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A KNOWLEDGE-BASED SYSTEM FOR
LIFE-CYCLE DESIGN CONSIDERATIONS IN
TWO-GIRDER I-SHAPED STEEL BRIDGES

by
Raymond Jeffrey Vogt

A Thesis
Presented to the Graduate Committee
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16 May 1986
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ABSTRACT

The work presented herein describes the development and implementation of a knowledge-based system for life-cycle design considerations of two-girder I-shaped steel bridges. The computer-based expert system embodies knowledge of one bridge expert and existing literature to provide design considerations not accounted for in existing design codes. The prototype system presented transfers knowledge to the user on how to minimize out-of-plane displacements in floor beam-to-girder and lateral-to-girder connections, that cause high stress concentrations which could lead to fatigue cracking. Described herein are: 1) an introduction to expert systems; 2) an overview of the program; 3) current connection design practice; 4) the development and implementation process; 5) design examples; 6) conclusions; and 7) recommendations for further work. The interactive system is a new application that blends computer graphics and knowledge-based systems for use as a learning tool and a medium for transfer of domain knowledge of connection design considerations in two-girder I-shaped steel bridges.

CHAPTER 1

INTRODUCTION

1.1 Background on Expert Systems

Applied artificial intelligence and knowledge-based systems, in particular, will have an increasing role in the engineering problem-solving process. This is because there exists a real need for design tools and aids to assist the engineer in the increasingly complex aspects of planning and design. Insight into the problem-solving methodologies of domain experts can also be made available through such expert systems. Knowledge in a particular area or domain can be represented in the form of facts and rules within a working system to provide a design aid.

Expert systems are computer-based systems used for aids in the decision-making process in some specific expert knowledge domain. The term "expert" is often used in describing such systems but generally misapplied due to the fact that the term implies such systems perform on the level of an expert with total expert knowledge and reasoning. Hence, the term "knowledge-based" will be used herein. In knowledge-based systems, rules and facts are

encoded in a logic programming language to represent, in some form, the knowledge and beliefs of experts. There are several types of knowledge-engineering applications [1]: interpretation and classification; prediction; diagnosis; design; planning; monitoring; debugging; repair; instruction; and control.

Interpretation knowledge-engineering applications infer situation descriptions from available data and observations. One civil engineering application is "GEOTOX" [2], a knowledge-based system for hazardous site assessment. Other uses include surveillance, speech understanding, image analysis, chemical structure elucidation and signal interpretation.

Prediction knowledge-engineering applications forecast likely possible consequences for given situations, and past or present data. Some uses are in areas of traffic prediction, weather forecasting, demographic predictions, crop estimates, and military forecasting.

Diagnostic knowledge-based systems are another application. Typically, problem symptoms for observed behavior patterns or irregularities are defined and then

related to the underlying causes. Diagnosis of steel bridges subject to fatigue and fracture is one example. Other uses include those in domains of medicine, electronics, and software coding.

Knowledge-base systems can also take the form of design tools. These types of systems possess the capability to allow a user to define a design from chosen available design parameters. Thus they are more interpretive than generative (they design by "constraint"). The design may be of a quantitative or qualitative nature. Effective expert systems for design incorporate the sometimes highly-iterative design process to arrive at the optimum solution, usually by minimization of an undesirable property of a potential design (e.g., cost). Such analytical (rather than synthetic) systems in use today exist in such problem domains as circuit layout and budgeting.

Knowledge-based planning systems are intended to interact with users to define a program of actions to meet a desired goal or outcome. The main emphasis is on objects that perform functions. Quite limited applications exist in automatic programming and planning

problems for robots, projects, routes, communication, experiments, and for defense.

Monitoring systems monitor behavior and sound alerts when intervention is required for process control. Applications, again quite elementary, exist for nuclear power plant, air traffic, medical, regulatory, and fiscal management tasks.

Debugging systems are used to predict remedies for malfunctions in existing computer programming applications.

Repair systems formulate remedial actions for a previously-diagnosed problem. Problem domains include automotive, network, avionic, and computer maintenance.

A very difficult, but nonetheless promising use of knowledge-base systems is for instructional and educational purposes. User interaction with an expert system can provide a two-way dialogue of questions and answers as opposed to the one-way passive approach of learning through standard texts or specification documents.

Control knowledge-engineering systems govern overall behavior of a system from interpretation, prediction, diagnosis, repair to monitoring systems. Application domains include air traffic control, business management, and battle management.

Furthermore, expert systems can be a combination of one or more of the above-described system types. The target level of knowledge of the intended user can vary widely from one system to the next (one system may be directed at a beginner user while another system may attempt to impart information more appropriate or useful to a user of an intermediate knowledge level). As more knowledge on the successful and effective development and implementation of knowledge-based systems is acquired and implemented, the target user knowledge level should rise.

One advance in the use of expert systems includes user interface enhancement through use of graphical displays for input and output. Also, the knowledge base can be "dynamic" to allow for the growth of knowledge domain through new research findings and/or experience. A book is a static body of knowledge which could be superceded by a more recent edition or an altogether

different source. Expert systems usually capture the knowledge of one or more domain experts and available literature. Effective expert systems possess the capability and flexibility to encode new knowledge in addition to providing an explanation of the reasoning process used.

CHAPTER 2

PROGRAM OVERVIEW

2.1 Program Description

The prototype system described is designed to transfer knowledge on bridge connection design considerations based in part on the extensive experience and research of Fritz Engineering Laboratory in this domain. The technical guidelines used in developing the system are: 1) AASHTO Specifications for design requirements [3]; 2) AISC Bridge Fatigue Guide for suggested design considerations [4]; and 3) a technical specialist (expert) [5] for current research findings and considerations in current practice and procedures.

2.2 Purpose

The intent of the prototype system presented here is to impart knowledge on design considerations to minimize distortion effects in bridge connections. The particular bridge connections examined are floor beam-to-girder and lateral-to-girder connections in two-girder I-shaped steel

bridges. The problem scope is also bounded by additional assumptions, discussed below, designed to keep the design within practical bounds.

The system is designed to serve as an educational tool. A student is guided through the design process by being prodded for information on specific design parameters. The explanation, help, and glossary facilities serve to define and clarify program terminology. These are available at any level within the program.

2.3 Scope

This program defines a floor beam-to-girder connection design through user interaction within the assumptions and limitations listed and explained below. The design is governed by the design parameters chosen by the user. These design parameters are chosen from a list of available options; the system does not account for probabilistic or fuzzy approaches to reasoning. Governing design parameters are the general layout of the bridge, connection location, connection components used, location of the connection components, and how the components are

connected. After a design is established an assessment of that design is made along with relevant notes on current practice, and economic and historical considerations.

It is assumed that the user has already decided upon the type and location of loading for the system along with member dimensions, girder spacing, outrigger length, lateral location, etc., which may be in part dictated by the AASHTO Specifications. The user is responsible for the quantitative validity check of the connection from geometric and loading conditions as this is not within the scope of the program. The program emphasis is not on the sizing of components to withstand the computed forces but rather to provide a qualitative design tool for knowledge transfer regarding design considerations.

Program assumptions are limitations set to handle "common practice" situations and to eliminate "special case" designs. All assumptions are clearly stated in the program description provided at the beginning of the program so that a new user can read them.

One limitation is that all welding is assumed to be performed under shop conditions due to quality control

problems and cost of equipment transfer and labor involved in field welding. All bolting is assumed to be done in the field during the erection procedure after shop fitup. Shop fitup involves the assembly (when possible) of components in the shop before shipping to ensure that components will fit together properly in the field.

Another system assumption is that full-depth connection angles are not used since labor and material costs are high when the brackets are used for the relatively large depth of the plate girder. Full-depth connection angles are angles that run the full girder depth, from top flange to bottom flange. They are a means of connection of the floor beam to the girder.

A third assumption is in the method of tie-plate attachment. Tie-plates are necessary when outriggers are used so that force continuity is achieved through the top flanges of the floor beam and outrigger over the girder. This system always places the tie-plate above the girder top flange. Web cutouts that allow the tie-plate to pass through the girder web are not considered because of the high potential that fatigue problems may occur.

2.4 Program-User Interaction

The system allows a user to define a connection design by choosing specific components to be used, where those components are placed and how they are connected; whether it is by bolting or welding. This user-defined or conceptual design is accomplished through a menu-driven question and answer interface providing available options with graphics and commentary for clarification. The user has options to let the system select the best choice or choices with the reasons outlined for why the system choice was made.

Available user options exist in the program to facilitate user desires. Available what and why facilities can be called on to clarify the available options (using intermediate graphical displays whenever possible) and to explain why a parameter is important and which parameter option is recommended. A user may retract a choice made or direct the system to make a choice based on the best option to minimize out-of-plane displacements. The user has the option of asking the system to suggest the best available option or, if the user is privileged, telling the system to deduce the best remaining parameter

values (that will minimize out-of-plane displacements) below a specified input level so that the design may be completed. A user can restart or quit at any time. Parameter values may be reviewed at any point. Also available to the user are a help facility and a glossary, with displays if desired.

Once the conceptual design is accomplished, a graphical display of final design is shown and an assessment is made of the connection. This assessment is presented as textual commentary on the preferred or recommended option at each level. Information on common practices, fabrication, erection procedures and economic considerations are given along with historical notes of importance. Problem areas in the connection are pointed out so that a user may be alerted to potential problems. References are given where appropriate so that a user knows where to find more information. Available review and hardcopy options exist at this final design stage.

2.5 Target User

The target user of the system is an undergraduate graduate or graduate student already possessing at least

an elementary design knowledge of the connections, but who would like to learn more about the distortion effects of alternative designs on the service life and performance level of a connection. Thus, the system is a qualitative rather than a quantitative system. It offers design considerations not directly addressed in current design specifications.

2.6 Hardware/Software Required

The system was implemented using the U.N.H. version of Edinburgh PROLOG and GKS (Graphical Kernel System - a graphics package) calls from FORTRAN programs on a Data General MV/10000 32 bit word computer using the AOS/VS operating system. PROLOG source code drives the system and executes the FORTRAN/GKS programs (graphical displays) when needed.

2.7 Project Work Division

The project work described herein was the joint effort of two graduate students; Ken Seiler and Raymond Vogt. Ken Seiler was primarily responsible for the PROLOG logic programming language implementation. Raymond Vogt

was primarily responsible for the FORTRAN/GKS programs, which generate the graphical displays. The knowledge acquisition and the resulting textual commentary was a jointly-accomplished task. Problem definition, scope, purpose, domain, developmental and implementation decisions, and refinement were accomplished by a coordinated effort of the domain expert (Dr. Ben Yen), the knowledge-base system expert and research advisor (Dr. John Wilson), Ken Seiler, and Raymond Vogt.

CHAPTER 3

CURRENT CONNECTION DESIGN PRACTICE

3.1 Overview of Current Connection Design Approach

Highway bridge design in the United States is performed according to AASHTO Specifications [3]. Design of components to resist fatigue is one of the many design considerations included in that document. AASHTO Specifications address the design for fatigue by providing an allowable fatigue stress range for a specific range or number of cycles and a certain stress category. The stress category depends on the particular type and orientation of connection detail with respect to the major stress direction. The number of cycles is determined from the ADDT or Average Daily Truck Traffic. Segments of the AASHTO Specifications are an attempt to minimize the high stress concentrations that can lead to fatigue cracking.

Out-of-plane displacements also cause high stress concentrations which may lead to fatigue cracking in connection components. Out-of-plane displacements are a displacement of a component in the direction offering the least resistance to forces. An example is a thin

plate-girder web that is pushed or pulled out-of-plane from a lateral force. Out-of-plane displacements result from poor choice of components used and/or how they are placed and/or how they are connected. AASHTO Specifications do not treat or comment on design considerations to limit out-of-plane displacements. This may be because design to minimize out-of-plane distortions is a judgemental design decision based on past experience and a sound understanding of structural behavior. "Engineering decisions" must be made.

Current design as it relates to displacement-induced stress problems is performed based on common sense, historical practice and past experience about the level of performance and service life of the detail. Level of performance can be loosely translated as deflection acceptability at service loads. Designs requiring periodic retrofit usually are the result of poor connection design. Better designs are often arrived at through "ad hoc approaches" based on experience related to their in-service life.

3.2 Shortcomings of Current Design Method

Actual cases where connection designs require retrofit, as documented in current literature [6], are indirectly related to shortcomings of the current design methodology. More attention should have been given to connection details so that relative movement or distortion would have been minimized [5]. Research has indicated that detailed analysis of floor beam-to-girder connections can be achieved through finite element analysis [7]. It appears that the structural engineers of the the many inadequate connection designs did not take into account considerations that would have minimized out-of-plane displacements. The lack of knowledge on these design considerations is not surprising, considering that not until the early 1970's did problems in welded steel bridges begin to be associated with out-of-plane displacements causing secondary web-bending stresses [8].

3.3 Recommendations for Improvement of Current Design Procedure

There is a fundamental need for design tools that point out potential displacement-induced stress problems as evident from examination of existing case studies [6]. In most cases, if not all, the structural designer did not

forsee the potential problems that would arise.

Knowledge-based expert systems can provide one such tool for this transfer of knowledge from experience and research to engineering design practice.

CHAPTER 4

INTERACTIVE DESIGN OF CONNECTIONS

4.1 Importance of Interactive Connection Design

An interactive dialogue with a knowledge-based expert system for connection design can provide insight on the impact of the variation of design parameters on the final design and the "value" of that final design. The "value" is the structural behavior acceptability and the level of performance. Deflections must be kept within acceptable limits to prevent unsightliness and high stresses which can lead to cracking. The level of maintainance is also a consideration. It is expensive to inspect, and replace bolts and other components frequently. The retrofit required for an inadequately designed connection is usually an expensive undertaking. Thus, it is important that designers realize the pertinent considerations that must be taken into account during the initial design.

