INSTRUCTION MANUAL FOR LOAD RATING THE I.B. PERRINE BRIDGE

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1 SCOPE

This instruction manual describes how to perform three tasks: (1) running a basic load rating analysis for a predefined load; (2) entering a new moving load pattern; and (3) modifying LRFR parameters used to estimate rating factors for varying bridge conditions and vehicle permits. The finite element model of the I.B. Perrine Bridge was created using LARSA 2000 Plus v6.08.65 and has been updated to LARSA 2000/4D v7 . Rating factors are calculated in accordance with the Draft Manual for Condition Evaluation and Load and Resistance Factor Rating of Highway Bridges (LRFR Manual, AASHTO, 2003). By default, LRFR rating factors are calculated for the Strength II limit state corresponding to permit vehicle loads.

2 Procedure for Basic LRFR Analysis

This section of the instruction manual describes how to perform a basic load rating analysis. Performing a basic load rating analysis involves: (1) performing a moving load analysis using LARSA 2000 Plus; (2) running the Excel LRFR load rating spreadsheet; and (3) interpreting the results of the LRFR load rating analysis. This is a basic LRFR analysis for predefined load patterns and LRFR rating.

The basic LRFR analysis considers a single-trip permit vehicle traveling in mixed traffic at posted speed limits. All structural components are assumed to be inspected and to satisfy good condition status. If the vehicle load pattern for a permit vehicle is not already included in the moving load database, it will need to be entered. Entering vehicle load patterns is described in Section 3. If the vehicle permit is not for a single trip traveling in mixed traffic; if the vehicle travels less than ten miles an hour; or if structural components are in a condition other than satisfactory, the LRFR rating parameters must be modified. Adjusting LRFR rating parameters is described in Section 4.

2.1 Performing a Moving Analysis

LARSA's moving load analysis estimates live load demands for all structural members. The results from the moving load analysis are used by the Excel spreadsheet to calculate LRFR rating factors for all bridge members. The I.B. Perrine Bridge Model was created in LARSA 2000 Plus, version 06.08.65, and has been updated to LARSA 2000/4D v7. Sections 2.1.1 and 2.1.2, describe how to run a moving load analysis and provide an example of a moving load analysis, respectively.

2.1.1 Instructions: Moving Load Analysis

1. Open LARSA 2000 Plus.
2. Open "PERRINE BRIDGE MASTER COPY" file.
    a. File → Open → Local Disk (D:) → Perrine Bridge Project folder → "PERRINE BRIDGE MASTER COPY"
3. Under the Explorer Menu, located on the right side of the screen, select the **Load Explorer**.

4. In the Load Explorer, under Load Cases (not Load Combinations), double-click **vehicle lane load** and in the screen that appears, select the **Moving Loads** Tab.

Figure 2- 1 shows the options for running a moving load analysis.

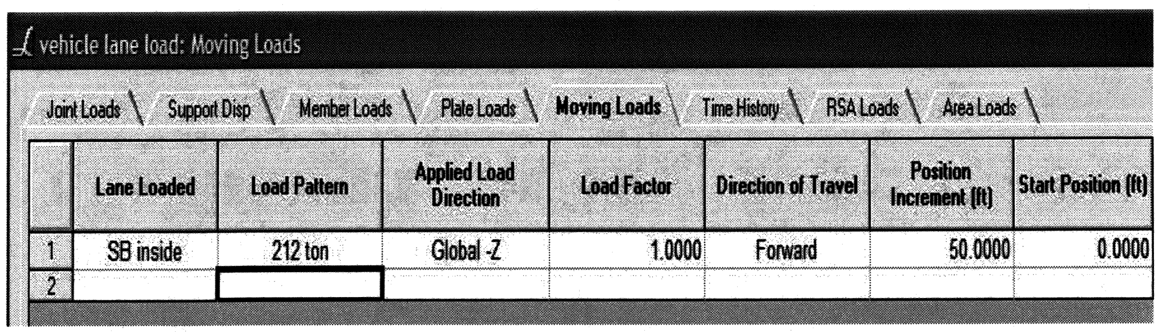

Figure 2- 1: Options to Run a Moving Load Analysis

5. Under **Lane Loaded** column, select the lane that the vehicle will travel on the bridge. The permit should specify that the vehicle shall travel in the lane for which the moving load analysis is performed, or the rating should be performed for both lanes in the desired travel direction.

   a. There are five lanes for northbound (NB) travel and five lanes for south bound (SB) travel (see Figure 2- 2).

   b. Lanes labeled "outside" and "inside" correspond to the striped lanes on either side of the bridge deck. Permit vehicles will travel in striped lanes unless otherwise required due to inadequate LRFR rating factor results in the striped lanes. ***For an initial analysis, choose a striped lane in the appropriate direction of travel, either north or southbound.***

   c. The lane labeled "middle" straddles the two striped lanes and can be used for extremely wide loads that will not fit in the striped lanes. Also, if an LRFR analysis is completed for travel in a striped lane and the LRFR factors are slightly less than adequate, the "middle" lane can be loaded to see if rating factors are adequate when the load proceeds along this travel path.

d. dNB and dSB correspond to design lanes on either side of the bridge. These lanes are used to create worst-case loading scenarios for model verification and will **NOT** be used for permit load rating. Design lanes follow typical AASHTO design requirements.

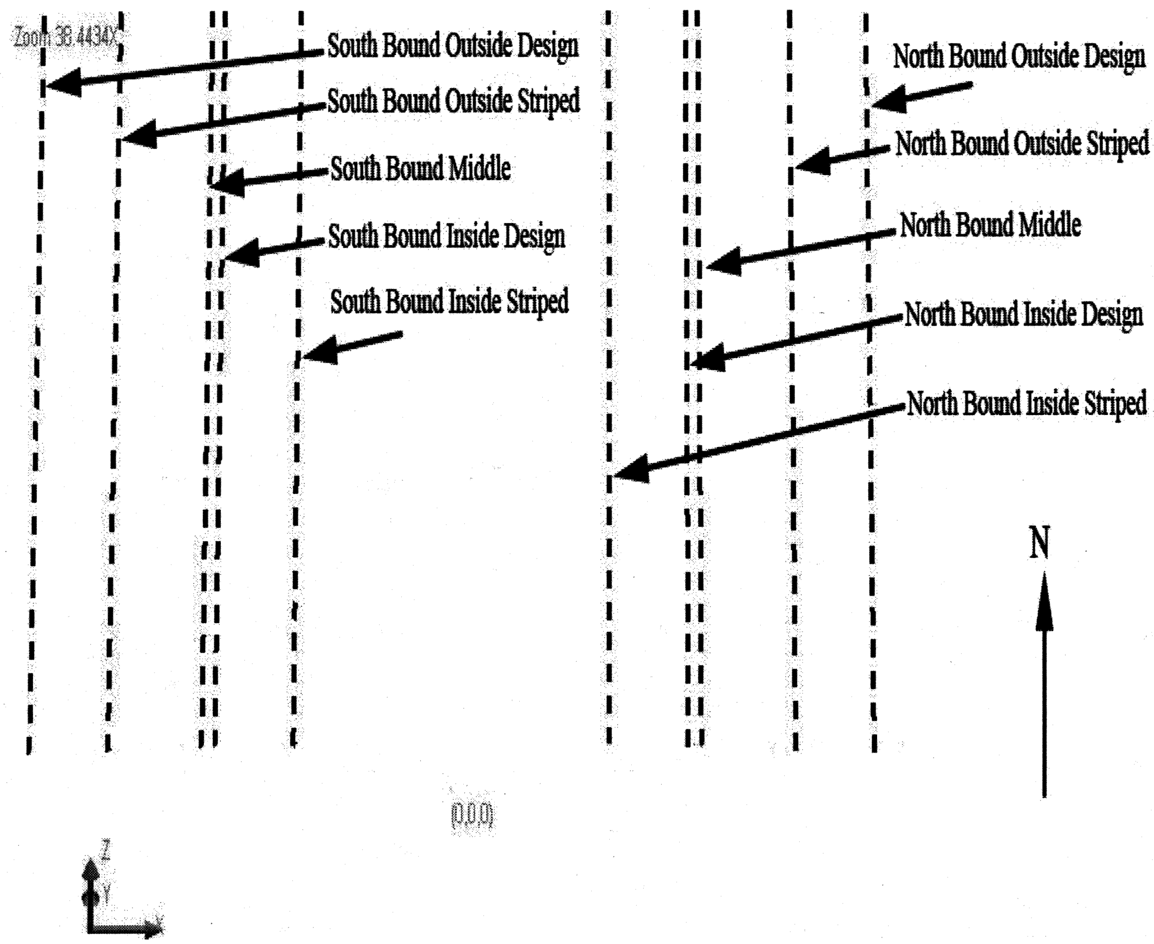

Figure 2- 2: Moving Load Paths

6. Under the **Load Pattern** column, select the vehicle load pattern that corresponds to the rating vehicle. If a vehicle load pattern needs to be added, see Section 3.
7. Under the **Position Increment** column, select the interval at which moving loads will be generated.

a. The default increment is set at 10.00 feet, which is appropriate for most analyses.

8. In the **Analysis** Drop-Down Menu, located at the top of the screen, select **Moving Load Analysis**.

    a. Click the **Analyze** button. This performs the moving load analysis.

    b. A prompt will appear that asks the user to save before running an analysis; select **Yes**. If No is selected the analysis will not run.

The user need only select the three options mentioned above to run a moving load analysis: loaded lane, load pattern, and position increment. All other options should remain unchanged from one moving analysis to another. The options that remain unchanged are the applied load direction (Global –Z), load factor (1.00), direction of travel (Forward), and start position (0.00)

2.1.2 Example: 212-Ton Vehicle Moving Load Analysis

The following example will demonstrate how a moving load analysis is performed for a 212-ton vehicle configuration that will be traveling southbound across the Perrine Bridge. The 212-ton vehicle configuration has already been created and is included in the load pattern database. This is the first moving load analysis for this vehicle configuration.

Once the "PERRINE BRIDGE MASTER COPY" file is open, select the **Load Explorer**. Figure 2- 3 shows where the Load Explorer is located.

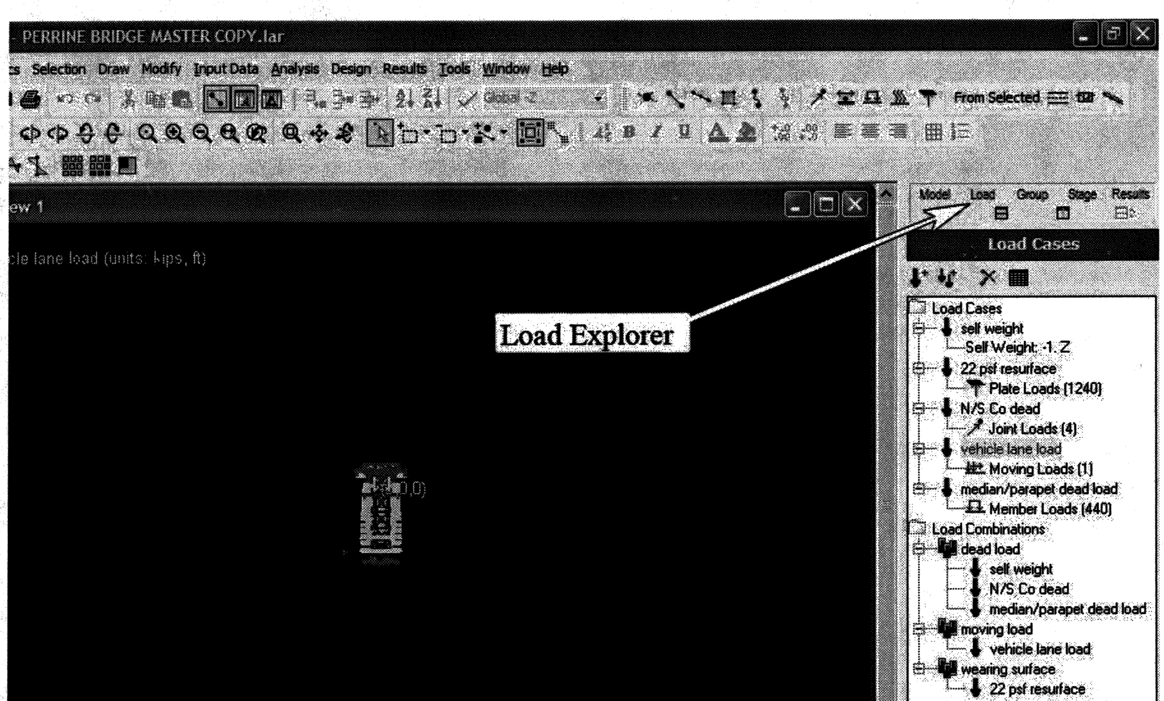

Figure 2- 3: Load Explorer

Next, double-click **vehicle lane load** and in the screen that appears, select the **Moving Loads** Tab. Figure 2- 4 shows the vehicle lane load icon, as well as the moving loads tab.

