Chapter 8

COMPUTER SOFTWARE

NDOT STRUCTURES MANUAL

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COMPUTER SOFTWARE

8.1   OVERVIEW

8.1.1 Introduction

The Structures Division uses a variety of computer programs for structural analysis and design, which can provide significant benefits. These include the capability of quickly analyzing several alternative designs (i.e., simulation capabilities), of reducing the probability of mathematical errors, and for saving time by avoiding laborious hand calculations. However, the user of any computer program must consider the following:

1.   Judgment and experience are critical to the proper interpretation of the computer outputs.

2.   The user should, after the computer run, recheck inputs for accuracy.

3.   The user should carefully check all outputs to ensure that answers are reasonable and logical and that there are no obvious errors. The check should include an equilibrium check in structural applications, for example, verifying that the sum of the applied loads equals the sum of the reactions. In addition, simple free-body diagrams can also be checked by cutting the structure at a section where a free body can easily be taken.

4.   Hand calculations based on simplifying assumptions may also be used to verify computer results.

5.   The user should be familiar with the applications and limitations of each program.

8.1.2 Chapter Content

Chapter 8 presents the majority of the commercially available computer programs used by the Structures Division. The Chapter provides a brief description of the program's application and function.

8.1.3 Coordination with *Structures Manual*

Throughout Part II of the *NDOT Structures Manual*, the text identifies, where applicable, any computer software that may be used for a specific structural element. For example, Section 17.1.4.3 discusses the use of StrainWedge, LPile Plus and COM624P to analyze the lateral soil-structure interaction in the design of foundations.

8.2   COMMERCIALLY AVAILABLE PROGRAMS

8.2.1 SAP2000

8.2.1.1 Description

SAP2000 is an integrated, general purpose structural analysis program with bridge-specific templates. The program and its element library are capable of simple line-girder, two-dimensional grid or three-dimensional finite-element type analyses. Bridge designers can use SAP2000 bridge templates for generating bridge models, automated bridge live load analysis and design, bridge base isolation, bridge construction sequence analysis, large deformation cable-supported bridge analysis and pushover analysis.

SAP2000 is available from Computers & Structures, Inc.

8.2.1.2 Inputs

The bridge geometry is defined through:

*   quick definition of a variety of bridge cross sections including concrete box girder sections, concrete tee-beam sections and steel composite bridge sections;

*   variable section parameters along the length of the bridge;

*   automatic model updates with changes in parameters; and

*   auto application of loads to the bridge structure.

8.2.1.3 Outputs

SAP2000's bridge-specific output includes:

*   AASHTO LRFD design checks,
*   influence lines and surfaces,
*   forces and stresses along and across the bridge,
*   displacement plots, and
*   animated stress plots.

In general, graphical and tabulated outputs are available.

8.2.2 GT Strudl

GT STRUDL performs general purpose structural analysis and design, plus structural data base processing, for a broad range of structural problems. GT STRUDL integrates graphical modeling, automatic mesh and data generation, finite-element analysis, structural frame design, interactive graphics and structural data base management into a menu-driven information processing system.

GT STRUDL contains a library of member and finite-element types consisting of seven member types (constant or variable cross-section), over 100 conventional, isoperimetric and hybrid formulation finite-element types, and many special transition elements.

8.2.3 **WinSEISAB**

8.2.3.1 **Description**

WinSEISAB was specifically developed to perform the seismic analysis of bridges. The overall objective is to provide the practicing bridge engineer with a usable design tool and mechanism for implementing the latest seismic design methodologies into the bridge engineering profession.

WinSEISAB is available from Imbsen Software Systems.

8.2.3.2 **Input**

Horizontal alignments composed of a combination of tangent and curved segments are described using alignment data taken directly from roadway plans. WinSEISAB has generating capabilities that will, with a minimum amount of input data, automatically provide a model consistent with the model currently being used to conduct dynamic analyses. The central theme underlying the development of WinSEISAB is to provide the bridge designer with an effective means of user-program communication using a problem-oriented language developed specifically for the bridge engineer. User input data is thoroughly checked for syntax and consistency prior to conducting an analysis, and numerous default values are assumed for the data not entered by the user.

