Moving Load Analysis for Bridge Structures

The moving load analysis function in MIDAS/Civil is used to statically analyze and design bridge structures for vehicle moving loads. Important features are included as follows:

**Generation of influence line and influence surface for displacements, member forces and reactions due to moving loads**

**Calculation of maximum/minimum nodal displacements, member forces and support reactions for a given moving vehicle load using the generated influence line and influence surface**

Moving load analysis of a bridge structure entails a series of analyses for all loading conditions created along the entire moving load path to find the maximum and minimum values, which are used as the results of the moving load case.

In order to carry out a moving load analysis, we define vehicle loads, traffic lanes or traffic surface lanes and the method of applying the vehicle loads, and then we apply a unit load at various points to traffic lanes or traffic surface lanes to calculate influence line or influence surface.

An Influence line is presented on the traffic lane and represents a specific component of analysis results obtained from static analyses of a bridge structure subjected to a unit load moving along the traffic lane. An influence surface represents a specific component of analysis results obtained from static analyses of the traffic lane plane of a bridge structure subjected to a unit load located at the plate element nodes and is presented on the points of load application. The components of results that can be calculated for influence lines or influence surfaces include nodal displacements of the structural model, member forces for truss, beam and plate elements, and support reactions.

An analysis procedure for a vehicle moving load using influence lines or influence surfaces can be summarized as follows:

1. Define vehicle loads, method of applying the moving loads and traffic lanes or traffic lane surfaces.
2. Calculate influence lines or influence surfaces for each component by performing static analyses for unit loads that are generated by the traffic lane or traffic surface lane.
3. Produce the analysis results due to the vehicle movement using influence line or influence surface according to the moving load application method.
The analysis procedure described above produces the maximum and minimum values for one moving load condition, and they can be combined with other loading conditions. The load combinations are performed separately for both maximum and minimum values. The analysis results include nodal displacements, support reactions and member forces for truss, beam and plate elements. In the case of other types of elements, only the stiffness is considered in the analysis, but the analysis results are not produced.

The unit load used in a vehicle moving load analysis for influence line or influence surface is applied in the negative Z-direction of the GCS. An unlimited number of moving load conditions can be specified.

Influence line and Influence surface analyses cannot be performed at the same time. Table 2.2 presents some features and applications of the two analyses.

<table>
<thead>
<tr>
<th>Description</th>
<th>Influence line analysis</th>
<th>Influence surface analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applications</td>
<td>Bridge behaviors governed by main girders or 2-dimensional elevation analysis of bridge (steel box girder bridge, etc.)</td>
<td>Large variation of structural behaviors under moving loads in the transverse direction (slab bridge, rigid frame bridge, etc.)</td>
</tr>
<tr>
<td>Display of Influence analysis results</td>
<td>Influence line presented along the traffic lane elements (beam elements)</td>
<td>Influence surface presented on the traffic surface lane elements (plate elements)</td>
</tr>
<tr>
<td>Analysis components</td>
<td>Nodal displacements, support reactions, member forces</td>
<td>Nodal displacements, support reactions, member forces</td>
</tr>
<tr>
<td>Element types for analysis</td>
<td>Truss, beam, plate elements (For other elements, only their stiffness are contributed to analysis)</td>
<td>Truss, beam, plate elements (For other elements, only their stiffness are contributed to analysis)</td>
</tr>
<tr>
<td>Method of applying loads</td>
<td>Wheel loads and traffic lane concentrated loads Applied as a concentrated load on the traffic lane elements (beam elements)Applied as a concentrated load on the nodes constituting a traffic lane</td>
<td>Uniform traffic lane loads Applied as a uniform load on the traffic lane elements (beam elements)Applied as a pressure load on the traffic surface lane elements (plate elements)</td>
</tr>
</tbody>
</table>

*Table 2.2 Features and applications of influence line and influence surface analyses*
An influence line is calculated by applying a unit load (vertical load or torsional moment) along the traffic lane. Influence lines can be produced for nodal displacements, member forces and reactions of all nodes, truss, beam and plate elements, and supports included in the model.

An influence surface is calculated from the analysis in which a unit load (vertical load) is applied to the nodes constituting plate elements in a traffic surface lane.

