RULES

ANTECEDENT :: YES

IF :: ($L > TH$)

THEN :: (CLEAR = "not O.K." AND PRINT "Clearance for the angles to be fitted to the beam web is not sufficient. press the F2 button and select NEW START to redesign the connection.")

RULE064

SUBJECT :: BOLTED-RULES

ANTECEDENT :: YES

IF :: ($(2.666666667 * D) > 3$)

THEN :: (PRINT "The bolt spacing in inches is less than 2.6667 times the diameter of the bolt. Please press the F2 button and select NEW START to redesign the connection.")

RULE065

```
SUBJECT :: BOLTED-RULES
ANTECEDENT :: YES
IF :: ((2.666666667 * D) < 3)
THEN :: (PRINT The bolt spacing is adequate.)
```

RULE066

```
SUBJECT :: BOLTED-RULES
ANTECEDENT :: YES
IF :: (L < (0.5 * TH))
THEN :: (PRINT "Stability during steel erection is not sufficient; the length of the angle has to be
increased to at least one-half of the distance between the web toes of the beam fillets (called the T
distances in part 1 of the L.R.F.D. manual). Length of the angle is increased by 3 inches, and
one more bolt is added." AND N = (N + 1) AND BOLTSHEAR = (DBASE-RETRIEVE "ii-a"
(QUAL D = D AND N = N ) BOLTSHEAR ) AND L = (L + 3) )
```

RULE068

```
SUBJECT :: BOLTED-RULES
IF :: (L <= TH)
THEN :: (CLEAR = O.K.)
```

RULE076

```
SUBJECT :: BOLTED-RULES
ANTECEDENT :: YES
IF :: (S >= RU AND (1.5 * D) > LV AND COPED > 0)
THEN :: (PRINT "Shear capacity of connection angles is O.K." AND BC = (((N - 1) * B) + BD) *
TW AND BCA = ((2 * T) * (((N - 1) * B) + BD)) AND S = S + 0)
```

RULE077

```
SUBJECT :: BOLTED-RULES
ANTECEDENT :: YES
IF :: (S < RU AND (1.5 * D) > LV AND COPED > 0)
THEN :: (PRINT "The shearing capacity of the connection angles is insufficient. The length of the
angle is increased by 3 inches, and one more bolt is added." AND N = (N + 1) AND DBASE-
MRETRIEVE BOLTSHEAR "II-A" (QUAL BOLTTYPE = "A325-N" AND D = D AND N = N
)BOLTSHEAR S "II-C" (QUAL D = D AND T = T AND N = N ) S AND BC = (((N - 1) * B) +
BD) * TW AND BCA = ((2 * T) * (((N - 1) * B) + BD ) ) AND L = (L + 3))
```

File: ANTECEDE.LKB

DOMAIN :: "Design of Partially Restrained Steel Connections"
ROOT FRAME :: CONNECTION

=====
Global KB data
=====

FRAME STRUCTURE ::
CONNECTION
SEATED
BOLTED

KB Files :: (BOLTED ANTECEDE.k1 SEATED ANTECEDE.k2)
Parameter groups :: (SEATED-PARMS CONNECTION-PARMS)
Rule groups :: (BOLTED-RULES SEATED-RULES CONNECTION-RULES META-RULES)
Number of rules :: 31
Number of meta-rules :: 0
Variables :: (DOMAIN)
TEXTAGS :: ()
Functions :: ()

=====
VARIABLES
=====

DOMAIN
VALUE :: "Design of Partially Restrained Steel Connections"

=====
Frame :: CONNECTION
=====

IDENTIFIER :: "CONNECTION-"
TRANSLATION :: (Design of standard bolted or welded connections according
to the LRFD manual.)
GOALS :: (TYPECONN)
PROMPTEVER :: (This is a program to design standard bolted or welded
connections according to the LRFD manual.)
DISPLAYRESULTS :: YES
PARMGROUP :: CONNECTION-PARMS
RULEGROUPS :: (CONNECTION-RULES)
ANTECEDENT :: YES
OFFSPRING :: (SEATED BOLTED)
CONNECTION-PARMS :: (TYPECONN)
CONNECTION-RULES :: (RULE020 RULE021)

=====

CONNECTION-PARMS

=====

TYPECONN

=====

TRANSLATION :: (type of connection)
PROMPT :: (Please enter the type of connection design, WELD for welded
 seated connection, and BOLT for bolted double angle connection.)
TYPE :: SINGLEVALUED
EXPECT :: SINGLE-LINE-INPUT
ANTECEDENT-IN :: (RULE020 RULE021)
USED-BY :: (RULE006)

=====

CONNECTION-RULES

=====

RULE020

=====

SUBJECT :: CONNECTION-RULES
ANTECEDENT :: YES
IF :: (TYPECONN = WELD)
THEN :: (CONSIDERFRAME SEATED)

RULE021

=====

SUBJECT :: CONNECTION-RULES
ANTECEDENT :: YES
IF :: (TYPECONN = BOLT)
THEN :: (CONSIDERFRAME BOLTED)

=====

Frame :: SEATED

=====

IDENTIFIER :: "SEATED-"
TRANSLATION :: (welded seated beam connections)
PARENTS :: (CONNECTION)
GOALS :: (OSL-CAPACI T ANGLE-SIZE WELD-SIZE TOP-ANGLE-SIZE MIN-SIZE)
INITIALDATA :: (SEAT-CONN)
PROMPT2ND :: (Would you care to redesign the welded seated beam connection?)
DISPLAYRESULTS :: YES
PARMGROUP :: SEATED-PARMS
RULEGROUPS :: (SEATED-RULES)

SEATED-PARMS :: (ANGLE-SIZE B BC BCA BD BOLTSHEAR BOLTTYPE C1 CLEAR D DBW
DEPTH DN DSG ELECTRODES FU FY H2 HOLE L LEG LV MIN-ED-DIS MIN-SIZE N OSL
OSL-CAPACI RU S SEAT-CONN SETBACK T T1 TF TH THICKER THICKEST
THICKNESS TOP-ANGLE-SIZE TW WEB-THICKN WELD-SIZE WGT XK)
SEATED-RULES :: (RULE003 RULE004 RULE007 RULE008 RULE009 RULE010 RULE011
RULE012 RULE013 RULE014 RULE015 RULE016 RULE017 RULE018 RULE019)

=====
SEATED-PARMS
=====

ANGLE-SIZE

=====

TRANSLATION :: (The size of the angle)
TYPE :: SINGLEVALUED
CONTAINED-IN :: (RULE004)

B

=

TRANSLATION :: (Design loads in kips for bearing)
TYPE :: SINGLEVALUED
CONTAINED-IN :: (RULE006 RULE030)

BC

==

TRANSLATION :: (Bearing capacity of bolts)
TYPE :: SINGLEVALUED
UPDATED-BY :: (RULE006)
UPDATED-IN :: (RULE030 SREFMARK RULE023 RULE022)
ANTECEDENT-IN :: (SREFMARK RULE023 RULE022)
CONTAINED-IN :: (SREFMARK RULE022)

BCA

===

TRANSLATION :: (bearing capacity (kips) of angles)
TYPE :: SINGLEVALUED
UPDATED-BY :: (RULE006)
UPDATED-IN :: (SREFMARK RULE025 RULE024)
ANTECEDENT-IN :: (SREFMARK RULE025 RULE024)

BD

==

TRANSLATION :: (bearing design load in kips)
TYPE :: SINGLEVALUED
CONTAINED-IN :: (RULE006)

BOLTSHEAR

=====

TRANSLATION :: (shear capacity of bolt)
TYPE :: SINGLEVALUED
CONTAINED-IN :: (RULE006)

BOLTTYPE

=====

TRANSLATION :: (the type of bolts used, eg. A325-SC, A490-SC, A325-N, or A490-N.)

PROMPT :: (eg. A325-SC, A490-SC, A325-N, A490-N, A325-X, A490-X, or A307)

TYPE :: SINGLEVALUED

EXPECT :: SINGLE-LINE-INPUT

ANTECEDENT-IN :: (RULE028)

CONTAINED-IN :: (RULE006)

C1

==

TRANSLATION :: (clearance c1 in inches according to the "assembling clearances" table in L.R.F.D.
manual on page 5-164)

TYPE :: SINGLEVALUED

CONTAINED-IN :: (RULE006)

CLEAR

=====

TRANSLATION :: (the clearance for the angle to be fitted to the beam web)

TYPE :: SINGLEVALUED

UPDATED-IN :: (RULE027)

D

=

TRANSLATION :: (bolt diameter)

PROMPT :: (bolt diameter in inches)

TYPE :: SINGLEVALUED

EXPECT :: POSITIVE-NUMBER

ANTECEDENT-IN :: (RULE028)

RANGE :: (0.75 1)

CONTAINED-IN :: (RULE006 RULE030)

DBW

===

TRANSLATION :: (distance in inches between bolts and edge of beam web)

PROMPT :: (enter the distance in inches between bolts and edge of beam web)

TYPE :: SINGLEVALUED

EXPECT :: POSITIVE-NUMBER

CONTAINED-IN :: (RULE006)

RANGE :: (2 3)

DEPTH

=====

TRANSLATION :: (the d distance in inches from the W shapes dimensions table in the L.R.F.D.
manual)

TYPE :: SINGLEVALUED

CONTAINED-IN :: (RULE006)

DN

==

TRANSLATION :: (designation)

PROMPT :: (Please enter the designation of the beam. Ex.: W21*62, designation is 21.)

TYPE :: SINGLEVALUED

EXPECT :: INTEGER

RANGE :: (4 40)

CONTAINED-IN :: (RULE004 RULE006)

DSG

===

TRANSLATION :: (designation of beam's shape)

PROMPT :: (W shapes are hot-rolled shapes which have essentially parallel flange surfaces. If the beam which is being connected is a W shape, please enter W.)

TYPE :: SINGLEVALUED

EXPECT :: SINGLE-LINE-INPUT

CONTAINED-IN :: (RULE004 RULE006)

ELECTRODES

=====

TRANSLATION :: (Types of electrodes, E60XX, or E70XX.)

PROMPT :: (Please type in the type of electrodes, eg. E60XX or E70XX. The system will only take E70XX at this point of time.)

TYPE :: SINGLEVALUED

EXPECT :: SINGLE-LINE-INPUT

USED-BY :: (RULE004)

FU

==

TRANSLATION :: (Specified minimum tensile strength in k.s.i. of the type of steel being used)

PROMPT(Please type in the specified minimum tensile strength in k.s.i. of the type of steel being used)

TYPE :: SINGLEVALUED

EXPECT :: INTEGER

CONTAINED-IN :: (RULE006)

RANGE :: (58 100)

FY

==

TRANSLATION :: (yield strength of steel)

PROMPT :: (What is the yield strength of steel in ksi?)

