Interactive Computer-Aided Design of Welded and Bolted Connections in Steel Buildings

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ABSTRACT

A microcomputer-aided design (MICROCAD) system has been developed for interactive design of connections in steel buildings made of standard rolled I-sections, called STEELCON. Design of different connections is based on the American Institute of Steel Construction specification. Connecting elements may be plates, angles, or T-sections. Connectors may be bolts or welds. The MICROCAD system can display/plot any isometric view of the connection plus three orthographic views, i.e., front, side, and top views. Application of the MICROCAD system for design of simple (type 2) shop-welded and field-bolted beam-column angle connections is presented. Microcomputer graphics for displaying the isometric and orthographic views including the dimensions and designations are presented.

Calcul des connections soudées verrouées dans les bâtiments en acier utilisant le micro-ordinateur

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Sommaire

Un système de micro-ordinateur pour le calcul interactif (MICRCAD) des bâtiments en acier construits des sections laminées en forme de I, nomées STEELCON, a été developé. Le calcul des differentes types de connections est basé sur les specifications de l'institut americain de la construction d'acier (AISC). Les elements à joindre peuvent être des plats, du forme d'angle ou de T. Les élements de connections peuvent être des verrous ou des soudures. Le MICROCAD système peut produire des vues isometriques ainsi que les trois vues orthogonales (de face, de côté, ou de dessus). Application du MICROCAD système pour le calcul de connections simples soudées à l'usine et verrouées sur le chantier est presenté. Les micro-ordinateur graphiques pour la production des vues isometriques et orthogonales avec dimensions sont presentees.

INTRODUCTION

This paper presents interactive design of connections in steel buildings on microcomputers. We are in the process of developing a user-friendly interactive MICROCAD system for design of beam-column connections in steel buildings, called STEELCON. In addition to designing the connection, the microcomputer program can display/plot any isometric view and three orthographic views (front face, side face, and top face views) of the connection. The program structure and graphic algorithms are presented in Ref. 1. This paper presents application of the MICROCAD system STEELCON for design of shop-welded and field-bolted beam column connections. Design of different types of connections is based on the American Institute of Steel Construction (AISC) specification[2]. Under no circumstances does the program violate the above specification, or allow the designer to enter data in violation of the AISC code. The approach of interactive design has been the subject of a number of recent articles by Adeli and co-workers[3-5]. In this approach, the user/designer is in charge and the CAD system works as an assistant to him.

The program allows the user/designer to correct his/her mistakes without causing the program to terminate or do any other undesirable action. Anytime the user is prompted to input something, a check is made to see if the inputted data is within the permissible range. If the data is outside the allowable range, an error message will be given and an audible signal will be heard. The user is then asked to reenter the data which caused the problem.

GENERAL DESIGN CONSIDERATIONS

At the beginning of the program a brief introduction to the program is presented to the user. Following the introduction, the user is provided with

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a menu for the selection of moment resisting or simple connections. The (MICROCAD) program can design connection types most often encountered in the design of steel buildings. Design of connections varies from one to another. Some elements of design are common to all types of connections, however. These are discussed in the following paragraphs.

I-Sections for Beams and Columns

The MICROCAD program is designed to handle standard steel rolled I-sections for all columns and beams. The user simply has to input the section desired by its standard designation, say W18x76. The inputted designation is then checked against a list of available I-sections in the AISC Manual stored in an external random access data file, called AISC.DAT. In addition to specifying the I-section desired, the user also specifies the type of steel used for the section. There are three common designations of steel offered for the user to select from: A-36, A572-grade 50, and A529. If the user does not desire any of these, he/she has the opportunity to enter the properties which characterize each type of steel, i.e., the ultimate strength (Fu) and the yield strength (Fy). In all cases a 1/2 in. nominal gap between beams and columns is used in the design of the connection. This distance is needed in case there is an overrun in the length of a section being connected. At the completion of the selection of all I-sections, the program prompts the user to enter the load in kips that the connection will be designed to carry. Any value less than six kips is rejected and the user is asked to enter a valid load (AISC 1.15.1).