Using the influence line or surface results, MIDAS/Civil calculates the maximum and minimum design values of nodal displacements, support reactions and member forces for truss, beam and plate elements based on AASHTO\(^1\), Caltrans\(^2\), AREA\(^3\) or user-defined vehicle live loads. In the case of beam elements, maximum and minimum axial forces and moments about strong and weak axes are produced along with the corresponding internal forces.

MIDAS/Civil applies vehicle loads considering all possible loading conditions including bi-directional traffic loading and eccentric torsional loading conditions for multiple traffic lanes and traffic surface lanes. It also considers individual impact factors for different spans. It then produces results for the most unfavorable loading condition (wheel loads, lane loads, etc.).

If elements other than truss, beam and plate elements (plane stress elements, solid elements, etc.) are included in the analysis model, their stiffnesses are utilized, but the member forces will not be produced. This limitation is imposed to reduce the data space and calculation time required for analysis. When vehicle loads are specified in an analysis, the same number of loading conditions equal to the number of loading points are generated in the program.

---

1. AASHTO, Standard Specifications for Highways Bridges, The American Association of State Highway and Transportation Officials, Inc in USA.
2. Caltrans, Bridges Design Specifications Manual, State of California, Department of Transportation in USA.
3. AREA, Manual for Railway Engineering, American Railway Engineering Association in USA.
The procedure for using the moving load analysis is as follows:

1. Model the structure by using (tapered) beam elements for traffic lanes or plate elements for traffic surface lanes.

2. Arrange traffic lanes or traffic surface lanes in the structural model considering the vehicle moving paths, number of design traffic lanes and traffic lane width.

3. Enter the vehicle loads to be applied to the traffic lanes or traffic surface lanes. The standard vehicle loads defined in AASHTO or other standard database can be used. Alternatively, user-defined wheel loads or traffic lane loads can be also specified.

4. Identify the traffic lanes or traffic surface lanes onto which the vehicle loads are to be applied, and enter the loading conditions as per the design requirements.

5. Define the locations of lane supports. The information is used to examine one of the requirements specified in various standards such as AASHTO which specifies “when the maximum negative moment due to traffic loads is calculated at a support in a continuous beam, the spans on each side of the support in question shall be loaded with the specified distributed load and a concentrated load equivalent to the sum of the distributed load at the most unfavorable location.”

6. Perform the analysis.

7. Combine the analysis results of the vehicle loading condition and other static or dynamic loading conditions.

If only influence line or influence surface analysis is of interest, only the first two steps need be considered. The step 5 above need not be considered if you choose not to consider the requirement.
Traffic Lane and Traffic Surface Lane

Bridge structures should be modeled such that the gravity direction is in the negative Z-direction in the Global Coordinate System (GCS).

Vehicle loads are applied to the traffic lanes or traffic surface lanes of a structure. Multiple traffic lanes or traffic surface lanes can be placed in the direction of the axis of a bridge, considering the number of design traffic lanes and design lane width as specified in the design standard. Traffic lanes are generally placed parallel with each other or traffic lane elements. Parallel placement of traffic lanes and traffic lane elements need not be always maintained such as at intersections where two or more roads are intersecting at a curved road intersection.

A single line of traffic lane elements can represent a bridge super-structure. Alternatively, if a grid model is used, longitudinal members can be modeled as lines of traffic lane elements. Plate elements may be used for modeling slab or rigid frame bridges as well.
Traffic Lane

A traffic lane is typically referred to as its centerline in MIDAS/Civil. A traffic lane defined in an influence line analysis is located on or at an offset to a line of prismatic/non-prismatic beam elements as shown in Figure 2.59. The line of beam elements being referenced to identify the traffic lane herein is defined as a line of traffic lane elements.

In a line of traffic lane elements, the i-th (N1) node of an element shall coincide with the j-th (or N2) node of the immediately preceding element. If coinciding the two nodes is not possible, a gap between two consecutive traffic lane elements in the direction of the traffic lane must be minimized as much as possible for the accuracy of analysis. For instance, if two or more concentrated axle loads are applied along a line of traffic lane elements, and if a gap between two consecutive traffic lane elements is farther apart than the longitudinal spacing between the axles, some concentrated loads cannot be included in analysis. However, gaps in the transverse or perpendicular direction of the traffic lane elements hardly affect the analysis results.