8.2.3.3 **Output**

WinSEISAB can be used to analyze simply supported or continuous deck, girder-type bridges with no practical limitation on the number of spans or the number of columns at a pier. In addition, seismic restrainer units may be placed between adjacent structural segments.

8.2.4 **RESPONSE 2000**

Response 2000 is a sectional analysis program that calculates the resistance and ductility of a reinforced-concrete cross section subjected to shear, moment and axial load. All three loads are considered simultaneously to determine the full load-deformation response using the modified compression field theory (MCFT).

Response 2000 can predict the shear resistance for sections that cannot easily be modeled, such as circular columns and tapered web beams.

8.2.5 **WinBDS**

8.2.5.1 **Description**

WinBDS analyzes or designs orthogonal bridge frames and is applicable to the majority of concrete bridges being designed today. However, the design methodology employed is the load factor design (LFD) methodology of the AASHTO *Standard Specifications for Highway Bridges.* Prestressed concrete analysis and design capabilities include:

- continuous prestress,
- simple span prestress,

- segmental prestress,
- 100 prestress cable paths per frame,
- 3D cable friction losses,
- primary and secondary effects,
- cross-section analysis,
- ultimate capacity check,
- AASHTO *Standard Specifications'* shear requirements,
- tendon elongations, and
- calculation of AASHTO *Standard Specifications'* long-term losses.

8.2.5.2 Input

Cross sections may by specified by using a predefined, standard box girder superstructure shape or by adding or subtracting geometric parts using predefined part codes. Live loads can be automatically generated for the AASHTO HS20-44 live-load model and the P13 permit truck. By providing the number of live loads, lanes may be applied to the structure by describing the axle loads, distance between axles and number of live load lanes. Uniform lane loads can be defined with moment and shear riders. Other automatically generated live loads include the Cooper Loading for railroad bridges and a user-defined vehicle of up to 97 axles.

8.2.5.3 Output

Output results are organized in the same order as the input data. All input data is echoed in the output reports. Output reports include section properties, dead load and additional fixed load results, live load force envelopes, prestress results including required P-Jack, mild steel requirements and shear design stirrup requirements. Additional reports are generated for the Rating Subsystem and Prestressed, Precast Girder Subsystem.

A graphical display of moment and shear envelopes is available after an analysis has been performed. Additional plots are available for deflections, top and bottom fiber stresses, prestress force, prestress cable path and influence lines. These plots can be displayed for all spans in the bridge or for an individual span or for any sequential list of spans. Where applicable, the plots include the different trials that are available, such as dead load, added dead load, live load (both negative and positive envelopes), prestress, etc. These loads can be plotted individually or combined into one load case.

8.2.6 BRASS-GIRDER(LRFD)™ and BRASS-GIRDER(LFD)™

8.2.6.1 Description

BRASS-GIRDER(LRFD)™ and BRASS-GIRDER(LFD)™ are comprehensive programs for the analysis of highway bridge girders. BRASS-GIRDER(LRFD)™ uses the finite element theory of analysis and the current AASHTO *LRFD Specifications*. The BRASS-GIRDER(LFD)™ program is primarily used by the Division for structure load rating.

The BRASS family of programs is available from the Wyoming Department of Transportation.

8.2.6.2 <u>Inputs</u>

BRASS-GIRDER(LRFD)™ uses Windows-based Graphical User Interfaces (GUI) for data input. System input is free format consisting of commands grouped logically to define the bridge structure, loads to be applied and the output desired.

Girder types may be simple span, continuous, hinged or cantilevered. Girders may be constructed of steel, reinforced concrete, or prestressed concrete (pre- and post-tensioned). Composite steel and composite prestressed concrete girders may be included. BRASS can analyze variable-depth girders, such as tapered or parabolic. The user may specify (by name) predefined cross sections that are stored in the cross section library. The library contains nearly all AISC rolled wide flange shapes and most AASHTO standard shapes for prestressed concrete I-beams. Using a library utility program, the user may modify the geometry of the existing sections, add new sections or delete existing sections.