TYPE :: SINGLEVALUED

EXPECT :: POSITIVE-NUMBER

USED-BY :: (RULE004)

RANGE :: (36 50)

H2

==

TRANSLATION :: (clearance h2 in inches according to the "assembling clearances" table in the L.R.F.D. manual on page 5-164)

TYPE :: SINGLEVALUED

CONTAINED-IN :: (RULE006)

L
=
TRANSLATION :: (length of angle in inches)
PROMPT :: (enter the length of the angle in inches)
TYPE :: SINGLEVALUED
EXPECT :: POSITIVE-NUMBER
ANTECEDENT-IN :: (RULE027)
RANGE :: (6 8)
CONTAINED-IN :: (RULE004 RULE006 RULE030)

LEG
===
TRANSLATION :: (length of the leg in inches which is bolted to the beam web)
TYPE :: SINGLEVALUED
UPDATED-BY :: (RULE006)

LV
==
TRANSLATION :: (Edge distance in inches of the top bolt from the top of the angle)
PROMPT :: (Enter the edge distance in inches of the top bolt from the top of the angle.)
TYPE :: SINGLEVALUED
EXPECT :: POSITIVE-NUMBER
CONTAINED-IN :: (RULE006)
RANGE :: (1 1.5)

MIN-ED-DIS
=====
TRANSLATION :: (MINIMUM EDGE DISTANCE IN INCHES)
PROMPT :: (ENTER THE MINIMUM EDGE DISTANCE IN INCHES)
TYPE :: SINGLEVALUED
EXPECT :: POSITIVE-NUMBER
CONTAINED-IN :: (RULE006 SREFMARK RULE026)
RANGE :: (1 2)

MIN-SIZE
=====
TRANSLATION :: (Minimum Size of the leg dimension of fillet Weld in inches.)
TYPE :: SINGLEVALUED
UPDATED-BY :: (RULE003)

N
=
TRANSLATION :: (number of bolts)
TYPE :: SINGLEVALUED
UPDATED-BY :: (RULE006)
UPDATED-IN :: (RULE030)
CONTAINED-IN :: (RULE006 RULE030)

OSL

===

TRANSLATION :: (OUTSTANDING LEG IN INCHES)
TYPE :: SINGLEVALUED
UPDATED-BY :: (RULE006)
UPDATED-IN :: (SREFMARK RULE026)
ANTECEDENT-IN :: (SREFMARK RULE026)

OSL-CAPACI

=====

TRANSLATION :: (outstanding leg capacity in kips)
TYPE :: SINGLEVALUED
EXPECT :: POSITIVE-NUMBER
UPDATED-BY :: (RULE004)
RANGE :: (13.6 102)
CONTAINED-IN :: (RULE004)

RU

==

TRANSLATION :: (factored end reaction)
PROMPT :: (End reaction in kips obtained from structural analysis with load factor included.)
TYPE :: SINGLEVALUED
EXPECT :: POSITIVE-NUMBER
ANTECEDENT-IN :: (RULE029 RULE030 SREFMARK RULE023 RULE025 RULE022 RULE024)
RANGE :: (0 200)
CONTAINED-IN :: (RULE004 RULE006)

S

=

TRANSLATION :: (Design shear in kips)
TYPE :: SINGLEVALUED
ANTECEDENT-IN :: (RULE029 RULE030)
CONTAINED-IN :: (RULE006 RULE030)

SEAT-CONN

=====

TRANSLATION :: (Connection between beam flange and seat angle.)
PROMPT :: (Is the beam flange welded to the seat angle?)
TYPE :: YES/NO
USED-BY :: (RULE003)

SETBACK

=====

TRANSLATION :: (the protrusion in inches which framing angles extend out from the beam web for
easy fitting of members together during steel erection)
PROMPT :: (enter the protrusion in inches which framing angles extend out from the beam web for
easy fitting of members together during steel erection)
TYPE :: SINGLEVALUED
EXPECT :: POSITIVE-NUMBER
CONTAINED-IN :: (RULE006)
RANGE :: (0.5 1)

T

=

TRANSLATION :: (angle thickness in inches)
TYPE :: SINGLEVALUED
UPDATED-BY :: (RULE004)
ANTECEDENT-IN :: (RULE028)
USED-BY :: (RULE007 RULE008)
CONTAINED-IN :: (RULE008 RULE004 RULE006 RULE030)

TF

==

TYPE :: SINGLEVALUED
USED-BY :: (RULE007 RULE008)
CONTAINED-IN :: (RULE007 RULE004)

TH

==

TRANSLATION :: (Distance between two flanges, or height of the web.)
PROMPT :: (T values in the W shapes Dimensions' tables under the "Distance" column.)
TYPE :: SINGLEVALUED
EXPECT :: POSITIVE-NUMBER
UPDATED-BY :: (RULE006)
ANTECEDENT-IN :: (RULE027)
RANGE :: (2.75 33.75)

THICKER

=====

TRANSLATION :: (Material Thickness of Thicker Part Joined in inches.)
TYPE :: SINGLEVALUED
UPDATED-BY :: (RULE007 RULE008)
USED-BY :: (RULE011 RULE009 RULE010 RULE012)

THICKEST

=====

TRANSLATION :: (Material Thickness of Thicker Part Joined in inches.)
TYPE :: SINGLEVALUED
UPDATED-BY :: (RULE011 RULE009 RULE010 RULE012)
CONTAINED-IN :: (RULE003)

TOP-ANGLE-SIZE

=====

TRANSLATION :: (the size and thickness of the top angle in inches)
PROMPT :: (When designing a seated connection, top angle must be provided. What is the size of the top angle? The L.R.F.D. manual suggests that the minimum size be L4*4*1/4. To provide end rotation for the beam, the top angle should be flexible.)
TYPE :: SINGLEVALUED
EXPECT :: SINGLE-LINE-INPUT

TW

==

TRANSLATION :: (thickness of the beam web in inches)

TYPE :: SINGLEVALUED

EXPECT :: POSITIVE-NUMBER

USED-BY :: (RULE013 RULE014 RULE015 RULE016 RULE017 RULE018 RULE019)

CONTAINED-IN :: (RULE004 RULE006 RULE030)

RANGE :: (0.1875 0.5625)

WEB-THICKN

=====

TRANSLATION :: (thickness of the beam's web)

TYPE :: SINGLEVALUED

UPDATED-BY :: (RULE013 RULE014 RULE015 RULE016 RULE017 RULE018 RULE019)

CONTAINED-IN :: (RULE004)

WELD-SIZE

=====

TRANSLATION :: (size of the weld in inches)

TYPE :: SINGLEVALUED

CONTAINED-IN :: (RULE004)

WGT

===

TRANSLATION :: (unit weight in lb. per ft.)

PROMPT :: (Please enter the unit weight of the beam. Ex.: W21*62, 62 is the unit weight.)

TYPE :: SINGLEVALUED

EXPECT :: INTEGER

RANGE :: (9 848)

CONTAINED-IN :: (RULE004 RULE006)

XK

==

TRANSLATION :: (The k distance in inches from the W shapes dimensions table in the L.R.F.D.
manual)

TYPE :: SINGLEVALUED

CONTAINED-IN :: (RULE006)

=====

SEATED-RULES

=====

RULE003

=====

SUBJECT :: SEATED-RULES

IF :: (SEAT-CONN)

THEN :: (MIN-SIZE = (DBASE-RETRIEVE "j2-5" (QUAL THICKNESS = THICKEST)MIN_SIZE))

RULE004

=====

SUBJECT :: SEATED-RULES

EXPLANATION :: (5/16 in. welds or smaller are single pass welds, they are more economical than the heavier welds.)

IF :: (FY = 36 AND ELECTRODES = E70XX)

THEN :: (DBASE-MRETRIEVE TW "aisc1" (QUAL DSG = DSG AND DN = DN AND WGT = WGT) TW TF "aisc1" (QUAL DSG = DSG AND DN = DN AND WGT = WGT) TF AND OSL-CAPACI = OSL-CAPACI AND DBASE-MRETRIEVE OSL-CAPACI "vi-a" (QUAL L = L AND OSL_CAPACI >= RU AND WEB_THICKN = WEB-THICKN) OSL_CAPACI AND T = (DBASE-RETRIEVE "vi-a" (QUAL L = L AND OSL_CAPACI = OSL-CAPACI AND WEB_THICKN = WEB-THICKN) T) AND DBASE-MRETRIEVE ANGLE-SIZE "vi-c" (QUAL CAPACITY >= RU AND MAX_THICK >= T AND MIN_THICK <= T AND WELD_SIZE <= 0.3125) ANGLE_SIZE WELD-SIZE "vi-c" (QUAL CAPACITY >= RU AND MAX_THICK >= T AND MIN_THICK <= T AND WELD_SIZE <= 0.3125) WELD_SIZE)

RULE007

=====

SUBJECT :: SEATED-RULES

IF :: (TF > T)

THEN :: (THICKER = (TF + 0))

RULE008

=====

SUBJECT :: SEATED-RULES

IF :: (TF <= T)

THEN :: (THICKER = (T + 0))

RULE009

=====

SUBJECT :: SEATED-RULES

IF :: (THICKER <= 0.25)

THEN :: (THICKEST = To 1/4 inclusive)

RULE010

=====

SUBJECT :: SEATED-RULES

IF :: (THICKER > 0.25 AND THICKER <= 0.5)

THEN :: (THICKEST = Over 1/4 to 1/2)

RULE011

=====

SUBJECT :: SEATED-RULES

IF :: (THICKER > 0.5 AND THICKER <= 0.75)

THEN :: (THICKEST = Over 1/2 to 3/4)

RULE012

=====

SUBJECT :: SEATED-RULES

IF :: (THICKER > 0.75)

THEN :: (THICKEST = Over 3/4)

RULE013

=====

SUBJECT :: SEATED-RULES

IF :: (TW >= 0.345 AND TW <= 0.405)

THEN :: (WEB-THICKN = 0.375)

RULE014

=====

SUBJECT :: SEATED-RULES

IF :: (TW >= 0.535 AND TW <= 0.59)

THEN :: (WEB-THICKN = 0.565)

RULE015

=====

SUBJECT :: SEATED-RULES

IF :: (TW >= 0.47 AND TW <= 0.53)

THEN :: (WEB-THICKN = 0.5)

RULE016

=====

SUBJECT :: SEATED-RULES

IF :: (TW >= 0.415 AND TW <= 0.46)

THEN :: (WEB-THICKN = 0.44)

RULE017

=====

SUBJECT :: SEATED-RULES

IF :: (TW >= 0.285 AND TW <= 0.34)

THEN :: (WEB-THICKN = 0.31)

RULE018

=====

SUBJECT :: SEATED-RULES

IF :: (TW >= 0.22 AND TW <= 0.28)

THEN :: (WEB-THICKN = 0.25)

RULE019

=====

SUBJECT :: SEATED-RULES

IF :: (TW >= 0.17 AND TW <= 0.2)

THEN :: (WEB-THICKN = 0.19)

=====

Frame :: BOLTED

=====

IDENTIFIER :: "BOLTED-"

TRANSLATION :: (Design of bolted double angle connection.)

PARENTS :: (CONNECTION)

GOALS :: (N T L S BC BCA OSL LEG CLEAR)

PROMPT2ND :: (Do you want to redesign the bolted double angle connection?)