The ECS z-axis of a traffic lane element must be parallel or close to parallel with the GCS Z-axis, and the ECS x-axis cannot be placed parallel with the GCS Z-axis.

All the vehicle loads in an influence line analysis are applied to the centerlines of traffic lanes and then transferred to the traffic lane elements. If the locations of a traffic lane (centerline) and a traffic lane element coincide, only the unit vertical load is applied to the traffic lane elements along the traffic lane. Where a traffic lane (centerline) is transversely eccentric to a traffic lane element, a unit torsional moment is applied to the traffic lane element in addition to a unit vertical load.

An eccentricity is defined as the offset distance between a traffic lane (centerline) and a traffic lane element in the perpendicular (local y-axis) direction. The signs are determined on the basis of the signs of the torsional moments about its local x-axis resulting from the offset vertical loads. A (+) eccentricity is attributed to a positive torsional moment.

Eccentricities can be separately defined for each traffic lane element, and as such a traffic lane (centerline) can vary relative to the traffic lane elements along the line of traffic lane elements.

Once the traffic lanes (centerlines) are specified as shown in Figure 2.59, a unit vertical load and a unit torsional moment (if an eccentricity is specified) are applied to the traffic lane elements to obtain the influence line. For each traffic lane element, the unit point load and torsional moment are applied to the nodal ends and the quarter points of the element length. The unit load application
sequentially proceeds in the direction from i-th node to j-th node automatically in the program.

Since the accuracy of analysis results substantially depends on the distances between loading points, a fine division of elements is recommended where accuracy is of an essence.
Figure 2.59 Relationship between traffic lane (centerline), traffic lane element and eccentricity
Traffic Surface Lane

A traffic surface lane is used to define a vehicle-moving range in rigid frame or slab bridges where the effect of two-way distribution of moving loads is significant. It is composed of traffic surface lane elements and a line of traffic lane nodes. The traffic surface lane illustrated in Figure 2.60 is used for an influence surface analysis from which a vehicle moving load analysis can be performed.

An influence surface represents a selective component (displacement, reaction, member force, etc.) of analysis results shown at the points of unit load application on a plane surface. The unit load is applied to all the locations of possible loading points. An influence surface retains the same concept of an influence line except for the added dimension. Likewise, this is an important aspect of moving load analyses.

The definable loading ranges in MIDAS/Civil include traffic surface lanes on which vehicles travel and plate elements that the user additionally creates for influence surface analysis. MIDAS/Civil performs a series of static analyses by individually applying a vertical unit load to all the plate element nodes included in the range of influence surface. It then generates influence surfaces pertaining to various components (displacement, reaction and member force).

Traffic surface lane elements define the range of traffic surface lane on which vehicles travel. They are identified in the model by lane width, a line of traffic lane nodes and eccentricities. Duplicate data entries are permitted. For each node, an impact factor relative to the span length(s) can be entered, and distributed uniform pressure loads can be specified.

The line of traffic lane nodes and eccentricities constitute the moving line of concentrated vehicle loads. A positive eccentricity is defined if the centerline of a traffic surface lane is located to the right side of the line of traffic lane nodes relative to the axis of the bridge. The opposite holds true for a negative eccentricity. The nodes are sequentially entered in the direction of traffic. Using the traffic lane width and eccentricity, the line of traffic lane nodes becomes a reference line by which traffic surface lane is created.

In addition to the moment resulting from the distributed load, the additional negative moment required by the design specifications can be obtained by entering the elements contiguous to a support.
Once the traffic lanes or traffic surface lanes are entered, MIDAS/Civil generates the influence lines or influence surfaces for the following 5 design variables based on the process above:

1. Influence lines or influence surfaces of displacements for 6 d.o.f of all nodes in the GCS
2. Influence lines or influence surfaces of reactions for 6 d.o.f of each support in the GCS
3. Influence lines or influence surfaces for axial forces of all truss elements in the ECS
4. Influence lines or influence surfaces for 6 components of member forces of all beam elements (or tapered beam elements) in the ECS at the end nodes and quarter points (5 points)
5. Influence lines or influence surfaces for 8 components of member forces per unit length of all plate elements in the ECS

The above influence lines or influence surfaces are graphically displayed on the screen or printed out through the post-processing mode.