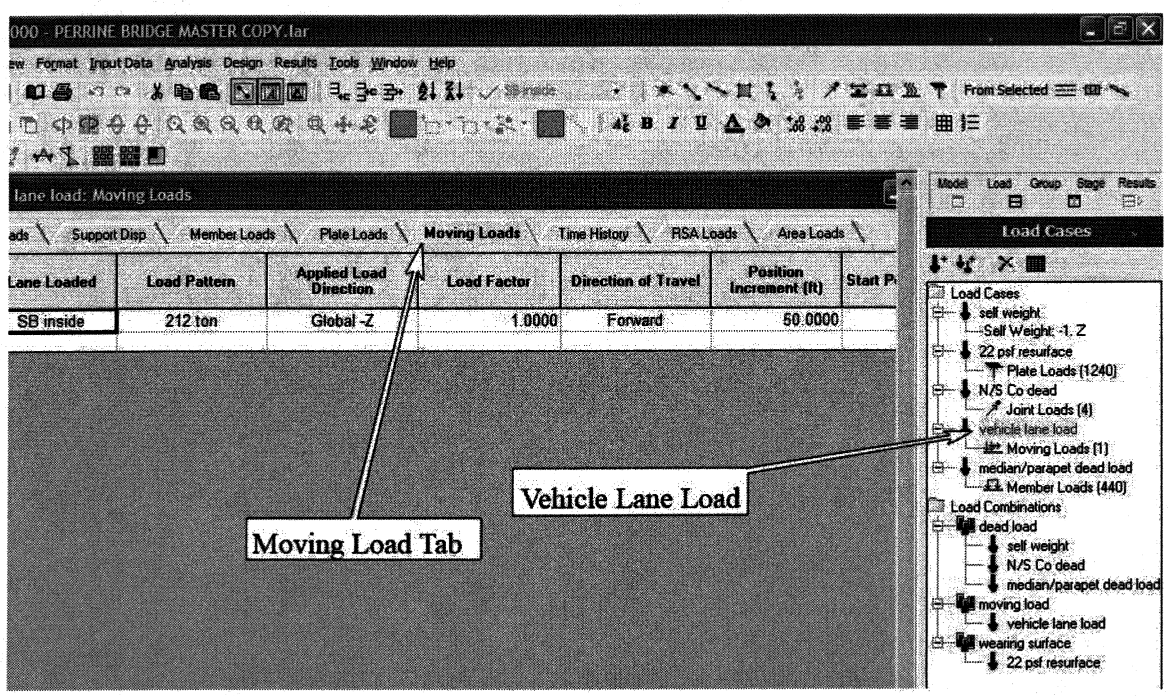

Figure 2- 4: Moving Loads Tab

Once the moving load screen appears, select a lane for the moving load analysis. Since the vehicle is traveling southbound and this is the first LRFR rating analysis, either the SB inside or SB outside lanes would be acceptable lane choices. The SB inside lane is chosen from the list of lanes available in the **Loaded Lane** pull-down menu. A striped lane should be selected for the initial moving load analysis and subsequent LRFR rating analysis because the vehicle will likely be traveling in a striped lane when it crosses the bridge. Further LRFR rating analyses can determine if the vehicle will be required to travel along another travel path.

Next, the load pattern for the moving load analysis must be selected. The **Load Pattern** menu is located adjacent to the **Lane Loaded** column. Figure 2- 5 illustrates superimposed pull-down menu screens for both the **Lane Loaded** and **Load Pattern** options.

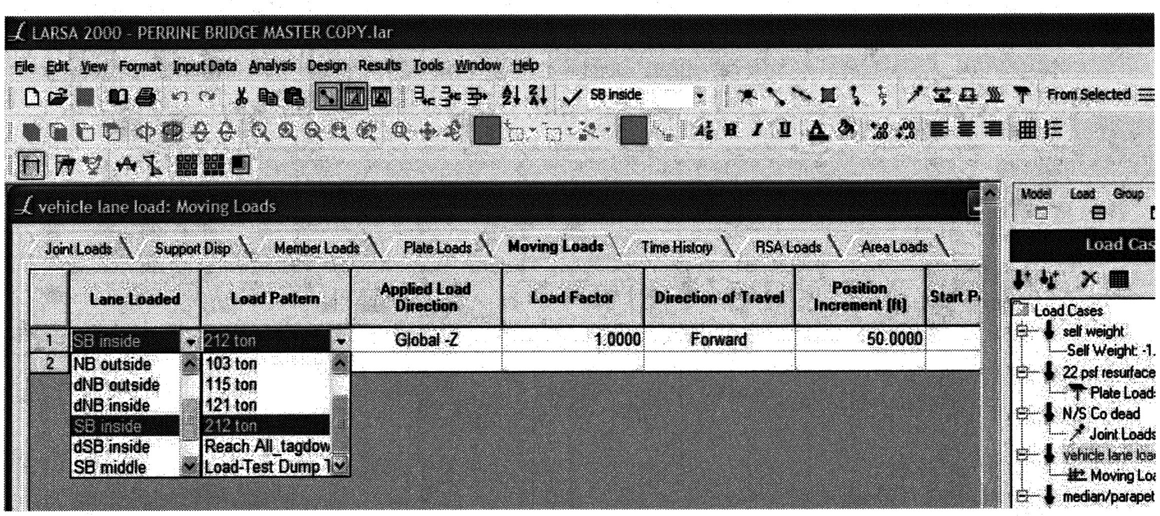

Figure 2- 5: Select Loaded Lane and Load Pattern

The 212-ton load pattern is selected from the available load patterns that are defined in a load pattern database. In this same screen, under the **Position Increment** column, enter the interval at which load cases will be generated for the moving load analysis. The default setting is ten feet.

Finally, in the Analysis Menu, located at the top of the screen, select **Moving Load Analysis**. This is illustrated in Figure 2- 6.

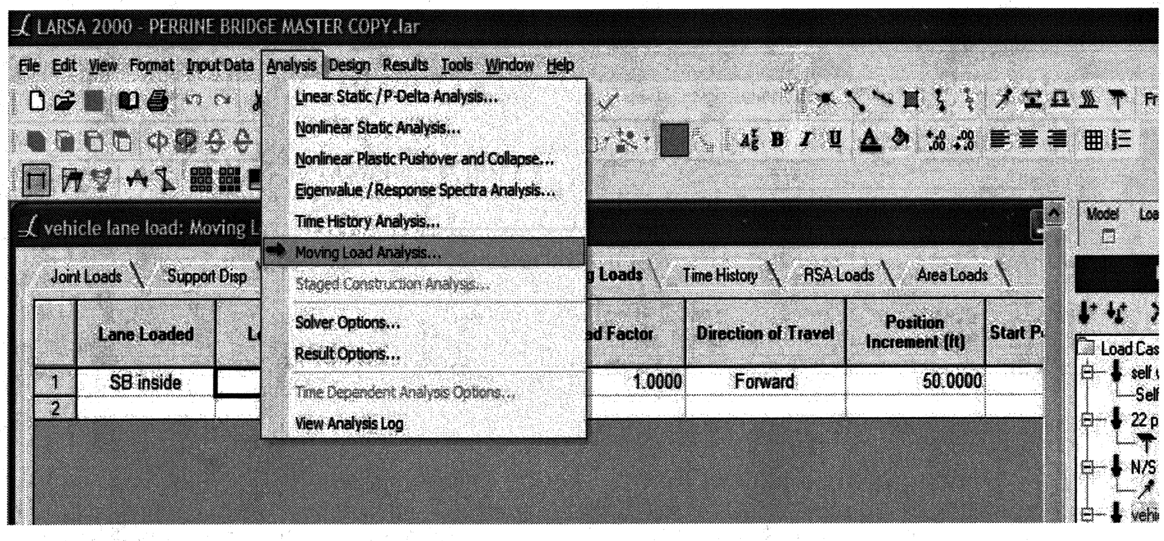

Figure 2- 6: Select Moving Load Analysis

Once the moving load analysis screen appears, select the **Analyze** button. This performs the moving load analysis. A prompt will ask the user to save the project before running an analysis; click **Yes**. If No is selected the analysis will not run. See Figure 2- 7.

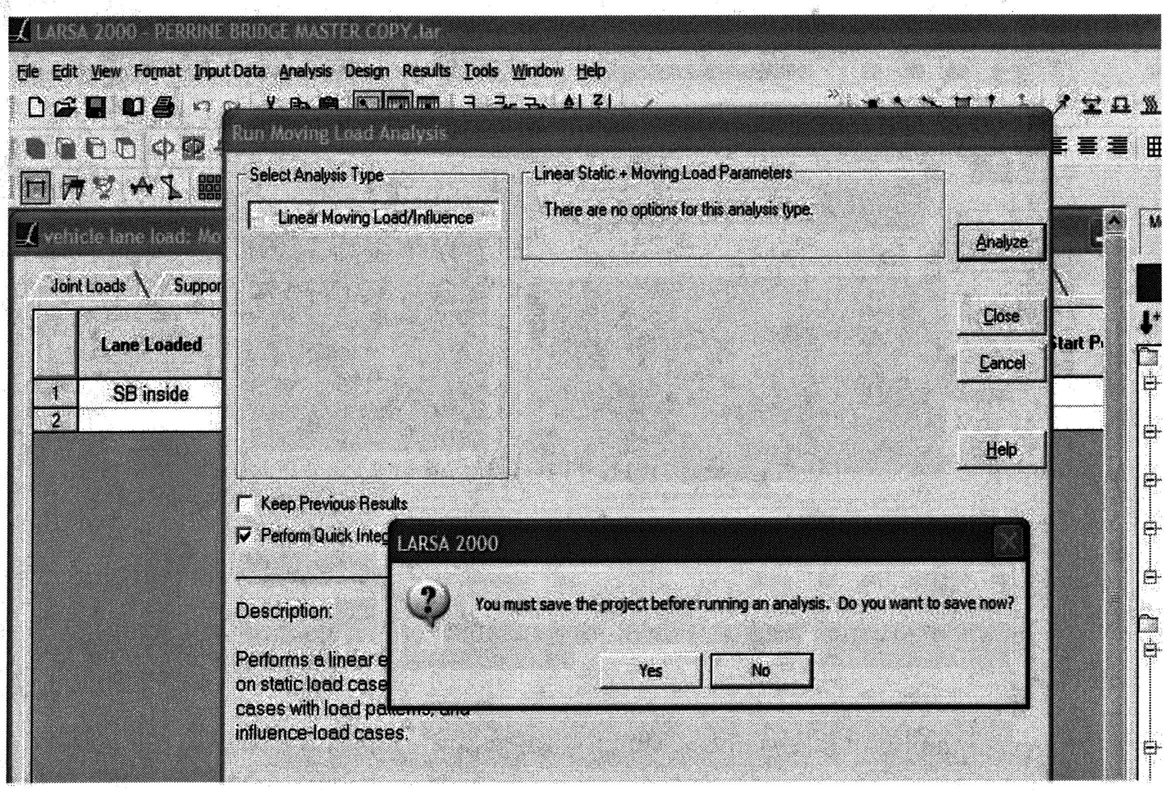

Figure 2- 7: Run Moving Load Analysis

Preparing and running the moving load analysis is completed. The 212-ton vehicle pattern will run forward along the inside, striped, southbound lane. Starting at the beginning of the lane (0.00 ft), load cases are generated every ten feet (or at every position increment if the default is changed) until the last axle of the vehicle configuration travels off the bridge model.

2.2 Performing an LRFR Analysis

The enveloped results from the LARSA moving load analysis are transferred to an Excel spreadsheet which calculates LRFR rating factors for structural members on the bridge. Dead, wearing surface, and live load effects are required to calculate LRFR rating factors; however, the dead and wearing surface load effects are already included in the Excel LRFR rating spreadsheet. The moving load analysis envelopes all applicable live load reaction data; imports the reaction data from LARSA into Excel; combines the live load envelope with the dead load effects and calculates LRFR rating factors for all bridge members. The instructions for performing an LRFR analysis in Excel are described in Section 2.2.1. Section 2.2.2 provides an example for performing an LRFR analysis.

2.2.1 Instructions: LRFR Analysis

Once a moving load analysis has been performed, an LRFR analysis should be performed to complete the load rating procedure. **LARSA 2000 Plus MUST remain open after a moving load analysis is performed and during the Excel LRFR load rating analysis.** If LARSA is closed, the Excel load rating spreadsheet will fail to operate.

1. Keep LARSA 2000 Plus open from the preceding moving load analysis.
2. Open Microsoft Excel.
3. Open "LOAD RATE_v1MASTER" file.
    a. File → Open → Local Disk (D:) → Perrine Bridge Project folder → "LOAD RATE_v706MASTER"
    b. Enable Macros
4. Save the file under an appropriate name describing the truck being rated and the lane loaded, etc.

   a. File → Save As → [descriptive file name]

5. Find the "Control Panel" worksheet at the bottom of the screen; this worksheet is the leftmost worksheet.

6. Click the **Populate Results** button in the upper right corner of the worksheet.

The **Populate Results** button clears previous live load results from the Excel worksheets; imports the moving analysis results from LARSA; calculates load rating factors; and sorts load rating factors into the "Rating Summary" and "Critical Member Summary" worksheets. The **Populate Results** button imports the moving load analysis results from the active file open in LARSA. It is important that the appropriate moving load analysis have been performed just before the LRFR analysis to avoid errors when analyzing moving load results. An LRFR rating analysis takes approximately two hours. Run-time estimates are based on analyses performed on a computer with an Intel Pentium 4 running at 3.00 GHz with 1.00 GB of RAM.

2.2.2 Example: LRFR Analysis for the 212-Ton Vehicle

The following example will demonstrate an LRFR analysis for a 212-ton vehicle traveling southbound across the Perrine Bridge. This example assumes that the corresponding 212-ton vehicle moving load analysis has already been performed (see Example 2.1.2) and that LARSA is open.

Start Excel and open the "LOAD RATE_v706MASTER" file. Find the worksheet titled "Control Panel" located at the bottom of the screen. This worksheet is the leftmost worksheet. Click the **Populate Results** button. This is illustrated in Figure 2- 8.