DISPLAYRESULTS :: YES

PARMGROUP :: SEATED-PARMS
 RULEGROUPS :: (BOLTED-RULES)
 SEATED-PARMS :: (ANGLE-SIZE B BC BCA BD BOLTSHEAR BOLTTYPE C1 CLEAR D DBW
 DEPTH DN DSG ELECTRODES FU FY H2 HOLE L LEG LV MIN-ED-DIS MIN-SIZE N OSL
 OSL-CAPACI RU S SEAT-CONN SETBACK T T1 TF TH THICKER THICKEST
 THICKNESS TOP-ANGLE-SIZE TW WEB-THICKN WELD-SIZE WGT XK)
 BOLTED-RULES :: (RULE006 RULE022 RULE023 RULE024 RULE025 RULE026 RULE027
 RULE028 RULE029 RULE030)

=====
 BOLTED-RULES
 =====

RULE006

=====

SUBJECT :: BOLTED-RULES
 IF :: (TYPECONN = BOLT)
 THEN :: (N = DATA-FROM-TABLE AND DBASE-MRETRIEVE BOLTSHEAR "ii-a" (QUAL
 BOLTTYPE = BOLTTYPE AND D = D AND BOLTSHEAR >= RU) BOLTSHEAR N "ii-a"
 (QUAL BOLTTYPE = BOLTTYPE AND D = D AND BOLTSHEAR >= RU) N T "ii-a"
 (QUAL BOLTTYPE = BOLTTYPE AND D = D) T L "ii-a" (QUAL BOLTTYPE =
 BOLTTYPE AND D = D AND BOLTSHEAR >= RU) L AND DBASE-MRETRIEVE S "II-C"
 (QUAL D = D AND T = T AND L = L AND N = N) S B "I-E" (QUAL FU = FU AND D = D)
 B TW "AISC1" (QUAL DSG = DSG AND DN = DN AND WGT = WGT) TW DEPTH
 "AISC1" (QUAL DSG = DSG AND DN = DN AND WGT = WGT) D XK "AISC1" (QUAL
 DSG = DSG AND DN = DN AND WGT = WGT) XK BD "I-F" (QUAL FU = FU AND LV =
 LV) BD H2 "assembli" (QUAL D = D) H2 C1 "assembli" (QUAL D = D) C1 AND BC = ((N *
 B) * TW) AND BCA = ((2 * T) * (((N - 1) * B) + BD)) AND OSL = ((T + C1) + H2) AND
 LEG = ((SETBACK + DBW) + MIN-ED-DIS) AND TH = (DEPTH - (2 * XK)))

RULE022

=====

SUBJECT :: BOLTED-RULES
 ANTECEDENT :: YES
 IF :: (BC >= RU)
 THEN :: (PRINT BC AND BC = adequate)

RULE023

=====

SUBJECT :: BOLTED-RULES
 ANTECEDENT :: YES
 IF :: (BC < RU)
 THEN :: (BC = inadequate)

RULE024

=====

SUBJECT :: BOLTED-RULES
 ANTECEDENT :: YES
 IF :: (BCA >= RU)
 THEN :: (BCA = ADEQUATE)

RULE025

=====

SUBJECT :: BOLTED-RULES
ANTECEDENT :: YES
IF :: (BCA < RU)
THEN :: (BCA = INADEQUATE)

RULE026

=====

SUBJECT :: BOLTED-RULES
ANTECEDENT :: YES
IF :: (OSL > 2.5 AND OSL < 3)
THEN :: (OSL = (3 + MIN-ED-DIS))

RULE027

=====

SUBJECT :: BOLTED-RULES
ANTECEDENT :: YES
IF :: (L < TH)
THEN :: (CLEAR = O.K.)

RULE028

=====

SUBJECT :: BOLTED-RULES
ANTECEDENT :: YES
IF :: (BOLTTYPE = A325-N AND D = 0.875 AND T = 0.375)
THEN :: (PRINT "Capacity is governed by net shear on angles for lengths L. For reduced value see
Table II-C. (L.R.F.D. manual, p.5-28, TABLE II-A, Notes: c)")

RULE029

=====

SUBJECT :: BOLTED-RULES
ANTECEDENT :: YES
IF :: (S >= RU)
THEN :: (PRINT Shear Capacity of Connection angles is O.K.)

RULE030

=====

SUBJECT :: BOLTED-RULES
ANTECEDENT :: YES
IF :: (S < RU)
THEN :: (N = (N + 1) AND DBASE-MRETRIEVE S "II-C" (QUAL D = D AND T = T
AND N = N) S L "II-C" (QUAL N = N) L AND BC = ((N * B) * TW))

File: ANTECEDE.TRC

Root Frame CONNECTION-1 created
Trace the following goals : TYPECONN
Tracing parameter : CONNECTION-1 TYPECONN
=== USER ENTRY === : CONNECTION-1 TYPECONN = ("BOLT" 100)
Setting parameter : CONNECTION-1 TYPECONN = "BOLT" cf 100
Mark the following antecedent rules for TYPECONN :: RULE020 RULE021
Try the marked antecedent rules RULE020 RULE021
Testing rule premise : CONNECTION-1 RULE020
Rule premise fails : CONNECTION-1 RULE020
Testing rule premise : CONNECTION-1 RULE021
Apply action : CONNECTION-1 RULE021 TALLY 100
Consider frame type : BOLTED RULE021

Frame BOLTED-1 created under CONNECTION-1
Trace the following goals : N T L S BC BCA OSL LEG CLEAR
Tracing parameter : BOLTED-1 N
Try the rules that deduce BOLTED-1 N : RULE006
Testing rule premise : BOLTED-1 RULE006
Tracing parameter : CONNECTION-1 TYPECONN
End tracing parameter: CONNECTION-1 TYPECONN
Apply action : BOLTED-1 RULE006 TALLY 100
Setting parameter : BOLTED-1 N = DATA-FROM-TABLE cf 100
Tracing parameter : BOLTED-1 BOLTTYPE
=== USER ENTRY === : BOLTED-1 BOLTTYPE = ("A325-N" 100)
Setting parameter : BOLTED-1 BOLTTYPE = "A325-N" cf 100
Mark the following antecedent rules for BOLTTYPE :: RULE028
Try the marked antecedent rules RULE028
Testing rule premise : BOLTED-1 RULE028
Rule premise fails : BOLTED-1 RULE028
End of marked antecedent rules
End tracing parameter: BOLTED-1 BOLTTYPE
Tracing parameter : BOLTED-1 D
=== USER ENTRY === : BOLTED-1 D = (0.875 100)
Setting parameter : BOLTED-1 D = 0.875 cf 100
Mark the following antecedent rules for D :: RULE028
Try the marked antecedent rules RULE028
Testing rule premise : BOLTED-1 RULE028
Rule premise fails : BOLTED-1 RULE028
End of marked antecedent rules
End tracing parameter: BOLTED-1 D
Tracing parameter : BOLTED-1 RU
=== USER ENTRY === : BOLTED-1 RU = (200 100)
Setting parameter : BOLTED-1 RU = 200 cf 100
Mark the following antecedent rules for RU :: RULE029 RULE030 SREFMARK
RULE023 RULE025 RULE022 RULE024
Try the marked antecedent rules RULE029 RULE030 SREFMARK (RULE023 RULE025
RULE022 RULE024)
Testing rule premise : BOLTED-1 RULE029
Rule premise fails : BOLTED-1 RULE029

Testing rule premise : BOLTED-1 RULE030
 Rule premise fails : BOLTED-1 RULE030
 Testing rule premise : BOLTED-1 RULE023
 Rule premise fails : BOLTED-1 RULE023
 Testing rule premise : BOLTED-1 RULE025
 Rule premise fails : BOLTED-1 RULE025
 Testing rule premise : BOLTED-1 RULE022
 Rule premise fails : BOLTED-1 RULE022
 Testing rule premise : BOLTED-1 RULE024
 Rule premise fails : BOLTED-1 RULE024
 End of marked antecedent rules
 End tracing parameter: BOLTED-1 RU
 Setting parameter : BOLTED-1 BOLTSHEAR = 422. cf 100
 Setting parameter : BOLTED-1 BOLTSHEAR = 380. cf 100
 Setting parameter : BOLTED-1 BOLTSHEAR = 338. cf 100
 Setting parameter : BOLTED-1 BOLTSHEAR = 295. cf 100
 Setting parameter : BOLTED-1 BOLTSHEAR = 253. cf 100
 Setting parameter : BOLTED-1 BOLTSHEAR = 211. cf 100
 Setting parameter : BOLTED-1 N = 10 cf 100
 Setting parameter : BOLTED-1 N = 9 cf 100
 Setting parameter : BOLTED-1 N = 8 cf 100
 Setting parameter : BOLTED-1 N = 7 cf 100
 Setting parameter : BOLTED-1 N = 6 cf 100
 Setting parameter : BOLTED-1 N = 5 cf 100
 Setting parameter : BOLTED-1 T = 0.375 cf 100
 Mark the following antecedent rules for T :: RULE028
 Setting parameter : BOLTED-1 T = 0.375 cf 100
 Setting parameter : BOLTED-1 T = 0.375 cf 100
 Setting parameter : BOLTED-1 T = 0.375 cf 100
 Setting parameter : BOLTED-1 T = 0.375 cf 100
 Setting parameter : BOLTED-1 T = 0.375 cf 100
 Setting parameter : BOLTED-1 T = 0.375 cf 100
 Setting parameter : BOLTED-1 T = 0.375 cf 100
 Setting parameter : BOLTED-1 T = 0.375 cf 100
 Setting parameter : BOLTED-1 L = 29.5 cf 100
 Mark the following antecedent rules for L :: RULE027
 Setting parameter : BOLTED-1 L = 26.5 cf 100
 Setting parameter : BOLTED-1 L = 23.5 cf 100
 Setting parameter : BOLTED-1 L = 20.5 cf 100
 Setting parameter : BOLTED-1 L = 17.5 cf 100
 Setting parameter : BOLTED-1 L = 14.5 cf 100
 Tracing parameter : BOLTED-1 T
 Try the marked antecedent rules RULE028 RULE027
 Testing rule premise : BOLTED-1 RULE028
 Apply action : BOLTED-1 RULE028 TALLY 100

Capacity is governed by net shear on angles for lengths L. For reduced value see Table II-C. (L.R.F.D. manual, p.5-28, TABLE II-A, Notes: c)