Knowledge transfer on important design considerations must take place through some communication medium, whether it is through the written or spoken word, or by direct observation. One effective method of obtaining knowledge

on efficient ways to design connections to minimize out-of-plane displacements is through comparisons of designs and their relative merits and drawbacks. Knowledge-based systems offer the possibility of such an approach.

4.2 Prototype Bridge Connection Design Considerations

The prototype system presented herein takes into consideration eighteen design parameters. They are listed in Table 1 with the corresponding available parameter options. These parameters were decided by the specialist to be the most important design parameters affecting the severity of out-of-plane displacements.

4.3 Prototype Structure

4.3.1 Hierarchical Data Structure

The prototype database is hierarchical. It can be viewed as an inverted tree-like structure, as shown in Figure 1 (Representative "Tree Structure"), with the first design parameter root at the top and the final design parameter at the bottom. Each point (node) in the inverted tree-like structure at which paths branch out

represents a user level at which several design parameter options are available and links between nodes represent the value of those parameters. Since there are eighteen design parameters, there is a maximum of eighteen levels or menus presented for a complete path. The particular path the user follows down the inverted tree-like structure is directly dependent upon the design parameters chosen. The process of entering the tree structure at the root node and continuing to a terminal node represents the design process of the system.

Choice of the data structure has a direct impact on the flexibility of the data structure for expansion. This was a necessary consideration during system design phase so that an incremental expansion of this system could be achieved.

4.3.2 Knowledge Base

The knowledge base consists of facts and rules. A fact is a relationship between two objects. One example of a fact would be "outriggers are used in a two-girder I-shaped steel bridge". A rule is one fact that depends on a group of other facts taking the basic form of IF

conditions THEN conclusions, and IF conditions THEN actions for a rule-based system such as the one described herein. One example of a rule is "if outriggers are used in a two-girder I-shaped steel bridge then use tie plates at the outrigger-to girder connection".

In the system described herein, the facts are primarily user input parameters values that define the final design. These facts can be changed by the user during the session. Rules in the knowledge base are used for program input/output content and format, and for system control so that the design procedure will be followed. Rules also specify how to generate (deduce) new facts based on input facts and also control the system selection of parameter values when necessary (when the skip or conclude option is chosen). An example of a rule to deduce a new fact is "if the floor beam is placed below the girder, the stringer must be placed at the same level as the girder". An example of a rule to control system selection of a parameter value is "when a full-depth connection plate is used, weld the connection plate to the girder flange".

4.3.3 Interface Mechanism, Control

The PROLOG logic programming language was used to implement the backward-chaining, antecedent-consequent rule-based system. These rules operate on the user-supplied database obtained through the menu-driven user interface. The inference mechanism used is the self-contained backchaining interpreter. This also allows use of the rule-ordering to control rule priority selection.

Backward-chaining systems are goal-driven systems that attempt to satisfy a final goal from known facts through satisfaction of intermediate subgoals. If a subgoal cannot be satisfied, then the system "backtracks" to the previously-fulfilled goal in an attempt to re-satisfy that goal with another fact, hence the name "backward-chaining". Backward-chaining systems are particularly suited to problems where facts are given and a final goal or hypothesis is to be satisfied. In the application described here, the system goal is the definition of a conceptual connection design and an assessment of that design from the standpoint of minimizing out-of-plane displacements.

PROLOG was used to control the flow from one menu

level or node to the next. The PROLOG predicate which describes the flow (developed by Ken Seiler and Raymond Vogt) controls the flow of menus and parameters. All other rules and facts needed for the program operation were built around the central flow system. Control exists to control menu/parameter flow, to control system selection of parameters, to control storage of acquired data, and to select commentary and explanations.

There are four types of rules that exist for control of menu/parameter flow; flow, prompt, menu_par_name, and menu_opt_name. These rules contain such items as the user prompt, the list of options, valid keywords, and pre-conditions that determine the appropriate version of the menu to be used for the particular parameter. These four main predicates or rules are described below. Each description shows the form of the rule, explains the arguments necessary, and gives an example of its use.

flow - used to control the flow of menus, and therefore control the order in which the parameters are defined during a session. Essentially, this is the internal representation of the parameter hierarchy.

```
flow (from_id,to_id) :- pre-conditions
```

```
where: from_id - menu ID of the current menu
       to_id   - menu ID of the subsequent menu
       pre-conditions - pre-conditions necessary to
                       follow the path of from_id - to_id. This
```

determines if a specific version of the rule applies, accounting from previously chosen options.

'flow' rules may exist without pre-conditions if only one path is available between from_id - to_id. 'flow' can also be used to control both forward and backward movement through the menu/parameter tree.

Example (menu flow from menu 3 to menu 5 if menu 2 chosen option was continuous and menu 3 chosen option was near_midspan):

```
flow (m3,m5) :- node (m2,continous,_),
                node (m3,near_midspan,_).
```

where the single underline character "_" is an anonymous variable used to match any variable in that location.

prompt - used to list the menu prompt and valid responses.

```
prompt (menu_id,[menu_message],[valid_options],
        [valid_keywords]) :- pre-conditions.
```

where: menu_id - menu/parameter ID
menu_message - message (prompt) to the user for the parameter
valid_options - list containing the valid option numbers and names for this menu to be used to check for valid input
valid_keywords - list containing the valid keywords for this menu to be used to check for valid input
pre-conditions - as described previously

Example:

```
prompt (m5, ['Are outriggers used at this connection?'],
        [1,'Yes - outriggers are used',outrig_yes,
         2,'No - outriggers are not used',outrig_no],
        [backup,restart,quit,review,what,why,help,
         glossary]).
```

The preconditions are used if the [valid_options] changes based on previous parameter values.

menu_par_name - predicate to relate the menu/parameter ID to the parameter name.

menu_par_name (id,prolog_name,screen_name).

where: id - menu/parameter ID
prolog_name - prolog version of the parameter name
screen_name - parameter name as it is written to the screen

Example:

menu_par_name (m5,outrigUsed,'Outriggers Used').

menu_opt_name - predicate to relate menu/parameter ID to the option names for that ID.

menu_opt_name (id,prolog_name,screen_name).

where: id - menu/parameter ID
prolog_name - prolog version of the option name
screen_name - option name as it is written to the screen

Example:

menu_opt_name (m5,outrig_yes,'Yes - outriggers are used').

To control the system selection of parameters, the **best_val** rules are placed in the database to define the best available parameter choice. These rules, as described below, are simply facts that define a best value under any pre-conditions.

best_val - contains the "best" value for a parameter if the system performs the selection.

best_val (menu_id,best_value,[explain]) :- pre-conditions.

where: menu_id - menu/parameter ID
best_value - value to be used for parameter
explain - reason why best_value is used
pre-conditions - as described previously

Example:

best_val (m7,fb_same,[Leads to a more monolithic
deck structure...]).

The pre-conditions would be used if previous parameter values would influence the selection of the best value.

To control the storage of acquired data, facts are asserted in the database for each parameter defined. The fact contains the menu I.D., the value of the parameter, and an indicator defining whether the value was user-defined or system-selected as described below:

node - fact for storing all parameter values.

node (menu_id,value,selected_by).

where: menu_id - menu/parameter ID
value - value for the parameter menu_id
selected_by - who defined the parameter value
(user, system, implied, concluded)

Example:

node (m7,fb_below,user_defined).

The selected_by item will be set to 'user_defined' if the user selected the parameter value. If the keyword skip were chosen for the parameter, then selected_by would be set to 'system_defined'. When the keyword conclude is used, selected_by is 'concluded', and 'implied_param' is used for selected_by if the node was implied by other parameter values. This will be used with the review keyword.

To select commentary and explanations, the files rules, as described below, in the database contain pointers for all commentary pertaining to a particular parameter. These pointers indicate the external files that are to be typed. This approach removes the necessity of storing information in core during execution. The necessary pre-conditions are used to guide the selection of the proper commentary, since it is generally undesirable to give the user information that does not pertain to the user's design parameter choices.

files - contains names of 'explanation' files for the parameter.

files (menu_id,what_file,why_file,graphic_file) :-
pre-conditions.

where: menu_id - menu/parameter ID
what_file - contains the file name for the what
keyword for menu_id
why_file - contains the file name for the why
keyword for menu_id
graphic_file - contains the file name of the
metafile for graphic display for menu_id
pre-conditions - as described previously

Example:

```
files (m8,m8_what,m8_why,m8_static_outtr)  
:- node(m5,outrig_yes,_).
```

4.3.4 Interface of PROLOG and FORTRAN/(GKS) GRAPHICS

The PROLOG - FORTRAN/GKS interface is also performed through use of pointers from PROLOG. At a particular level at which a FORTRAN/GKS program is needed an operating system command is made from PROLOG to execute the appropriate FORTRAN/GKS program. PROLOG has the capability to perform operating system commands while in PROLOG.

4.3.5 FORTRAN/GRAPHICS Programs

Fortran programs containing the international standard GKS (Graphical Kernel System - a two-dimensional graphics package) calls to a graphics library were used for the graphical displays. There are two types of FORTRAN/GKS programs utilized by the system.

The first type draws connection components based on the menu parameters read from a PROLOG file. This program is used to create all intermediate displays and final design displays. This program also reads menu parameter choices from the PROLOG-created datafile. Internal Fortran logic in the program then calls an appropriate subroutine to draw an individual component. The calling order is performed so that individual components overlap

each other correctly in the frontal view of the girder cross-section displayed. The actual GKS graphics calls are in the separate Fortran subroutines, each of which draws an individual component. For example, one subroutine draws the border on the screen, another draws the girder, one draws the floor beam, one draws a connection plate, and two more draw the hidden line at the connection and the bolt group.

The other FORTRAN/GKS program type is composed of static (constant) displays used in the upper levels (before the final design is arrived at) of the program. These intermediate displays are encoded in GKS metafiles that were created by a program very similar to the program that draws the final design. Metafiles are files used for long-term storage of graphical displays. They contain only the information necessary to display the image. The real value in metafile usage is that the graphics program need not be executed each time the image needs to be redisplayed; it is only necessary to execute one program to write these metafiles on the screen. The program used to display the metafiles is executed by PROLOG when appropriate. Other individual programs were written to generate the metafiles necessary for the specialized

displays. The specialized displays associated with the specific options at certain menu levels are used for visual clarification of points that are difficult to explain in textual form.

4.4 Stages of Development

4.4.1 Problem Definition

The first step in undertaking the described work was identification of a realistic and manageable problem domain suitable for knowledge-base system development. The project domain, floor beam-to-girder connection design considerations to minimize out-of-plane displacements, was chosen from among several possible project domains.

The primary reason for the choice of this particular application, other than the availability and accessibility of the domain expert, were the usefulness of this particular knowledge-engineering application. It was the opinion of the domain expert that such a system could serve as a useful design aid and educational tool because the knowledge to be contained in the system was not present in current design codes. Knowledge on design considerations to minimize out-of-plane displacements is

almost exclusively acquired through years of experience and research.

It was also determined, by the knowledge-base system expert (research advisor) that such a prototype system could be developed within the time and resource limitations. The available hardware (Data General MV/10000) and software (PROLOG, FORTRAN/GKS) resident in the Civil Engineering Computer-Aided Engineering Laboratory was deemed sufficient for the task at hand. If the CAE Laboratory facility was not readily available, a hardware and software choice would have had to have been made. It should be mentioned here that the program could have been totally implemented in Fortran and GKS, but development and coding would have been considerably longer and less efficient than the PROLOG implementation. Also, PROLOG, by the very nature of its language structure, is suited to the type of problem at hand and lends itself to easy expansion and modification.

The target user was identified, in part, by examination of the potential usefulness of an operational knowledge-base system on design considerations to minimize out-of-plane displacements. The program was designed to

fulfill a need for a design aid or tool to impart these design considerations based on experience and research. Since the system provides qualitative rather than quantitative design considerations, it would have to be assumed that the user is familiar with quantitative steel design (component sizing and method of connection to withstand the calculated forces). Thus, the primary user was identified as a graduate or upper-level undergraduate student familiar with steel design.

Next, a more specific idea was formulated on how the program would function and the exact nature and form of the user interface. Tentative problem input and output was outlined and potential user sessions were constructed.

Input consisted of the design parameters influencing the connection susceptibility to out-of-plane displacements. Desired program output as discussed in Chapter 2 was tentatively defined with graphical displays playing an integral role in the program-user interaction. Also, desired user options and capabilities at each parameter level, as discussed in Chapter 2 (e.g. review, backup, skip, etc.) were formulated. It was at this stage that a menu-driven system was decided by the knowledge engineers (Ken Seiler and Raymond Vogt) to be the most flexible from

the user's point of view and from programming considerations.

4.4.2 Knowledge Acquisition Process

The acquisition of knowledge for the system was the next major developmental step once the problem was defined. The knowledge acquisition process was initiated by determination of the design parameters that influence connection susceptibility to out-of-plane displacements. This was done through verbal interaction with the domain expert and review of published literature. These sessions were tape-recorded where questions were posed to the domain expert regarding the impact of alternative design considerations and associated information on economic considerations along with historical and current practice. The tapes of the meetings were then transcribed, edited and categorized to capture notes and important points made by the domain expert but not listed during the meetings.

Also determined at this stage was the ordering of the design parameters to be presented to the user by the program. Parameters were arranged from the most global (comprehensive), e.g. either right or skew bridge, down to

the parameters at the localized connection location, e.g. method of connection of the connection plate to the girder flange. Design parameters were then organized into the hierarchical knowledge-base data structure described in Section 4.3.1 and 4.3.2.

Throughout the knowledge acquisition process the tentative ordering and choice of the design parameters were continuously evaluated to determine the best knowledge representation to be presented to the user in the program, and also to keep the scope manageable. The limiting assumptions of the system as described in Chapter 2 were a direct byproduct of the knowledge acquisition process.

