Windows-Based Computer Analysis of 3-D Sign Bridge Structures

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IBC-02-13

KEYWORDS: Analysis; AASHTO Codes; Steel; Aluminum; computer applications; computer programs; Sign Bridge; structural

ABSTRACT: Design and erection of highway sign supports has been made easier by development of a dedicated computer program, **WIN-SABRE**, a **Sign Bridge Analysis and Evaluation System.** The program contains many special features. With these special features, it is now possible to design and analyze a fairly complicated sign bridge structure in minutes rather than hours, resulting in a significant increase in productivity. The program also serves as an evaluation tool in sign structure Management Systems.

INTRODUCTION

An important feature of the modern highway system is the sign support structure. A sign support structure, as its name implies, supports highway signs. A more practical method of analyzing a sign bridge is with the use of a general purpose structural analysis computer program such as SAP2000, STAADIII, etc. The use of such a program, however, while it should yield acceptable results, also would tend to be time consuming and tedious. Each joint and member of the bridge would have to be entered individually into the program along with its structural properties and loading conditions. The analysis of a typical sign bridge using a general purpose program could take several days to complete. Ideally, a dedicated computer program is preferred. It was with this in mind that SABRE was created.

The Windows version of the SIGN BRIDGE program has been developed recently in the BEST Center at the University of Maryland, under the direction of the author. The program contains many special features to the personal computers. With these special features, it is now possible to design and analyze a fairly complicated sign bridge structure in minutes rather than hours, resulting in a significant increase in productivity.

DESCRIPTION

WIN-SABRE – Sign Bridge Analysis and Evaluation System runs on Windows platform personal computers and includes preprocessor, analysis, and postprocessor modules. The preprocessor includes data entry/editing, mesh generation, and on-screen graphing, among other functions. The analysis module uses the general stiffness method to perform static analysis of space frames and includes automatic load calculation (dead, wind, and ice), stress analysis, and code checking. The analysis is based upon the 2001 AASHTO "Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals," 4th Edition. These specifications standardize the requirements for load application, methods of analysis, allowable stresses and design details for sign supports and, as a result, have made easier the design and erection of sign supports.

The postprocessor includes on-screen graphing, review of analysis results, base plate fatigue check and design of base plates and splice plates. The key new addition is the fatigue check. Three types of loading (galloping, natural wind gust and truck-induced gust) are considered for cantilevered steel and aluminum sign structures based upon the new (2001) AASHTO Specifications.

All of the entry and editing of data is accomplished with the aid of windows input screens. This relieves the user of the responsibility of creating and maintaining the formatted text files required for analysis. Each screen is divided into a number of data cells which can be edited individually. The user can move freely from screen to screen and from cell to cell and can concentrate on the meaning of the data rather than whether it is entered into the proper location. Also, a number of utilities are provided to aid in the review and editing of the data, such as on-screen graphics and output file viewing.

The mesh generation capabilities cover thirty of the most common sign bridge configurations used in most of the states. This frees the user from the task of calculating and typing each structure joint and member into a data file. That data can now be generated automatically. Also, the structure solved by the stiffness method can be code-checked automatically and the status of the code check can be viewed graphically.

SIGN BRIDGE COMPONENTS

A sign bridge is constructed of the following components, which together define the structure.

1. Sign bridge configuration – Five most popular sign configurations are available in the program (see Table 1).
2. Tower types – Two types of towers are allowed, single post towers or double posts (see Table 2).
3. Beam types – Eight basic beam types are allowed (see Table 3). The beam chord can be either prismatic or linearly tapered.
4. Sign Bridge types – The four beam types and two tower types can be combined into six different sign bridge types – (a) Monotube on single Post, (b) Plane Truss on Single Post, (c) Trichord on Single Post, (d) Trichord on Double Posts (as shown in Table 4), (e) Box Truss on Single Post, and (f) Box Truss on Double Posts.
5. Member types – The program includes four different member types as shown in Table 5.
6. Section types – Eight section types are recognized, four tubular shapes (Round, Dodecagonal, Octagonal, Square as shown in Table 6) and four general shapes (Rectangular, Angle, Wide Flange, Z).
7. Sign types – Only one sign type, rectangular sign, is considered.
8. Walkway types – Only one walkway type, rectangular walkways parallel to the bridge beams, is considered.
9. Vertical attachment member (VAM) types.

OVERVIEW OF WIN-SABRE COMPONENTS

The WIN-SABRE program consists of an integrated environment for the analysis and design of sign bridge support structures. Included in the environment are a preprocessor module for data and file management, an analysis module, and a postprocessor module for screen graphics and output review.

The WIN-SABRE program contains several special features developed to make the program as easy as possible to use and to shorten the design/analysis cycle. These features are outlined below.