Completed action : BOLTED-1 RULE028

Testing rule premise : BOLTED-1 RULE027

Rule premise fails : BOLTED-1 RULE027

End of marked antecedent rules

End tracing parameter: BOLTED-1 T
 Tracing parameter : BOLTED-1 L
 End tracing parameter: BOLTED-1 L
 Special processing for parameter N already being traced.
 Tracing parameter : BOLTED-1 FU
 == USER ENTRY == : BOLTED-1 FU = (58 100)
 Setting parameter : BOLTED-1 FU = 58 cf 100
 End tracing parameter: BOLTED-1 FU
 Tracing parameter : BOLTED-1 DSG
 == USER ENTRY == : BOLTED-1 DSG = ("W" 100)
 Setting parameter : BOLTED-1 DSG = "W" cf 100
 End tracing parameter: BOLTED-1 DSG
 Tracing parameter : BOLTED-1 DN
 == USER ENTRY == : BOLTED-1 DN = (27 100)
 Setting parameter : BOLTED-1 DN = 27 cf 100
 End tracing parameter: BOLTED-1 DN
 Tracing parameter : BOLTED-1 WGT
 == USER ENTRY == : BOLTED-1 WGT = (94 100)
 Setting parameter : BOLTED-1 WGT = 94 cf 100
 End tracing parameter: BOLTED-1 WGT
 Tracing parameter : BOLTED-1 LV
 == USER ENTRY == : BOLTED-1 LV = (1.25 100)
 Setting parameter : BOLTED-1 LV = 1.25 cf 100
 End tracing parameter: BOLTED-1 LV
 Setting parameter : BOLTED-1 S = 192. cf 100
 Mark the following antecedent rules for S :: RULE029 RULE030
 Setting parameter : BOLTED-1 B = 91.3 cf 100
 Setting parameter : BOLTED-1 TW = 0.49 cf 100
 Setting parameter : BOLTED-1 DEPTH = 26.92 cf 100
 Setting parameter : BOLTED-1 XK = 1.4375 cf 100
 Setting parameter : BOLTED-1 BD = 54.4 cf 100
 Setting parameter : BOLTED-1 H2 = 1.5 cf 100
 Setting parameter : BOLTED-1 C1 = 1.375 cf 100
 Special processing for parameter N already being traced.
 Tracing parameter : BOLTED-1 B
 Try the marked antecedent rules RULE029 RULE030
 Testing rule premise : BOLTED-1 RULE029
 Rule premise fails : BOLTED-1 RULE029
 Testing rule premise : BOLTED-1 RULE030
 Apply action : BOLTED-1 RULE030 TALLY 100
 Special processing for parameter N already being traced.
 Setting parameter : BOLTED-1 N = 6 cf 100
 Special processing for parameter N already being traced.
 Special processing for parameter N already being traced.
 Setting parameter : BOLTED-1 S = 232. cf 100
 Mark the following antecedent rules for S :: RULE029 RULE030
 WARNING: Parameter BOLTED-1 L has been traced.
 ***** Value change may cause logical inconsistency.
 Existing value: ((14.5 100 RULE006))
 New value assignment: ((17.5 100 RULE030))
 Setting parameter : BOLTED-1 L = 17.5 cf 100
 Mark the following antecedent rules for L :: RULE027

WARNING: Parameter BOLTED-1 L has been traced.
 ***** Value change may cause logical inconsistency.
 Existing value: ((17.5 100 RULE030))
 New value assignment: ((17.5 100 RULE030))
 Setting parameter : BOLTED-1 L = 17.5 cf 100
 Special processing for parameter N already being traced.
 Tracing parameter : BOLTED-1 B
 End tracing parameter: BOLTED-1 B
 Tracing parameter : BOLTED-1 TW
 End tracing parameter: BOLTED-1 TW
 Setting parameter : BOLTED-1 BC = 268.422 cf 100
 Mark the following antecedent rules for BC :: SREFMARK RULE023 RULE022
 Completed action : BOLTED-1 RULE030
 Testing rule premise : BOLTED-1 RULE029
 Apply action : BOLTED-1 RULE029 TALLY 100

Shear Capacity of Connection angles is O.K.
 Completed action : BOLTED-1 RULE029
 Rule already fired : BOLTED-1 RULE030
 Testing rule premise : BOLTED-1 RULE027
 Rule premise fails : BOLTED-1 RULE027
 Testing rule premise : BOLTED-1 RULE023
 Rule premise fails : BOLTED-1 RULE023
 Testing rule premise : BOLTED-1 RULE022
 Apply action : BOLTED-1 RULE022 TALLY 100
 Tracing parameter : BOLTED-1 BC
 End tracing parameter: BOLTED-1 BC

268.422

WARNING: Parameter BOLTED-1 BC has been traced.
 ***** Value change may cause logical inconsistency.
 Existing value: ((268.422 100 RULE030))
 New value assignment: (("adequate" 100 RULE022))
 Setting parameter : BOLTED-1 BC = "adequate" cf 100
 Mark the following antecedent rules for BC :: SREFMARK RULE023 RULE022
 Completed action : BOLTED-1 RULE022
 Testing rule premise : BOLTED-1 RULE023
 Rule premise fails : BOLTED-1 RULE023
 Rule already fired : BOLTED-1 RULE022
 End of marked antecedent rules
 End tracing parameter: BOLTED-1 B
 WARNING: Parameter BOLTED-1 BC has been traced.
 ***** Value change may cause logical inconsistency.
 Existing value: (("adequate" 100 RULE022))
 New value assignment: ((223.685 100 RULE006))
 Setting parameter : BOLTED-1 BC = 223.685 cf 100
 Mark the following antecedent rules for BC :: SREFMARK RULE023 RULE022
 Special processing for parameter N already being traced.
 Tracing parameter : BOLTED-1 BD
 Try the marked antecedent rules SREFMARK (RULE023 RULE022)
 Testing rule premise : BOLTED-1 RULE023
 Rule premise fails : BOLTED-1 RULE023

Rule already fired : BOLTED-1 RULE022
 End of marked antecedent rules
 End tracing parameter: BOLTED-1 BD
 Setting parameter : BOLTED-1 BCA = 383.175 cf 100
 Mark the following antecedent rules for BCA :: SREFMARK RULE025 RULE024
 Tracing parameter : BOLTED-1 C1
 Try the marked antecedent rules SREFMARK (RULE025 RULE024)
 Testing rule premise : BOLTED-1 RULE025
 Rule premise fails : BOLTED-1 RULE025
 Testing rule premise : BOLTED-1 RULE024
 Apply action : BOLTED-1 RULE024 TALLY 100
 Setting parameter : BOLTED-1 BCA = "ADEQUATE" cf 100
 Mark the following antecedent rules for BCA :: SREFMARK RULE025 RULE024
 Completed action : BOLTED-1 RULE024
 Testing rule premise : BOLTED-1 RULE025
 Rule premise fails : BOLTED-1 RULE025
 Rule already fired : BOLTED-1 RULE024
 End of marked antecedent rules
 End tracing parameter: BOLTED-1 C1
 Tracing parameter : BOLTED-1 H2
 End tracing parameter: BOLTED-1 H2
 Setting parameter : BOLTED-1 OSL = 3.25 cf 100
 Mark the following antecedent rules for OSL :: SREFMARK RULE026
 Tracing parameter : BOLTED-1 SETBACK
 === USER ENTRY === : BOLTED-1 SETBACK = (0.5 100)
 Setting parameter : BOLTED-1 SETBACK = 0.5 cf 100
 Try the marked antecedent rules SREFMARK (RULE026)
 Testing rule premise : BOLTED-1 RULE026
 Rule premise fails : BOLTED-1 RULE026
 End of marked antecedent rules
 End tracing parameter: BOLTED-1 SETBACK
 Tracing parameter : BOLTED-1 DBW
 === USER ENTRY === : BOLTED-1 DBW = (2 100)
 Setting parameter : BOLTED-1 DBW = 2 cf 100
 End tracing parameter: BOLTED-1 DBW
 Tracing parameter : BOLTED-1 MIN-ED-DIS
 === USER ENTRY === : BOLTED-1 MIN-ED-DIS = (1 100)
 Setting parameter : BOLTED-1 MIN-ED-DIS = 1 cf 100
 End tracing parameter: BOLTED-1 MIN-ED-DIS
 Setting parameter : BOLTED-1 LEG = 3.5 cf 100
 Tracing parameter : BOLTED-1 DEPTH
 End tracing parameter: BOLTED-1 DEPTH
 Tracing parameter : BOLTED-1 XK
 End tracing parameter: BOLTED-1 XK
 Setting parameter : BOLTED-1 TH = 24.045 cf 100
 Mark the following antecedent rules for TH :: RULE027
 Completed action : BOLTED-1 RULE006
 No rules left for : BOLTED-1 N
 Try the marked antecedent rules RULE027
 Testing rule premise : BOLTED-1 RULE027
 Apply action : BOLTED-1 RULE027 TALLY 100
 Setting parameter : BOLTED-1 CLEAR = O.K. cf 100

Completed action : BOLTED-1 RULE027
 End of marked antecedent rules
 End tracing parameter: BOLTED-1 N
 Tracing parameter : BOLTED-1 S
 End tracing parameter: BOLTED-1 S
 Tracing parameter : BOLTED-1 BCA
 End tracing parameter: BOLTED-1 BCA
 Tracing parameter : BOLTED-1 OSL
 End tracing parameter: BOLTED-1 OSL
 Tracing parameter : BOLTED-1 LEG
 End tracing parameter: BOLTED-1 LEG
 Tracing parameter : BOLTED-1 CLEAR
 End tracing parameter: BOLTED-1 CLEAR
 Goal trace complete for frame BOLTED-1
 Number of bolts is as follows: 6
 Angle thickness in inches is as follows: 0.375
 Length of angle in inches is as follows: 17.5
 Design shear in kips is as follows: 232.
 Bearing capacity of bolts is as follows: 223.685
 Bearing capacity kips of angles is as follows: ADEQUATE
 OUTSTANDING LEG IN INCHES is as follows: 3.25
 Length of the leg in inches which is bolted to the beam web is as follows:
 3.5
 The clearance for the angle to be fitted to the beam web is as follows: O.K.

Frame creation refused for : BOLTED
 Completed action : CONNECTION-1 RULE021
 End of marked antecedent rules
 End tracing parameter: CONNECTION-1 TYPECONN
 Goal trace complete for frame CONNECTION-1
 Type of connection is as follows: BOLT

Consultation log: Design of Partiall... ::
 type of connection :: BOLT
 the type of bolts used, eg. A325-SC,... :: A325-N
 bolt diameter :: .875
 factored end reaction :: 200
 Specified minimum tensile strength i... :: 58
 designation of beam's shape :: W
 designation :: 27
 unit weight in lb. per ft. :: 94
 Edge distance in inches of the top b... :: 1.25
 the protrusion in inches which frami... :: .5
 distance in inches between bolts and... :: 2
 MINIMUM EDGE DISTANCE IN INCHES :: 1
 2:Design of bolted double angle conn... :: NO

Conclusions for frame: BOLTED-1

Number of bolts is as follows: 6

Angle thickness in inches is as follows: 0.375

Length of angle in inches is as follows: 17.5

Design shear in kips is as follows: 232.

Bearing capacity of bolts is as follows: 223.685

Bearing capacity kips of angles is as follows: ADEQUATE

OUTSTANDING LEG IN INCHES is as follows: 3.25

Length of the leg in inches which is bolted to the beam web is as follows:
3.5

The clearance for the angle to be fitted to the beam web is as follows: O.K.

Conclusions for frame: CONNECTION-1

Type of connection is as follows: BOLT

===== QUIT =====

.