The knowledge acquisition process also consisted of the formulation of the commentary structure (explanation facility) and summary points. A scheme was outlined for collection and organization of the information obtained in the interactive sessions with the domain expert and through readings of published literature. This frame-based scheme consisted of indexing to record the information to be used in the whats and the whys for each menu level. The indexing included the menu level, whether

the information pertained to a what or a why, and the textual commentary.

Also determined at this stage were the locations, content and use of the graphical displays. Since the hierarchical structure was tentatively defined, specific graphical displays could be identified and associated with each parameter level in the data structure. The displays at each parameter level are, of course, path-dependent, i.e. based on the parameter selections made by the user.

4.4.3 Program Implementation

The program implementation stage consisted of the actual PROLOG and FORTRAN/GKS programming. The hierarchical structure served as the working model for the global structure. The types of rules and their grouping were determined at this stage. PROLOG coding was written to conform to the tentatively-defined data structure. For the graphics, intermediate graphical displays and a methodology for creating the program to create the final displays was chosen and then implemented. The graphics programming is described in Section 4.3.5. External files (e.g. the why commentary for menu no. 4) needed by PROLOG

were built. These files included the glossary and commentary associated with the what and why keywords. The final result of this developmental stage was a functioning prototype.

4.4.4 Refinement Process

The refinement process stage consisted of completeness and consistency checks of the functioning prototype system. Refinement or revisions to the knowledge base and commentary were also incorporated during this stage.

Completeness checks were performed by using the system and taking alternate available paths through choice of different design parameters. Available user options and capabilities were tested by Ken Seiler and Raymond Vogt to ensure they functioned as intended. Text and graphical displays at each stage were tested by representative target users for completeness and clarity. Menu flow and menu content (user prompts and physical text layout) were examined and determined to be satisfactory for an undergraduate user.

A form of a consistency check was performed by comparison of textual commentary and of graphical displays at every menu parameter level to ensure there were no inconsistencies. Notes from the knowledge acquisition process were re-examined and verified by the domain expert (Dr. Ben Yen) to ensure that the domain expert's knowledge was best and concisely represented.

Tests for completeness and consistency were performed through program usage by the domain expert, the knowledge-base expert, the knowledge engineers, graduate students and undergraduate students. Feedback gained through consultation with the above-mentioned users was invaluable in fine-tuning the system as these users were representative of the intended target users.

4.4.5 Validation

Prototype system validation was accomplished through defining conceptual designs that were used as actual test cases, under the guidance of the domain expert. The final design, associated commentary, and summary points on the connection were matched against these actual test case results. Three test cases were run and the results from

the prototype system were considered satisfactory by the domain expert (Dr. B. T. Yen).

CHAPTER 5
DESIGN EXAMPLES

Two design examples are presented for illustration of use of the prototype knowledge-based system described next. User entries are underlined for clarity with the "↓" symbol representing entry of the newline or carriage return key.

The first design example is an actual case study of the George Wade (North) Bridge [9] located in Harrisburg, Pennsylvania. The second design example is a representative user session where the user has defined all connection design parameters from the top to the bottom. Here, available program options were chosen for illustration purposes, when deemed appropriate. Such illustrated program options are the glossary, what, why, help, review, suggest, and backup. The restart option was not chosen because that option brings the user back to the top of the design process to start all over again. All options at the program start, including a description of the keywords, were chosen so that the reader may obtain a clearer view of the system operation and results. A listing of the whats, whys, and summary points are

provided at the end of the design session.

5.1 Design Example 1

```
) x prolog pr481.2 ↵
```

```
--- UNH Prolog version 1.3 (Syracuse CIS) ---
```

```
[ "pr481.2" consulted ]
```

```
! ?- go. ↵
```

Bridge Connection Design Program

Written by Ken Seiler and Ray Vogt

Version 1.0 5/14/86

To select an option, enter the number, then press NEWLINE.
If this is the first time you have used this program, you
should go through each of the options starting with 1.

Select one of the following:

1. Program Description
2. Program Operation
3. Menu Keyword Descriptions
4. Graphical Display of Bridge and Connection Components
5. Set Terminal Type (Default is G300 Graphics Terminal)
6. Begin Connection Design Session

Enter option number ==> 6 ↵

Menu ID: ml

Valid Keywords:
quit what why help glossary

General layout of the bridge:

Options:

1. Right
2. Skew

Enter option number or keyword ==> 1 ↵

Menu ID: #2

Valid Keywords:

backup quit review what why help glossary

Type of span where connection is located:

Options:

1. Simple
2. Continuous

Enter option number or keyword ==> 2 ↵

Menu ID: #3

Valid Keywords:

backup restart quit review what why help glossary

Floorbeam location along span:

Options:

1. Near support
2. Near midspan (central)

Enter option number or keyword ==> 2 ↵

This implies at menu level #4 :

Moment region is positive in central locations (away from supports) in continuous structures

Press NEWLINE to continue... ==> ↵

Menu ID: #5

Valid Keywords:

backup restart quit review what why help glossary

Are outriggers used at this connection?

Options:

1. Yes - outriggers are used
2. No - outriggers are not used

Enter option number or keyword ==> 1 ↵

Menu ID: a6

Valid Keywords:

backup restart quit review what why help glossary

Are laterals attached to the girder at this connection?

Options:

1. Yes, attached to the bottom flange of the girder
2. Yes, attached to the girder web via gusset plate
3. No, laterals are not present at this connection

Enter option number or keyword ==> 2 }

Menu ID: a7

Valid Keywords:

backup restart quit review what why suggest help glossary

Level of the TOP flange of the floorbeam with respect to the
TOP flange of the girder:

Options:

1. Same level as the girder top flange
2. Below the level of the girder top flange

Enter option number or keyword ==> 2 }

This implies at menu level a8 :

If the top flange of the floorbeam is below the top flange of
the girder, the stringers must be above the floorbeams to
support the deck.

Press NEWLINE to continue... ==> }

Menu ID: a9

Valid Keywords:

backup restart quit review what why suggest help glossary

Level of the TOP flange of the outrigger with respect to the
TOP flange of the girder:

Options:

1. Same level as the girder top flange
2. Below girder top flange (at level of floorbeam top flange)

Enter option number or keyword ==> 1 }

Menu ID: m10

Valid Keywords:

backup restart quit review what why suggest help glossary

Attachment of floorbeam to girder is via:

Options:

1. Full depth connection plate (welded to girder web)
2. Short connection plate or connection angle

Enter option number or keyword ==> 1 }

Menu ID: m11

Valid Keywords:

backup restart quit review what why suggest help glossary

Brackets used at floorbeam to girder connection:

Options:

1. Top bracket
2. Top and bottom bracket

Enter option number or keyword ==> 1 }

Menu ID: m12

Valid Keywords:

backup restart quit review what why suggest help glossary

Pre-attachment of brackets to floorbeam/connection plate:

Options:

1. Shop welded to connection plate
2. Shop welded to floorbeam

Enter option number or keyword ==> 2 }

Menu ID: n13

Valid Keywords:

backup restart quit review what why suggest help glossary

Method of attachment of the connection plate to the TOP
flange of the girder:

Options:

1. Welded
2. Fitted
3. Cut Short

Enter option number or keyword ==> 1)

Menu ID: n14

Valid Keywords:

backup restart quit review what why suggest help glossary

Method of attachment of the connection plate to the BOTTOM
flange of the girder:

Options:

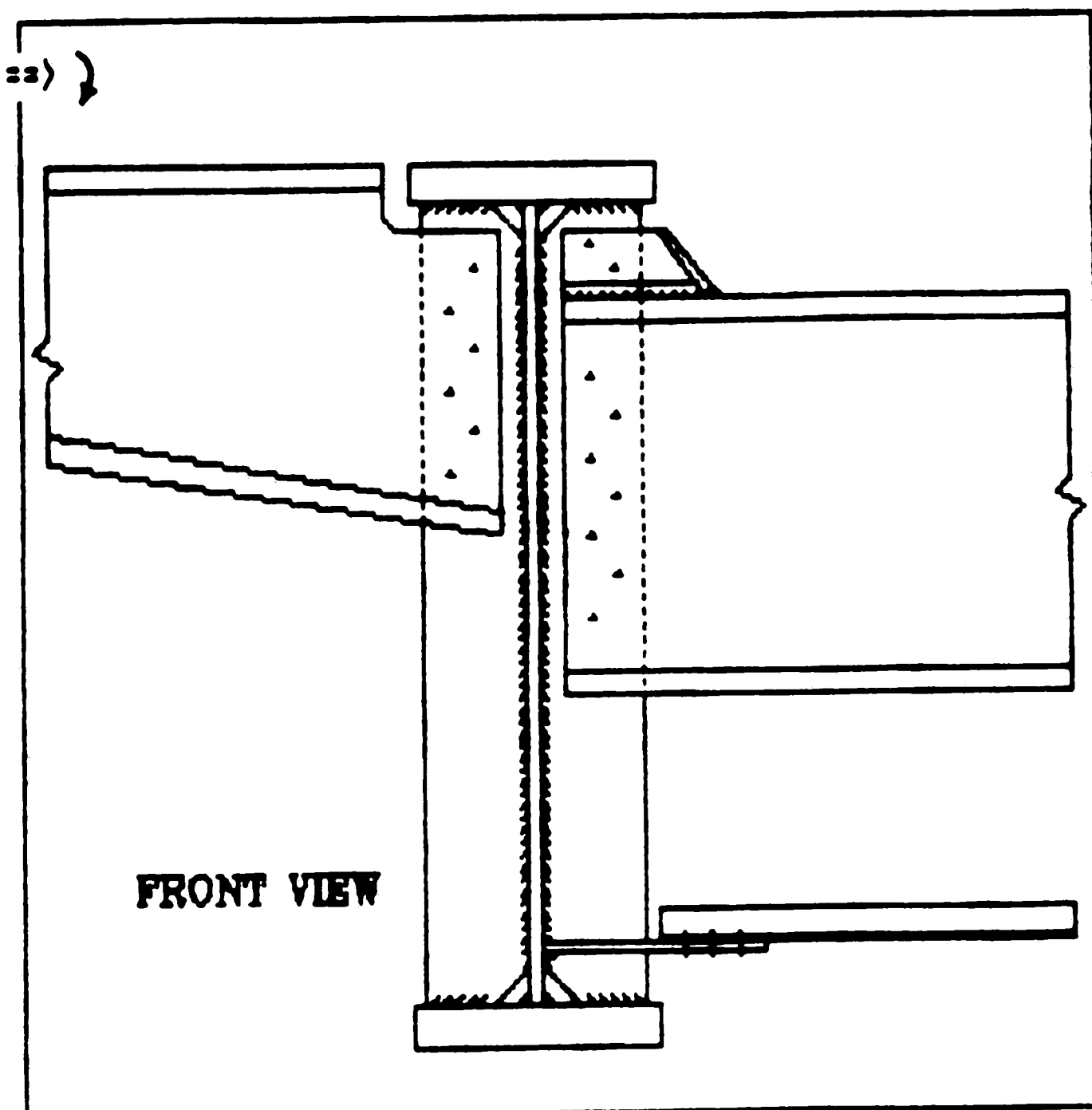
1. Welded
2. Fitted
3. Cut Short

Enter option number or keyword ==> 1)

Review of final design parameters:

Parameter	Value	Defined by
Bridge Layout	Right	User
Type of Span	Continuous	User
Floorbeam Location	Near Midspan	User
Moment Region	Positive	Implied
Outriggers Used	Yes	User
Connection of Laterals to Girder	Yes, @ girder web	User
Level of Floorbeam Top Flange	Below girder level	User
Level of Stringers	Above the floorbeams	Implied
Level of Outrigger Top Flange	Same as girder	User
Floorbeam to Girder Connection	Full depth conn. pl.	User
Brackets Used	Top bracket	User
Attachment of Brackets to Floorbeam/Girder	Welded to floorbeam	User
Connection Plate Attachment at Top	Welded	User
Connection Plate Attachment at Bottom	Welded	User

Press NEWLINE for graphical display of final design... ==>)



Menu ID: n99

Valid Keywords:

restart quit review help glossary

Final design options:

Options:

1. Re-display design
2. Obtain hardcopy of final design
3. List whys for all parameters
4. List summary points
5. Create a summary file

Enter option number or keyword ==> 5 }

Enter file name to contain summary ==> design_example_1 }

Enter the title for this design

==> design example 1 }

Summary to design_example_1 proceeding....

Summary to design_example_1 completed.

Press NEWLINE to continue... ==> }

Menu ID: n99

Valid Keywords:

restart quit review help glossary

Final design options:

Options:

1. Re-display design
2. Obtain hardcopy of final design
3. List whys for all parameters
4. List summary points
5. Create a summary file

Enter option number or keyword ==> 3 }

PARAMETER: Bridge Layout

WHY: The angle of skew influences the magnitude of differential girder displacements and floor beam end rotations. These displacements and rotations result in out-of-plane displacements of girder web and may consequently lead to fatigue cracking. Other factors influencing the magnitude of differential girder displacements are: angle of connection between floor beam and girder; girder, floor beam, stringer spacing; dimension of these components; etc.. Floor beams connected perpendicular to girders in skew bridges have high relative displacements, yet this arrangement is usual practice because it is more economical.

Skew bridges require a more detailed analysis in the connection location because differential displacements and floor beam end rotations causing out-of-plane displacements of girder web are more pronounced in a skew bridge. Current AASHTO Specs do not distinguish between right and skew bridges.
[See BRIDGE FATIGUE GUIDE, publisher: AISC, pp. 41-42 for more info]

Press NEWLINE to continue...=>)

PARAMETER: Type of Span

WHY: Span type, dictated by the overall bridge design, is needed because it indicates whether a floor beam is in a +ve or -ve moment region. A +ve moment causes tension in the girder bottom flange and a -ve moment causes compression in the girder bottom flange.