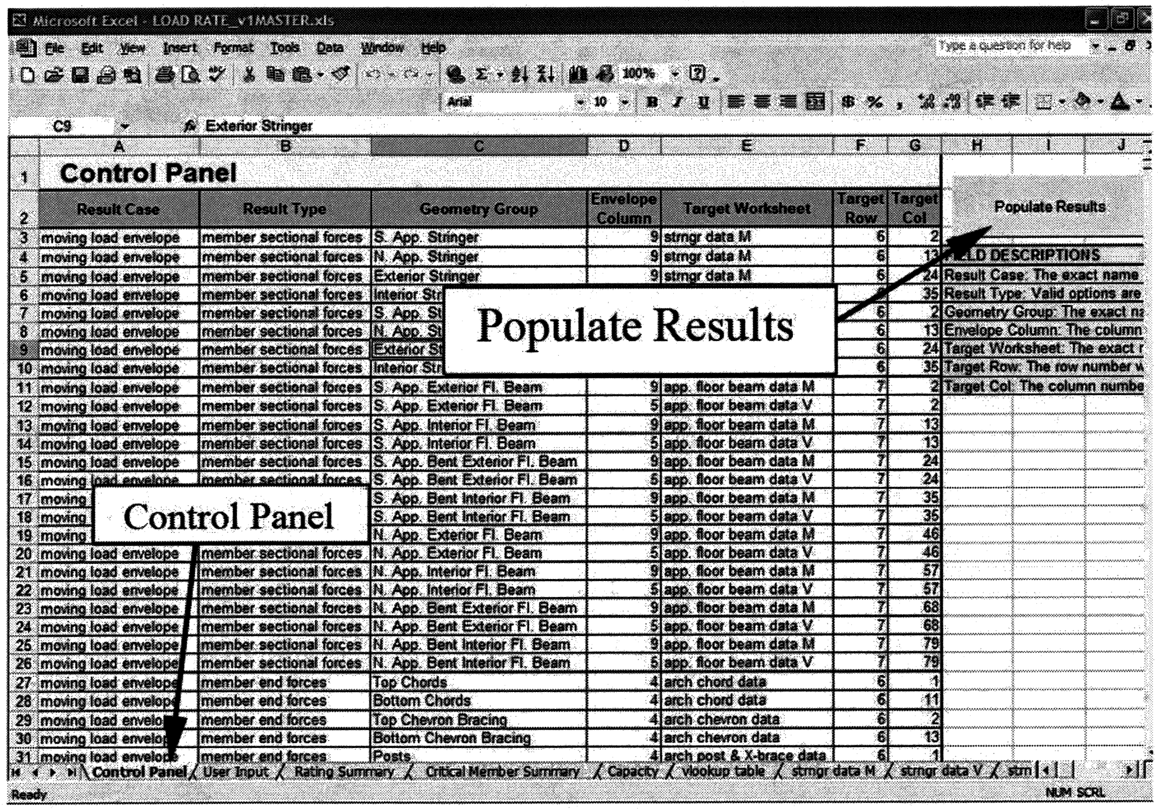

Figure 2- 8: Excel Control Panel Worksheet

The **Populate Results** button performs the load rating procedure on the active file currently open in LARSA, in this case, the 212-ton vehicle.

2.3 LRFR Analysis Results

LRFR rating factors are summarized in the "Critical Member Summary" worksheet. This worksheet is located three worksheets to the right of the "Control Panel" worksheet. The organization of structural members and "Critical Member Summary" worksheet is presented in Sections 2.3.1and 2.3.2, respectively. Finally, a description of the LRFR rating factor is included in Section 2.3.3.

2.3.1 Structure Groups

Related structural components of the bridge are organized in Structure Groups in LARSA. For example, stringers of the south approach, north approach, and main arch spans are in three separate structure groups. Similarly, each diaphragm of the bridge deck is in a separate structure group. Structure groups are labeled according to the structure type they represent (e.g. south approach stringer, arch span floor beam, or spandrel column). Structure groups allow for efficient selection of a group of similar structural components when retrieving analysis results. There are a total of fifty-one structure groups used to retrieve moving load analysis results. LRFR rating factors are summarized according the structure group organization. The member identification numbers for all members within a structure group are listed in the Excel worksheets that both store reaction data and a load rating factor for a specific structure group.

2.3.2 Critical Member Summary Worksheet

The "Critical Member Summary" worksheet contains five pages listing the lowest five rating factors and their corresponding member identification numbers for all applicable reactions of every structure group. Examples of an applicable reaction would be bending moments and shear forces for bending members and axial compression and tensile forces for two-force members, such as diaphragm or arch truss members. The member or span identification number (see Section 5.1.1) corresponds to a unique member or span within the LARSA model. The following list outlines the structure groups contained in the summary worksheet and which rating factors are calculated for each structure group.

Page 1: Stringers & Approach Floor Beams

- Shear
- Positive Moment
- Negative Moment*

Page 2: Arch Truss Members

Top/Bottom Chords, Top/Bottom Chevron Bracing, Cross-Bracing

- Axial Compression
- Axial Tension

Posts

- Axial Compression

Diagonals

- Axial Tension

Top/Bottom Struts

- Shear
- Strong Axis Bending Moment

- Weak Axis Bending Moment
- Axial Compression
- Axial Tension

Page 3: Spandrel Columns & Deck Bracing Members

Spandrel Columns

- Axial Compression

Deck Bracing Members

- Axial Compression
- Axial Tension

Page 4: Bent Columns, Bent Column Bracing, & Prismatic Plate Girders

Bent Columns

- Axial Compression

Bent Column Bracing

- Axial Compression
- Axial Tension

Prismatic Plate Girders

- Shear
- Positive Moment
- Negative Moment*

Page 5: Arch Floor Beams & Haunch Plate Girders

- Shear
- Positive Moment
- Negative Moment*

*Column headings for negative moment values are labeled "M(-):" the values in those columns are the absolute values as provide by LARSA.

2.3.3 Summarizing LRFR Rating Factor Results

The LRFR rating factor represents the ratio of the member's live load capacity divided by the maximum live load demand from the rating vehicle. Rating factors greater than one are satisfactory since the live load capacity is greater than the demand. Rating factors between zero and one indicate that the live load capacity is less than required for the rating vehicle. For the uncalibrated bridge model, there are some rating factors that are negative. Negative rating factors would indicate that the self-weight and wearing surface load effects exceed a member's capacity. Design capacities are calculated according to the AASHTO LRFD Bridge Design Specifications (2005 Interim Revision). Negative numbers are displayed with parenthesis in the "Critical Member Summary" worksheet. Members with negative rating factors are misleading because the bridge can obviously support self-weight and wearing surface loads, in addition to live load demands. The uncalibrated bridge model may erroneously be estimating larger load effects for members with negative rating factors. In the calibrated bridge model, the acceptable range of rating factors will be numbers greater than or equal to zero. The procedure for calculating LRFR rating factors is described in Section 4.

The Excel spreadsheet sorts through all LRFR rating factors and displays the five lowest rating factors and their corresponding member identification numbers for each of the applicable reactions listed in Section 2.3.2. **Using the calibrated computer model, the operator will be required to check the "Critical Member Summary" worksheet to ensure that there are NO rating factors below one.**

If an LRFR analysis results in rating factors less than one, additional LRFR analyses can be performed after changing the loaded lane in the moving analysis to determine if satisfactory rating factors can be achieved. The permit should require the vehicle to travel over the bridge in the lane that yields satisfactory rating factors. Additionally, parameters used in calculating LRFR rating factors can also be modified in a second LRFR analysis depending on the type of trip allowed across the bridge (e.g. single trip with traffic, single trip without traffic, and multiple trip permits). Section 6.4.5.5 of the LRFR Manual (AASHTO, 2003) indicates that the dynamic load allowance may be reduced if the vehicle is restricted to speeds less than ten mph. Adjusting the parameters for LRFR rating factors is described in Section 4.

3 Procedure for adding new vehicle Pattern

This section describes how to input a new moving load pattern into the moving load database so that it can be used for a moving load analysis.

3.1 Instructions: Adding New Vehicle Pattern

Over-permit vehicles will likely require a new vehicle load pattern be entered before running a moving load analysis. A vehicle load pattern is a file that indicates the location of wheel contact points with respect to the load path and the magnitude of the forces at the contact points. The moving load database contains pre-defined American standard vehicle load patterns as well as custom load patterns including ITD's Type 3, Type 3S2, Type 3-3, 121-ton and 212-ton rating vehicles. A new vehicle load pattern is added to the moving load database as follows.

1. Open LARSA 2000 Plus.
2. Open "PERRINE BRIDGE MASTER COPY" file.
   a. File → Open → Local Disk (D:) → Perrine Bridge Project folder → "PERRINE BRIDGE MASTER COPY"
3. Under the **Input Data** Menu, located at the top of the screen, select **Edit Databases**.

   Comments:

   After selecting the Edit Databases tab, the attached databases are shown in the Database Editor screen. The only database that is attached is "movedata_Perrine_Bridge.dml." Only one moving load pattern database can be attached at a time, so additional vehicle load patterns **MUST** be added to this database file.

   When LARSA is run for the first time on a new machine, the program will ask for the location of the moving loads database. Select movedata_Perrine_Bridge.dml from the appropriate directory in the dialog box. Otherwise, once LARSA is running, Under the **Input Data** menu located at the top of the screen, select **Connect Databases...** and select "movedata_Perrine_Bridge.dml." in the dialog box.

4. Select the **(+) Button** located on the left hand side of the screen, about mid-height.

   Comments:

   This creates a new moving load pattern record. The name will remain "new record" until it is renamed. Single-click the left mouse button over the "new record" to rename a record.

5. Select the new record to show load pattern information.

   Comments:

   At this point, this is a new load pattern file. No information will be displayed.

6. Under the **Spreadsheet** tab, select the first cell under the **Type** column and press **Enter**.

   Comments:

   A load pattern consists of individual wheel loads, rather than axle loads, with the wheel locations defined as longitudinal distances measured rearward from the front axle and transverse distances measured from the vehicle centerline. The following steps describe how to enter the load pattern data for a permit vehicle. The options for entering wheel loads are displayed in Figure 3- 1.

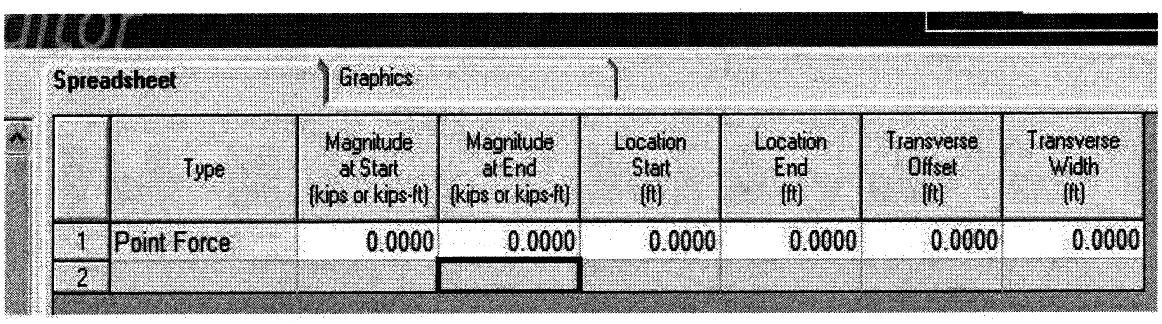

Figure 3- 1: Options For Entering Wheel Load

   a. All Contact points are entered as **POINT FORCE**.

   b. For an individual point force, Start and End Magnitudes are identical and represent the magnitude of the force (in kips) at the specific wheel location, i.e., half the axle weight . Two contact points are required per axle, one corresponding to each side of the axle.

Comments:

LARSA allows an option of entering distributed forces where the Start and End Magnitudes may differ depending on the nature of the distributed force. Since all wheel loads are entered as Point Forces, as opposed to Distributed Forces, both Magnitudes are identical. Using half the axle weight as the magnitude of the force at a wheel contact point assumes that the vehicle load is evenly distributed across the axle. If additional information is provided concerning an unbalanced vehicle load, individual wheel loads may be entered to more accurately model an unbalanced load.

c. Start and End Locations are also identical and represent the longitudinal distance (in feet) from the front axle to the axle in question (i.e., the first axle is entered as 0.000 ft for start location and 0.000 ft for end location).

d. Transverse Offset is the lateral spacing of the centroid of the tire footprint with respect to the centerline of the vehicle load pattern. Note: two offsets are entered per axle: one places a wheel load at a transverse offset equal to (+) width/2 and the other at (–) width/2.

e. Transverse Width should be zero for all Point Force loads entered.

Comments:

The Transverse Width corresponds to the width of the tire footprint. When the Transverse Width is zero, the wheel contact load is simplified to a point load. If more accuracy is desired and the width of the tire footprint is known, the wheel contact loads can be distributed along the Transverse Width. Typically, wheel contact loads are entered as point loads, neglecting the width of the tire footprint.

f. Repeat steps a – e for all wheel contact points to finish the custom load pattern.

Comments:

The lane selection in LARSA does not check for interference between the moving load and the median, or pedestrian barriers. The operator must verify that the vehicle width does not exceed the width of the lane selected for the analysis (see 5Figure 2-2).

7. Once the load pattern is created and named (step 4) and defined (step 6), click the **Save Database Button**. This is located near the top of the database editor screen.

Comments:

This step adds the vehicle configuration to the "movedata_Perrine_Bridge.dml" moving load pattern database file.

8. Once a new load pattern is added to the moving load pattern database, the LRFR moving load analysis and rating described in Section 2 can be performed using the new load pattern.

9. Moving load patterns can be removed from the database by selecting a load pattern (as in step 5) and selecting the **(-) Button** located next to the (+) Button of step 4. Select **Save Database** to save changes to database.

This concludes the instructions to enter a custom moving load pattern to the moving load pattern database.