D	H2	C1
0.625	1.250	1.0000
0.750	1.375	1.2500
0.875	1.500	1.3750
1.000	1.625	1.4375
1.125	1.875	1.5625
1.250	2.000	1.6875
1.375	2.125	1.7500
1.500	2.250	1.8750
0.000	0.000	0.0000

FIELD	L.R.F.D.
D	Bolt Dia.
H2	H ₂
C1	C ₁

Table on page 5-164, "THREADED FASTENERS" Assembling clearances: A325 AND A490 HIGH-STRENGTH BOLTS ENTERING AND TIGHTENING CLEARANCES

THICKNESS	MIN_SIZE
To 1/4 inclusive	0.1250
Over 1/4 to 1/2	0.1875
Over 1/2 to 3/4	0.2500
Over 3/4	0.3125

FIELD	L.R.F.D.
THICKNESS	Material Thickness of Thicker Part Joined (in.)
MIN_SIZE	Minimum Size of Fillet Weld (in.)

TABLE J2.5 Minimum Size of Fillet Welds

D	SHEARED	ROLLED
0.500	0.875	0.750
0.625	1.125	0.875
0.750	1.250	1.000
0.875	1.500	1.125
1.000	1.750	1.250
1.125	2.000	1.500
1.250	2.250	1.625
0.000	0.000	0.000

FIELD	L.R.F.D.
D	Nominal Rivet or Bolt Diameter (in.)
SHEARED	At Sheared Edges
ROLLED	At Rolled Edges of Plates, Shapes or Bars or Gas Cut Edges

TABLE J3.7 Minimum Edge Distance

ASTM	FY	FU
A36	36	58
A529	42	60
A441	42	63
A441	46	67
A441	50	70
A572-Grade42	42	60
A572-Grade50	50	65
A572-Grade60	60	75
A572-Grade65	65	80
A242	42	63
A242	46	67
A242	50	70
A588	50	70

FIELD	L.R.F.D.
ASTM	ASTM Designation
FY	Fy Minimum Yield Stress (ksi)
FU	Fu Tensile Stress (ksi)

TABLE 1 Availability of Shapes, Plates and Bars According to
ASTM Structural Steel Specifications

Database File: I-E.DBF

FU	D	B
58	0.750	78.3
58	0.875	91.3
58	1.000	104.4
65	0.750	87.9
65	0.875	102.4
65	1.000	117.0
70	0.750	94.5
70	0.875	110.2
70	1.000	126.0
100	0.750	135.0
100	0.875	157.5
100	1.000	180.0

FIELD	L.R.F.D.
FU	F_u
D	Bolt dia.
B	Bearing design loads in kips

TABLE I-E. "BEARING" Slip-critical and Bearing-type Connections

Database File: 1-F.DBF

FU	LV	BD
56	1.000	43.5
58	1.125	49.0
58	1.250	54.4
58	1.500	65.3
65	1.000	48.8
65	1.125	54.9
65	1.250	61.0
65	1.500	73.1
70	1.000	52.5
70	1.125	59.0
70	1.250	65.6
70	1.500	78.8
100	1.000	75.0
100	1.125	84.4
100	1.250	93.5
100	1.500	113.0
0	0.000	0.0

FIELD	L.R.F.D.
FU	F_u
LV	Edge Distance l_v in.
BD	'Bearing', Design Loads, Kips(for one fastener, 1" thick material)

TABLE I-F. "EDGE DISTANCE"

Database File: I-F1.DBF

D	D1_5	FU	BD
1.000	1.5000	58	104.0
0.875	1.3125	58	91.3
0.750	1.1250	58	78.3
1.000	1.5000	65	117.0
0.875	1.3125	65	102.0
0.750	1.1250	65	87.8
1.000	1.5000	70	126.0
0.875	1.3125	70	110.0
0.750	1.1250	70	94.5
1.000	1.5000	100	180.0
0.875	1.3125	100	158.0
0.750	1.1250	100	135.0

FIELD	L.R.F.D.
D	Bolt Dia.
D1_5	1 1/2 d In.
FU	F _u
BD	Values when edge distance is 1 1/2 d or greater

TABLE I-F. "EDGE DISTANCE"

Database File: I-611.DBF

LH	LV	C1
1.000	1.250	63.8
1.000	1.375	65.8
1.000	1.500	67.8
1.000	1.625	69.8
1.000	1.750	71.9
1.000	1.875	73.9
1.000	2.000	75.9
1.000	2.250	80.2
1.000	2.500	84.0
1.000	2.750	88.1
1.000	3.000	92.1
1.125	1.250	69.2
1.125	1.375	71.2
1.125	1.500	73.2
1.125	1.625	75.3
1.125	1.750	77.3
1.125	1.875	79.3
1.125	2.000	81.3
1.125	2.250	85.4
1.125	2.500	89.4
1.125	2.750	93.5
1.125	3.000	97.5
1.250	1.250	74.6

1.250	1.375	76.7
1.250	1.500	78.7
1.250	1.625	80.7
1.250	1.750	82.7
1.250	1.875	84.8
1.250	2.000	86.8
1.250	2.250	90.8
1.250	2.500	94.9
1.250	2.750	98.9
1.250	3.000	103.0
1.375	1.250	80.1
1.375	1.375	82.1
1.375	1.500	84.1
1.375	1.625	86.1
1.375	1.750	88.2
1.375	1.875	90.2
1.375	2.000	92.2
1.375	2.250	96.3
1.375	2.500	100.0
1.375	2.750	104.0
1.375	3.000	108.0
1.500	1.250	85.5
1.500	1.375	87.5
1.500	1.500	89.6
1.500	1.625	91.6
1.500	1.750	93.6

1.500	1.875	95.6
1.500	2.000	97.7
1.500	2.250	102.0
1.500	2.500	106.0
1.500	2.750	110.0
1.500	3.000	114.0
1.625	1.250	90.9
1.625	1.375	93.0
1.625	1.500	95.0
1.625	1.625	97.0
1.625	1.750	99.0
1.625	1.875	101.0
1.625	2.000	103.0
1.625	2.250	107.0
1.625	2.500	111.0
1.625	2.750	115.0
1.625	3.000	119.0
1.750	1.250	96.4
1.750	1.375	98.4
1.750	1.500	100.0
1.750	1.625	102.0
1.750	1.750	104.0
1.750	1.875	107.0
1.750	2.000	109.0
1.750	2.250	113.0
1.750	2.500	117.0

1.750	2.750	121.0
1.750	3.000	125.0
1.875	1.250	102.0
1.875	1.375	104.0
1.875	1.500	106.0
1.875	1.625	108.0
1.875	1.750	110.0
1.875	1.875	112.0
1.875	2.000	114.0
1.875	2.250	118.0
1.875	2.500	122.0
1.875	2.750	126.0
1.875	3.000	130.0
2.000	1.250	107.0
2.000	1.375	109.0
2.000	1.500	111.0
2.000	1.625	113.0
2.000	1.750	115.0
2.000	1.875	117.0
2.000	2.000	119.0
2.000	2.250	123.0
2.000	2.500	128.0
2.000	2.750	132.0
2.000	3.000	136.0
2.250	1.250	118.0
2.250	1.375	120.0

2.250	1.500	122.0
2.250	1.625	124.0
2.250	1.750	126.0
2.250	1.875	128.0
2.250	2.000	130.0
2.250	2.250	134.0
2.250	2.500	138.0
2.250	2.750	142.0
2.250	3.000	146.0
2.500	1.250	129.0
2.500	1.375	131.0
2.500	1.500	133.0
2.500	1.625	135.0
2.500	1.750	137.0
2.500	1.875	139.0
2.500	2.000	141.0
2.500	2.250	145.0
2.500	2.500	149.0
2.500	2.750	153.0
2.500	3.000	157.0
2.750	1.250	140.0
2.750	1.375	142.0
2.750	1.500	144.0
2.750	1.625	146.0
2.750	1.750	148.0
2.750	1.875	150.0

2.750	2.000	152.0
2.750	2.250	156.0
2.750	2.500	160.0
2.750	2.750	164.0
2.750	3.000	168.0
3.000	1.250	151.0
3.000	1.375	153.0
3.000	1.500	155.0
3.000	1.625	157.0
3.000	1.750	159.0
3.000	1.875	161.0
3.000	2.000	163.0
3.000	2.250	167.0
3.000	2.500	171.0
3.000	2.750	175.0
3.000	3.000	179.0

FIELD	L.R.F.D.
LH	l_h
LV	l_v
C1	Coefficient C_1

TABLE I-G.1 COEFFICIENTS FOR WEB TEAR-OUT (BLOCK SHEAR)

'Based on standard holes and 3" fastener spacing' 'Shear yield,
Tension fracture'

TABLE I-G.2 COEFFICIENTS FOR WEB TEAR-OUT (BLOCK SHEAR)

'Tension yield, Shear fracture'

Note: Database file I-G11 is the first part of table I-G.1, and database
file I-G21 is the first part of table I-G.2.

Database File: I-621.DBF

LH	LV	CI
1.000	1.250	59.6
1.000	1.375	62.9
1.000	1.500	66.2
1.000	1.625	69.4
1.000	1.750	72.7
1.000	1.875	75.9
1.000	2.000	79.2
1.000	2.250	85.7
1.000	2.500	92.3
1.000	2.750	98.8
1.000	3.000	105.3
1.125	1.250	63.0
1.125	1.375	66.3
1.125	1.500	69.5
1.125	1.625	72.8
1.125	1.750	76.1
1.125	1.875	79.3
1.125	2.000	82.6
1.125	2.250	89.1
1.125	2.500	95.6
1.125	2.750	102.0
1.125	3.000	109.0
1.250	1.250	66.4

1.250	1.375	69.6
1.250	1.500	72.9
1.250	1.625	76.2
1.250	1.750	79.4
1.250	1.875	82.7
1.250	2.000	86.0
1.250	2.250	92.5
1.250	2.500	99.0
1.250	2.750	106.0
1.250	3.000	112.0
1.375	1.250	69.8
1.375	1.375	73.0
1.375	1.500	76.3
1.375	1.625	79.5
1.375	1.750	82.8
1.375	1.875	86.1
1.375	2.000	89.3
1.375	2.250	95.9
1.375	2.500	102.0
1.375	2.750	109.0
1.375	3.000	115.0
1.500	1.250	73.1
1.500	1.375	76.4
1.500	1.500	79.7
1.500	1.625	82.9
1.500	1.750	86.2

1.500	1.875	89.4
1.500	2.000	92.7
1.500	2.250	99.2
1.500	2.500	106.0
1.500	2.750	112.0
1.500	3.000	119.0
1.625	1.250	76.5
1.625	1.375	79.8
1.625	1.500	83.0
1.625	1.625	86.3
1.625	1.750	89.6
1.625	1.875	92.8
1.625	2.000	96.1
1.625	2.250	103.0
1.625	2.500	109.0
1.625	2.750	116.0
1.625	3.000	122.0
1.750	1.250	79.9
1.750	1.375	83.1
1.750	1.500	86.4
1.750	1.625	89.7
1.750	1.750	92.9
1.750	1.875	96.2
1.750	2.000	99.5
1.750	2.250	106.0
1.750	2.500	113.0