Press NEWLINE to continue...=>)

PARAMETER: Floorbeam Location

WHY: floor beam connection location indicates relative fixity and relative differential displacements of girder flanges. Relative differential displacements are larger near midspan than near supports because girders are freer to move near midspan.

Press NEWLINE to continue...=>)

PARAMETER: Moment Region

WHY: In +ve moment regions, cracking of girder web is more frequent at the girder bottom flange. In -ve moment regions, upper flange location cracking is more frequent. A more detailed analysis is recommended for flanges in tension because crack growth is more serious there. A +ve moment causes tension in the girder bottom flange and a -ve moment causes compression in the girder bottom flange.

Press NEWLINE to continue...=>)

PARAMETER: Outriggers Used

WHY: The use of outriggers can provide a counter-balancing moment to the floor beam end moment at the floorbeam-girder connection. Moment continuity is achieved when outrigger and floor beam flanges are directly opposite each other. Problems occur when the depth of the outrigger, or more commonly the depth of the floor beam, exceeds that of the member on the opposite side of girder. Flange forces are then transmitted through the thin web which offers weak resistance to out-of-plane forces. Web cracking is a problem in this situation. Floor beam end moments which the web must resist are higher when no outriggers are used.

Depths of outriggers are usually reduced toward the edge of the bridge where the moment is less to save material. Current Practice is to use outrigger and floor beam sections of equal depth at the girder and connected at coincident levels to avoid out-of-plane displacements of the girder web.

If outriggers are used, it is assumed that tie plates are used to maintain force continuity across the girder top flange. Girder web cut-outs are not allowed by the system, due to associated fatigue problems.

Press NEWLINE to continue...=>)

PARAMETER: Connection of Laterals to Girder

WHY: Laterals transmit horizontal forces caused by girder differential displacements and floor beam end rotations, and by wind loading. Laterals may produce severe out-of-plane displacements if not connected properly. When connected to the girder web, cracking can occur at the gusset plate-to-girder region.

It is recommended that laterals be bolted to the girder bottom flange because the flange is a stiffer component to resist the out-of-plane displacements.

Press NEWLINE to continue...=>)

PARAMETER: Level of Floorbeam Top Flange

WHY: The level of floor beam connection dictates structural behavior of the girder-floor beam system, e.g. displacements, and relative movement between members. Relative movement between members is best minimized by placing girder, floor beam and stringer top flanges at the same level, thus achieving a monolithic deck structure. By embedding more member top flanges in the deck slab, load distortion problems are minimized.

Current practice is to place the floor beam top flange separate from the deck as it requires less labor to run the stringers continuous rather than make connections at each floor beam. Yet, in the early 1900's it was common practice to place all at the same level.

It is assumed tie plates are used when the floor beam is at the same level as the girder to provide force continuity across the girder top flange. If the floor beam is placed at the same level as the girder and stringers are placed above the girder, it is recommended that the tie plate not be connected to the girder to avoid possible fatigue cracking.

[See Bridge Fatigue Guide, Publisher: AISC, pp.39-40 for more info]

Press NEWLINE to continue...==>)

PARAMETER: Level of Stringers

WHY: The situation where the top flanges of all components are at the same level creates a monolithic deck structure. All top flanges are imbedded in the concrete deck, thus relative movement between members is minimized. Yet this is a more expensive choice since more connections must be made.

The recommended option is to place the stringer's top flange at the same level as the floor beam's top flange.

Press NEWLINE to continue...==>)

PARAMETER: Level of Outrigger Top Flange

WHY: The level of the outrigger's top flange influences its behavior. By embedding all flanges in the bridge deck a monolithic deck structure is achieved and less differential displacement between deck and outrigger is induced.

The recommended option is to place the outrigger's top flange at the same level as the girder's top flange so that both top flanges may be embedded in the bridge deck.

Press NEWLINE to continue...==>)

PARAMETER: Floorbeam to Girder Connection

WHY: Rigidity of the floor beam-to-girder connection is directly influenced by the type of connection. A full depth connection plate provides more floor beam end restraint than the alternatives where a short connection plate or angle is used.

It is recommended that full depth connection plates be used rather than a short connection plate or angle.

Press NEWLINE to continue...=> }

PARAMETER: Brackets Used

WHY: Connection rigidity is highly dependent on the use of brackets. Connections are more rigid when brackets are used on the bottom, and if possible, on the top. A connection is made even more rigid by welding or bolting the connection plates to girder flanges.

Brackets are used for several reasons: to provide a seat for floor beam and to create diaphragm action. The recommended option is to use brackets wherever possible and firmly attach brackets to the flanges.

Press NEWLINE to continue...=> }

PARAMETER: Attachment of Brackets to Floorbeam/Girder

WHY: Method of bracket connection is determined by how the components are erected. Since there is usually no field welding, only field bolting, the bracket is welded to the floorbeam prior to shipping and bolted to a connection plate, or the bracket is welded to girder prior to shipping and bolted to the floor beam.

Press NEWLINE to continue...=> }

PARAMETER: Connection Plate Attachment at Top

WHY: Connection rigidity is directly influenced by the method of attachment. More rigid connections decrease distortion of girder but increase floorbeam end moment. More flexible connections increase distortion but decrease floorbeam end moment.

It is recommended that the connection plate be welded to the girder flanges since this provides a more positive attachment which minimizes distortion. For this reason, a Nov. 1985 FHWA directive was issued which stated that diaphragm connection plates **MUST** be positively attached to girder flanges. A positive attachment could be achieved by either bolting or welding.

It is more economical to shop weld the connection plate to the flanges. This also results in a weight savings. Bolting with angles is rarely done for economic reasons except in retrofit. It is expensive to bolt because more labor and material are required.

Press NEWLINE to continue... ==>)

PARAMETER: Connection Plate Attachment at Bottom

WHY: Connection rigidity is directly influenced by the method of attachment. More rigid connections decrease distortion of girder but increase floorbeam end moment. More flexible connections increase distortion but decrease floorbeam end moment.

It is recommended that the connection plate be welded to the girder flanges since this provides a more rigid attachment which minimizes distortion. For this reason, a Nov. 1985 FHWA directive was issued which stated that diaphragm connection plates MUST be positively attached to girder flanges. A positive attachment could be achieved by either bolting or welding.

It is more economical to shop weld the connection plate to the flanges. This also results in less weight. Bolting with angles is rarely done for economic reasons except in retrofit. It is expensive to bolt because more labor and material are required.

Press NEWLINE to continue... ==>)

Menu ID: m99

Valid Keywords:

restart quit review help glossary

Final design options:

Options:

1. Re-display design
2. Obtain hardcopy of final design
3. List whys for all parameters
4. List summary points
5. Create a summary file

Enter option number or keyword ==> quit)

Current Values:

Parameter	Value	Defined by
Bridge Layout	Right	User
Type of Span	Continuous	User
Floorbeam Location	Near Midspan	User
Moment Region	Positive	Implied
Outriggers Used	Yes	User
Connection of Laterals to Girder	Yes, @ girder web	User
Level of Floorbeam Top Flange	Below girder level	User
Level of Stringers	Above the floorbeams	Implied
Level of Outrigger Top Flange	Same as girder	User
Floorbeam to Girder Connection	Full depth conn. pl.	User
Brackets Used	Top bracket	User
Attachment of Brackets to Floorbeam/Girder	Welded to floorbeam	User
Connection Plate Attachment at Top	Welded	User
Connection Plate Attachment at Bottom	Welded	User

Prolog execution halted

) type design_example_1)

design example 1

Review of final design parameters:

Parameter	Value	Defined by
Bridge Layout	Right	User
Type of Span	Continuous	User
Floorbeam Location	Near Midspan	User
Moment Region	Positive	Implied
Outriggers Used	Yes	User
Connection of Laterals to Girder	Yes, @ girder web	User
Level of Floorbeam Top Flange	Below girder level	User
Level of Stringers	Above the floorbeams	Implied
Level of Outrigger Top Flange	Same as girder	User
Floorbeam to Girder Connection	Full depth conn. pl.	User
Brackets Used	Top bracket	User
Attachment of Brackets to Floorbeam/Girder	Welded to floorbeam	User
Connection Plate Attachment at Top	Welded	User
Connection Plate Attachment at Bottom	Welded	User

«««««««« Summary »»»»»»»»»

PARAMETER: Connection of Laterals to Girder
VALUE: Yes, attached to the girder web via gusset plate
PROS: —
CONS: May lead to cracking due to out-of-plane forces - web is weak in lateral direction.
COMMENTS: Connect the laterals or gussets to bottom flange by bolting. Flange is stronger than web in lateral direction.

PARAMETER: Level of Floorbeam Top Flange
VALUE: Below the level of the girder top flange
PROS: Common practice. Allows stringers to be placed on floorbeams for economical arrangement.
CONS: Allows floorbeam end to rotate more displacing girder.
COMMENTS: Place girder, floorbeam and stringer top flanges at same level.

PARAMETER: Level of Outrigger Top Flange
VALUE: Same level as the girder top flange
PROS: Minimizes displacements if top flange is embedded in deck.
CONS: Outrigger connection at girder may be difficult if floorbeam top flange is below girder top flange.
COMMENTS: Place outrigger, girder and floorbeam top flanges at same level.

PARAMETER: Floorbeam to Girder Connection
VALUE: Full depth connection plate used
PROS: Rigidity of girder web against out-of-plane displacement is provided. Easy to attach floorbeam web.
CONS: Gusset plate for floorbeam flange connection intersects vertical connection plate.
COMMENTS: Connection plate should be attached to flanges.

PARAMETER: Brackets Used
VALUE: Top bracket
PROS: Use of brackets improves rigidity and allows diaphragm action to take place.
CONS: Bracket material and connection required.
COMMENTS: Top bracket could be omitted by placing top flange of floorbeam and girder at same level.

PARAMETER: Attachment of Brackets to Floorbeam/Girder
VALUE: Shop welded to floorbeam
PARAMETER: Brackets Used
VALUE: Top bracket
PROS: Allows shipping of floorbeam and bracket as one piece. Also allows bolting of floorbeam/bracket component to connection plate.
CONS: Does not provide seat for floorbeam during erection.
COMMENTS: —

PARAMETER: Connection Plate Attachment at Top

VALUE: Welded

PROS: Provides positive attachment of connection plate to girder flange,
minimizing out-of-plane displacements of girder web.

CONS: More shop work required.

COMMENTS: Attachment of connection plate to flanges is required by code.

PARAMETER: Connection Plate Attachment at Bottom

VALUE: Welded

PROS: Provides positive attachment of connection plate to girder flange,
minimizing out-of-plane displacements of girder web.

CONS: More shop work required.

COMMENTS: Attachment of connection plate to flanges is required by code.

)

0

5.2 Design Example 2

```
) x prolog pr481.2 )
```

```
--- UNH Prolog version 1.3 (Syracuse CIS) ---
```

```
[ "pr481.2" consulted ]
```

```
: ?- go. )
```

Bridge Connection Design Program

Written by Ken Seiler and Ray Vogt

Version 1.0 5/14/86

To select an option, enter the number, then press **NEULINE**.
If this is the first time you have used this program, you
should go through each of the options starting with 1.

Select one of the following:

1. Program Description
2. Program Operation
3. Menu Keyword Descriptions
4. Graphical Display of Bridge and Connection Components
5. Set Terminal Type (Default is G300 Graphics Terminal)
6. Begin Connection Design Session

```
Enter option number ==> 1 )
```

Program Description/Scope:

This system aids in the conceptual design of a floorbeam to girder connection, including cantilevered floorbeams (outriggers), for twin steel I-shaped girder bridges. Conceptual design refers to the qualitative design dealing primarily with the factors that effect the overall integrity and performance of the connection during its life cycle. The program is therefore considered a design aid for the user, primarily targeted at students. The program provides the user with insight into the implications of choosing alternative design options on the performance of the connection.

Program Limitations:

The program considers straight girders only, with no consideration given to curved girders. This is due to the lack of information and experience available with curved girder systems. Right or skew bridges may be considered, although there is currently no distinction made between right and skew designs in the current bridge specifications (The American Association of State Highway and Transportation Officials "Standard Specifications for Highway Bridges" hereafter referred to as AASHTO Specs).

Other limitations are set to handle "common practice" situations and to eliminate "special case" designs. Limitations are placed on bolting and welding procedures. All welding is assumed to be performed under shop conditions, due to quality control problems that arise under field welding conditions. All bolting is considered to be done in the field during the erection procedure.

Another of these limitations is the use of full depth connection angles (angles that run from the top to bottom flanges of the girder). Due to the relatively long depth of girders in a two girder system, full depth angles are not used.

A third limitation is in the method of tie plate attachment. Tie plates are necessary when outriggers are used to maintain the continuity of the top flanges of the floorbeam and outrigger over the girder. This program always places the tie plate above the girder top flange. Web cutouts that allow the tie plate to pass through the girder web are not considered because of the associated fatigue problems that may occur.

User Preparation:

It is assumed that the user has decided upon the type and location of loading for the system along with the member dimensions, girder spacing, outrigger length, lateral location, etc., which may in part be dictated by the AASHTO specs.

Program Output:

The program output will consist of a graphical display of the connection with components as specified during the program. A brief summary may also be obtained to alert the user to some of the advantages and disadvantages of the design, along with suggestions (comments) to enhance the connection integrity. As stated earlier, this is a conceptual design of the connection. The user will have to check the validity of the connection from geometric conditions and assess the situation from a quantitative design standpoint.

Guidelines of Program:

Sources of guidance for the system are:

1. AASHTO Specifications for design requirements
2. AISC Bridge Fatigue Guide for suggested design considerations
3. A Technical Specialist for current research findings/considerations and current practice/procedures.

Press NEWLINE to continue...==>)

Bridge Connection Design Program

Written by Ken Seiler and Ray Vogt

Version 1.0 5/14/86

To select an option, enter the number, then press NEWLINE.
If this is the first time you have used this program, you
should go through each of the options starting with 1.