1. Pull-Down Menu System – A pull-down menu system is provided as a means of navigating through the program.
2. Data Entry and Editing – All data required by WIN-SABRE is entered by the user into input cells, generally via the computer keyboard.
3. Automatic Joint and Member Renumbering – If a joint or member is deleted or inserted, the remaining joints and members are renumbered automatically to maintain their relative positions.
4. Shape Files – A shape file is a user-created text file containing a table of dimensions for a particular structural shape. An example would be a file containing dimensions of the various AISC side flange shapes.
5. On-Screen Help – The program provides extensive on-screen help during operation. This may be in the form of a brief description of the data expected, allowable values, or other pertinent information. Help is available at all times except during analysis.
6. Automatic Mesh Generation – Because the calculation and entry of the structural joints and members can be time consuming, the automatic generation of these data is provided. When used, the mesh generator can create all data required to define the joints and members of a sign bridge.
7. On-Screen Graphics – An image of a sign bridge structure can be viewed (Figure 1). This capability provides a convenient means of checking the data used to define a particular structure.

STRUCTURAL ANALYSIS CAPABILITIES

The WIN-SABRE program can analyze support structures for a wide variety of configurations, boundary conditions, member types, and loading conditions. The analysis capabilities are described further below.

1. Configurations – The five basic support configurations are allowed with the six beam-tower types, for a total of thirty possible types. These thirty sign bridge types comprise the most common structures currently used.
2. Coordinate System – Each joint is defined by X, Y, and Z coordinates. This coordinate system is right-handed, and is termed the structural (or global) coordinate system.
3. Boundary Conditions – Boundary conditions consist of two distinct quantities, reactions, and member releases. These are made

necessary by various construction details such as u-bolts, where no moment can be transmitted from a horizontal member to the vertical tower members.

4. Prismatic or Tapered Members – Structural members can be either prismatic or tapered. To accommodate tapering, members can be grouped into a unit which can be assigned different cross sections at the two ends.
5. Loadings – The program allows for both automatic load generation and for manual load input. The automatic load generation follows the AASHTO code for all dead, ice, wind load and fatigue calculations.
6. Sign Bridge Details – The sign bridge details are composed of components such as signs, vertical attachment members (used to attach the sign to the structure), and walkway units. These can be placed at any location on the structure and the effects of their dead weights, wind loads, and ice loads then are included automatically during analysis.
7. Structural Analysis – The stiffness matrix method with a three-dimensional frame formulation is used in the analysis of the sign support structure. The method yields joint displacements, member end moments, torques, shears, axial forces, and reactions. The results of the analysis, printed in an ASCII text file, form a complete report of the analyzed structure, including input verification, section properties, joint loads, deflections, stresses, etc. The user is then free to review the results graphically, import the reactions for design purposes, and perform other postprocessing operations.
8. Stress Analysis – The stress analysis performed by the program follows the AASHTO Specifications, Reference 1. The stress investigation itself involves the determination of stresses and their interaction (i.e., the Combined Stress Ratio) for all members throughout the structure.
9. Fatigue Check – Cantilevered support structures shall be designed for fatigue to resist each of the equivalent static wind loads due to galloping, vortex shedding, natural wind gusts, and truck gusts (Figure 2).

DESIGN CAPABILITIES

Two special features of sign bridges may be designed within the program, base plates and splice plates. The data required for either a base of splice plate (e.g., yield stresses, forces, moments, etc.) can be entered by hand or imported from a WIN-SABRE output file. The results can be viewed on-screen or be sent to a printer.

Together, the features and options described above provide a comprehensive system for sign bridge analysis.

SIGN STRUCTURE MANAGEMENT SYSTEM

A proto-type of SSMS (Sign Structure Management System) was developed for the Washington, DC Department of Public Work to track the sign structure inventory and schedule maintenance of existing structures and install replaced structures. The system identifies the types and conditions of sign structures. A database correlated with the District's GIS was established (Figure 3). The inventory is capable of cataloging all structures and electrical components, including posts, chords, foundations, sign size and materials. The SABRE program provides the functionality for the overall design analysis and evaluation details of the sign structures.