1.750	2.750	119.0
1.750	3.000	126.0
1.875	1.250	83.3
1.875	1.375	86.5
1.875	1.500	89.8
1.875	1.625	93.0
1.875	1.750	96.3
1.875	1.875	99.6
1.875	2.000	103.0
1.875	2.250	109.0
1.875	2.500	116.0
1.875	2.750	122.0
1.875	3.000	129.0
2.000	1.250	86.6
2.000	1.375	89.9
2.000	1.500	93.2
2.000	1.625	96.4
2.000	1.750	99.7
2.000	1.875	103.0
2.000	2.000	106.0
2.000	2.250	113.0
2.000	2.500	119.0
2.000	2.750	126.0
2.000	3.000	132.0
2.250	1.250	93.4
2.250	1.375	96.6

2.250	1.500	99.9
2.250	1.625	103.0
2.250	1.750	106.0
2.250	1.875	110.0
2.250	2.000	113.0
2.250	2.250	118.0
2.250	2.500	126.0
2.250	2.750	133.0
2.250	3.000	139.0
2.500	1.250	100.0
2.500	1.375	103.0
2.500	1.500	107.0
2.500	1.625	110.0
2.500	1.750	113.0
2.500	1.875	116.0
2.500	2.000	120.0
2.500	2.250	126.0
2.500	2.500	133.0
2.500	2.750	139.0
2.500	3.000	146.0
2.750	1.250	107.0
2.750	1.375	110.0
2.750	1.500	113.0
2.750	1.625	117.0
2.750	1.750	120.0
2.750	1.875	123.0

2.750	2.000	126.0
2.750	2.250	133.0
2.750	2.500	140.0
2.750	2.750	146.0
2.750	3.000	153.0
3.000	1.250	114.0
3.000	1.375	117.0
3.000	1.500	120.0
3.000	1.625	123.0
3.000	1.750	127.0
3.000	1.875	130.0
3.000	2.000	133.0
3.000	2.250	140.0
3.000	2.500	146.0
3.000	2.750	153.0
3.000	3.000	159.0

Database File: I-G12.DBF

D	N	C2
0.750	2	37.5
0.750	3	86.1
0.750	4	135.0
0.750	5	183.0
0.750	6	232.0
0.750	7	281.0
0.750	8	329.0
0.750	9	378.0
0.750	10	426.0
0.875	2	35.8
0.875	3	84.4
0.875	4	133.0
0.875	5	182.0
0.875	6	230.0
0.875	7	279.0
0.875	8	327.0
0.875	9	376.0
0.875	10	425.0
1.000	2	34.1
1.000	3	82.7
1.000	4	131.0
1.000	5	180.0
1.000	6	228.0

1.000	7	277.0
1.000	8	326.0
1.000	9	374.0
1.000	10	423.0

FIELD	L.R.F.D.
D	Bolt Dia., In.
N	n
C2	Coefficient C ₂

Note: Database file I-G12 is the second part of table I-G.1, and database file I-G22 is the second part of table I-G.2.

Database File: I-622.DBF

D	N	CC
0.750	2	46.5
0.750	3	104.0
0.750	4	161.0
0.750	5	218.0
0.750	6	275.0
0.750	7	332.0
0.750	8	389.0
0.750	9	446.0
0.750	10	503.0
0.875	2	41.0
0.875	3	95.0
0.875	4	149.0
0.875	5	203.0
0.875	6	257.0
0.875	7	311.0
0.875	8	365.0
0.875	9	418.0
0.875	10	472.0
1.000	2	36.7
1.000	3	87.3
1.000	4	138.0
1.000	5	188.0
1.000	6	238.0

1.000	7	290.0
1.000	8	340.0
1.000	9	391.0
1.000	10	441.0

Database File: II-A.DBF

BOLTTYPE	D	T	L	N	BOLTSHEAR
A325-N	0.750	0.3125	5.5	2	62.0
A325-N	0.750	0.3125	8.5	3	93.0
A325-N	0.750	0.3125	11.5	4	124.0
A325-N	0.750	0.3125	14.5	5	155.0
A325-N	0.750	0.3125	17.5	6	186.0
A325-N	0.750	0.3125	20.5	7	217.0
A325-N	0.750	0.3125	23.5	8	248.0
A325-N	0.750	0.3125	26.5	9	279.0
A325-N	0.750	0.3125	29.5	10	310.0
A325-N	0.875	0.3750	5.5	2	84.4
A325-N	0.875	0.3750	8.5	3	127.0
A325-N	0.875	0.3750	11.5	4	169.0
A325-N	0.875	0.3750	14.5	5	211.0
A325-N	0.875	0.3750	17.5	6	253.0
A325-N	0.875	0.3750	20.5	7	295.0
A325-N	0.875	0.3750	23.5	8	338.0
A325-N	0.875	0.3750	26.5	9	380.0
A325-N	0.875	0.3750	29.5	10	422.0
A325-N	1.000	0.6250	5.5	2	110.0
A325-N	1.000	0.6250	8.5	3	165.0
A325-N	1.000	0.6250	11.5	4	221.0

A325-N	1.000	0.6250	14.5	5	276.0
A325-N	1.000	0.6250	17.5	6	331.0
A325-N	1.000	0.6250	20.5	7	386.0
A325-N	1.000	0.6250	23.5	8	441.0
A325-N	1.000	0.6250	26.5	9	496.0
A325-N	1.000	0.6250	29.5	10	551.0

FIELD	L.R.F.D.
BOLTTYPE	Bolt Type
D	Bolt dia. d, In.
T	Angle Thickness t, In.
L	L In.
N	n
BOLTSHEAR	Bolt Shear

TABLE II-A Bolt Shear

Database File: II-C.DBF

D	T	L	N	S
0.750	0.3125	29.5	10	349.0
0.750	0.3125	26.5	9	313.0
0.750	0.3125	23.5	8	277.0
0.750	0.3125	20.5	7	242.0
0.750	0.3125	17.5	6	206.0
0.750	0.3125	14.5	5	170.0
0.750	0.3125	11.5	4	135.0
0.750	0.3125	8.5	3	99.0
0.750	0.3125	5.5	2	63.0
0.875	0.3750	29.5	10	394.0
0.875	0.3750	26.5	9	354.0
0.875	0.3750	23.5	8	315.0
0.875	0.3750	20.5	7	276.0
0.875	0.3750	17.5	6	237.0
0.875	0.3750	14.5	5	198.0
0.875	0.3750	11.5	4	159.0
0.875	0.3750	8.5	3	120.0
0.875	0.3750	5.5	2	81.0
0.750	0.2500	29.5	10	279.0
0.750	0.2500	26.5	9	250.0
0.750	0.2500	23.5	8	222.0
0.750	0.2500	20.5	7	193.0
0.750	0.2500	17.5	6	165.0

0.750	0.2500	14.5	5	136.0
0.750	0.2500	11.5	4	108.0
0.750	0.2500	8.5	3	79.1
0.750	0.2500	5.5	2	50.6
0.750	0.3750	29.5	10	418.0
0.750	0.3750	26.5	9	376.0
0.750	0.3750	23.5	8	333.0
0.750	0.3750	20.5	7	290.0
0.750	0.3750	17.5	6	247.0
0.750	0.3750	14.5	5	204.0
0.750	0.3750	11.5	4	161.0
0.750	0.3750	8.5	3	119.0
0.750	0.3750	5.5	2	75.9
0.750	0.5000	29.5	10	558.0
0.750	0.5000	26.5	9	501.0
0.750	0.5000	23.5	8	444.0
0.750	0.5000	20.5	7	387.0
0.750	0.5000	17.5	6	330.0
0.750	0.5000	14.5	5	272.0
0.750	0.5000	11.5	4	215.0
0.750	0.5000	8.5	3	158.0
0.750	0.5000	5.5	2	101.0
0.875	0.2500	29.5	10	263.0
0.875	0.2500	26.5	9	236.0
0.875	0.2500	23.5	8	209.0
0.875	0.2500	20.5	7	182.0

0.875	0.2500	17.5	6	155.0
0.875	0.2500	14.5	5	128.0
0.875	0.2500	11.5	4	101.0
0.875	0.2500	8.5	3	74.2
0.875	0.2500	5.5	2	47.3
0.875	0.3125	29.5	10	328.0
0.875	0.3125	26.5	9	295.0
0.875	0.3125	23.5	8	261.0
0.875	0.3125	20.5	7	227.0
0.875	0.3125	17.5	6	194.0
0.875	0.3125	14.5	5	160.0
0.875	0.3125	11.5	4	126.0
0.875	0.3125	8.5	3	92.8
0.875	0.3125	5.5	2	59.1
0.875	0.5000	29.5	10	525.0
0.875	0.5000	26.5	9	471.0
0.875	0.5000	23.5	8	418.0
0.875	0.5000	20.5	7	364.0
0.875	0.5000	17.5	6	310.0
0.875	0.5000	14.5	5	256.0
0.875	0.5000	11.5	4	202.0
0.875	0.5000	8.5	3	148.0
0.875	0.5000	5.5	2	94.6
0.875	0.6250	29.5	10	657.0
0.875	0.6250	26.5	9	589.0
0.875	0.6250	23.5	8	522.0

0.875	0.6250	20.5	7	455.0
0.875	0.6250	17.5	6	387.0
0.875	0.6250	14.5	5	320.0
0.875	0.6250	11.5	4	253.0
0.875	0.6250	8.5	3	186.0
0.875	0.6250	5.5	2	118.0
1.000	0.2500	29.5	10	246.0
1.000	0.2500	26.5	9	221.0
1.000	0.2500	23.5	8	196.0
1.000	0.2500	20.5	7	170.0
1.000	0.2500	17.5	6	145.0
1.000	0.2500	14.5	5	120.0
1.000	0.2500	11.5	4	94.6
1.000	0.2500	8.5	3	69.3
1.000	0.2500	5.5	2	44.0
1.000	0.3125	29.5	10	308.0
1.000	0.3125	26.5	9	276.0
1.000	0.3125	23.5	8	245.0
1.000	0.3125	20.5	7	213.0
1.000	0.3125	17.5	6	181.0
1.000	0.3125	14.5	5	150.0
1.000	0.3125	11.5	4	118.0
1.000	0.3125	8.5	3	86.7
1.000	0.3125	5.5	2	55.1
1.000	0.3750	29.5	10	369.0
1.000	0.3750	26.5	9	332.0

1.000	0.3750	23.5	6	294.0
1.000	0.3750	20.5	7	256.0
1.000	0.3750	17.5	6	218.0
1.000	0.3750	14.5	5	160.0
1.000	0.3750	11.5	4	142.0
1.000	0.3750	8.5	3	104.0
1.000	0.3750	5.5	2	66.1
1.000	0.5000	29.5	10	493.1
1.000	0.5000	26.5	9	442.0
1.000	0.5000	23.5	8	392.0
1.000	0.5000	20.5	7	341.0
1.000	0.5000	17.5	6	290.0
1.000	0.5000	14.5	5	240.0
1.000	0.5000	11.5	4	189.0
1.000	0.5000	8.5	3	139.0
1.000	0.5000	5.5	2	88.1
1.000	0.6250	29.5	10	616.0
1.000	0.6250	26.5	9	553.0
1.000	0.6250	23.5	8	489.0
1.000	0.6250	20.5	7	426.0
1.000	0.6250	17.5	6	363.0
1.000	0.6250	14.5	5	300.0
1.000	0.6250	11.5	4	237.0
1.000	0.6250	8.5	3	173.0
1.000	0.6250	5.5	2	110.0