Select one of the following:

1. Program Description
2. Program Operation
3. Menu Keyword Descriptions
4. Graphical Display of Bridge and Connection Components
5. Set Terminal Type (Default is G300 Graphics Terminal)
6. Begin Connection Design Session

Enter option number ==> 2 ↵

Program Operation:

This program is a menu driven system. Menus contain a prompt or question for the user to answer. The valid options (responses) for the question are listed below the question. To select an option, simply enter the option number, then press NEWLINE.

The valid keywords for a menu are listed at the top of the screen. To select a valid keyword, type the word as shown, then press NEWLINE.

Occasionally, the prompt "Press NEWLINE to continue..." appears. To respond, simply press NEWLINE. Questions that require yes/no answers also appear in the program. When asked, they display "(yes/no)" after the question. Enter yes or no to answer the question, then press NEWLINE.

When a graphical display is drawn, the '==>' prompt appears. After examining the display, press NEWLINE to continue with the program.

NOTE: All alpha-numeric input MUST be lower case!

Press NEWLINE to continue... ==> ↵

Bridge Connection Design Program

Written by Ken Seiler and Ray Vogt

Version 1.0 5/14/86

To select an option, enter the number, then press NEWLINE.
If this is the first time you have used this program, you
should go through each of the options starting with 1.

Select one of the following:

1. Program Description
2. Program Operation
3. Menu Keyword Descriptions
4. Graphical Display of Bridge and Connection Components
5. Set Terminal Type (Default is G300 Graphics Terminal)
6. Begin Connection Design Session

Enter option number ==> 3)

Menu Keyword Descriptions:

-
- backup - Re-displays the previous menu, and allows the user to select an option from that menu, thus over-riding the previous value.
 - skip - Allows the user to have the system select the "best" value for the parameter in question. The systems choice is displayed along with the reason for its selection.
 - conclude - Tells the system to deduce the remaining parameter values. The selected values are displayed and the final design is shown.
 - restart - Displays all defined parameters to your current menu level, then initializes the system and starts a new session.
 - quit - Lists all defined parameter values and exits the system.
 - review - Lists all currently defined parameters and values, and their method of determination (user selected, implied, system selected).
 - what - Explains the current question and the options in more detail. A graphical display may also be presented for clarification.
 - why - Explains why one option may be better than another for any of several reasons including economic, design, fabrication, and erection.
 - suggest - Tells the user the best value for the option, along with the reason for its recommendation.
 - help - Lists the available keywords for the current menu level along with a short description of their functions.
 - glossary - Lists technical terms and definitions used in this system. A graphical display of connection components can also be called up.

Press NEWLINE to continue...==>)

Bridge Connection Design Program

Written by Ken Seiler and Ray Vogt

Version 1.0 5/14/86

To select an option, enter the number, then press NEWLINE.
If this is the first time you have used this program, you
should go through each of the options starting with 1.

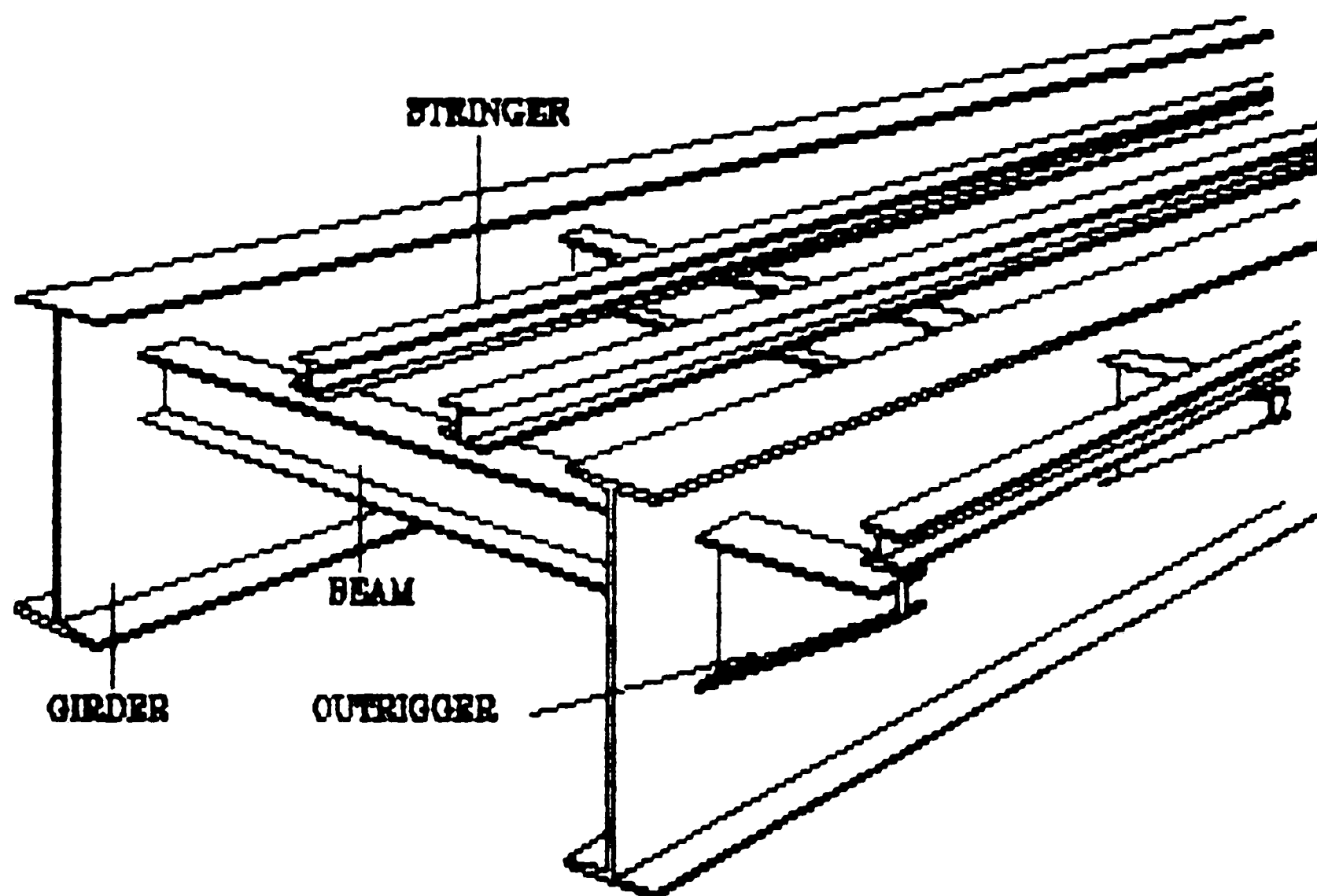
Select one of the following:

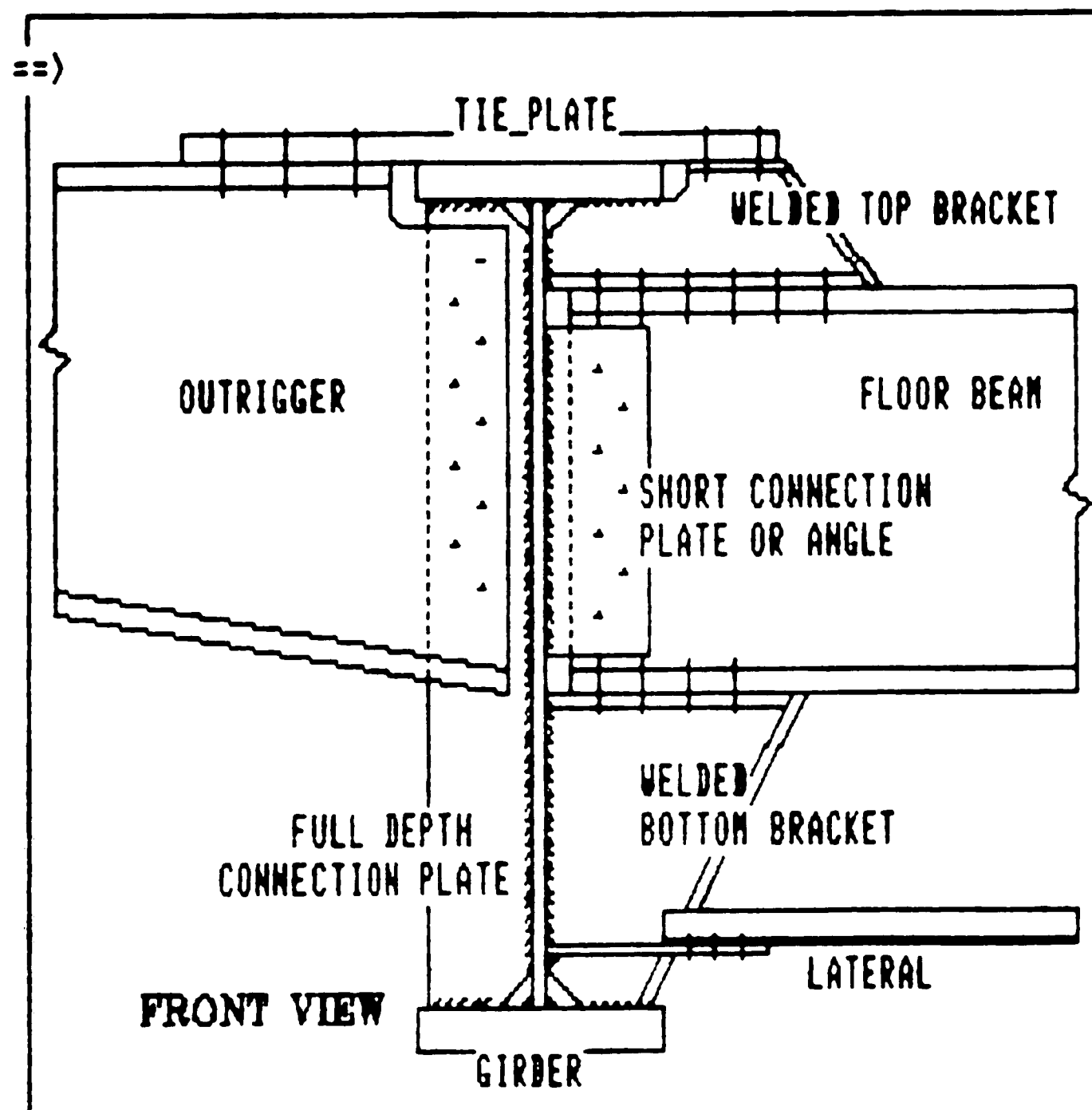
1. Program Description
2. Program Operation
3. Menu Keyword Descriptions
4. Graphical Display of Bridge and Connection Components
5. Set Terminal Type (Default is G300 Graphics Terminal)
6. Begin Connection Design Session

Enter option number ==> 4 ↵

==> ↵

BRIDGE COMPONENTS





Bridge Connection Design Program

Written by Ken Seiler and Ray Vogt

Version 1.0 5/14/86

To select an option, enter the number, then press NEWLINE.
If this is the first time you have used this program, you should go through each of the options starting with 1.

Select one of the following:

1. Program Description
2. Program Operation
3. Menu Keyword Descriptions
4. Graphical Display of Bridge and Connection Components
5. Set Terminal Type (Default is G300 Graphics Terminal)
6. Begin Connection Design Session

Enter option number ==> 6 ↵

Menu ID: n1

Valid Keywords:

quit what why help glossary

General layout of the bridge:

Options:

1. Right
2. Skew

Enter option number or keyword ==> glossary)

Graphical display of Bridge Components ready...

Do you wish to see the graphical display? (yes/no) ==> no)

GLOSSARY

Bracket: T or I-shaped components used above and/or below the floorbeam to provide a means of connection for the floorbeam to the girder. Bracket web is in-line with the floorbeam web. If a connection plate is used, the bracket is connected to the connection plate. Brackets are used to create diaphragm action and/or to provide a seat for the floorbeam.

Bridge Fatigue Guide: Guide published by AISC (American Institute of Steel Construction).

Connection Plate: Long, thin component connected to girder so that its direction of minimum thickness is parallel to longitudinal centerline of bridge. Used to provide means of connection of floorbeam to girder.

Cut Short: A condition at the bracket or connection plate-to-girder flange location where the component is terminated just short of the girder flange rather than connected directly to girder flange.

Diaphragm: A set of components connected transverse to girder and used to maintain cross-sectional shape of bridge.

FHWA: Federal Highway Administration

Fitted to Bear Against: A condition at connection plate or bracket-to-girder flange location where the component is cut to bear right up against the girder flange rather than welded or cut short.

Floorbeam: Member connected transverse to girder and used to carry loads from deck and stringers to the girders.

Girder: The main load carrying members used in bridges. Girders run parallel to the longitudinal direction of bridge.

Lateral: Laterals are members used in cross-bracing to transmit horizontal forces. They are connected at or near bottom girder flanges parallel to bridge deck and are usually angles framed in an X fashion as seen if looking up at underside of bridge.

Negative Moment: A moment creating compression in the bottom flange. A negative moment region is that region where the bottom flange is in compression.

Out-of-plane distortion: A member displacement in the direction offering the weakest resistance to load or in direction not intended or designed to carry load. For example, a girder web being pulled or pushed sideways by a transverse member would create an out-of-plane distortion.

Outrigger: Outriggers are cantilevered floorbeams extending out from main girders. They are used when overall bridge deck width exceeds girder spacing (spacing dictated by AASHTO Specs).

Positive Attachment: A firm, rigid attachment of two components either by bolting or welding.

Positive Moment: A moment creating tension in the girder bottom flange. A positive moment region is that region where the girder bottom flange is in tension.

Short connection angle: Angle component used to connect floorbeam to girder. Short connection angles usually span the full floorbeam web depth.

Short connection plate: Component used to connect floorbeam to girder web. If there is no field welding, the short connection plate is welded to girder in shop and bolted to floorbeam in field. A short connection plate is the same as a full depth connection plate but it only spans the floorbeam depth, not the girder depth.