Stage construction may be modeled by respective cycles of the system for girder configuration and load application. Cycles are automatic if desired. The dead load of structure members is automatically calculated if desired. Additional distributed loads and point loads may be applied in groups, and each group assigned to a specific construction stage. Distributed loads may be uniform or tapered and divided into sections to model sequential slab pours. Loads due to prestressing are calculated and applied internally. Live loads may be moving trucks or uniform lane loads, which include the HL-93 vehicle described in the AASHTO *LRFD Specifications*. Impact may be user defined, as specified by AASHTO, or the user may reduce impact to model reduced speed limits.

8.2.6.3 <u>Outputs</u>

The program computes moments, shears, axial forces, deflections and rotations caused by dead loads, live loads, settlements and temperature changes. These actions are used by various subroutines to analyze user-specified sections of the girder.

8.2.7 <u>CONSPAN™</u>

8.2.7.1 <u>Description</u>

CONSPAN™ is a comprehensive program for the design and analysis of prestressed, precast concrete beams using either the AASHTO LFD or LRFD design methodologies. The program accommodates simple spans and multiple simple spans made continuous for live loads. CONSPAN™ incorporates both LFD and LRFD AASHTO Specifications into one interface.

Simple-span static analysis is performed for dead loads resisted by the precast sections. Continuous static analysis is performed for dead loads acting upon the composite structure. A continuous moving load analysis is performed for the live load.

CONSPAN™ is available from LEAP Software, Inc.

8.2.7.2 <u>Input</u>

CONSPAN™ simplifies the entry of project data with a system of tab screens, dialog boxes, graphical button, menus and wizards. Designs are completed with either the CONSPAN™ automated features or the user-specified input.

8.2.7.3 Output

CONSPAN™ presents analysis results in a variety of easy-to-view formats, from a one-page design summary to comprehensive project reports. Analysis results and graphical sketches can be exported to spreadsheets and .dxf formats.

For individual beam designs, various design parameters such as distribution factors, impact/dynamic allowance factors, and allowable stresses are established. The strand and debonding/shielding patterns can be automatically generated by CONSPAN™ or specified by the user. Debonding constraints limiting the number of debonded strands can also be user-specified. Service load stress envelopes, generated by combining the results of the analysis, are checked against allowable limits. Factored positive moments and shears are checked against the ultimate strength capacity of the effective section. Mild reinforcement in the deck, at the piers, is computed for factored negative and positive moments. Many other code criteria (e.g., cracking moments, horizontal shear, stresses at limit states) are also automatically checked.

8.2.8 CONBOX™

8.2.8.1 Description

CONBOX™ is specifically developed for the analysis and design of post-tensioned and cast-in-place reinforced concrete box girder and slab bridges constructed on falsework. By incorporating both AASHTO Standard and LRFD Specifications in one interface, CONBOX™ makes the transition to LRFD simple and efficient. The program accommodates span hinges and a variety of column shapes and fixity conditions.

CONBOX™ is available from LEAP Software, Inc.

8.2.8.2 Input

CONBOX™ requires that users specify bridge layout information such as alignment, span lengths and cross-sections; pier, hinge and abutment locations; and superstructure-to-substructure connectivity. CONBOX™ can import BDS input files to simplify workflow.

8.2.8.3 Output

CONBOX™ computes ultimate moment calculations based on AASHTO equations or strain compatibility. The capacity/demand ratio and factor of safety are reported at each checkpoint for stresses, ultimate moment and shear length. Top and bottom flange stresses are checked, and the required shear and moment reinforcement capacity is calculated. CONBOX™ also calculates the approximate level of post-tensioning force required to satisfy stress and the minimum compressive strength necessary to satisfy AASHTO compressive stress checks. Detailed shear and moment calculations are also automatically computed.

8.2.9   MDX™

8.2.9.1   Description

MDX™ (Curved & Straight Steel Bridge Design & Rating) designs and rates steel I-shaped or box girder bridges for compliance with AASHTO Specifications — the 17th Edition of the AASHTO *Standard Specifications* for Allowable Stress Design (ASD) and Load Factor Design (LFD), and the 4th Edition of the *LRFD Bridge Design Specifications*. Analysis methods include line-girder and system analysis using grid or plate-and-eccentric-beam, finite-element models for up to 20 spans and 60 girders.