FIELD	L.R.F.D.
D	Bolt Dia. d, In.
T	Angle Thickness t, In.
L	L In.
N	n
S	Design Shear kips

TABLE II-C Design Shear in Connection Angles for A36 Material

Database File: VI-A.DBF

OSL	L	T	WEB_THICKN	OSL_CAPACI
3.5or4	6	0.375	0.190	13.6
3.5or4	6	0.500	0.190	18.5
3.5or4	6	0.625	0.190	22.6
4	6	0.750	0.190	26.8
4	6	1.000	0.190	29.8
3.5or4	8	0.375	0.190	15.7
3.5or4	8	0.500	0.190	20.7
3.5or4	8	0.625	0.190	25.0
4	8	0.750	0.190	29.6
4	8	1.000	0.190	32.8
3.5or4	6	0.375	0.250	15.7
3.5or4	6	0.500	0.250	23.3
3.5or4	6	0.625	0.250	30.0
4	6	0.750	0.250	34.9
4	6	1.000	0.250	43.3
3.5or4	8	0.375	0.250	18.1
3.5or4	8	0.500	0.250	26.5
3.5or4	8	0.625	0.250	32.6
4	8	0.750	0.250	38.1
4	8	1.000	0.250	43.3
3.5or4	6	0.375	0.310	17.5
3.5or4	6	0.500	0.310	26.4
3.5or4	6	0.625	0.310	35.4

3.5or4	6	0.750	0.310	44.5
4	6	1.000	0.310	57.3
3.5or4	8	0.375	0.310	20.3
3.5or4	8	0.500	0.310	30.0
3.5or4	8	0.625	0.310	39.8
3.5or4	8	0.750	0.310	49.3
4	8	1.000	0.310	60.7
3.5or4	6	0.375	0.375	19.2
3.5or4	6	0.500	0.375	29.2
3.5or4	6	0.625	0.375	39.5
3.5or4	6	0.750	0.375	49.9
4	6	1.000	0.375	70.3
3.5or4	8	0.375	0.375	22.2
3.5or4	8	0.500	0.375	33.1
3.5or4	8	0.625	0.375	44.3
3.5or4	8	0.750	0.375	55.6
4	8	1.000	0.375	75.0
3.5or4	6	0.375	0.440	20.8
3.5or4	6	0.500	0.440	31.9
3.5or4	6	0.625	0.440	43.3
3.5or4	6	0.750	0.440	55.0
3.5or4	6	1.000	0.440	78.4
3.5or4	8	0.375	0.440	24.0
3.5or4	8	0.500	0.440	36.1
3.5or4	8	0.625	0.440	48.6
3.5or4	8	0.750	0.440	61.2

4	8	1.000	0.440	86.5
3.5or4	6	0.375	0.500	22.2
3.5or4	6	0.500	0.500	34.4
3.5or4	6	0.625	0.500	47.1
3.5or4	6	0.750	0.500	59.9
3.5or4	6	1.000	0.500	85.8
3.5or4	8	0.375	0.500	25.6
3.5or4	8	0.500	0.500	38.9
3.5or4	8	0.625	0.500	52.6
3.5or4	8	0.750	0.500	66.5
3.5or4	8	1.000	0.500	94.4
3.5or4	6	0.375	0.565	23.5
3.5or4	6	0.500	0.565	36.8
3.5or4	6	0.625	0.565	50.6
3.5or4	6	0.750	0.565	64.6
3.5or4	6	1.000	0.565	93.0
3.5or4	8	0.375	0.565	27.2
3.5or4	8	0.500	0.565	41.6
3.5or4	8	0.625	0.565	56.5
3.5or4	8	0.750	0.565	71.6
3.5or4	8	1.000	0.565	102.0

FIELD	L.R.F.D.
OSL	Outstanding Leg, In.
L	Angle Length, In.
T	Angle Thickness, In.
WEB_THICKN	Beam Web Thickness In.
OSL_CAPACI	Outstanding Leg Capacity, Kips

TABLE VI-A Outstanding Leg Capacity ($F_y=36\text{k.s.i.}$)

TABLE VI-B Outstanding Leg Capacity ($F_y=50\text{k.s.i.}$)

Note: Database files VI-A and VI-B were taken from tables VI-A and VI-B respectively.

Database File: V1-2.DBF

OSL	L	T	WEB_THICKN	OSL_CAPACI
3.5or4	6	0.375	0.190	16.0
3.5or4	6	0.500	0.190	23.2
3.5or4	6	0.625	0.190	28.3
4	6	0.750	0.190	33.4
4	6	1.000	0.190	41.5
3.5or4	8	0.375	0.190	18.5
3.5or4	8	0.500	0.190	25.3
3.5or4	8	0.625	0.190	31.0
4	8	0.750	0.190	36.7
4	8	1.000	0.190	41.5
3.5or4	6	0.375	0.250	18.5
3.5or4	6	0.500	0.250	28.0
3.5or4	6	0.625	0.250	37.7
3.5or4	6	0.750	0.250	44.3
4	6	1.000	0.250	56.6
3.5or4	8	0.375	0.250	21.3
3.5or4	8	0.500	0.250	31.8
3.5or4	8	0.625	0.250	41.2
4	8	0.750	0.250	47.9
4	8	1.000	0.250	60.2
3.5or4	6	0.375	0.310	20.7
3.5or4	6	0.500	0.310	31.7
3.5or4	6	0.625	0.310	43.1

3.5or4	6	0.750	0.310	54.7
4	6	1.000	0.310	73.7
3.5or4	8	0.375	0.310	23.9
3.5or4	8	0.500	0.310	36.0
3.5or4	8	0.625	0.310	48.3
3.5or4	8	0.750	0.310	60.9
4	8	1.000	0.310	78.8
3.5or4	6	0.375	0.375	22.6
3.5or4	6	0.500	0.375	35.2
3.5or4	6	0.625	0.375	48.3
3.5or4	6	0.750	0.375	61.5
3.5or4	6	1.000	0.375	88.2
3.5or4	8	0.375	0.375	26.1
3.5or4	8	0.500	0.375	39.9
3.5or4	8	0.625	0.375	53.9
3.5or4	8	0.750	0.375	68.2
4	8	1.000	0.375	96.9
3.5or4	6	0.375	0.440	24.5
3.5or4	6	0.500	0.440	38.5
3.5or4	6	0.625	0.440	53.1
3.5or4	6	0.750	0.440	68.0
3.5or4	6	1.000	0.440	98.1
3.5or4	8	0.375	0.440	28.2
3.5or4	8	0.500	0.440	43.5
3.5or4	8	0.625	0.440	59.3
3.5or4	8	0.750	0.440	75.2

3.5or4	8	1.000	0.440	106.0
3.5or4	6	0.375	0.500	26.1
3.5or4	6	0.500	0.500	41.7
3.5or4	6	0.625	0.500	57.8
3.5or4	6	0.750	0.500	74.3
3.5or4	6	1.000	0.500	108.0
3.5or4	8	0.375	0.500	30.2
3.5or4	8	0.500	0.500	47.0
3.5or4	8	0.625	0.500	64.3
3.5or4	8	0.750	0.250	82.0
3.5or4	8	1.000	0.500	118.0
3.5or4	6	0.375	0.565	27.7
3.5or4	6	0.500	0.565	44.7
3.5or4	6	0.625	0.565	62.4
3.5or4	6	0.750	0.565	80.4
3.5or4	6	1.000	0.565	117.0
3.5or4	8	0.375	0.565	32.0
3.5or4	8	0.500	0.565	50.3
3.5or4	8	0.625	0.565	69.2
3.5or4	8	0.750	0.565	88.5
3.5or4	8	1.000	0.565	128.0

Database File: VI-C.DBF

WELD_SIZE	ANGLE_SIZE	CAPACITY	MAX_THICK	MIN_THICK
0.2500	4*3.5	17.3	0.50	0.375
0.3125	4*3.5	21.5	0.50	0.375
0.3750	4*3.5	25.8	0.50	0.375
0.4375	4*3.5	30.2	0.50	0.375
0.5000	5*3.5	25.8	0.75	0.375
0.6250	5*3.5	32.3	0.75	0.375
0.7500	5*3.5	38.7	0.75	0.375
0.8750	5*3.5	45.2	0.75	0.375
1.0000	5*3.5	51.6	0.75	0.375
1.2500	5*3.5	64.5	0.75	0.375
1.5000	5*3.5	71.0	0.75	0.375
0.2500	6*4	32.7	0.75	0.375
0.3125	6*4	41.0	0.75	0.375
0.3750	6*4	49.1	0.75	0.375
0.4375	6*4	57.3	0.75	0.375
0.5000	6*4	65.4	0.75	0.375
0.6250	6*4	81.8	0.75	0.375
0.7500	6*4	90.0	0.75	0.375
0.2500	7*4	42.8	0.75	0.375
0.3125	7*4	53.4	0.75	0.375
0.3750	7*4	64.1	0.75	0.375
0.4375	7*4	74.7	0.75	0.375
0.5000	7*4	83.4	0.75	0.375

0.6250 7*4	107.0	0.75	0.375
0.6875 7*4	117.0	0.75	0.375
0.2500 8*4	53.4	1.00	0.500
0.3125 8*4	66.8	1.00	0.500
0.3750 8*4	80.1	1.00	0.500
0.4375 8*4	93.5	1.00	0.500
0.5000 8*4	107.0	1.00	0.500
0.6250 8*4	134.0	1.00	0.500

FIELD	L.R.F.D.
WELD_SIZE	Weld Size, In.
ANGLE_SIZE	Seat Angle Size (long leg vertical)
CAPACITY	Weld Capacity, Kips
MAX_THICK	Range of Available Seat Angle Thicknesses, Maximum
MIN_THICK	Range of Available Seat Angle Thicknesses, Minimum

TABLE VI-C Weld Capacity

An example of a particular testing session:

During a test of the prototype expert system CONDSIGN by Dr. Fortey, several questions were raised. For instance, some prompts given by CONDSIGN were not clearly understood; so they had to be reworded. The prompt for parameter SETBACK was changed to 'enter the protrusion in inches which framing angles extend out beyond the cut end of the beam for easy fitting of members together during steel erection.' In database VI-A.DBF the angle length L is either 6 or 8 inches. Therefore the prompt for parameter L should read: enter 6 or 8 for the length of the angle in inches.

Persons with different areas of expertise will not see things in the same perspective. A seasoned structural design engineer like Prof. Johnson will know that table VI-A only has angle lengths of 6 and 8 inches. For the prototype to accept values between whole numbers, additional rules will be added to design by calculation. Or a separate file can be set up in FORTRAN to handle the mathematics, and link it to the expert system. Dr. Fortey suggested that a couple of rules be created to advise the user when L is too short or too long. An angle too short will present a problem of instability; and when it is too long, it will tend to buckle easily under stress.