3.2 Example: Adding New Vehicle Configuration

This example describes how a custom moving load pattern is entered for a three-axle dump truck. The dump truck has the following information (obtained from a weigh station):

- Gross Vehicle Weight (GVW): 53.16 kips
- Drive (Front) axle (1): Width 6.8 feet, Load 15.4 kips
- Axle (2): Width 7.2 feet, Load 18.88 kips
- Axle (3): Width 7.2 feet, Load 18.88 kips
- Longitudinal Axle Spacing: (1-2) 15.1 feet, (2-3) 4.4 feet

Once LARSA 2000 Plus and "PERRINE BRIDGE MASTER COPY" is open, select the **Edit Database Button**. This is illustrated in Figure 3- 2.

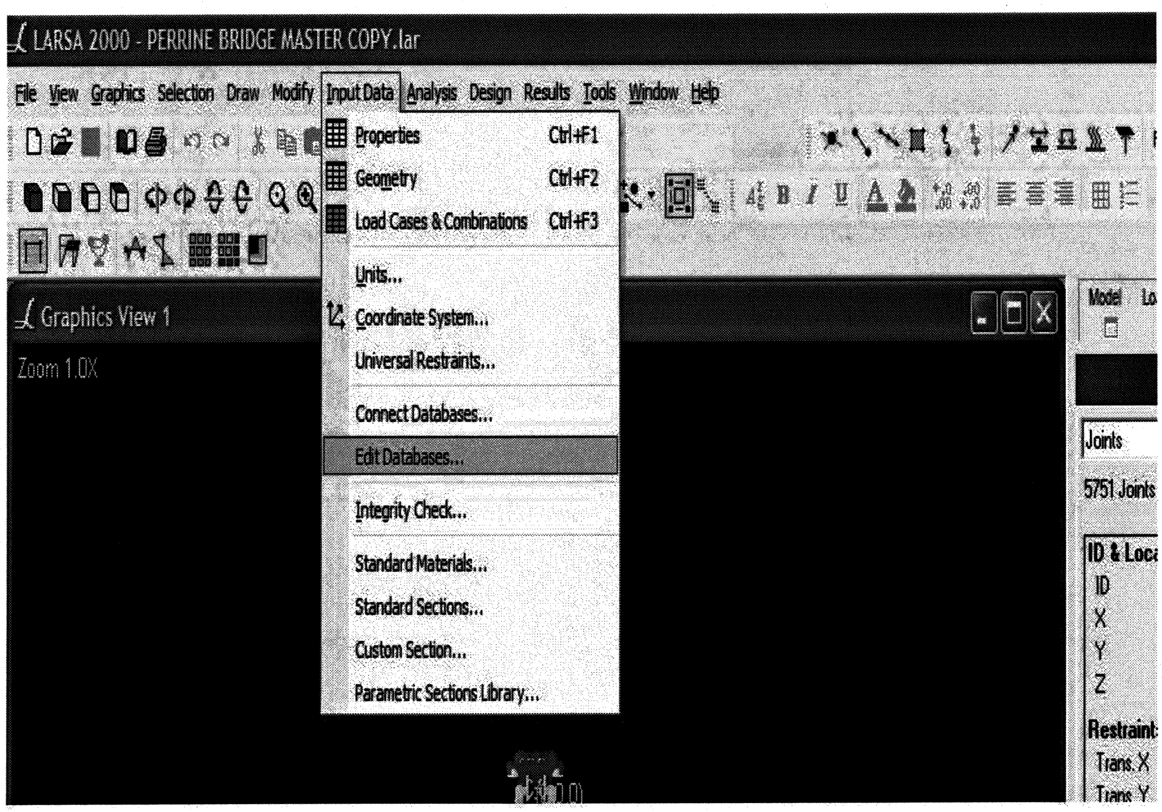

Figure 3- 2: Select Edit Databases from Input Data Menu

Next, select the **(+) Button** to add a new vehicle pattern. Figure 3- 3 shows where this button is located in the Database Editor screen.

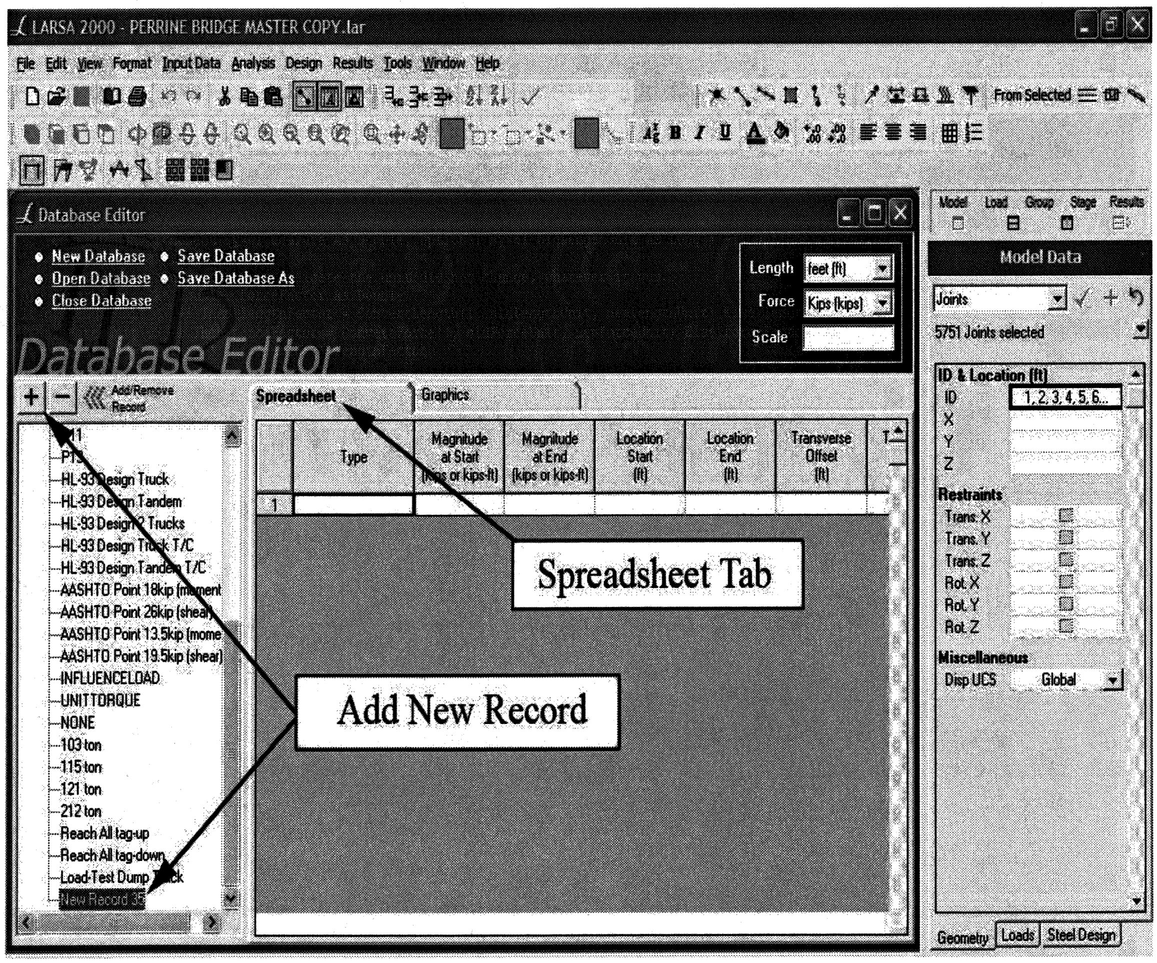

Figure 3- 3: Add New Record to Database

The new load pattern is renamed to "Dump Truck" by left clicking the "new record 35" cell. Load information is now entered to create the new load pattern. Figure 3- 4 shows the appropriate spreadsheet for the "Dump Truck" geometry.

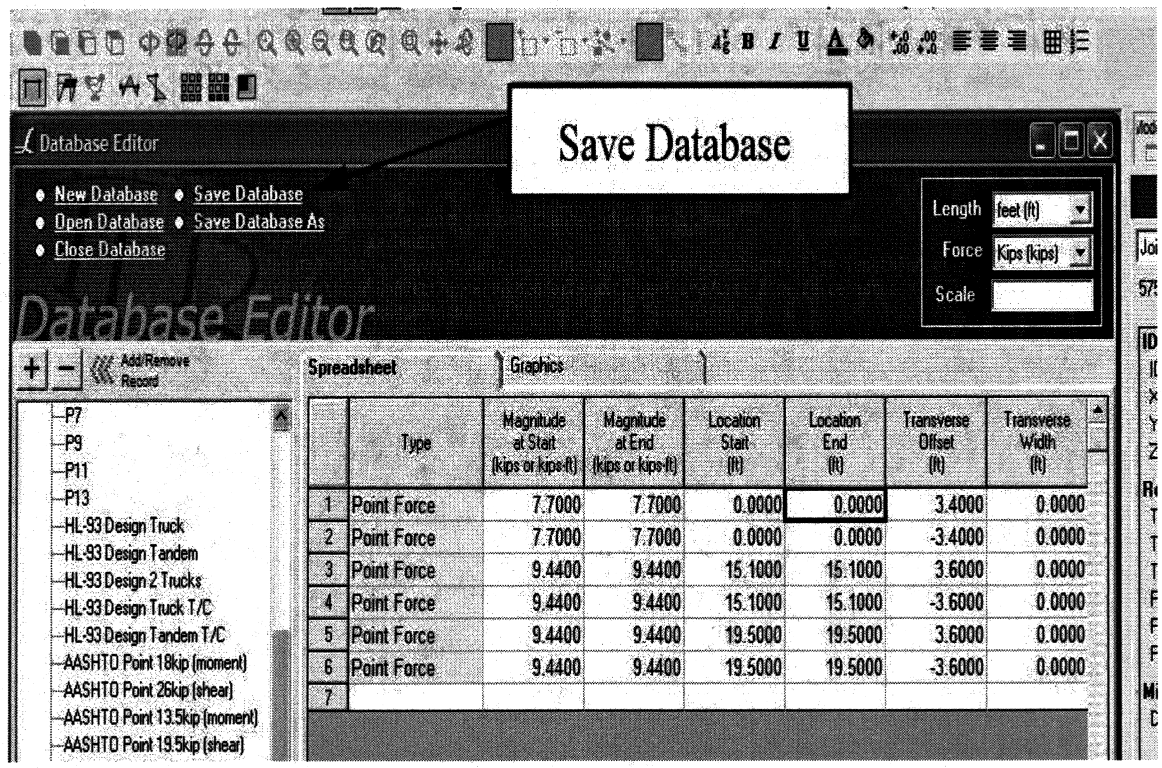

Figure 3- 4: Input Moving Load Pattern

All contact points are entered as **POINT FORCE**. Note that axle weights are divided by two and entered on two rows, one row for each contact point on either side of the axle. Also note that the transverse offset is (+/-) axle width/2 for the two rows corresponding to the same axle. The load pattern can be visually checked for the appropriate geometry by selecting the graphics tab, located next to the spreadsheet tab. Figure 3- 5 displays the graphics view for the "Dump Truck." Downward arrows indicate load locations and corresponding forces.

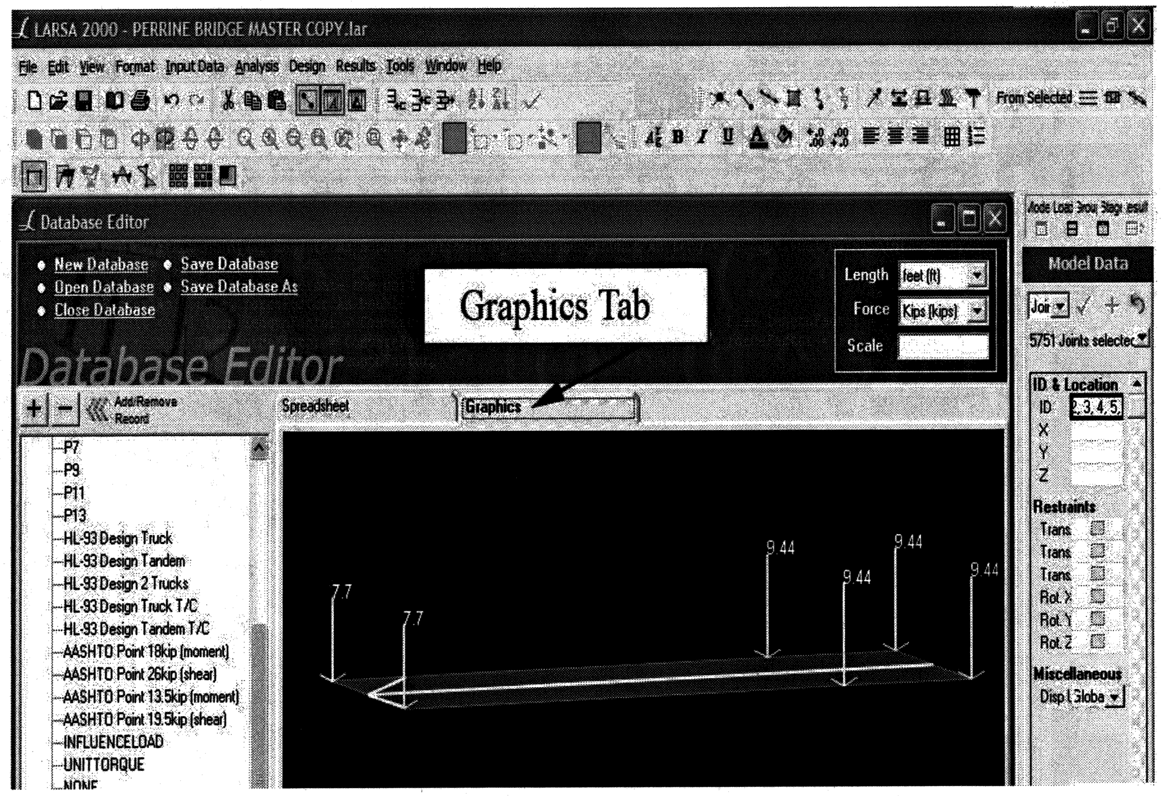

Figure 3- 5: Graphics View Tab

Once the new "Dump Truck" pattern is entered for all contact point in the configuration, click the **Save Database Button** (See Figure 3- 4). At this point the new vehicle configuration is entered. Once the database is saved, follow the instructions in Section 2 for a typical LRFR analysis.