Stringer: Secondary load carrying member used to transmit forces from bridge deck to floorbeam. Stringers run parallel to girders.

Tie Plate: Plate used to connect floorbeam top flange to girder top flange and/or outrigger top flange. The tie plate provides force continuity across the girder top flange.

Transverse Stiffener: Component used to stiffen girder against web buckling. They are connected so that the transverse stiffener direction of minimum distance is parallel to longitudinal axis of girder. Transverse stiffeners are used at regular intervals along girder and at locations of concentrated forces such as supports.

Web Gap: Girder web region between the girder flange and the termination of a cut short connection plate or transverse stiffener.

Welded: Condition where components are welded - other choices are cut short and fitted when referring to bracket or connection plate attachment to girder flange.

Welded Bracket: Component above and/or below floorbeam to connect floorbeam to girder. They are called "Welded Brackets" because they are almost always welded to girder flange and sometimes to girder flange. The exception to this connection method is when field welding is done or when brackets are bolted to both the girder and floorbeam in the field.

Press NEWLINE to continue...=>)

Menu ID: a1

Valid Keywords:

quit what why help glossary

General layout of the bridge:

Options:

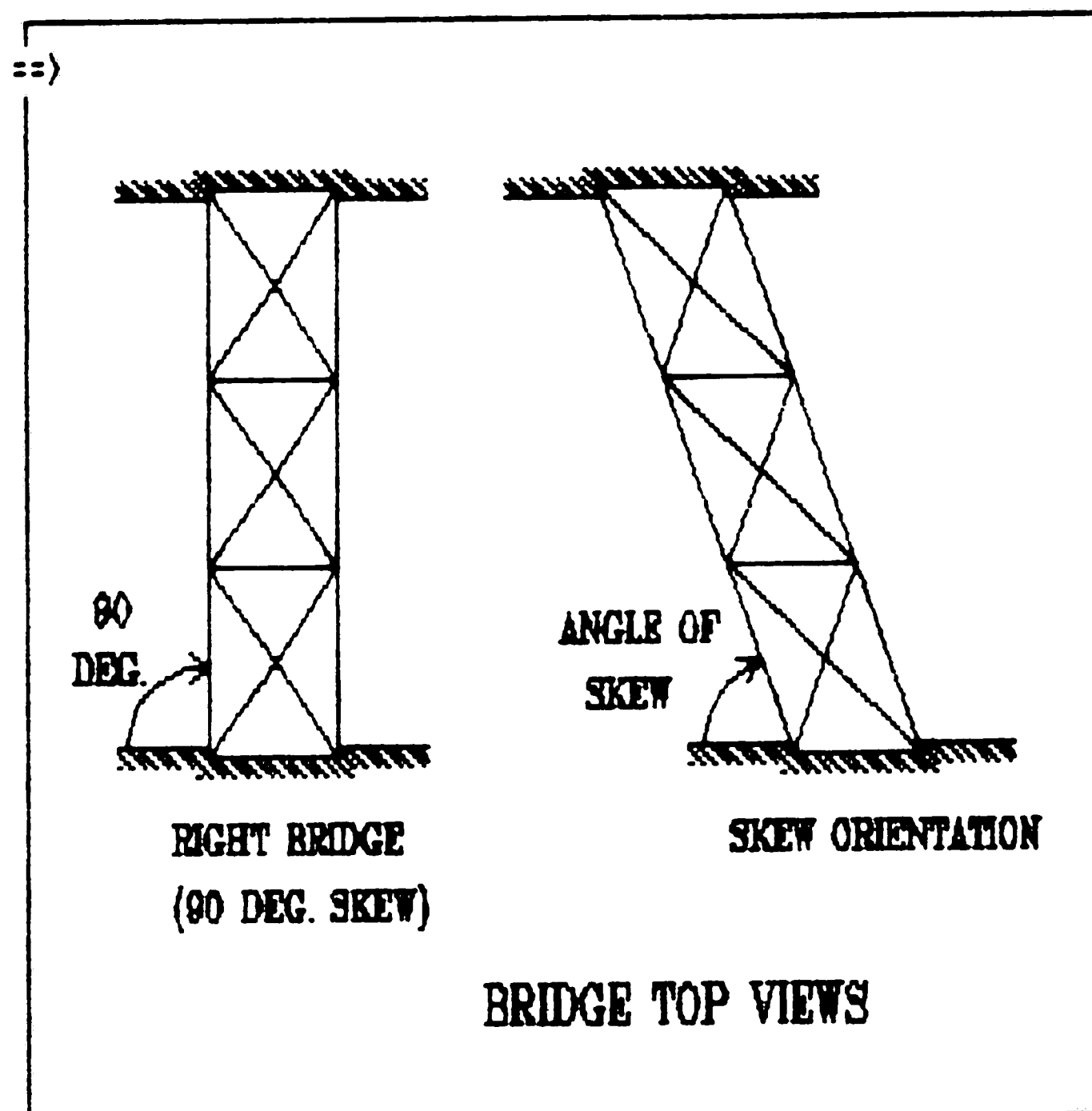
1. Right
2. Skew

Enter option number or keyword ==> what ↵

WHAT: A right bridge is a 90 Degree skew bridge. Angle of skew is defined as the angle (less than 90 degrees) between the end floor beam and a girder.

Press NEWLINE to continue... ==> ↵

Do you wish to see the graphical display? (yes/no) ==> yes ↵



Menu ID: m1

Valid Keywords:

quit what why help glossary

General layout of the bridge:

Options:

1. Right
2. Skew

Enter option number or keyword ==> 2)

Menu ID: m2

Valid Keywords:

backup quit review what why help glossary

Type of span where connection is located:

Options:

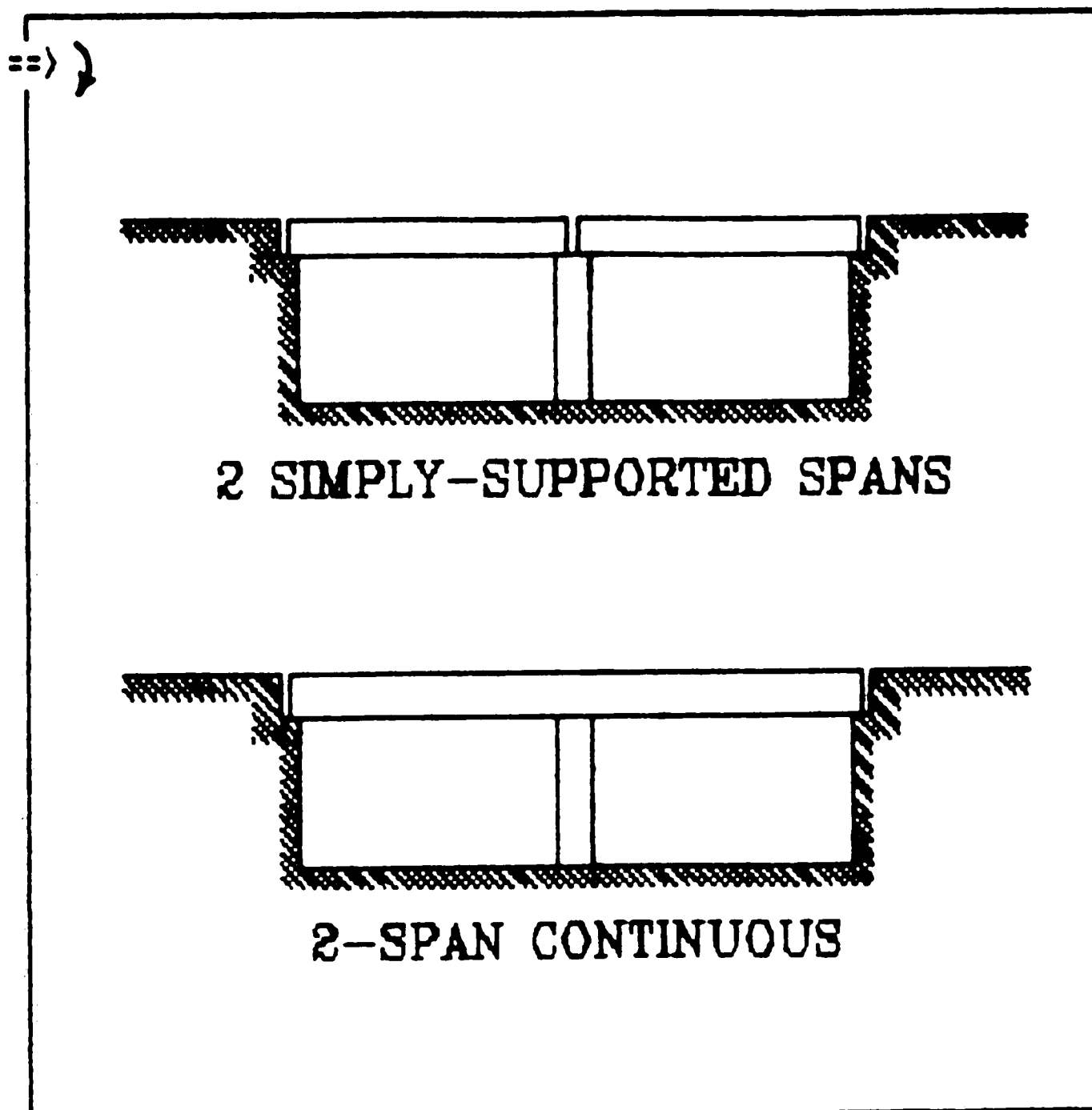
1. Simple
2. Continuous

Enter option number or keyword ==> what)

WHAT: Simple spans are spans where girders and bridge deck are not continuous over bridge supports. Continuous spans are continuous over interior supports. Therefore forces are transmitted from one span to adjacent span(s).

Press NEWLINE to continue... ==>)

Do you wish to see the graphical display? (yes/no) ==> yes)



Menu ID: n2

Valid Keywords:

backup quit review what why help glossary

Type of span where connection is located:

Options:

1. Simple
2. Continuous

Enter option number or keyword ==> 1 }

This implies at menu level n4 :

Moment region is positive everywhere along simple spans.

Press NEWLINE to continue... ==> }

Menu ID: m3

Valid Keywords:

backup restart quit review what why help glossary

Floorbeam location along span:

Options:

1. Near support
2. Near midspan (central)

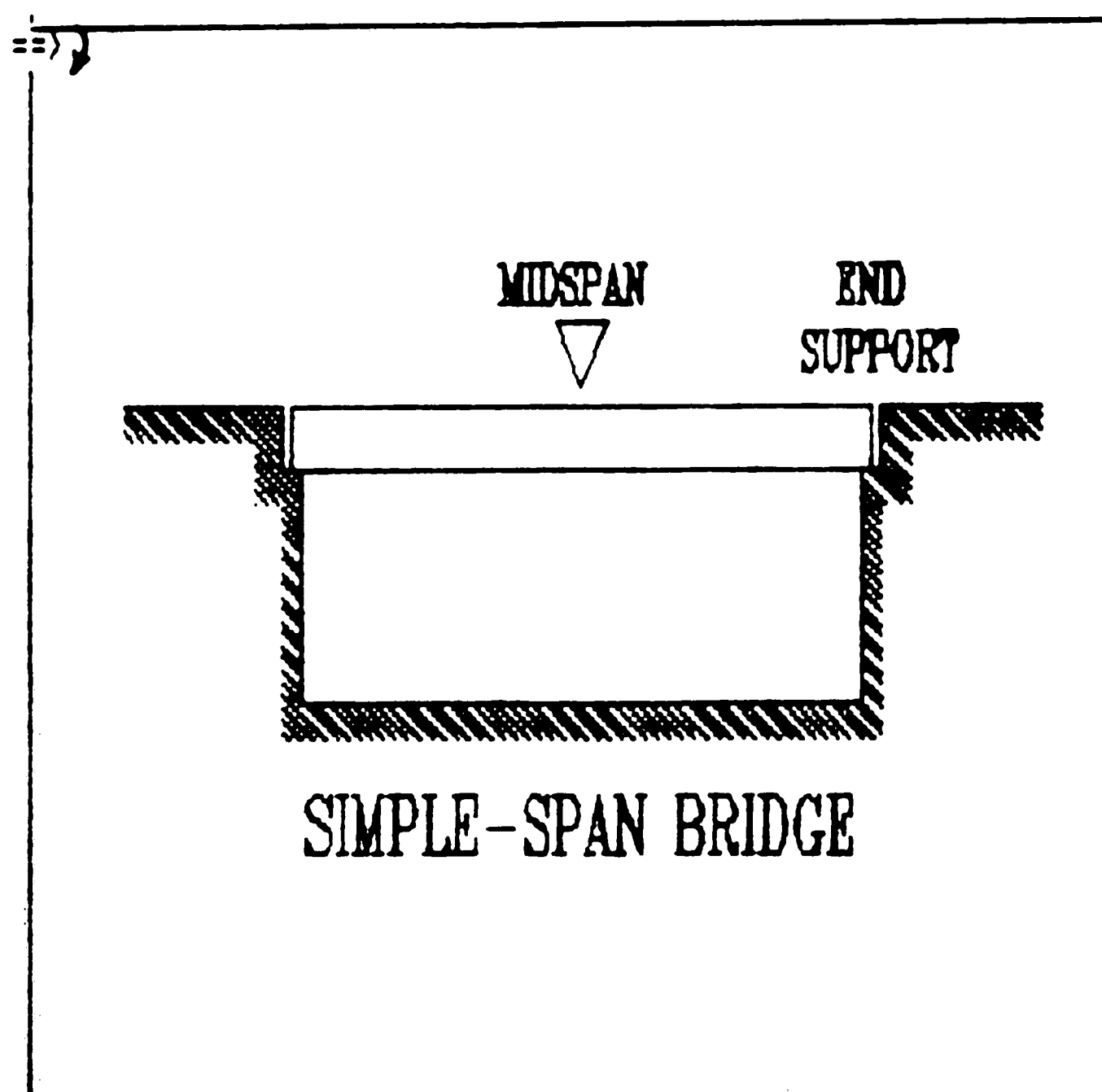
Enter option number or keyword ==> what)

WHAT: Near Support is defined as "close" to the supports where the moment region may be +ve or -ve. Central is the region in the middle of the span where the moment region is +ve.