Using the influence lines or influence surfaces to calculate the structural response due to vehicle moving loads, MIDAS/Civil uses linear interpolation for zones between the points of load applications.
Moving Load Analysis for Bridge Structures

(a) Influence line for shear at point A

(b) Influence line for bending moment at point A

(c) Influence line for vertical displacement at point B

(d) Influence line for vertical reaction at support C

Figure 2.61 Influence lines for various components of a cable stayed bridge
(a) Influence surface for displacement ($D_z$) at the center node in left span

(b) Influence surface for reaction ($F_z$) at the center node on center pier
Influence surface for moment ($M_{xx}$) of center plate element in left span

Influence surface for shear ($V_{xx}$) of center plate element in left span

*Figure 2.62 Influence surfaces for various components of a rigid frame bridge*
Vehicle Moving Loads

MIDAS/Civil provides two ways for entering vehicle moving loads.

1. User-defined wheel loads and traffic lane loads
2. Standard vehicle loads as per AASHTO, Caltrans, AREA, etc.

The first method enables the user to directly define the design wheel loads and lane loads. In order to specify the wheel loads, the design concentrated wheel loads and the axle spacings are defined as shown in Figure 2.63. If the spacing between the last and the second last axles is not constant, the maximum and minimum values of the spacing are entered together at the last entry.

A design traffic lane load consists of a uniform load and concentrated lane loads whose locations are variable as presented in Figure 2.64. The concentrated traffic lane loads are composed of the loads PLM, PLV and PL. PLM and PLV are used to calculate the maximum and minimum moments and the maximum and minimum shear forces respectively. PL is applied to all the analysis results regardless of moments or shear forces. The distributed load is assumed to act over the entire length of the traffic lane. MIDAS/Civil adjusts the loading zones so that most unfavorable design results can be obtained among all possible conditions. Most design specifications do not stipulate simultaneous loading of vehicle wheel loads and uniform traffic lane load. Nevertheless, MIDAS/Civil permits simultaneous loading of these two types if the user so desires.

The second method enables us to use the standard vehicle loads defined in various standard specifications by simply selecting vehicle types from the built-in database contained in MIDAS/Civil. The built-in database is presented in Table 2.3 and the figures below.

<table>
<thead>
<tr>
<th>Specifications</th>
<th>Designation for standard vehicle loads</th>
</tr>
</thead>
<tbody>
<tr>
<td>AASHTO Standard</td>
<td>H15-44, HS15-44, H15-44L, HS15-44L</td>
</tr>
<tr>
<td></td>
<td>H20-44, HS20-44, H20-44L, HS20-44L, AML</td>
</tr>
<tr>
<td>AASHTO LRFD</td>
<td>HL93-TRK, HL93-TDM, HS20-FTG</td>
</tr>
<tr>
<td>Caltrans Standard</td>
<td>P5, P7, P9, P11, P13</td>
</tr>
<tr>
<td></td>
<td>Permit Load (user defined)</td>
</tr>
<tr>
<td>KS Standard Load (Specification for</td>
<td>DB-24, DB-18, DB-13.5, DL-24, DL-18,</td>
</tr>
<tr>
<td>Roadway Bridges)</td>
<td>DL-13.5</td>
</tr>
</tbody>
</table>

Table 2.3 Types of standard vehicle loads
$n_{\text{max}} = 20$

$P^\#$: Concentrated wheel load

For influence line

For influence surface

Figure 2.63 Definition of concentrated wheel loads

Figure 2.64 Definition of design traffic lane loads
Figure 2.65 DB and DL loads of KS Specifications for Roadway Bridges
Figure 2.66. HS Vehicle Loads of AASHTO Standard and Alternative Military Load
Figure 2.67 Caltrans Standard Permit Loads
Moving Load Analysis for Bridge Structures

(a) Standard train loads (L load)

(b) Standard train load (S load)

(c) HL standard train load (high speed train)

Figure 2.68 KS train loads
Figure 2.69 Other train loads

Figure 2.70 illustrates a permit vehicle, which can be used to represent a special purpose vehicle usually used to transport a heavy, wide and long payload (super load). The center of the permit vehicle is defined relative to the center of an adjacent lane. The direction of the permit vehicle in Figure 2.70 is from right to left, and the Eccentricity from the Center of the Reference Lane is to the right (positive). The user can define up to 100 axles and the locations of the corresponding wheels. A permit vehicle can be loaded using Moving Load Case.