4 Adjusting the LRFR Rating Factors

This section describes both the calculation of the LRFR rating factor and the load and resistance factors used in the rating factor calculation. As both system characteristics and over-permit vehicle types vary, the LRFR rating factor analysis must be modified to reflect current system conditions and vehicle loads. For example, the default condition factor assumes that regular bridge inspections reveal that all bridge components are in good condition. Likewise, the default LRFR rating factor analyses assume that vehicles are single-trip permits traveling in mixed traffic and that vehicles travel at posted speed limits (speeds are not reduced). Section 4.1 describes the LRFR rating factor and Section 4.2 defines the individual parameters used in the rating factor calculation.

4.1 General Rating Factor Equation

The load rating analysis spreadsheet rates bridge members for permit loads at a Strength II limit state. The general rating factor used to determine the load rating of each component subjected to a single force effect (i.e., axial force, flexure, or shear) can be described by the following equation (LRFR Manual, AASHTO, 2003):

$$RF = \frac{\phi_c \cdot \phi_s \cdot \phi \cdot R_n - \gamma_{DC} \cdot DC - \gamma_{DW} \cdot DW \pm \gamma_P \cdot P}{\gamma_L \cdot (LL + IM)}$$

Where:

RF = Rating factor

φ_c = Condition factor

φ_s = System factor

φ = LRFD resistance factor

γ_{DC} = LRFD load factor for structural components and attachments

γ_{DW} = LRFD load factor for wearing surfaces and utilities

γ_L = Evaluation live-load factor

γ_P = LRFD load factor for permanent loads other than dead loads = 1.0

DC = Dead-load effect due to structural components and attachments

DW = Dead-load effect due to wearing surface and utilities

IM = Dynamic load allowance

LL = Live-load effect

P = Permanent loads other than dead loads

R_n = Nominal member resistance (as-inspected)

No other permanent loads other than structural components, attachments, wearing surface, and utilities are considered (i.e., P equals zero). Therefore, the general rating factor equation simplifies to:

$$RF = \frac{\phi_c \cdot \phi_s \cdot \phi \cdot R_n - \gamma_{DC} \cdot DC - \gamma_{DW} \cdot DW}{\gamma_L \cdot (LL + IM)}$$

Both the dead load effects of the components and attachments (*DC*) and wearing surface and utilities (*DW*) are calculated prior to a moving load analysis. The results from both previously calculated dead load analyses are included in data worksheets within the load rating spreadsheet. Once a moving load analysis is performed, live load effects (*LL*) are enveloped for each bridge member in LARSA and imported into the load rating spreadsheet corresponding to the appropriate structure group. The load rating spreadsheet refers to spreadsheets containing the nominal member resistance (R_n) for all bridge members which have been estimated according to AASHTO LRFD Bridge Design Specifications (2005 interim revision). The Excel files estimating nominal resistances for all bridge members are "MEMBER CAPACITY.xls" and "COMPOSITE MEMBER CAPACITY.xls"

4.2 Input Parameters for LRFR Analysis

Input parameters are variables that the user can easily modify, as opposed to variables requiring significant effort to modify, such as dead load effects, live load effects, and nominal member resistances. All input parameters are included in the "User Input" worksheet of the "LOAD RATE_v706 MASTER.xls" file. The "User Input" worksheet is located adjacent to the "Control Panel" worksheet. The following subsections describe the factors considered as input parameters and describe acceptable values for LRFR analyses. Unless otherwise stated, all section, table, and page numbers referenced in the subsequent subsections are from the AASHTO Draft Manual for Condition Evaluation and Load and Resistance Factor Rating of Highway Bridges (LRFR Manual, AASHTO 2003).

4.2.1 Permanent Load Factors: γ_{DC} & γ_{DW}

The dead load factor (γ_{DC}) for the self-weight of structural components and attachments is 1.25 for the Strength II limit state (LRFR Manual, AASHTO, 2003). Load factors are taken from the LRFR Manual Table 6-1, pg. 6-14. The self-weight load factor should not be modified for any reason. The wearing surface load factor (γ_{DW}) is 1.50 for the Strength II limit state. However, the load factor for DW at the strength limit state may be taken as 1.25 where the thickness has been field measured (LRFR Manual, AASHTO, 2003).

4.2.2 Condition Factor: φ_c

According to the LRFR Manual, the condition factor is considered at the discretion of the governing agency (LRFR Manual, AASHTO, 2003). However, it has been included for the LRFR rating factor calculation. The LRFR Manual states, "The condition factor provides a reduction to account for the increased uncertainty in the resistance of deteriorated members and the likely increased future deterioration of these members during the period between inspection cycles" (LRFR Manual, AASHTO, 2003). Damage due to vehicle accidents, collisions, or any other accident is not considered by this factor.

Table 4- 1 (Table 6-2 from the LRFR Manual) defines the condition factor, φ_c, (LRFR Manual, AASHTO, 2003). All members are assumed to be in satisfactory condition; however, condition factors can be changed for various structure types to reflect the structural condition determined by inspection.

Table 4- 1: Condition Factor, φ_c

Structural Condition of Member	φ_c
Good or Satisfactory:	1.00
Fair:	0.95
Poor:	0.85

The LRFR spreadsheet includes condition factors for nine types of structural components: stringers and girders, floor beams, arch chords, arch posts, arch diagonals, chevron braces, arch struts, columns, and bracing. These components are labeled: Strngr, Fl. Beam, A. Chord, A. Posts, A. Diag. Chevron, Arch Strut, Column, Bracing, respectively. Stringers include main arch stringers and north and south approach plate girders and stringers. Floor beams include the plate floor beams supported by columns in the main arch span and the floor beams supporting stringers that are attached to plate girders in both approach spans (see Figure 5- 1). Arch chords, diagonals, chevron braces, and struts consider both upper and lower structural components for the arch truss. Columns include both spandrel columns supporting the main arch span and bent columns supporting both approaches. Finally, bracing considers any diaphragm, lateral, or transverse brace anywhere in the entire bridge. The condition factor is applied to ALL members within the structure type it is classified. For example, if a stringer in the south approach is in "Fair" condition, then φ_c equal to 0.95 would be applied to ALL stringer members of the south approach, north approach, and main arch span.

4.2.3 System Factor: φ_s

The system factor (φ_s) for bridges is discussed in Section 6.4.2.4, page 6-16 of the LRFR Manual. This factor adds a reserve capacity such that the overall system reliability is increased for non-redundant systems (LRFR Manual, AASHTO, 2003). Since the I.B. Perrine Bridge is a nine-girder bridge over the arch main span (> four girders), the system factor equals 1.0 over the main arch span (see Table 6-3 of the LRFR Manual, AASHTO, 2003). In the approach spans, the stringer subsystem between the floor beams is assumed to provide adequate redundancy such that the system factor equals 1.0. For columns and principle arch truss members where load paths are not redundant, the system factor is equal to 0.90. This factor is used for riveted members in truss/ arch bridges. Therefore, the system factor is 1.0 for all bridge spans, except columns and principal arch truss members. This factor should not require modification.

4.2.4 Resistance Factor: φ

Resistance factors are found in AASHTO LRFD Bridge Design Specifications 2005 Interim Revision, Section 6.5.4.2. For shear and flexural resistance, φ equals 1.0. The compression resistance factor (φ equal to 0.90) is multiplied in the "MEMBER CAPACITY.xls" file. These factors should not be modified for any reason.

4.2.5 Live Load Factor: γ_L

The live load factor is a load magnification factor applied to the live load effects calculated by moving load analyses of the finite element model. Live load factors for permit load rating are presented in the LRFR Manual Section 6.4.5.4, page 6-26. For the Perrine Bridge, the average daily truck traffic (ADTT) for one direction is taken as greater than five thousand vehicles per day. Live load factors are presented in the LRFR Manual, Table 6-6.

Table 4- 2: Permit Live Load Factors (AASHTO, LRFR Table 6-6)

Permit Type	Frequency	Loading Condition	*DF*[a]	ADTT (one direction)	Load Factor by Permit Weight[b]	
					Up to 100 kips	≥150 kips
Routine or Annual	Unlimited Crossings	Mix with traffic (other vehicles may be on the bridge)	Two or more lanes	>5000	1.80	1.30
				=1000	1.60	1.20
				<100	1.40	1.10
					All Weights	
Special or Limited Crossing	Single-Trip	Escorted with no other vehicles on the bridge	One lane	N/A	1.15	
	Single-Trip	Mix with traffic (other vehicles may be on the bridge)	One lane	>5000	1.50	
				=1000	1.40	
				<100	1.35	
	Multiple-Trips (less than 100 crossings)	Mix with traffic (other vehicles may be on the bridge)	One lane	>5000	1.85	
				=1000	1.75	
				<100	1.55	

Notes:

[a] DF = LRFD-distribution factor. When one-lane distribution factor is used, the built-in multiple presence factor should be divided out.

[b] For routine permits between 100 kips and 150 kips, interpolate the load factor by weight and ADTT value. Use only axle weights on the bridge.

Select the permit live load distribution factor that applies to the permit type needed. The default permit live load factor is 1.50, corresponding to a single trip, traveling in mixed traffic. This corresponds more closely to the Inventory Rating level in previous AASHTO rating procedures. The live load factors for "Routine or Annual" permits correspond more closely with the Operating Rating level.

4.2.6 Dynamic Load Allowance: IM

The dynamic load allowance increases the static loads of trucks for the strength limit state to account for the dynamic effects resulting from moving vehicles. In the "User Input" worksheet of the "LOAD RATE v706 MASTER.xls" load rating file, the highlighted cells, A Str. and Other, stand for arch stringers and all other bridge components, respectively. These two cells apply the dynamic impact factor (IM) to all bridge components in the load rating worksheet. Under typical traveling conditions all bridge members, except main arch span stringers, receive a thirty-three percent dynamic load allowance (IM equals 0.33). Main arch span stringers span approximately fifty-two feet. For longitudinal members spanning greater than forty feet the dynamic load allowance may be reduced depending on the riding surface conditions. Table 4- 3 summarizes the LRFR Manual Table C6-3 with an additional dynamic load allowance for vehicles traveling at speed less than ten miles per hour (LRFR Manual, AASHTO, 2003).

Table 4- 3: Dynamic Load Allowance: Arch Span Stringers

Riding Surface Conditions	**IM**
Smooth riding surface at approaches, bridge deck, and expansion joints	0.10
Minor surface deviations or depressions	0.20
Vehicles traveling < 10 mph	0.00

Arch stringers have a dynamic load allowance of 0.20 which corresponds to minor surface deviations on the wearing surface. This factor may be reduced if a new (smooth) riding surface is added at a later time. Section 6.4.5.5 of the LRFR Manual (AASHTO, 2003) indicates that the dynamic load allowance can be eliminated (i.e., IM equals 0.00) for all structural components when vehicles are restricted to traveling at speeds less than ten miles per hour, which is reflected in the third entry in Table 4-4.

5 Locating Elements Within the Perrine Bridge Model

This section describes how to locate an element within the I.B. Perrine Bridge model. A bridge engineer may need to locate a bridge component if the member has a failing LRFR rating factor calculated by the load rating procedure described in Section 2. The procedure described in this section for locating elements in LARSA is one of many possible methods by which an operator can select specific elements within the bridge model. The LARSA User's Manual provides supplemental information for describing functions and features available in LARSA 2000 Plus.

5.1 Finding Member Identification Numbers from Load Rating Report

The lowest five rating factors and their corresponding span or member identification numbers are shown for every structure group in the "Critical Member Summary" worksheet of the "LOAD RATE v706 MASTER.xls" Excel load rating file. The following subsections describe span and member identification numbers.

5.1.1 Span Identification Numbers

Beams in structures are often modeled as multiple beam elements connected along the length of the actual beam. These beam elements are known as analytical elements, as opposed to physical members, because they are defined for the sake of analysis (LARSA, 2004). All of the analytical elements modeling a beam are called a span. Figure 5- 1 illustrates analytic elements modeling portions of an approach span on the Perrine Bridge. This figure shows portions of five spans: two plate girder spans, two stringer spans, and one floor beam span. The floor beam in Figure 5- 1 is a span modeled using three analytic elements.