MDX™ is available from MDX Software, Inc.

8.2.9.2   Input

Input features include:

- geometry generation feature for laying out parallel/concentric girder systems, including those with variable horizontal curvature and skewed supports;

- nodal coordinate input feature for accommodating complex girder system framing plans and roadway layouts;

- standard trucks and user-defined trucks (including rail loading); and

- lane loading on influence surfaces or wheel load distribution on influence lines.

8.2.9.3   Output

Output features include:

- camber data and live load deflections,
- incremental stress and deflection tables from slab pour sequence analysis,
- performance ratio output, and
- girder rating according to ASD, LFD or LRFD.

8.2.10   BRIDGE DESIGNER II

BRIDGE DESIGNER II (BD2) analyzes and designs concrete segmental bridges. BD2 uses basic matrix structural analysis formulation, combined with time-dependent material properties, to provide a time simulation of a structure under construction. During this process, all stress conditions are checked at every construction step and in service. The composite section capability is directly applicable to precast/prestressed concrete bridges using continuous spliced girders or bulb-tees. Because of the age difference in slabs and girders due to the chosen construction sequence, these structures often exhibit specific behavior due to stress redistributions in composite state (i.e., differential creep and shrinkage).

BD2 is an appropriate tool to evaluate the time-dependent behavior of concrete structures because it builds upon a time-dependent stiffness solution and provides a flexible environment for construction simulation. In addition, it provides a solution for creep and shrinkage in composite structures built in stages, incorporating the concept of self-equilibrating stresses

while assuming that the composite sections remain in a plane due to full shear transfer at the connection girder-slab. BD2 also provides accurate stress combinations in the composite sections under live loads (HL-93) and non-linear thermal gradients applied to the composite sections.

8.2.11   WinRECOL

8.2.11.1   Description

WinRECOL analyzes, designs or checks a reinforced concrete column. The program has the option to choose one of the following design specifications:

- CLFD = Caltrans Bridge Design Specification LFD, September 2004, with Revisions

- ALFD = AASHTO Bridge Design Specification LFD, Sixteenth Edition, 1996, 1998 Interims and Division I-A Seismic Design Article

- CLRFD = AASHTO LRFD Bridge Design Specification, Third Edition, 2004, 2006 Interims with Caltrans Amendments, (Blue Sheets v0.06)

- ALRFD = AASHTO LRFD Bridge Design Specification, Third Edition, 2004, 2006 Interims

WinRECOL is based upon the theory of ultimate strength and uses standard or arbitrarily described cross sections with predefined or arbitrary rebar patterns to perform three different solution types.

8.2.11.2   Input

Column shapes may be specified by using predefined, standard geometric shapes commonly used for bridges or by specifying coordinates for an arbitrarily shaped symmetrical cross section. Voids may also be included when coordinates are used to describe the cross section.

Rebar patterns are specified by using predefined rebar configurations commonly used for reinforced concrete columns or by specifying the coordinates for each bar. Coordinates for the rebar pattern are generated automatically from a minimum amount of input data.

8.2.11.3   Output

Solution types in the program include: 1) "Analyze," 2) "Design," and 3) "Check." "Analyze" is used to compute the coordinates of an interaction surface in the first quadrant for planes in 15° increments. "Design" is used to determine the amount of reinforcing steel area required for the selected Design Specification (AASHTO LFD/LRFD or Caltrans LFD/LRFD). "Check" is used to check the adequacy of the designed column for the Design Specification selected and to perform a plastic hinging analysis.

Output in the check mode includes column spiral reinforcement required for column confinement, minimum reinforcement and shear due to plastic hinging.

A graphical display of the column cross section, plus moment interaction diagrams at 15° intervals, can be displayed after an analysis or check has been performed.