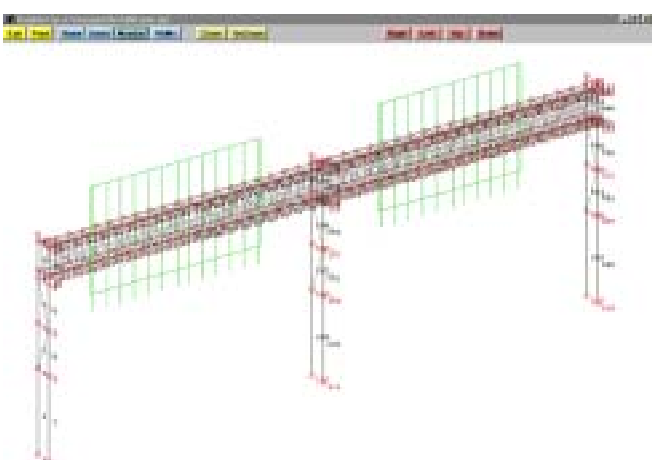


Figure 1 – On-screen Graphics for a Sample Sign Bridge

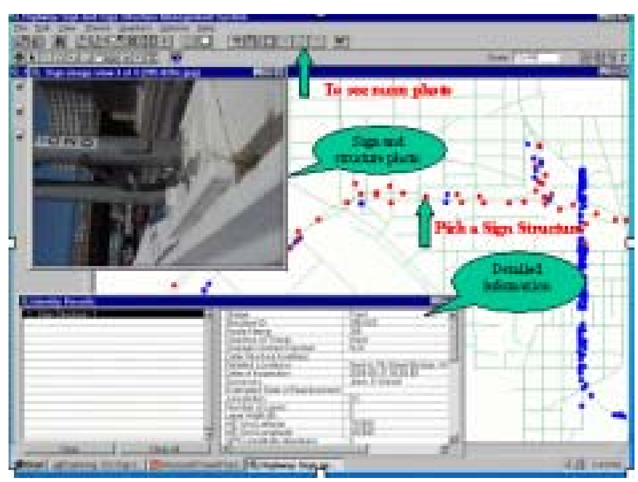


Figure 2 – Sign Structure Management System in GIS

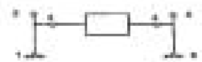
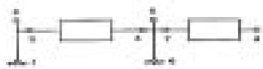
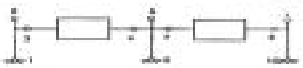
TABLE 1 - SIGN BRIDGE CONFIGURATIONS		
CONFIG. NUMBER	DESCRIPTION	BASIC JOINT AND MEMBER NUMBERING SEQUENCE
1	Cantilever	
2	Single Span	
3	Butterfly	
4	Single Span with Canti-lever	
5	Double Span	

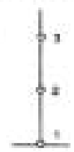
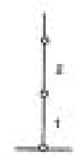
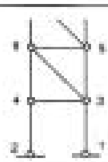
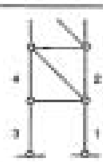
TABLE 2 - SIGN BRIDGE TOWER TYPES			
TYPE ID	DESCRIPTION	BASIC JOINT NUMBERING SEQUENCE	BASIC MAIN MEMBER NUMBERING SEQUENCE
1	Single Post		
2	Double Post		

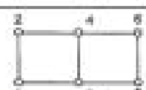
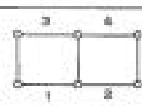
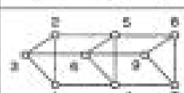
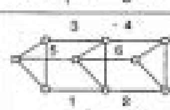
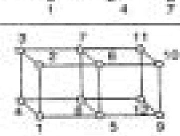
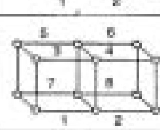
TABLE 3 - SIGN BRIDGE BEAM TYPES			
TYPE ID	DESCRIPTION	BASIC JOINT NUMBERING SEQUENCE	BASIC MAIN MEMBER NUMBERING SEQUENCE
1	Monotube, Cantilever		
2	Plane Truss, Cantilever		
3	Trichord Truss, Cantilever		
4	Box Truss, Cantilever		

TABLE 4 - ACTUAL STRUCTURE TYPE vs. MODEL		
TYPE ID	SIGN BRIDGE TYPE	MODEL
1		

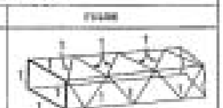
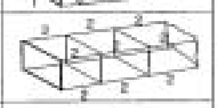
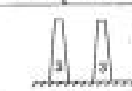
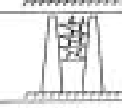
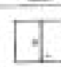
TABLE 5 - MEMBER TYPE AND CATEGORY [illegible]			
MEMBER		STRUCTURAL COMPONENT	
TYPE	CATEGORY	DESCRIPTION	FIGURE
1	Secondary	Interior truss members for plane, trichord and box trusses	
2	Primary	Exterior truss members for plane, trichord and box trusses	
3	Primary	Vertical (tower) members	
4	Secondary	Interior truss members for tower	

TABLE 6 - TUBULAR SHAPES				
SHAPE ID	TYPE	FIGURE	STRESS CONCENTRATION FACTOR	COMMENTS
1		Not Used		
2	Round		Not Required	Note the definition of the outer diameter D.
3	Dodecagonal		Table 1.1.1 [illegible] AASHTO Spec.	Note the definition of the outer diameter D.
4	Octagonal		Table 1.1.1 [illegible] AASHTO Spec.	Note the definition of the outer diameter D.
5	Square		Table 1.1.1 [illegible] AASHTO Spec.	Note the definition of the outer diameter D.