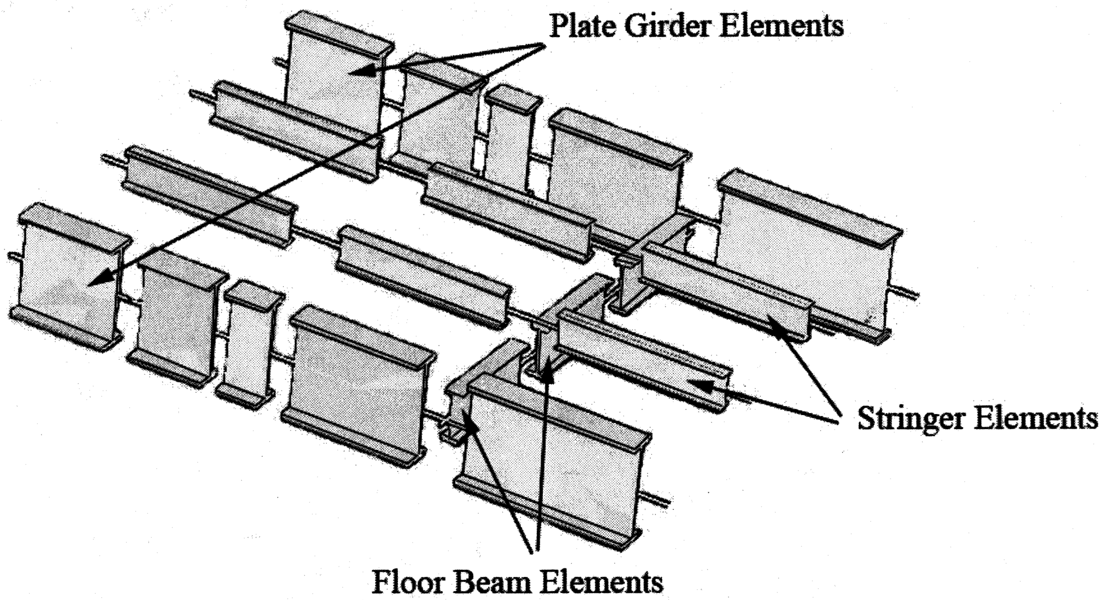

Figure 5- 1: Analytic Elements Modeling Real Beams

All spans within a structure group are numbered sequentially. All span identification numbers are shown in the load rating worksheets corresponding to their structure group. Every span has a load rating factor calculated in the load rating worksheet corresponding to its structure group. Figure 5- 2 shows a sample of span results for stringer structure groups from the five-page load rating summary report generated from a load rating analysis. The five lowest rating factors and their corresponding span identification numbers are listed in order of lowest-to-highest rating factors.

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	***Critical Member/ Failure Summary Page 1:***												
2	***STRINGERS***					***Minimum rating factor for stringers and floor beams***							0.3
3	***South Approach Stringer***							***North Approach Stringer***					
4		Shear		M (+)		M (-)			Shear		M (+)		M (-)
5	Span	RF	Span	RF	Span	RF		Span	RF	Span	RF	Span	RF
6	ID	-	ID	-	ID	-		ID	-	ID	-	ID	-
7	36	11.43	11	9.91	36	1.24		201	4.75	226	6.72	221	0.32
8	21	16.42	1	11.92	31	1.49		236	5.39	221	8.53	216	0.69
9	11	16.70	16	12.54	26	1.63		226	7.43	236	8.86	222	0.70
10	16	18.39	41	13.17	27	2.51		206	7.50	201	9.23	211	0.88
11	31	21.26	56	15.88	32	2.66		196	8.60	196	9.60	223	1.24
12	***Exterior Arch Stringer***							***Interior Arch Stringer***					
13		Shear		M (+)		M (-)			Shear		M (+)		M (-)
14	Span	RF	Span	RF	Span	RF		Span	RF	Span	RF	Span	RF
15	ID	-	ID	-	ID	-		ID	-	ID	-	ID	-
16	88	41.00	88	17.18	61	2.69		71	12.54	179	9.65	62	1.03
17	106	42.23	106	17.77	70	2.95		89	13.63	107	10.08	71	1.05
18	70	42.38	178	17.93	79	3.24		179	15.19	125	10.44	80	1.27
19	178	43.68	70	18.07	88	3.82		161	15.92	161	10.96	89	1.31
20	124	47.06	124	18.52	187	4.18		170	16.73	89	10.99	63	1.51

Figure 5- 2: Sample Load Rating Report (Spans)

If the rating factors are less than one, the bridge analyst will need to be able to find the failing span identification number(s) so that the span location can be located in the computer model.

5.1.2 Member Identification Numbers

Many bridge components can be modeled using one element. Arch truss, column, and diaphragm members are examples where one element models an entire bridge component. All members within a structure group are numbered sequentially and their member identification numbers are shown in the load rating worksheets corresponding to their structure group. Every member has a load rating factor calculated in the load rating worksheet corresponding to its structure group. Figure 5- 3 shows a sample of arch member results for principle arch truss structure groups from the five-page load rating summary report generated from a load rating analysis. The five lowest rating factors and their corresponding member identification numbers are listed in order of lowest rating factor.

	Critical Member/ Failure Summary Page 2:							
2	ARCH MEMBERS		Minimum rating factor (not including struts and bracing)					1.69
3	Top Chords		Bottom Chords		Post		Diagonal	
4		Axial		Axial		Axial		Axial
5	Member	RF	Member	RF	Member	RF	Member	RF
6	ID	Comp.	ID	Comp.	ID	Comp.	ID	Tensile
7	2035	3.87	2155	7.58	2371	1.69	2269	2.73
8	2043	4.06	2121	7.60	2369	2.44	2207	2.77
9	2041	4.06	2159	7.72	2361	2.71	2205	2.86
10	2019	4.11	2117	7.81	2307	2.91	2271	2.86
11	2033	4.12	2157	7.97	2315	3.30	2215	3.26

Figure 5- 3: Sample Load Rating Report (Members)

Again, if a rating factor is less than one, the bridge analyst will need to be able to find the failing member identification number(s) so that the member location can be located in the computer model.

5.2 Finding Elements in the Perrine Bridge Model

This section describes how to find an element within the computer model. Knowing the failing span and/or member identification number from the "Critical Member Summary" worksheet, the user can find the element within the Perrine Bridge computer model. Begin in LARSA by making sure that members are showing. This can be done by selecting the graphics button (top left button) > show > check box next to members, select "OK."

5.2.1 Knowing Span Identification Number, Find Elements

This example will select members from span 45 of the Perrine Bridge computer model. Elements from any other span can be selected following the same procedure.

1. Determine failing span identification number from "Critical Member Summary" worksheet located in the load rating file.
2. Open LARSA 2000 Plus, if it is not already open.
3. Open "PERRINE BRIDGE MASTER COPY," if it is not already open.
4. Select Input Data > Geometry (see Figure 5- 4)

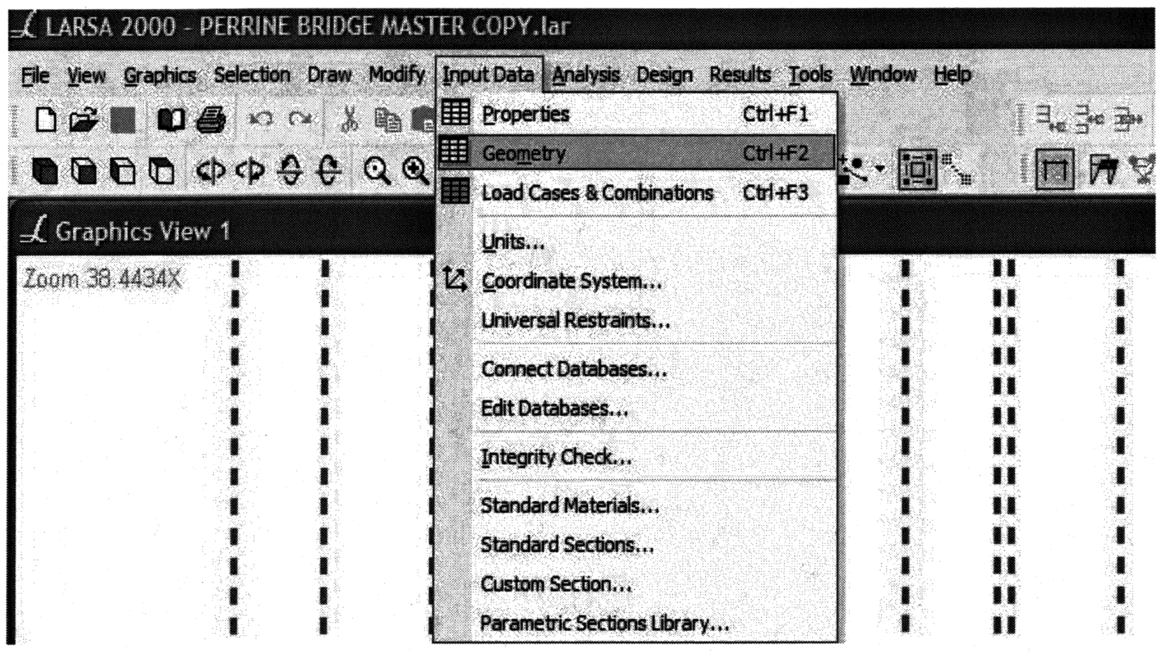

Figure 5- 4: Input Data > Geometry

5. Determine what elements are in span

   a. Select "Member" Tab (See Figure 5- 5)

   b. Select "Span" button (See Figure 5- 5)

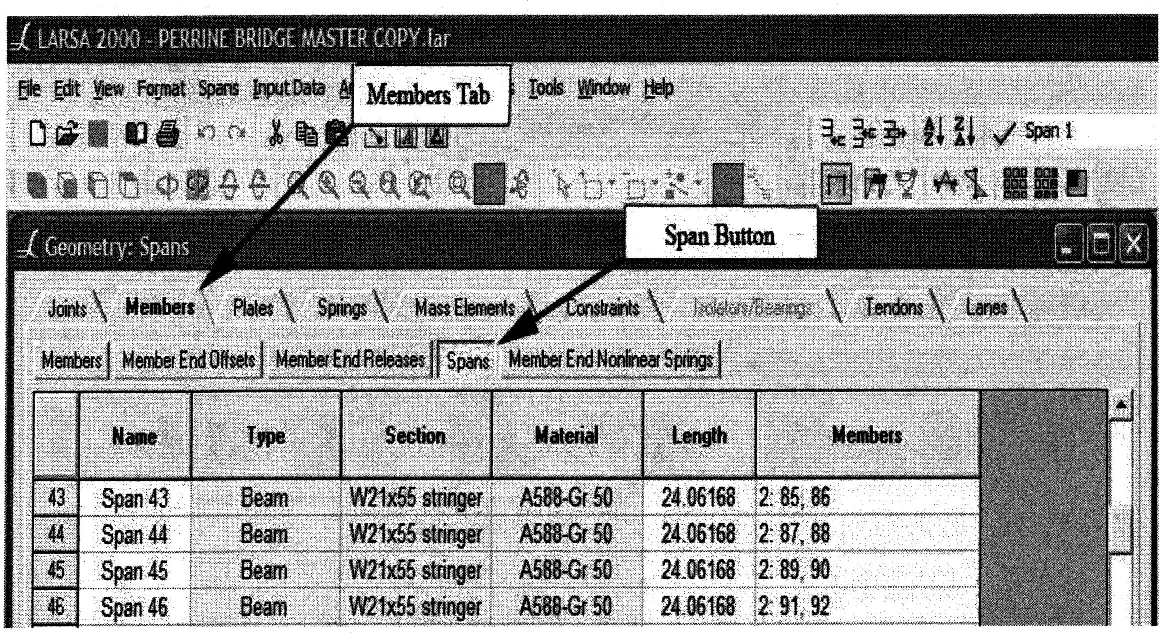

Figure 5- 5: Find Elements in Span

Comments: In Figure 5- 5, the "name" column lists the span identification number. The user will need to scroll down to the span identification number in question (Span 45 for this example). The right-most column in this screen is labeled "members." The "members" column lists the member identification numbers for the members comprising a span. For span 45 there are two members (89 and 90) defining that span.

6. Select the "Graphics View" button in the lower left corner of the screen (see Figure 5- 6).

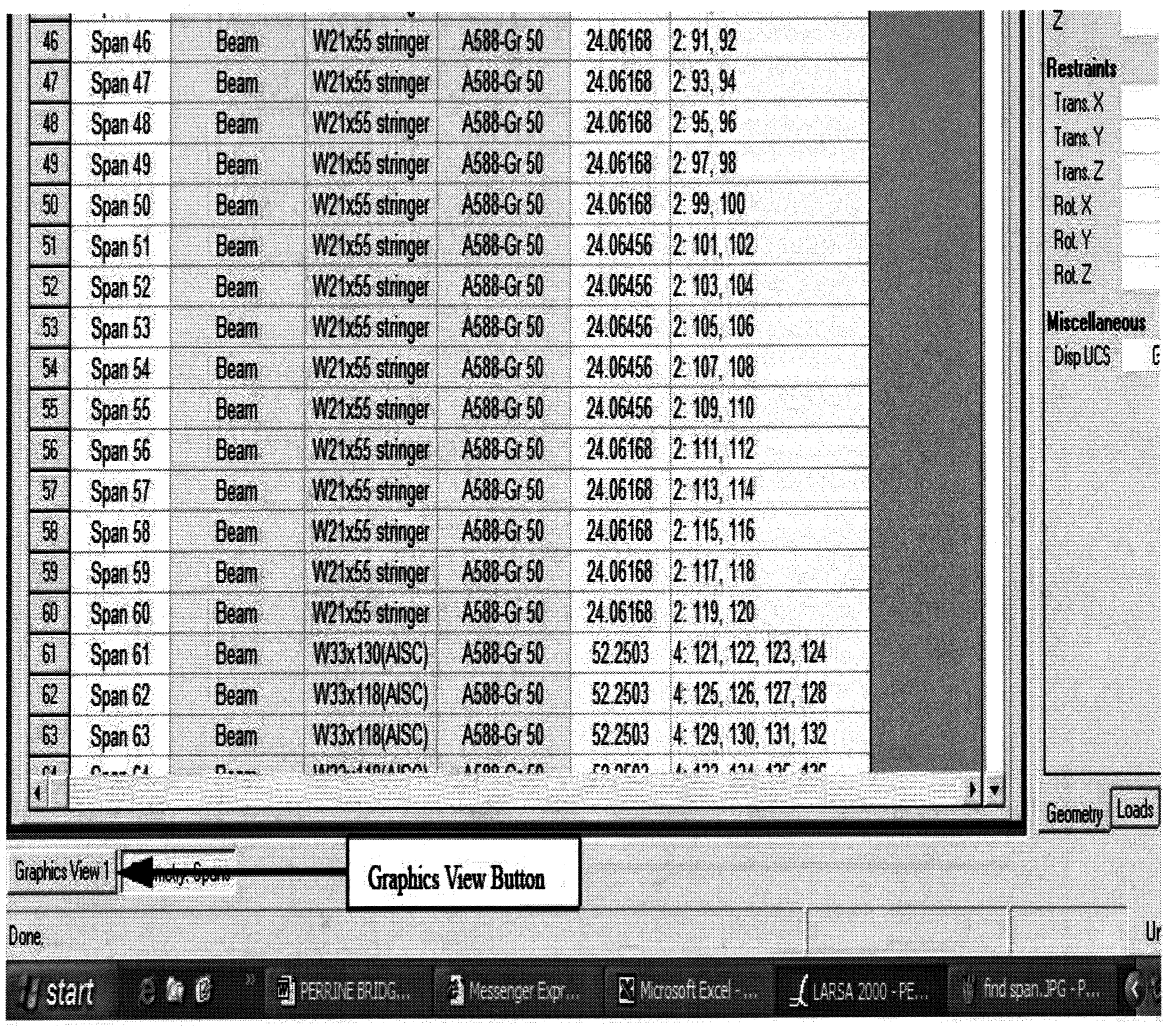

Figure 5- 6: Graphics View Button

7. Under the "Graphics" menu, select "Find." In the "Show" dialog box, select "Member" from the pull-down menu in the top entry, enter the member number, and click on the "Show" button. OR