Along the lines of wheels based on the gages of axles, influence lines are internally generated for each wheel line. All the wheel loads are applied in the direction of travel on the basis of the influence lines, thereby resulting in maximum and minimum values for the moving load case. All the wheels carrying a permit vehicle are assumed active at all times. Unlike the standard vehicle loads, unloading certain axle loads based on the signs of influence lines does not occur.
Once the design traffic loads are specified as described above, they are applied in the negative direction of the GCS Z-axis. The maximum and minimum design values such as nodal displacements, reactions and member forces are produced for the specified moving loads using the influence line or influence surface already generated.

The concept of calculating the design variables by using the influence line or influence surface is as follows:

In order to calculate a design variable at a particular location under the influence of a concentrated vehicle load, the value of the corresponding influence line or influence surface is multiplied by the concentrated vehicle load. In the case of a uniform load, the maximum and minimum design variables at a given location are found by multiplying the integrated values of the influence line or influence surface for positive and negative zones by the distributed vehicle load (See Figure 2.71).

Upon defining supports for a distributed load, additional concentrated loads in the magnitudes equivalent to the distributed loads on two spans at the most unfavorable locations must be simultaneously applied. This is a requirement to obtain the maximum negative moment at a support typically stipulated in design standards such as AASHTO (See Figure 2.72).
(a) Calculation of maximum/minimum moments due to a concentrated vehicle load ($P$)

maximum positive moment at point $A = P \times I_{\text{max}}$

maximum negative moment at point $A = P \times I_{\text{min}}$

(b) Calculation of maximum/minimum moments due to a distributed lane load ($W$)

maximum positive moment at point $B = W \times (A_2 + A_3)$

maximum negative moment at point $B = W \times (A_1 + A_4)$

Figure 2.71 Calculation of maximum/minimum design variables due to concentrated and distributed loads
If the wheel spacing (axle gage) is to be reflected in moving load analysis, Wheel Spacing needs to be defined while defining traffic lanes. If Wheel Spacing is defined, influence lines are generated along the wheel lines as shown in Figure 2.73, and each individual wheel loads are separately applied in the analysis. If Wheel Spacing is zero, a single influence line along the center of a vehicle is used. In the dialog boxes for defining traffic lanes, the default value for Wheel Spacing automatically changes according to the Moving Load Code.
MIDAS/Civil provides 3 ways of applying multiple axle loads for effective analysis process.

1. In the first method, individual concentrated loads forming the multiple axle concentrated loads are sequentially applied to every point of loading application along the traffic lane. When a concentrated load is applied at a point of loading application, those remaining concentrated loads that do not fall on the points of loading application are calculated on the basis of linear interpolation of the influence line or influence surface. The results obtained through this method are as accurate as the given influence line or influence surface. Since all the concentrated loads are applied to all the points of loading application, excessive analysis time is its drawback. This method is denoted as ‘E’ (Exact) in the manual (See Figure 2.747).

2. The second method is basically identical to the first method except that the concentrated loads are applied at the locations of maximum and minimum values in the influence line or influence surface. This method is denoted as ‘Q’ (Quick) in the manual (See Figure 2.75).

3. The third method is also similar to the first method except that a reference concentrated axle load is defined. In this method, only the reference concentrated axle load is applied to the points of loading application. The reference axle is defined as the axle closest to the center of the vehicle load. This method is denoted as ‘P’ (Pivot) in the manual (See Figure 2.76).

It is recommended that Method 2 be used for preliminary design, and Methods 1 and 3 be used for final design.

When a group of two or more concentrated loads are applied as a moving load condition, bi-directional effects must be considered. Multiple axle loads are not generally symmetrical and thus result in different structural responses depending on the direction of the moving loads.
A moving vehicle load composed of two axle loads ① & ②

Stage 1
- Axle load ① applied to the starting point of load application
- Axle load ② applied to the starting point

Stage 2
- Axle load ① applied between the starting point and the 2nd point of loading application
- Axle load ② applied to the starting point

Stage 3
- Axle load ① applied between the 2nd & 3rd points of loading application
- Axle load ② applied to the 2nd point of loading application

Stage 4
- Axle load ① applied to the end point

Last stage

Figure 2.74 Concept of applying concentrated loads as per ‘E’ (Exact) Method
A moving vehicle load composed of two axle loads ① & ②