8.2.12 StrainWedge

StrainWedge characterizes the behavior of single piles, pile groups and pile caps embedded in uniform or layered soils when subjected to lateral loads. The program is based upon the concepts of the strain wedge model. The characterization of lateral load behavior associated with single piles and pile groups embedded in uniform or layered soils can be accomplished using the strain wedge model. The strain wedge model for laterally loaded pile behavior is a predictive method that relates the stress-strain behavior of soil in the developing three-dimensional passive wedge in front of the pile (denoted as the strain wedge) under lateral load to the one-dimensional, beam-on-elastic foundation parameters commonly employed in "p-y" curve analyses. The strain wedge model has been developed to analyze individual piles, or a square or rectangular pile group with its associated pile cap, under lateral loading. The strain wedge model can account for both free- and fixed-head conditions and uniform or layered soil conditions. The strain wedge model also has the ability to predict the working pile head load of a single pile and/or that of each pile in a group, the working load associated with a pile cap, the pile head deflection, the maximum bending moment for a single pile or each pile in a group, and p-y curves for a single pile.

Based on the strain wedge model, the computer program DFSAP provides a direct assessment of the three-dimensional/rotational spring stiffnesses of an isolated short, intermediate or long pile/shaft or similar stiffness of a pile/shaft group with our without a cap. Accordingly, the bridge engineer will be able to assess the various springs of the foundation stiffness matrix with disregard for the complexity of the soil profile, the type and arrangement of piles/shafts and nonlinear material behavior. Soil liquefaction and the associated induced pore water pressures are considered in the assessed foundation stiffness. Lateral spreading of the soil is an important phenomenon and is also handled by the DFSAP program.

8.2.13 LPILE Plus

8.2.13.1 Description

LPILE Plus is a special purpose program based on rational procedures for analyzing a pile under lateral loading. Soil behavior is modeled with p-y curves internally generated by the computer program following published recommendations for various types of soils; alternatively, the user can manually introduce other p-y curves. Special procedures are programmed for developing p-y curves for layered soils and for rocks.

A single, user-friendly interface written for the Microsoft Windows© environment is provided for the preparation of input and analytical run and for the graphical observation of data contained in the output file. The program has been written in 32-bit programming codes for compatibility with the latest versions of the Microsoft Windows operating system. The program produces plain-text input and output files that may be observed and/or edited for their inclusion in project reports.

8.2.13.2 Inputs

Several types of pile-head boundary conditions may be selected, and the properties of the pile can also vary as a function of depth.

8.2.13.3 Outputs

The program computes deflection, shear, bending moment and soil response with respect to depth in nonlinear soils. Components of the stiffness matrix at the pile head may be computed internally by the program to assist users in superstructure analysis. Several pile lengths may be automatically checked by the program to help the user produce a design with an optimum pile penetration. LPILE Plus has capabilities to compute the ultimate-moment capacity of a pile section and can provide design information for rebar arrangement. The user may optionally ask the program to generate and consider nonlinear values of flexural stiffness (EI) that are generated internally based on specified pile dimensions, material properties and cracked/uncracked concrete behavior.

8.2.14 COM624P

8.2.14.1 Description

Laterally Loaded Pile Analysis, Version 2.0. COM624P uses the p-y curve method to analyze pile foundations subjected to lateral loads. The program determines the pile deflection, rotation, bending moment and shearing forces using an iterative process that considers the nonlinear response of the foundation soils. This program uses the MS DOS operating system.

8.2.14.2 Input

The program's menu-driven input includes the characterization of the piles and soil, and the applied loads.

8.2.14.3 Output

COM624P determines stresses and distortions of piles or drilled shafts under lateral loads and reports them in graphic output.

8.2.15 BRASS-CULVERT

BRASS-CULVERT analyzes and designs reinforced concrete box culverts. The program has an easy-to-use windows GUI input and produces GUI plot results and a text output file. The program is part of the BRASS family of programs available from the Wyoming Department of Transportation.

8.2.16 Retain Pro

8.2.16.1 Description

Retain Pro designs and checks cantilevered or restrained retaining walls in accordance with AASHTO, ACI, IBC and other standards.

8.2.16.2 <u>Input</u>

Retain Pro takes the designer through a series of design tabs where design criteria, loads, and wall and footing dimensions are entered. There is a visual input screen where previous inputs can be seen or edited.

8.2.16.3 <u>Output</u>

Retain Pro calculates the wall stability ratios, soil pressures, wall and footing dimensions, and required reinforcing steel. The program also features graphics showing the final wall configuration, wall loading, and shear and moment diagrams.