8. Unselect all members (see Figure 5- 7).

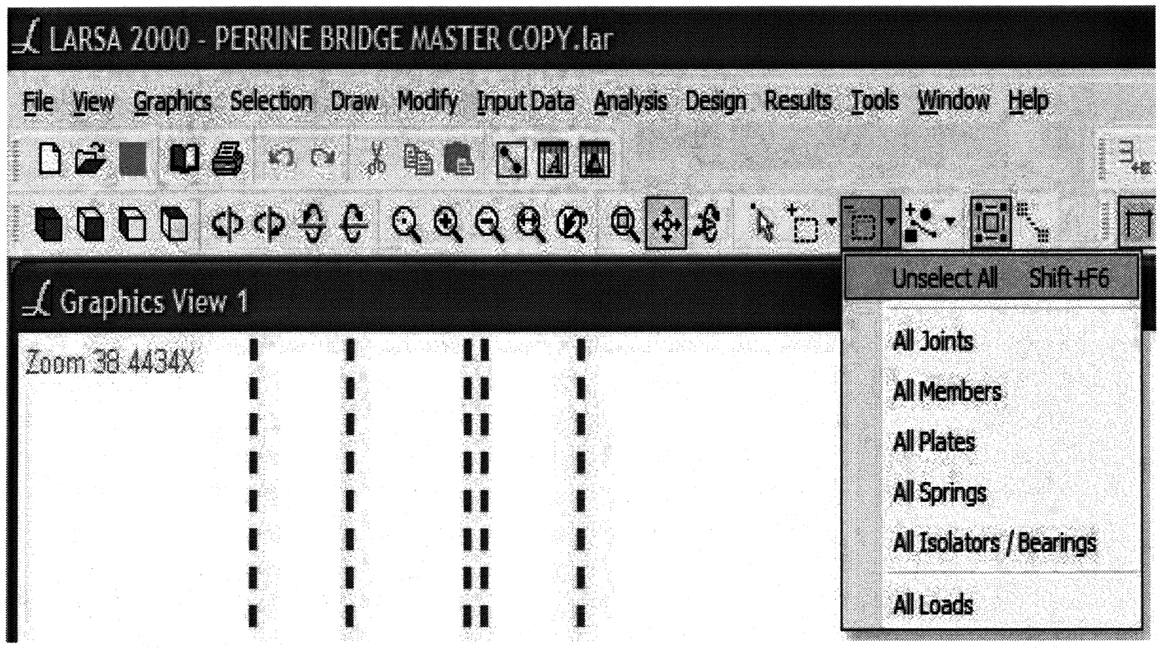

Figure 5- 7: Unselect All Members

9. Open "Select Special" screen (see Figure 5- 8)

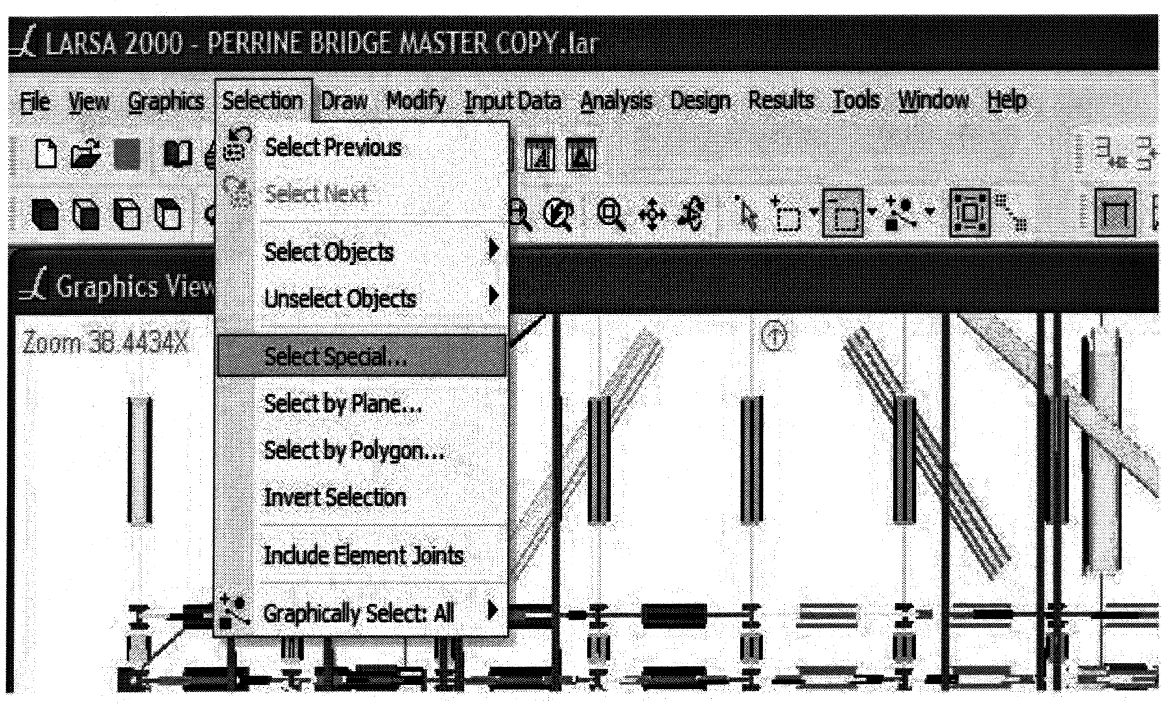

Figure 5- 8: Select Special

10. In the Select Special screen, under geometry, select "members" (see Figure 5- 9).

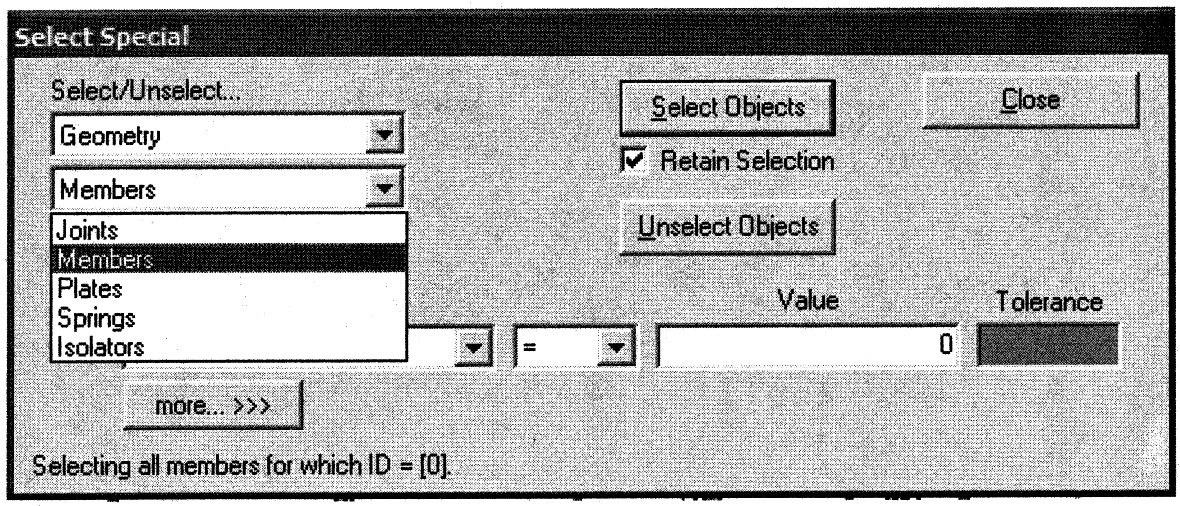

Figure 5- 9: Select by Member Identification Number

11. Enter member identification number(s) from step 5. Figure 5- 10 illustrates where members 89 and 90 of span 45 are entered in the select special screen. Press the "Select Objects" button. Once the member(s) has been selected press the "Close" button.

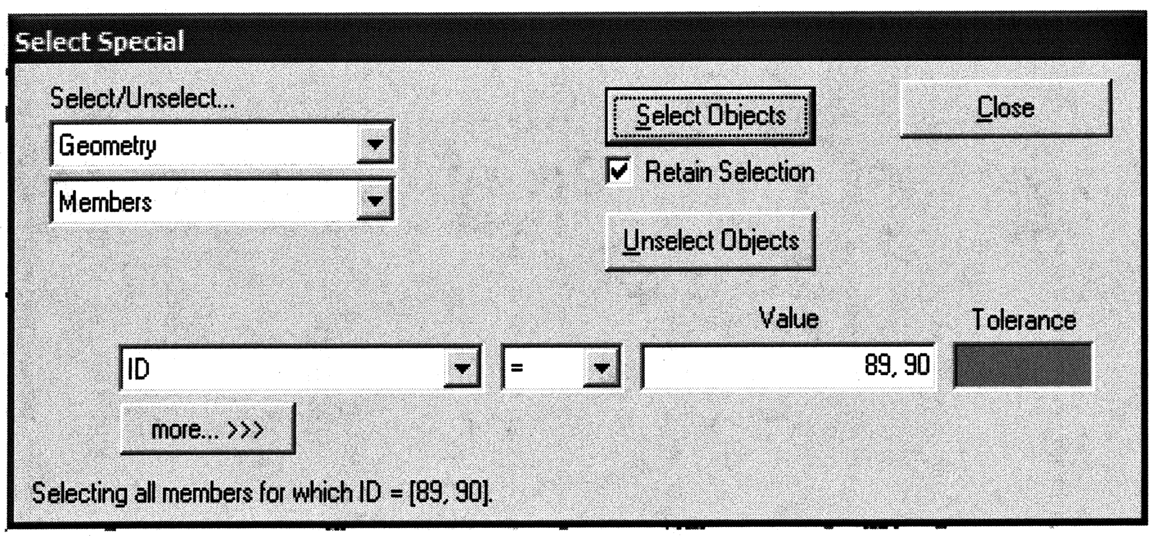

Figure 5- 10: Select Members

12. Press the "Hide" button (see Figure 5- 11)

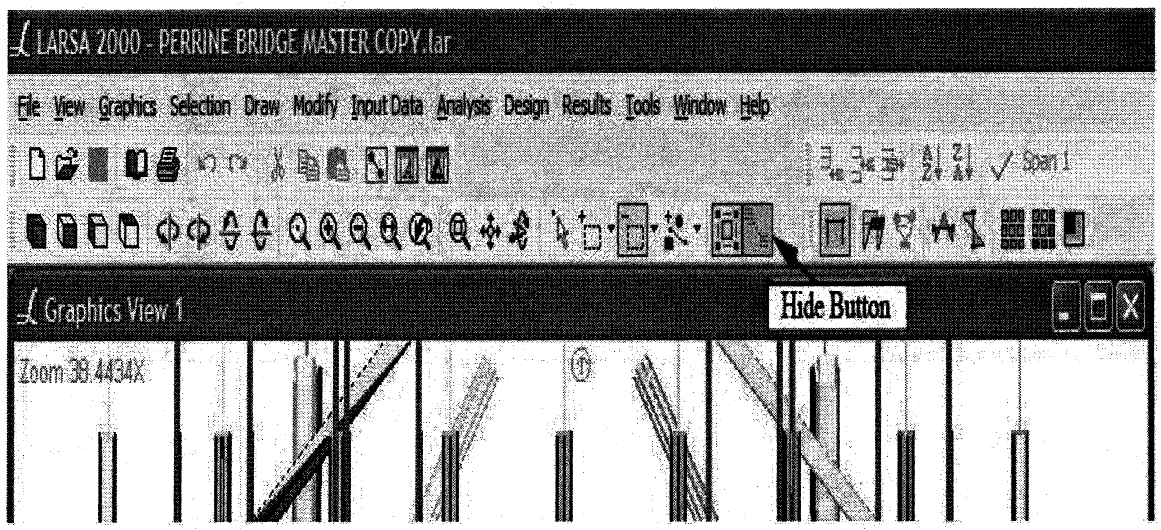

Figure 5- 11: Hide Button

Comments: The "Hide" button only shows selected members. Step 7 unselects all members and step 10 selects the members in question. Therefore, only the members selected in step 10 will be shown in the graphics view screen.

13. Use the "Zoom" features and the "Dynamic Panning" button to locate selected members (see Figure 5- 12). This feature allows the user to move around the screen/model. The user should find the selected members easily since these members will be the only members shown in the screen.