Stage 1

Axle load ① applied to the location of maximum positive moment
Axle load ② applied next to the location of maximum positive moment

Stage 2

Axle load ② applied to the location of maximum positive moment
Axle load ① applied next to the location of maximum positive moment

Stage 3

Axle load ① applied to the location of maximum negative moment
Axle load ② applied next to the location of maximum negative moment

Stage 4

Axle load ② applied to the location of maximum negative moment
Axle load ① applied next to the location of maximum negative moment

Figure 2.75 Concept of applying concentrated loads as per ‘Q’ (Quick) Method
A moving vehicle load composed of two axle loads ① & ② if axle load ② is reference axle

Stage 1

Stage 2

Stage 3

Stage 4

Figure 2.76 Concept of applying concentrated loads as per ‘P’ (Pivot) Method
Vehicle Load Loading Conditions

To find the most critical design parameters (member forces, displacements and support reactions) in the analysis of a bridge structure, all the conditions of vehicle loads must be considered. Especially, when a number of design vehicle load groups and traffic lanes are involved, all the conditions that may affect the design parameters must be examined: a) whether or not the design vehicle load groups are simultaneously loaded; b) if only the worst-case design vehicle load group is to be applied among the load groups; c) if a specific lane is selected for loading the design vehicle load groups; and d) what load reduction factor is to be applied if a number of traffic lanes are loaded.

Considering the design conditions noted above, MIDAS/Civil produces the maximum and minimum design parameters for all possible cases through permutations.

MIDAS/Civil requires the following data to generate the maximum and minimum design parameters:

Vehicle load classes and loaded traffic lane numbers

Maximum and minimum numbers of traffic lanes that can be loaded simultaneously

- Multi-lane scale factors (load reduction factors for loading multiple lanes simultaneously)
- Specific input method is used for Permit Load

Figure 2.77 Bridge structure model
The following are examples illustrating the concept of generating loading combinations for moving loads:

**Example 1.** Analysis of a bridge with 4-traffic lanes under AASHTO HS20-44 truck and lane loads

1. Enter the traffic line lanes (centerlines of traffic lanes).
   From the Main Menu, select *Load>Moving Load Analysis Data>Traffic Line Lanes* to display the *Define Design Traffic Line Lanes* dialog box as shown in Figure 2.78 (a). Click **Add** to define a new traffic line lane in the dialog box shown in Figure 2.78 (b). Enter the lane name in the Lane Name entry field, select the beam elements and then define the lane by entering the eccentricities and impact factors.

![Figure 2.78 Define Design Traffic Line Lanes dialog box](image-url)
2. Enter the vehicle loads.

From the Main Menu, select *Load>Moving Load Analysis Data>Vehicles* and click *Add Standard* to choose the desired standard and load (AASHTO Standard Load is used here).

![Vehicle Load Definition](image)

*Figure 2.79 Definition of vehicular loads*

To consider the more critical condition between HS20-44 and HS20-44L, the same vehicle load group, Class 1, is used as shown in Figure 2.80.
3. Enter the method of applying the moving load. From the Main Menu, select Analysis > Moving Load Analysis Control to choose ‘Exact’ and define the load application method.

![Figure 2.80 Vehicle load class input](image1)

**Figure 2.80 Vehicle load class input**

![Figure 2.81 Definition of load application method](image2)

**Figure 2.81 Definition of load application method**
4. Enter the multi-lane scale factors for lanes loaded concurrently. Specify the load reduction factors for multi-lanes from 1 lane to 4 lanes as shown in Figure 2.82 below.

![Figure 2.82 Multi-lane scale factors for lanes loaded concurrently](image)

**Figure 2.82** Multi-lane scale factors for lanes loaded concurrently
Define the vehicle load cases by specifying the vehicle load classes (groups), loaded lanes and the maximum/minimum number of the loaded lanes as shown in Figure 2.83.