The debugging process is very important. Emphasis should be made to allow as many people, experts or novices, as possible to use the prototype and obtain their feedbacks. If not, the above mentioned might not ever come to light. The feedback process should never have to come to an end.

Appendix B: Design Examples.

The following were examples which ran on CONDSIGN.

Example 4: Taken from example 1 on page 5-18 in the LRFD manual.

Given: ASTM , Type of Steel:	A36
D , Bolt Diameter:	0.75 inch
COPED , Beam cope:	2.0 inches
RU , Factored Load:	65 kips
DSG , Beam Designation:	W18x50
SETBACK , Beam Web Setback:	0.5 inch
DBW , Distance Between the Row of Bolts' Holes in the Web and the End of the Beam Web:	2.0 inch

Solution:

LV, Edge distance

from the top of the angle to the top bolt:	1.25 inches
--	-------------

N, Number of bolts: 3

T, Angle thickness: 0.25 inch

L, Length of angle: 8.5 inches

STABLE, Stability during steel erection: sufficient

CLEAR, Clearance for angles to fit beam web: OK

BOLTSHEAR, Shear capacity of bolts: 93 kips

S, Design shear for angles: 79.1 kips

BC, Bearing capacity of beam web: 83.4 kips

BCA, Bearing capacity of angles: 117.45 kips

RBS, Resistance to block shear: 68.6 kips

BSC, Block shear check: OK

OSL, Shorter leg of angle: 3.5 inches

LEG, Length of the other leg: 4.0 inches

MIN, Minimum flange width if frames into column 8.355 inches

Examples 5, 6, 8, 9, 10, and 11 are made up; example 7 is from Gaylord and Gaylord.

<u>Example</u>	<u>5</u>	<u>6</u>	<u>7</u>
<u>ASTM</u>	A36	A36	A36
<u>D</u>	0.75	0.875	0.75
<u>COPED</u>	2.0	2.0	0
<u>RU</u>	30.0	55.0	45.0
<u>DSG</u>	W21x62	W18x50	W16x31
<u>SETBACK</u>	0.5	0.5	0.5
<u>DBW</u>	2.0	2.0	2.0
<u>LV</u>	1.25	1.25	1.25
<u>N</u>	4.0	3.0	3.0
<u>T</u>	0.25	0.3125*	0.25
<u>L</u>	11.5	8.5	8.5
<u>STABLE</u>	sufficient	sufficient	sufficient
<u>CLEAR</u>	OK	OK	OK
<u>BOLTSHEAR</u>	124.0	127.0	93.0
<u>S</u>	108.0	92.8	79.1
<u>BC</u>	125.3	84.1	64.6
<u>BCA</u>	156.6	148.1	105.5
<u>RBS</u>	99.0	67.9	
<u>BSC</u>	OK	OK	
<u>OSL</u>	3.5	5.0	3.5
<u>LEG</u>	4.0	5.0	4.0
<u>MIN</u>	8.4	10.355	8.275

* Angle thickness was 0.25 in., but a 5x5 angle cannot be found.

<u>Example</u>	<u>8</u>	<u>9</u>	<u>10</u>	<u>11</u>
<u>ASTM</u>	A36	A36	A36	A36
<u>D</u>	1.0	1.0	0.875	1.0
<u>COPED</u>	0	0	0	0
<u>RU</u>	150	100	350	500
<u>DSG</u>	W14x120	W12x96	W30x132	W33x221
<u>SETBACK</u>	0.5	0.5	0.5	0.5
<u>DBW</u>	2.0	2.0	2.0	2.0
<u>LV</u>	1.25	1.25	1.25	1.25
<u>N</u>	3	2	9	10
<u>T</u>	0.625	0.625	0.375	0.625
<u>L</u>	8.5	5.5	26.5	29.5
<u>STABLE</u>	sufficient	sufficient	sufficient	sufficient
<u>CLEAR</u>	OK.	OK.	OK.	OK.
<u>BOLTSHEAR</u>	165.0	110.0	380.0	551.0
<u>S</u>	173.0	110.0	354.0	616.0
<u>BC</u>	184.8	114.8	505.3	809.1
<u>BCA</u>	329.0	198.5	588.6	1242.5
<u>OSL</u>	5.0	5.0	5.0	5.0
<u>LEG</u>	5.0	5.0	5.0	5.0
<u>MIN</u>	10.6	10.6	10.6	10.8

Example 12 is taken from the LRFD manual, example 13 is from Salmon and Johnson, examples 14, 15, and 16 are made up.

SEAT-CONN: Is the seat angle welded to the beam flange?

OSL-CAPACI: Outstanding leg capacity in kips.

ANGLE-SIZE: The length of the angle legs in inches.

WELD-SIZE: Size of the weld in inches.

MIN-SIZE: Minimum size of the leg dimension of fillet weld.

COMPATIB: Compatibility check of weld size to thinner part joined.

<u>Example</u>	<u>12</u>	<u>13</u>	<u>14</u>	<u>15</u>	<u>16</u>
<u>SEAT-CONN</u>	YES	YES	NO	NO	NO
<u>ASTM</u>	A36	A36	A36	A572-G50	A36
<u>DSG</u>	W21x62	W12x40	W33x118	W14x30	W6x9
<u>L</u>	8.0	8.0	6.0	8.0	6.0
<u>RU</u>	50.0	24.8	91.0	45.0	26.7
<u>OSL-CAPACI</u>	55.6	30.0	93.0	47.9	26.8
<u>T</u>	0.75	0.5	1.0	0.75	0.75
<u>ANGLE-SIZE</u>	7x4	5x3.5	8x4	7x4	6x4
<u>WELD-SIZE</u>	0.3125	0.25	0.4375	0.3125	0.25
<u>MIN-SIZE</u>	0.25	0.25			
<u>COMPATIB</u>	OK	OK			

Example 17 is a test to make sure that the user does not choose a beam which has a web thickness too big for tables vi-a or vi-b. Example 18 gives an error message when a steel type with F_y other than 36 or 50 is picked.

Appendix C

Examples which were run on CONXPRT to verify CONDSIGN.

<u>Example</u>	<u>1</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>
<u>Beam</u>	W30x108	W27x94	W18x50	W21x62	W18x50
<u>Steel</u>	A36	A36	A36	A36	A36
<u>Cope</u>	0	0	2.0	2.0	2.0
<u>Vu</u>	160	200	65	30.0	55.0
<u>Bolt Type</u>	A325-N	A325-N	A325-N	A325-N	A325-N
<u>Bolt Dia.</u>	3 / 4	7 / 8	3 / 4	3 / 4	7 / 8
<u>Spacing</u>	3	3	3	3	3
<u>No. of Bolts</u>	6	6	3	4	3
<u>Angle</u>	4x3 ¹ / ₂ x5 ⁵ / ₁₆	5x5x3 ³ / ₈	4x3 ¹ / ₂ x1 ¹ / ₄	4x3 ¹ / ₂ x1 ¹ / ₄	5x5x5 ⁵ / ₁₆
<u>Length</u>	17.5	17.5	8.5	11.5	8.5

<u>Example</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>	<u>11</u>
<u>Beam</u>	W16x31	W14x120	W12x96	W30x132	W33x221
<u>Steel</u>	A36	A36	A36	A36	A36
<u>Cope</u>	0	0	0	0	0
<u>Vu</u>	45.0	150.0	100.0	350.0	500.0
<u>Bolt Type</u>	A325-N	A325-N	A325-N	A325-N	A325-N
<u>Bolt Dia.</u>	3 / 4	1	1	7 / 8	1
<u>Spacing</u>	3	3	3	3	3
<u>No. of Bolts</u>	3	3	2	9	10
<u>Angle</u>	4x3 ¹ / ₂ x1 ¹ / ₄	5x5x5 ⁵ / ₈	5x5x5 ⁵ / ₈	5x5x3 ³ / ₈	5x5x5 ⁵ / ₈
<u>Length</u>	8.5	8.5	5.5	26.5	29.5

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Appendix D: Tests with Prof. Johnson's Program.

Example	1	3	4	5	6
<u>Bolt Type</u>	A325-N	A325-N	A325-N	A325-N	A325-N
<u>Bolt Dia.</u>	0.75	0.875	0.75	0.75	0.875
<u>End Shear</u>	160	200	65	30	55
<u>Bolt Spacing</u>	3	3	3	3	3
<u>F_y</u>	36	36	36	36	36
<u>F_u</u>	58	58	58	58	58
<u>Depth</u>	29.83	26.92	17.99	20.99	17.99
<u>T Distance</u>	26.75	24.045	15.5	18.25	15.5
<u>Web Thk.</u>	0.545	0.49	0.355	0.4	0.355
<u>LH</u>	2.0	2.0	2.0	2.0	2.0
<u>Cope Depth</u>	0	0	2.0	2.0	2.0
<u>No. of Bolts</u>	6	5	3	4	3
<u>Angle Length</u>	17.5	14.5	8.5	11.5	8.5
<u>Min.Ang.Thk.</u>	0.243	0.39	0.205	0.07	0.185
<u>Web Brg.Cap.</u>	257.0	224.0	84.0	126.0	84.9
<u>Blk. Shr. Cap.</u>	0	0	68.0	99.0	65.0
<u>Web H Avail.</u>	26.75	24.05	14.75	17.62	14.75
Example	7	8	9	10	11
<u>Bolt Type</u>	A325-N	A325-N	A325-N	A325-N	A325-N
<u>Bolt Dia.</u>	0.75	1.0	1.0	0.875	1.0
<u>End Shear</u>	45.0	150.0	100.0	350.0	500.0
<u>Bolt Spacing</u>	3.0	3.0	3.0	3.0	3.0
<u>F_y</u>	36	36	36	36	36
<u>F_u</u>	58	58	58	58	58
<u>Depth</u>	15.88	14.48	12.71	30.31	33.93
<u>T Distance</u>	13.625	11.25	9.5	26.75	29.75
<u>Web Thk.</u>	0.275	0.59	0.55	0.615	0.775
<u>LH</u>	2	2	2	2	2
<u>Cope Depth</u>	0	0	0	0	0
<u>No. of Bolts</u>	3	3	2	9	10
<u>Angle Length</u>	8.5	8.5	5.5	26.5	29.5
<u>Min.Ang.Thk.</u>	0.142	0.54	0.568	0.371	0.507
<u>Web Brg.Cap.</u>	65.0	185.0	115.0	506.0	810.0
<u>Blk. Shr. Cap.</u>	0	0	0	0	0
<u>Web H Avail.</u>	13.63	11.25	9.5	26.75	29.75

VITA

Eng-Kian Koh was born in Singapore on November 25, 1958. He attended primary school in that country, and was graduated from Maris Stella High School in December 1974. In March 1975 he entered National Junior College, and in December 1976 he graduated.

In September of 1979, he entered The University of Tennessee, Knoxville, as an undergraduate student. He received a Bachelor of Science degree in Civil Engineering in June of 1982. In January 1983, he entered the Graduate School, and received the Master of Engineering degree with a major in Civil Engineering in August of 1984.

The author is a member of Chi Epsilon, and he had served in the Singapore Student Association during some of his years at the university.