A +ve moment causes tension in the girder bottom flange.
A -ve moment causes compression in the girder bottom flange.

Press NEWLINE to continue... ==>)

Do you wish to see the graphical display? (yes/no) ==> yes)



Menu ID: n3

Valid Keywords:

backup restart quit review what why help glossary

Floorbeam location along span:

Options:

1. Near support
2. Near midspan (central)

Enter option number or keyword ==> 1 ↵

Menu ID: n5

Valid Keywords:

backup restart quit review what why help glossary

Are outriggers used at this connection?

Options:

1. Yes - outriggers are used
2. No - outriggers are not used

Enter option number or keyword ==> 1 ↵

Menu ID: n6

Valid Keywords:

backup restart quit review what why help glossary

Are laterals attached to the girder at this connection?

Options:

1. Yes, attached to the bottom flange of the girder
2. Yes, attached to the girder web via gusset plate
3. No, laterals are not present at this connection

Enter option number or keyword ==> 2 ↵

Menu ID: a7

Valid Keywords:

backup restart quit review what why suggest help glossary

Level of the TOP flange of the floorbeam with respect to the
TOP flange of the girder:

Options:

1. Same level as the girder top flange
2. Below the level of the girder top flange

Enter option number or keyword ==> backup)

"Connection of Laterals to Girder" parameter value retracted.

Press NEWLINE to continue... ==>)

Menu ID: a6

Valid Keywords:

backup restart quit review what why help glossary

Are laterals attached to the girder at this connection?

Options:

1. Yes, attached to the bottom flange of the girder
2. Yes, attached to the girder web via gusset plate
3. No, laterals are not present at this connection

Enter option number or keyword ==> 1)

Menu ID: a7

Valid Keywords:

backup restart quit review what why suggest help glossary

Level of the TOP flange of the floorbeam with respect to the
TOP flange of the girder:

Options:

1. Same level as the girder top flange
2. Below the level of the girder top flange

Enter option number or keyword ==> 1)

This implies at menu level a9 :

When the floorbeam top flange is at the same level as the girder
top flange, the outrigger cannot be below this level.

Press NEWLINE to continue... ==>)

Menu ID: m8

Valid Keywords:

backup restart quit review what why suggest help glossary

Level of the stringers with respect to the floorbeams:

Options:

1. Same level as the floorbeams
2. Above the floorbeams

Enter option number or keyword ==> 2)

Menu ID: m10

Valid Keywords:

backup restart quit review what why suggest help glossary

Attachment of floorbeam to girder is via:

Options:

1. Full depth connection plate (welded to girder web)
2. Short connection plate or connection angle

Enter option number or keyword ==> review)

Current Values:

Parameter	Value	Defined by
Bridge Layout	Skew	User
Type of Span	Simple	User
Moment Region	Positive	Implied
Floorbeam Location	Near Support	User
Outriggers Used	Yes	User
Connection of Laterals to Girder	Yes, @ bottom flange	User
Level of Floorbeam Top Flange	Same as girder	User
Level of Outrigger Top Flange	Same as girder	Implied
Level of Stringers	Above the floorbeams	User

Press NEWLINE to continue... ==>)

Menu ID: m10

Valid Keywords:

backup restart quit review what why suggest help glossary

Attachment of floorbeam to girder is via:

Options:

1. Full depth connection plate (welded to girder web)
2. Short connection plate or connection angle

Enter option number or keyword ==> 2)

This implies at menu level m15 :

Since a full depth connection plate is not used, you must use a bracket at the connection, namely a bottom bracket.

Press NEWLINE to continue...==>)

Menu ID: m16

Valid Keywords:

backup restart quit review what why suggest help glossary

Method of attachment of floorbeam to girder:

Options:

1. Bolted to connection plate
2. Bolted to connection angle

Enter option number or keyword ==> 1)

Menu ID: m18

Valid Keywords:

backup restart quit review what why suggest help glossary

Method of attachment of bracket to BOTTOM flange of girder:

Options:

1. Welded
2. Fitted
3. Cut short

Enter option number or keyword ==> suggest)

I suggest you select "Welded"
for "Bracket Attachment to Bottom Flange"
because:

Welding provides positive attachment of the connection bracket to
the flange (as required by the new FHWA directive - Nov. 1985)
which minimizes distortion effects.

Press NEWLINE to continue...==>)

Menu ID: m18

Valid Keywords:

backup restart quit review what why suggest help glossary

Method of attachment of bracket to BOTTOM flange of girder:

Options:

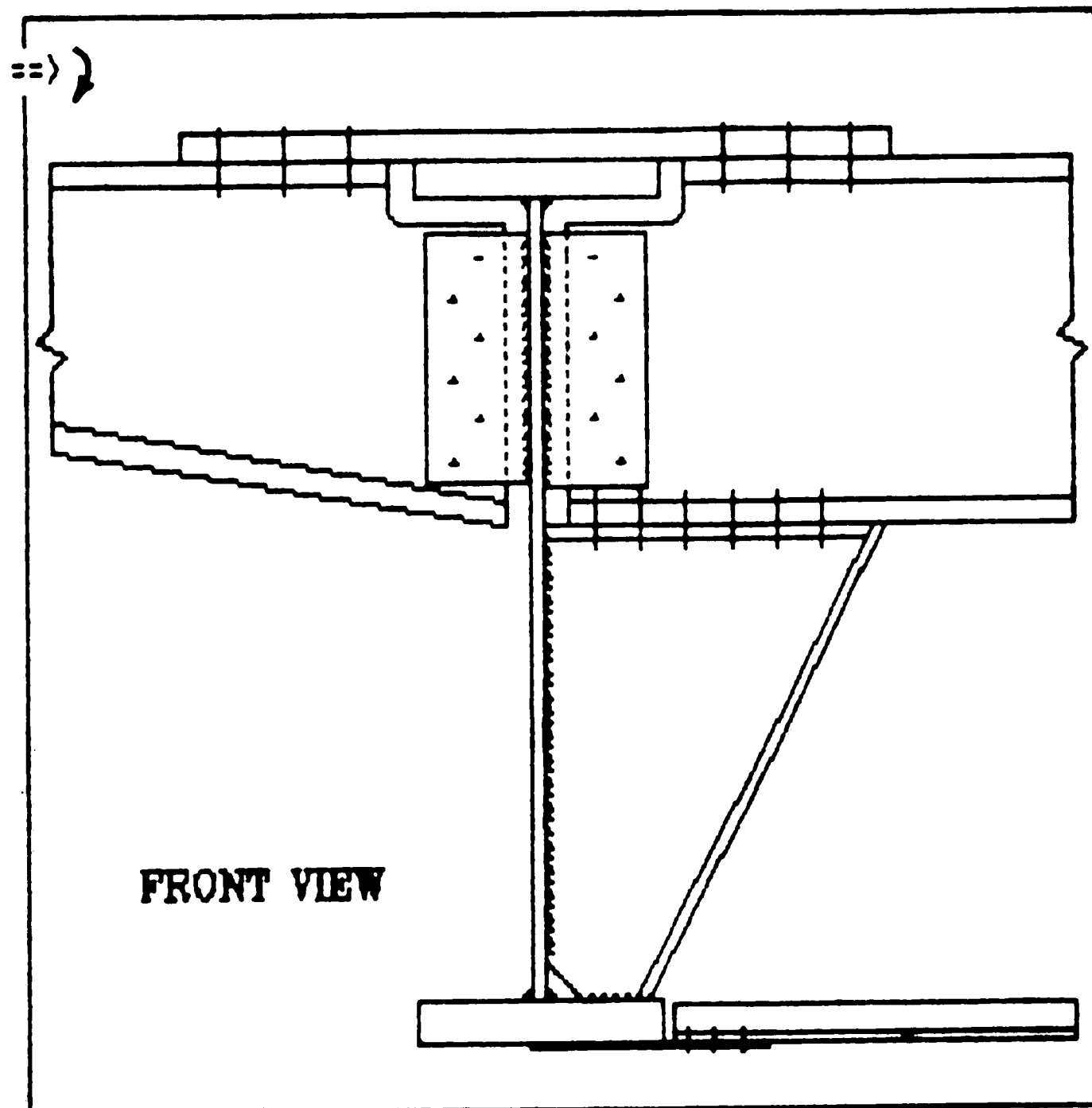
1. Welded
2. Fitted
3. Cut short

Enter option number or keyword ==> 1)

Review of final design parameters:

Parameter	Value	Defined by
Bridge Layout	Skew	User
Type of Span	Simple	User
Moment Region	Positive	Implied
Floorbeam Location	Near Support	User
Outriggers Used	Yes	User
Connection of Laterals to Girder	Yes, @ bottom flange	User
Level of Floorbeam Top Flange	Same as girder	User
Level of Outrigger Top Flange	Same as girder	Implied
Level of Stringers	Above the floorbeams	User
Floorbeam to Girder Connection	Short conn pl./angle	User
Welded Brackets Used	Bottom bracket	Implied
Floorbeam Attachment to Girder	Bolt to short plate	User
Bracket Attachment to Bottom Flange	Welded	User

Press NEWLINE for graphical display of final design...==>)



Menu ID: m99

Valid Keywords:

restart quit review help glossary

Final design options:

Options:

1. Re-display design
2. Obtain hardcopy of final design
3. List whys for all parameters
4. List summary points
5. Create a summary file

Enter option number or keyword ==> 3)

PARAMETER: Bridge Layout

WHY: The angle of skew influences the magnitude of differential girder displacements and floor beam end rotations. These displacements and rotations result in out-of-plane displacements of girder web and may consequently lead to fatigue cracking. Other factors influencing the magnitude of differential girder displacements are: angle of connection between floor beam and girder; girder, floor beam, stringer spacing; dimension of these components; etc.. Floor beams connected perpendicular to girders in skew bridges have high relative displacements, yet this arrangement is usual practice because it is more economical.

Skew bridges require a more detailed analysis in the connection location because differential displacements and floor beam end rotations causing out-of-plane displacements of girder web are more pronounced in a skew bridge. Current AASHTO Specs do not distinguish between right and skew bridges.
[See BRIDGE FATIGUE GUIDE, publisher: AISC, pp.41-42 for more info]

Press NEWLINE to continue...=>)

PARAMETER: Type of Span

WHY: Span type, dictated by the overall bridge design, is needed because it indicates whether a floor beam is in a +ve or -ve moment region. A +ve moment causes tension in the girder bottom flange and a -ve moment causes compression in the girder bottom flange.

Press NEWLINE to continue...=>)

PARAMETER: Floorbeam Location

WHY: floor beam connection location indicates relative fixity and relative differential displacements of girder flanges. Relative differential displacements are larger near midspan than near supports because girders are freer to move near midspan.

Press NEWLINE to continue...=> }

PARAMETER: Moment Region

WHY: In +ve moment regions, cracking of girder web is more frequent at the girder bottom flange. In -ve moment regions, upper flange location cracking is more frequent. A more detailed analysis is recommended for flanges in tension because crack growth is more serious there. A +ve moment causes tension in the girder bottom flange and a -ve moment causes compression in the girder bottom flange.

Press NEWLINE to continue...=> }

PARAMETER: Outriggers Used

WHY: The use of outriggers can provide a counter-balancing moment to the floor beam end moment at the floorbeam-girder connection. Moment continuity is achieved when outrigger and floor beam flanges are directly opposite each other. Problems occur when the depth of the outrigger, or more commonly the depth of the floor beam, exceeds that of the member on the opposite side of girder. Flange forces are then transmitted through the thin web which offers weak resistance to out-of-plane forces. Web cracking is a problem in this situation. Floor beam end moments which the web must resist are higher when no outriggers are used.

Depths of outriggers are usually reduced toward the edge of the bridge where the moment is less to save material. Current Practice is to use outrigger and floor beam sections of equal depth at the girder and connected at coincident levels to avoid out-of-plane displacements of the girder web.

If outriggers are used, it is assumed that tie plates are used to maintain force continuity across the girder top flange. Girder web cut-outs are not allowed by the system, due to associated fatigue problems.

Press NEWLINE to continue...=> }

PARAMETER: Connection of Laterals to Girder

WHY: Laterals transmit horizontal forces caused by girder differential displacements and floor beam end rotations, and by wind loading. Laterals may produce severe out-of-plane displacements if not connected properly. When connected to the girder web, cracking can occur at the gusset plate-to-girder region.

It is recommended that laterals be bolted to the girder bottom flange because the flange is a stiffer component to resist the out-of-plane displacements.

Press NEWLINE to continue...==>)

PARAMETER: Level of Floorbeam Top Flange

WHY: The level of floor beam connection dictates structural behavior of the girder-floor beam system, e.g. displacements, and relative movement between members. Relative movement between members is best minimized by placing girder, floor beam and stringer top flanges at the same level, thus achieving a monolithic deck structure. By embedding more member top flanges in the deck slab, load distortion problems are minimized.

Current practice is to place the floor beam top flange separate from the deck as it requires less labor to run the stringers continuous rather than make connections at each floor beam. Yet, in the early 1900's it was common practice to place all at the same level.

It is assumed tie plates are used when the floor beam is at the same level as the girder to provide force continuity across the girder top flange. If the floor beam is placed at the same level as the girder and stringers are placed above the girder, it is recommended that the tie plate not be connected to the girder to avoid possible fatigue cracking.