Angles

The angle selection process references an external random access data file, ANG.DAT, containing data for standard angles. The criteria for initial selection of the angles are ordered as follows. First, the angle thickness should be as thin as possible. Second, the short leg width should be as short as possible. Finally, the long leg width should be as short as possible. The angles in ANG.DAT are ordered in the same way as the above criteria. After the initial angle selection, the user has the option to select an angle other than the one selected by the program. Any change in the angle selection is checked to make sure that the two widths and the thickness of the new angle are adequate. If the angle is not adequate and thus rejected by the program, the user will be then told why the angle is rejected and given another opportunity to select an adequate angle.

Bolts

There are six possible bolt types that can be selected. The selection of the bolt types is a two-step process. First, the user selects either ASTM A325 or ASTM A490 bolts which are the most frequently used types of bolts. After the first selection, the user must specify the fastner type used, i.e., friction-type connection (F), bearing-type connection with threads included in the shear plane (N), or bearing-type connection with threads excluded from the shear plane (X).

Diameters of the bolts range from 5/8 in. to 1-1/2 in. in 1/8 in. increments. The minimum number of bolts used in any connection part is two. Every design uses standard holes 1/16 in. larger than the bolt diameter (AISC 1.23.4.1). The design of the bolts has three parameters to be

considered, number of bolts needed, diameter of the bolts, and center-to-center spacing or pitch of the bolts.

The initial design returns the smallest bolt diameter capable of carrying the design load. The initial pitch is three in. or three times the bolt diameter, whichever is larger. The spacing selection is not the minimum allowed by the code, but instead is the preferred spacing used in most connection designs. If the user wishes to try a smaller pitch, he/she has the opportunity to do so after the initial bolt design. An initial edge distance of 1-1/2 in. for one inch or smaller bolt diameters, or 1-3/4 times the bolt diameter for bolts greater than one inch in diameter, is used in the design process. This is a modification of the requirement of AISC 1.16.5.1 considering practical concerns.

After the initial design for the bolts, the user has the opportunity to change the design parameters repeatedly. The calculations are quite fast so the user can explore many different possibilities within a short time to reach a final selection for the bolts.

Welds

The welding process assumed for all welding is Shielded Metal Arc Welding (SMAW). The electrode selection is left for the user. Grades ranging from E-60 to E-110 are available to the user.

The possible fillet weld leg sizes range from 1/8 in. to 1 in. A 1/8 in. weld is the minimum size allowed by the specification (AISC 1.17.2). The increments of possible weld sizes between the two extreme limits are 1/16 in. for 1/8 in. to 1/2 in. welds and 1/8 in. for weld legs greater than 1/2 in. In the following sections, we present a sample application for simple (type 2) connections using shop welds and field bolts.

BEAM-COLUMN ANGLE CONNECTION USING SHOP WELDS AND FIELD BOLTS

This connection type is constructed with the shop weld connecting the angle to the beam web and the field bolts connecting the angle to the column flange. If the procedure is reversed, i.e., the angle is connected to the column flange by shop welds and the beam web by field bolts, a problem arises, because the beam cannot be placed between the two connecting angles. Resolving this problem requires that the bottom flange of the beam be coped to allow the "scissoring" of the beam web between the two framing angles. Coping the beam involves extra labor as well as reduces the section's strength. Thus, it should be avoided if possible. Therefore, the second alternative for the shop weld and field bolts is not used.

A sample design example for an angle beam-column connection using shop welds and field bolts is presented here. This example is similar to the one in the AISC Manual on page 4-29[2]. The menu for selection of simple (type 2) connections is shown in Fig. 1. The main graphics menu which is displayed after all arrays are set up is shown in Fig. 2. The first choice, an isometric view, allows the user to select any viewing rotations desired about the X and Y axes. An example is shown in Fig. 3. In orthographic views after the connection is displayed on the screen, a second graphic menu appears at the bottom of the screen, as shown in the front face view of Fig. 4.