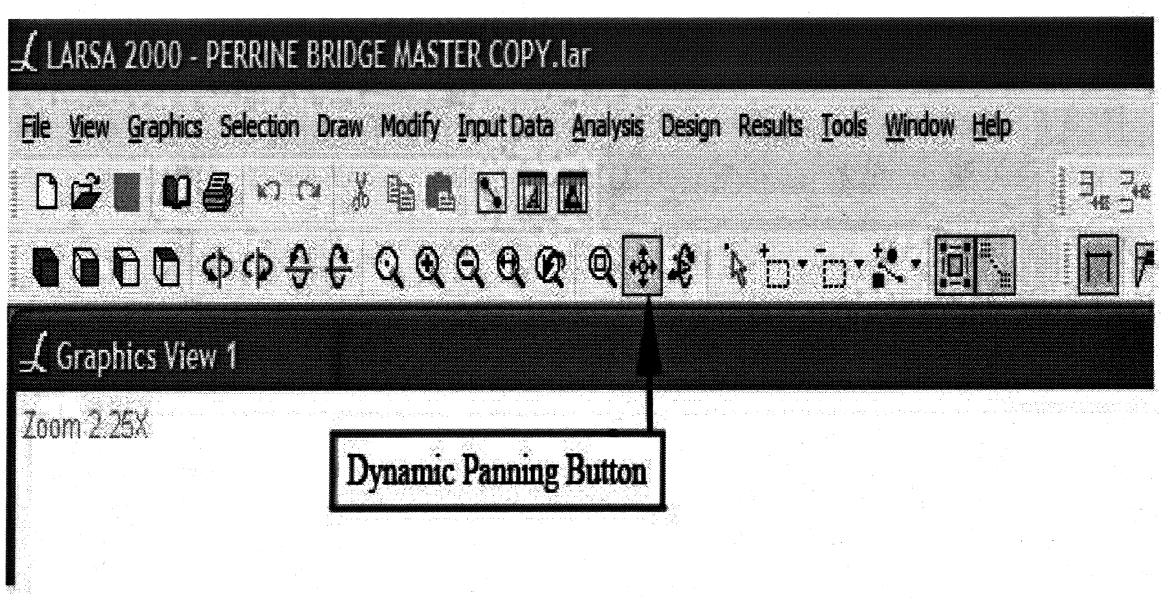

Figure 5- 12: Dynamic Panning Button

14. Select the “Hide” button again to show all members. This will show where the selected members are located within the model because all members (selected and unselected) will be shown. See Figure 5- 11 to locate the “Hide” button.

5.2.2 Knowing Member Identification Number, Find Elements

Selecting elements knowing the member identification number is similar to selecting span elements. Knowing the member identification number, follow Section 5.2.1 steps 7 through 14.

6 File Management

Input and output files are created each time the rating process is repeated, and systematic procedures will be needed to manage the resulting data.

6.1 LARSA Input Files

As indicated in Section 3.2, each truck entered for a moving load is saved as a separate record in the LARSA database: "movedata_Perrine_Bridge.dml." Typically this database is saved in the same directory as the "PERRINE BRIDGE MASTER COPY" file.

The "movedata_Perrine_Bridge.dml." should be periodically archived. To archive this database:

1. Copy the database to an archive directory or CD:
    a. Open Windows Explorer and go to the working directory containing the database and right click on "movedata_Perrine_Bridge.dml"
    b. Select "copy" from the drop-down menu.
    c. "Paste" the copy in the desired archive directory.
    d. Rename the archived file, possibly with a filename indicating when the archive was made.
    e. If the archive directory is a CD, write (i.e., "burn") the files on a blank CD.

After the database has been archived and renamed it can be replaced by the "original" database containing only the standard rating trucks, reducing the number of trucks in the database.

2. Retrieve a copy of the original database:
    a. Open Windows Explorer and select the CD (or a copy of the CD) provided by the University of Idaho. Open the directory containing the original moving load database and right click on "movedata_Perrine_Bridge.dml"
    b. Select "copy" from the menu.
3. Paste the copy of the original moving load database in the working directory.
    a. In the directory where the working moving load database was found, select "paste"

b. When prompted, select "copy and replace" to overwrite the existing database.

LARSA will open the moving load database, which will only contain the standard rating trucks. New permit trucks can be added as needed. If LARSA does not automatically link to the moving load database, the link to that database will have to be redefined (see Section 3.1).

6.2 Excel Output Files

As suggested in Section 2.2.1, a new Excel rating file will be created for every rating analysis. In some cases, several rating cases will be considered for a single truck to allow for different lanes (Figure 2- 2), trip conditions (Section 4.2.5) or vehicle speeds (Section 4.2.6). Each of the Excel rating files is large (about 95 MB). A systematic archiving process will be needed to manage the large amount of data this generates. File compression significantly reduces the size of the Excel rating files and is recommended for the archived files. (See the Windows™ Help File for information regarding file compression.)

7 Glossary of LARSA Terminology

7.1 Analytic Element

A physical beam is often modeled as multiple analytic beam elements connected along the length of the physical beam. These beam elements are known as analytical elements, as opposed to physical members because they are defined for the sake of analysis (LARSA, 2004). See Figure 7.1 and Sections 2.1.2.1 and 4.2.1 of *Load Rating the Perrine Bridge.*

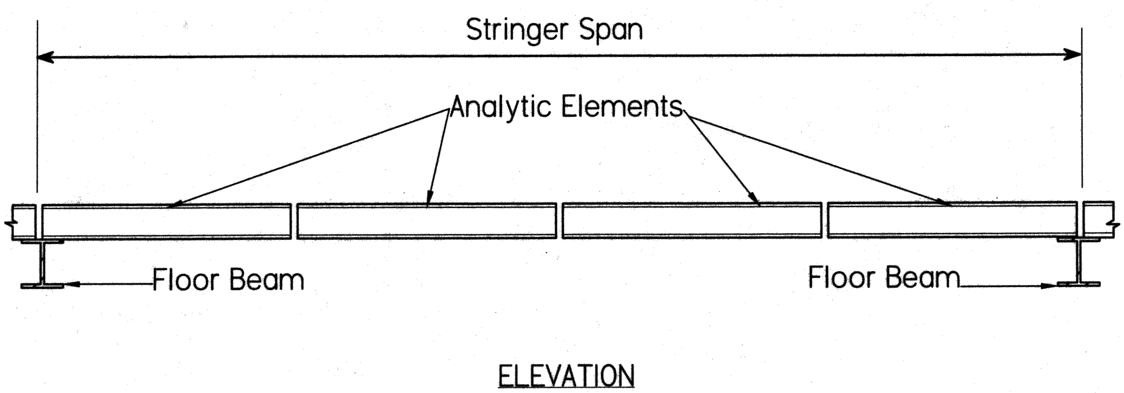

Figure 7- 1: Analytic Elements and Stringer Span

7.2 Geometry Group

See Section 7.6 of this Instruction Manual, and Section 4.1.2.3 of *Load Rating the Perrine Bridge.*

7.3 Lane Element

Multiple beam elements are typically combined to declare one lane which spans an entire structure. Structural beam elements are rarely coincidentally aligned with travel lanes. Therefore virtual beam elements (lane elements) are added to conveniently define moving load paths. See Figure 7.2 and Section 2.3.2 of *Load Rating the Perrine Bridge.*

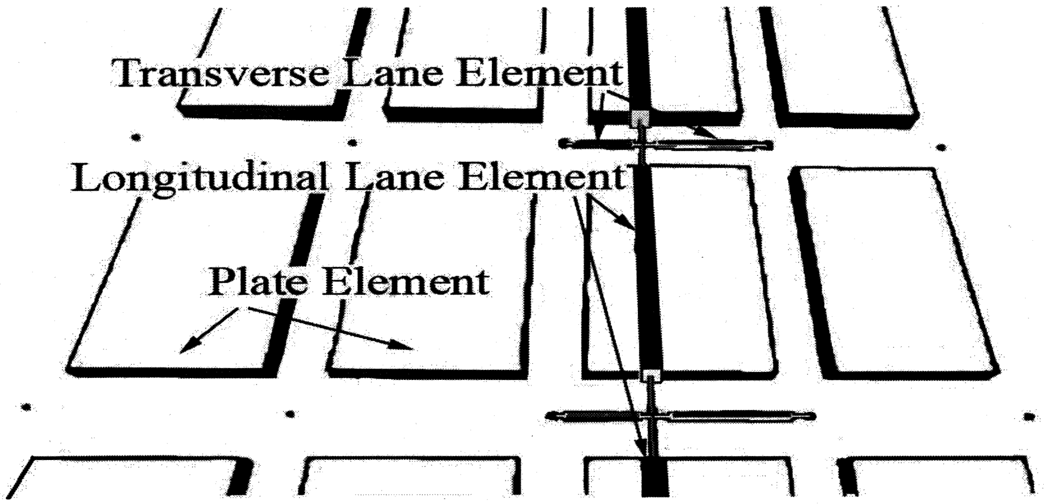

Figure 7- 2: Lane Elements and Deck Super Structure

7.4 Rigid Link Element

Rigid links connect beam elements where a connection cannot be made through a mutual joint between two beam elements. This is common when intersecting beam element centerlines do not align. See Figure 7.3 and Section 2.1.6 of *Load Rating the Perrine Bridge*.

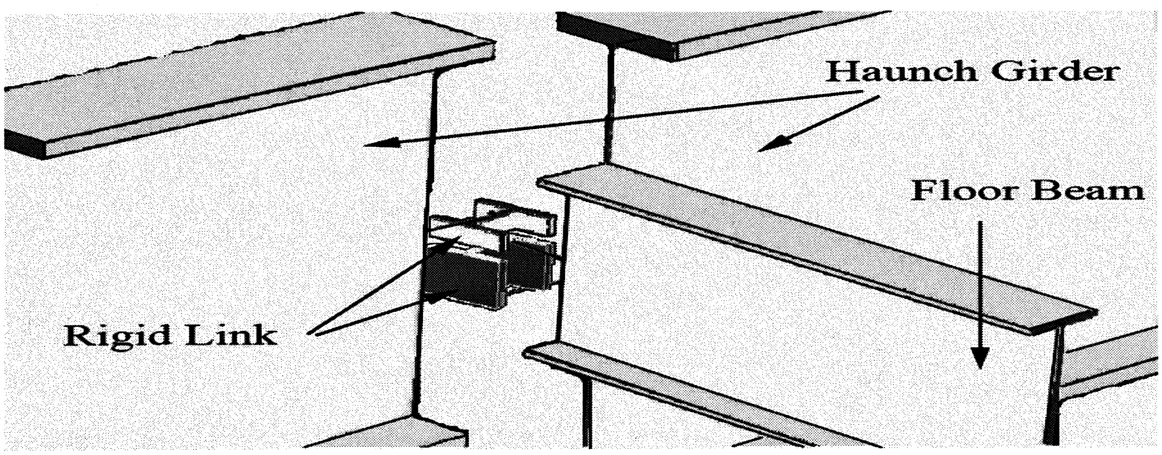

Figure 7 - 3: Rigid Link Elements at Haunch Girder/Floor Beam Intersection

7.5 Spans

7.5.1 Stringer Span

A stringer span is a single physical element (from support to support). Numerous analytic elements comprise stringers spans. See Figure 7- 1 and Section 4.2.1.1 of *Load Rating the Perrine Bridge*.

7.5.2 Section Span

A section span is a span on a plate girder that has constant capacity (i.e., constant section properties). Varying numbers of analytic elements comprise section spans on plate girders. See Figure 7- 4 and Section 4.2.1.1 of *Load Rating the Perrine Bridge*.

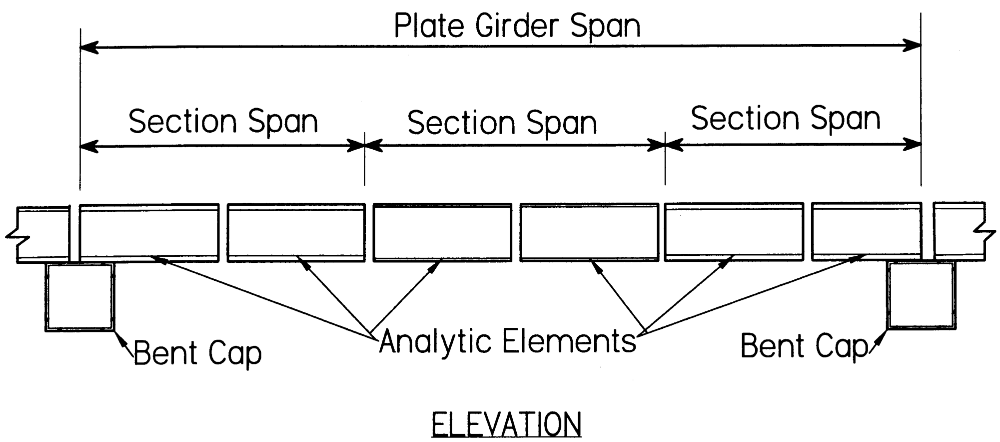

Figure 7 - 4: Plate Girder Analytic Elements, Section Spans, and Plate Girder Span

7.6 Structure Group

Structure or Geometry Groups allow for efficient selection of a group of similar structural components to retrieve analysis results from LARSA. Related structural components of the bridge are organized into fifty-one Structure Groups in the Perrine Bridge model. For example, stringers of the south approach, north approach, and main arch spans are organized in three separate structure groups. Similarly, each diaphragm of the bridge deck is in a separate structure group. Structure groups are labeled according to the structure type they represent (e.g. "south approach stringer", "ext. S. approach plate girder," "arch span floor beam," or "spandrel column"). Rating factors are summarized according to the structure groups in the Excel load rating spreadsheet.