[See Bridge Fatigue Guide, Publisher: AISC, pp.39-40 for more info]

Press NEWLINE to continue...==>)

PARAMETER: Level of Outrigger Top Flange

WHY: The level of the outrigger's top flange influences its behavior. By embedding all flanges in the bridge deck a monolithic deck structure is achieved and less differential displacement between deck and outrigger is induced.

The recommended option is to place the outrigger's top flange at the same level as the girder's top flange so that both top flanges may be embedded in the bridge deck.

Press NEWLINE to continue...==>)

PARAMETER: Level of Stringers

WHY: The situation where the top flanges of all components are at the same level creates a monolithic deck structure. All top flanges are imbedded in the concrete deck, thus relative movement between members is minimized. Yet this is a more expensive choice since more connections must be made.

The recommended option is to place the stringer's top flange at the same level as the floor beam's top flange.

Press NEWLINE to continue...=>)

PARAMETER: Floorbeam to Girder Connection

WHY: Rigidity of the floor beam-to-girder connection is directly influenced by the type of connection. A full depth connection plate provides more floor beam end restraint than the alternatives where a short connection plate or angle is used.

It is recommended that full depth connection plates be used rather than a short connection plate or angle.

Press NEWLINE to continue...=>)

PARAMETER: Welded Brackets Used

WHY: The use of brackets influences connection rigidity. Connections are more rigid when brackets are used on the bottom, and if possible, on the top. A connection is made even more rigid by a firm connection of the brackets to the girder flange through welding or bolting.

Brackets are used for several reasons:

- to provide a seat for the floor beam
- to create diaphragm action when the floor beam is not deep enough to do this itself. This is left to the discretion of the designer.

When outriggers are used and the floor beam top flange is placed below the girder top flange, a top bracket must be used to provide continuity between floor beam and outrigger. If no outriggers are used and the floor beam top flange is placed below the girder top flange, use of a bracket is advised. It is recommended that brackets be used wherever possible and that they be firmly attached all around through welding or bolting.

Press NEWLINE to continue...=>)

PARAMETER: Floorbeam Attachment to Girder

WHY: Method of floor beam attachment is determined by erection procedure. It is recommended that the floor beams be field bolted to connection plates which are shop-welded to the girders as this is most economical. This also results in a weight savings over the use of a connection angle.

Press NEWLINE to continue...==>)

PARAMETER: Bracket Attachment to Bottom Flange

WHY: The bracket connection to girder flange influences connection rigidity. Brackets connected to girder flange offer higher rigidity because in the horizontal direction the flange is a stiff, rigid component relative to the web. It is recommended that the bracket be welded to girder flange for this reason regardless if in +ve or -ve moment region. A +ve moment causes tension in the girder bottom flange and a -ve moment causes compression in the girder bottom flange.

Bolting with angles is also a possibility but rarely done for economic reasons except in retrofit. It is expensive to bolt because more labor and material are required.

Press NEWLINE to continue...==>)

Menu ID: m99

Valid Keywords:

restart quit review help glossary

Final design options:

Options:

1. Re-display design
2. Obtain hardcopy of final design
3. List whys for all parameters
4. List summary points
5. Create a summary file

Enter option number or keyword ==> 5)

Enter file name to contain summary ==> design_example_2)

Enter the title for this design

==> design example 2)

Summary to design_example_2 proceeding....

Summary to design_example_2 completed.

Press NEWLINE to continue...==>)

Menu ID: a99

Valid Keywords:

restart quit review help glossary

Final design options:

Options:

1. Re-display design
2. Obtain hardcopy of final design
3. List whys for all parameters
4. List summary points
5. Create a summary file

Enter option number or keyword ==> quit)

Current Values:

Parameter	Value	Defined by
Bridge Layout	Skew	User
Type of Span	Simple	User
Moment Region	Positive	Implied
Floorbeam Location	Near Support	User
Outriggers Used	Yes	User
Connection of Laterals to Girder	Yes, @ bottom flange	User
Level of Floorbeam Top Flange	Same as girder	User
Level of Outrigger Top Flange	Same as girder	Implied
Level of Stringers	Above the floorbeams	User
Floorbeam to Girder Connection	Short conn pl./angle	User
Welded Brackets Used	Bottom bracket	Implied
Floorbeam Attachment to Girder	Bolt to short plate	User
Bracket Attachment to Bottom Flange	Welded	User

Prolog execution halted

) type design_example_2)

design example 2

Review of final design parameters:

Parameter	Value	Defined by
Bridge Layout	Skew	User
Type of Span	Simple	User
Moment Region	Positive	Implied
Floorbeam Location	Near Support	User
Outriggers Used	Yes	User
Connection of Laterals to Girder	Yes, @ bottom flange	User
Level of Floorbeam Top Flange	Same as girder	User
Level of Outrigger Top Flange	Same as girder	Implied
Level of Stringers	Above the floorbeams	User
Floorbeam to Girder Connection	Short conn pl./angle	User
Welded Brackets Used	Bottom bracket	Implied
Floorbeam Attachment to Girder	Bolt to short plate	User
Bracket Attachment to Bottom Flange	Welded	User

Summary

PARAMETER: Bridge Layout
 VALUE: Skew
 PROS: —
 CONS: Increased out-of-plane movement can occur because of additional end rotation due to differential vertical movement between the ends of the floorbeam.
 COMMENTS: Account for increased out-of-plane movements in actual quantitative analysis and design of connection.

PARAMETER: Connection of Laterals to Girder
 VALUE: Yes, attached to the bottom flange of the girder
 PROS: Flange is stronger than web in lateral direction.
 CONS: Bolt holes in bottom flange.
 COMMENTS: —

PARAMETER: Level of Floorbeam Top Flange
 VALUE: Same level as the girder top flange
 PARAMETER: Level of Stringers
 VALUE: Above the floorbeams
 PROS: More economical than placing top flanges of stringers and floorbeams at the same level.
 CONS: Displacements cannot be minimized by embedding in deck.
 COMMENTS: Place stringer top flange at same level as floorbeam top flange.

PARAMETER: Level of Outrigger Top Flange
 VALUE: Same level as the girder top flange
 PROS: Minimizes displacements if top flange is embedded in deck.
 CONS: Outrigger connection at girder may be difficult if floorbeam top flange is below girder top flange.
 COMMENTS: Place outrigger, girder and floorbeam top flanges at same level.

PARAMETER: Floorbeam to Girder Connection
VALUE: Short connection plate/angle used
PROS: May be some weight savings from using short plate or angle.
CONS: Connection not as rigid as it would be with full depth conn plate.
COMMENTS: Use full depth connection plate for attachment of floorbeam.
Attachment of connection plate to flange required by code.

PARAMETER: Welded Brackets Used
VALUE: Bottom bracket
PROS: Use of brackets improves rigidity and allows diaphragm action to take place.
CONS: Bracket material and connection required.
COMMENTS: Extend bottom bracket to bottom flange of girder.

PARAMETER: Floorbeam Attachment to Girder
VALUE: Bolted to connection plate
PROS: Short connection plate saves material and weight over connection angle.
CONS: —
COMMENTS: —

PARAMETER: Bracket Attachment to Bottom Flange
VALUE: Welded
PROS: Provides positive attachment of bracket to girder flange, minimizing out-of-plane displacements of girder web.
CONS: —
COMMENTS: —

)

CHAPTER 6

CONCLUSIONS

The main purpose of the system is for education and knowledge transfer from research to engineering practice. The system provides one domain expert's knowledge which represents years of experience in research and consulting not found in current design specifications.

The prototype system presented herein is a new approach blending computer graphics and knowledge-based systems.

The described system is an interactive design system. It allows a user to conceptually define a connection by choice of the governing design parameters. The conversational nature of the program encourages user interaction, which provides an active two-way process as opposed to a one-way passive process as is the case with textbooks. This system should encourage thought on how a more rational design may be arrived at.

Graphics are used in the system to clarify user options and display the final design. The graphics

displays offer a quick summary in the form of a visual image, thus sparing the user of time and frustration spent reading text explanations which could be unclear.

Alternative designs may be compared more readily through examination of graphical displays.

CHAPTER 7

RECOMMENDATIONS FOR FURTHER STUDY

The following recommendations are viewed by the author as areas for possible further work:

1. The integration of the program with a quantitative bridge connection analysis design package. Connection component sizing to accommodate calculated loads based on girder, floor beam and stringer spacing, could be quantitatively calculated by a pre-processor package prior to using the qualitative program described herein.
2. Expansion/revision of explanation facility (what and why) and summary points to facilitate effective usage by users of intermediate or advanced intermediate knowledge levels. This could be accomplished by providing two or more user levels to choose from at the start of the session; one for the beginner and one for the intermediate user.
3. Expansion of program to incorporate other technical considerations such as qualitative design of diaphragm

connections.

4. Expansion of program to facilitate connection design considerations in multi-girder I-shaped steel bridges.
5. Addition of references to and information on relevant connection case studies in the textual why commentary and the summary points.
6. Implementation of program on other computers such as personal computers.

PROTOTYPE SYSTEM DESIGN PARAMETERS

Parameter -----	Options -----
1. Bridge Layout	right or skew
2. Type of Span	simple or continuous
3. Floor Beam Location Along Span	near support or near midspan
4. Moment Region	positive or negative
5. Outriggers Used	yes or no
6. Connection of Laterals to Girders	into web or into flange or none used
7. Level of Floor Beam Top Flange	same as girder or below
8. Level of Stringers	same as girder or below
9. Level of Outrigger Top Flange	same as girder or below
10. Floor Beam to Girder Connection	full-depth connection plate used or not
11. Brackets Used	top, or bottom, or both top and bottom, or none
12. Attachments of Brackets to Floor Beam/Girder	welded to floorbeam or welded to connection plate
13. Connection Plate Attachment at Top	welded, or fitted or cut short
14. Connection Plate Attachment at Bottom	welded, or fitted or cut short
15. Welded Brackets Used	top, or bottom, or top and bottom
16. Floor beam Attachment to Girder	bolted to connection plate or bolted to connection angle
17. Bracket Attachment to Top Flange	welded, or fitted or cut short
18. Bracket Attachment to Bottom Flange	welded, or fitted or cut short

TABLE 1

REPRESENTATIVE "TREE STRUCTURE"

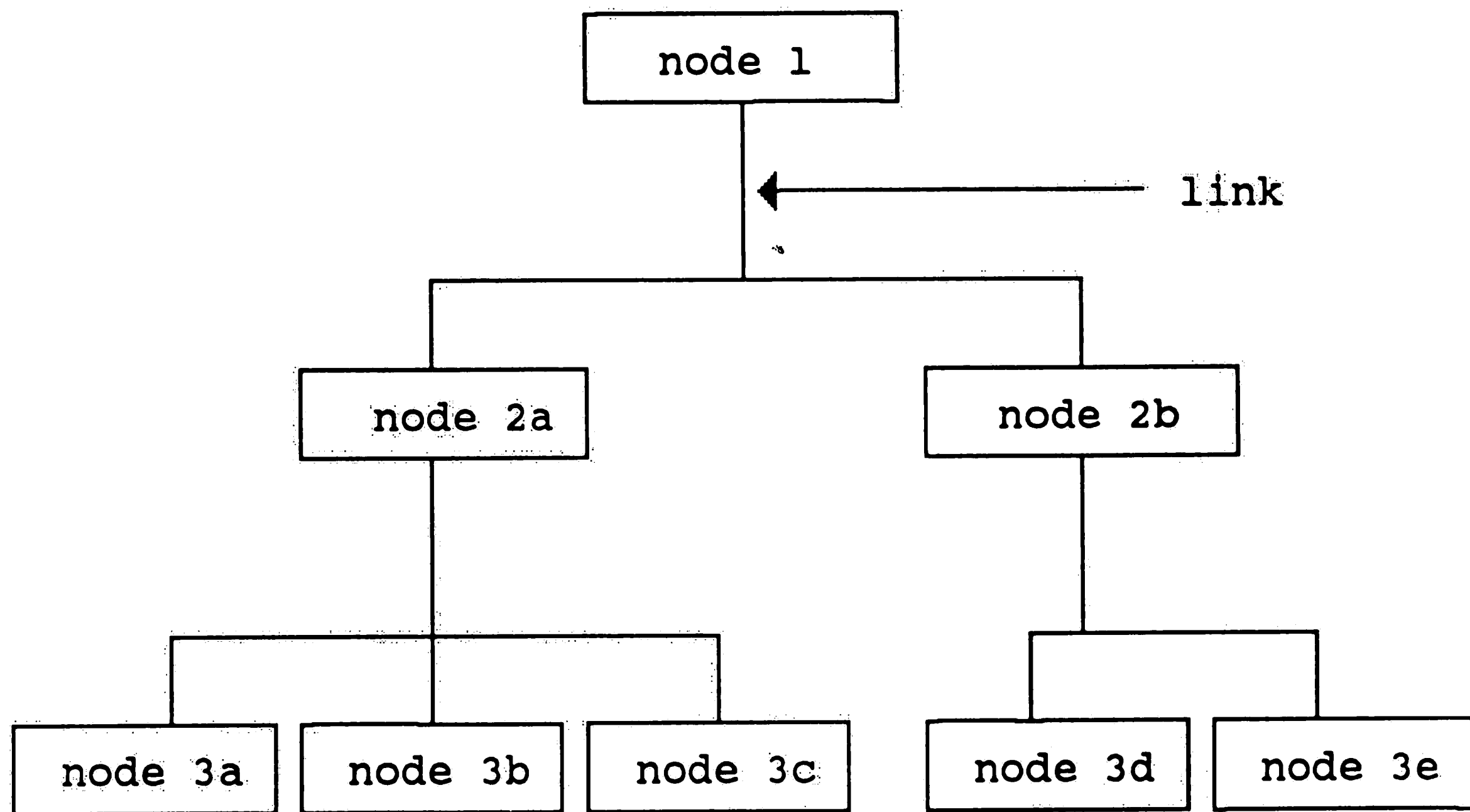


FIGURE 1

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