The option to show dimensions and designations on the screen is quite useful to the user. If this choice is selected by the user from the previous menu, he/she is immediately given another menu at the bottom of the screen. This dimension menu allows the user to specify which dimensions and designations he/she would like to see. For example, Figs. 4, 5, and 6 show the front face view with dimensions for I-sections, angles, and bolts, respectively. The same three dimensions and designation types are given for the side face view in Figs. 7 through 9. Figure 10 shows the top face view with dimensions and designations for I-sections. In the top face view of Fig. 11, I-sections are not included. This enables the display to show parts of the connections that are obscured by the beam's top flange. The option to display the top view without the I-sections is provided immediately after the user selects the top view from the main graphics menu.

If the user wishes to magnify the current display, he/she is prompted to enter the desired magnification value. Values under unity are not accepted. In addition to the magnification value, the user is prompted to enter the X and Y coordinates desired as the center point, i.e., focus of the window. Figure 12 shows the top face view of the Fig. 11 after it has been magnified.

CONCLUSION

Interactive design of simple (type 2) shop-welded and field-bolted beam-column connections in steel buildings on microcomputers is presented in this paper. Application of STEELCON for design of moment-resisting (type 1) connections is presented in Ref. 6. Using the MICROCAD system STEELCON, the user can explore many alternatives within a short time. The orthographic displays include all necessary information and details for constructing the connections. Thus, the MICROCAD system may be used as an effective tool for actual design of steel building connection.

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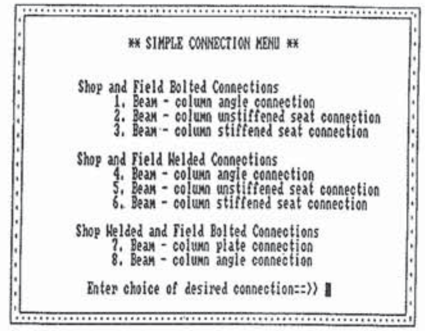


Fig. 1

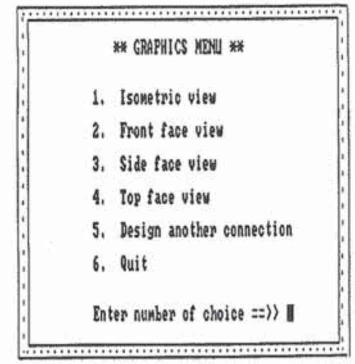


Fig. 2

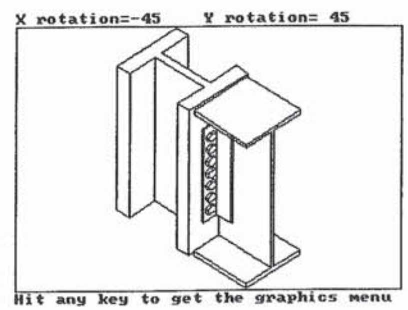
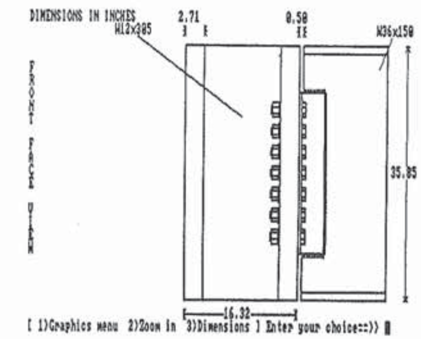


Fig. 3



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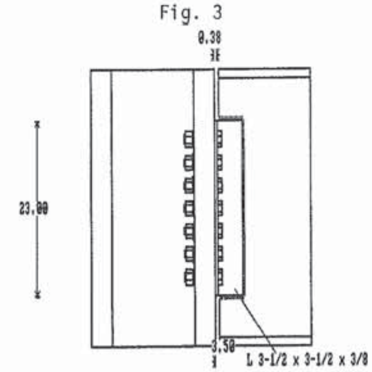

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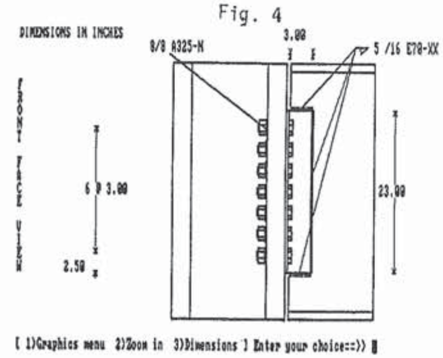

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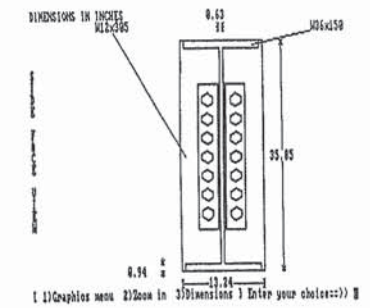

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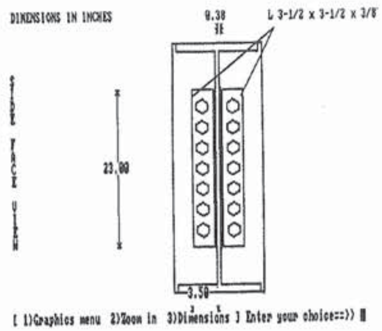

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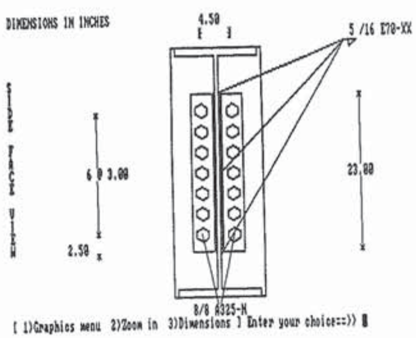

Fig. 9

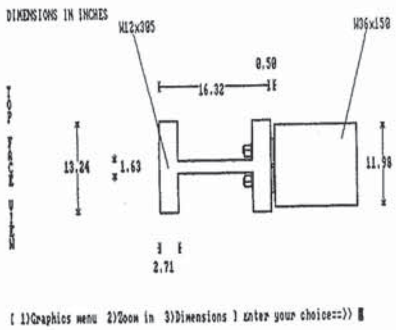

Fig. 10

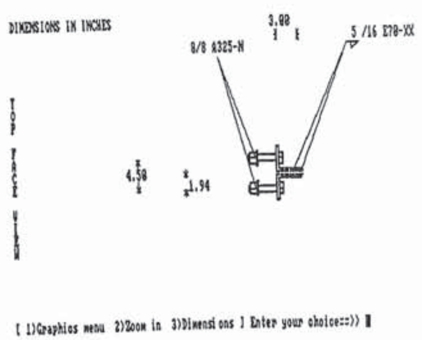

Fig. 11

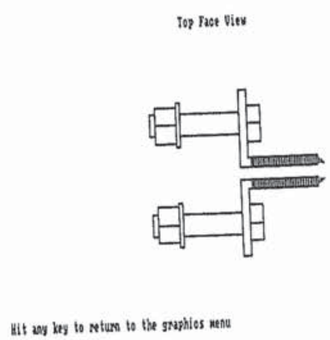

Fig. 12

A COMPUTER-AIDED ROOM ALLOCATION MODEL WITH CONCEPTS OF FRAMABLENESS AND FLEXIBLE CONDITIONS

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Computer-aided Design, Room Allocation, Framableness, Flexible Condition, Fuzzy Set Theory.

ABSTRACT

On the Computer-aided room allocation system, it is required to treat the particularities of architectural design. Major particularities we must consider in CAD of architecture are 1) one of building system and 2) one of design process.
On the building system, we found that it was difficult to make a reasonable plan from an architectural viewpoint through simulation studies by the conventional room-allocation CAD which had not the concept of framableness.
Therefore, we make a criterion of framableness which is defined by the geometrical relationship of beams, columns and walls. In the algorithm, we apply the multi-stage searching method developed in the field of artificial problem solving.
On the design process, a slight violation for given initial condition sometimes is allowed because the initial condition is not so rigid and the condition itself is reevaluated and modified by architect in the design process. From this viewpoint, we establish the concept of "flexible condition" and formulated by use of Fuzzy set theory. For the design under the flexible condition, we built a room allocation CAD system in which we apply the artificial learning system in order to fit the response of system to judgment of architect.