![Vehicle loading case identifying vehicle load class and traffic lanes](image)

From the above design conditions, the maximum and minimum design parameters are obtained from the most critical values of the total 15 loading conditions, which are automatically generated using permutations as shown in Table 2.4.
### Table 2.4 Load conditions in Example 1 (AASHTO)

<table>
<thead>
<tr>
<th>Combination Number</th>
<th>Loaded traffic line lane number</th>
<th>Multi-lane scale factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>HS20-44 or HS20-44L</td>
<td>1.0</td>
</tr>
<tr>
<td>2</td>
<td>HS20-44 or HS20-44L</td>
<td>1.0</td>
</tr>
<tr>
<td>3</td>
<td>HS20-44 or HS20-44L</td>
<td>1.0</td>
</tr>
<tr>
<td>4</td>
<td>HS20-44 or HS20-44L</td>
<td>1.0</td>
</tr>
<tr>
<td>5</td>
<td>HS20-44 or HS20-44L</td>
<td>1.0</td>
</tr>
<tr>
<td>6</td>
<td>HS20-44 or HS20-44L</td>
<td>1.0</td>
</tr>
<tr>
<td>7</td>
<td>HS20-44 or HS20-44L</td>
<td>1.0</td>
</tr>
<tr>
<td>8</td>
<td>HS20-44 or HS20-44L</td>
<td>1.0</td>
</tr>
<tr>
<td>9</td>
<td>HS20-44 or HS20-44L</td>
<td>1.0</td>
</tr>
<tr>
<td>10</td>
<td>HS20-44 or HS20-44L</td>
<td>1.0</td>
</tr>
<tr>
<td>11</td>
<td>HS20-44 or HS20-44L</td>
<td>0.9</td>
</tr>
<tr>
<td>12</td>
<td>HS20-44 or HS20-44L</td>
<td>0.9</td>
</tr>
<tr>
<td>13</td>
<td>HS20-44 or HS20-44L</td>
<td>0.9</td>
</tr>
<tr>
<td>14</td>
<td>HS20-44 or HS20-44L</td>
<td>0.9</td>
</tr>
<tr>
<td>15</td>
<td>HS20-44 or HS20-44L</td>
<td>0.75</td>
</tr>
</tbody>
</table>

"HS20-44 or HS20-44L" indicates that CIVIL produces more critical maximum/minimum design parameters of the two loading conditions.
Example 2. Using the model of Example 1, a bridge analysis is performed for the P13 load applied to a lane and the HS vehicle load of the AASHTO applied to one of the remaining lanes, as specified in Caltrans Combination Group Ipw.

1. Define the traffic line lanes (centerlines of traffic lanes) relative to the traffic lane elements as in Example 1.

2. As shown in Figure 2.84, enter the vehicle loads and classify them into Class 1 (HS20-44, HS20-44L) and Class 2 (P13).

3. Use the load application method “Exact” as in Example 1.

4. Define the vehicle load cases by specifying the vehicle load classes (groups), loaded lanes and the maximum/minimum number of loaded lanes as shown in Figure 2.85.

Refer to "Load> Moving Load Analysis Data>Moving Load Cases" of On-line Manual.
Caltrans Combination Group Ipw specifies that the P13 load be loaded on a lane and the HS load be loaded on one of the remaining lanes. It also specifies that the cases without considering the HS load be also examined. Accordingly, the HS and P13 loads are separated into Classes 1 and 2 in Step 2. Also, the minimum and maximum numbers of loaded lanes are specified as 0 and 1 for the HS load and 1 and 1 for the P13 load respectively in Step 4.

From the above design conditions, a total of 16 loading conditions are automatically generated using permutations as shown in Table 2.5.
When a moving load case is created for a special purpose permit vehicle, data entry specific to the characteristics of the load is required. The following process is adopted in MIDAS/Civil for defining a load case using a permit vehicle. In order to account for irregular axle spacing and gages with varying numbers of axles, the load conditions must be accurately specified. The table below illustrates the load conditions for a permit vehicle using the Caltrans Combination Group Ipw.

### Table 2.5 Load conditions in Example 2 (Caltrans Combination Group Ipw)

<table>
<thead>
<tr>
<th>Combination number</th>
<th>Loaded traffic line lane number</th>
<th>Multi-lane scale factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>P13</td>
<td>1.0</td>
</tr>
<tr>
<td>2</td>
<td>P13</td>
<td>1.0</td>
</tr>
<tr>
<td>3</td>
<td>P13</td>
<td>1.0</td>
</tr>
<tr>
<td>4</td>
<td>P13</td>
<td>1.0</td>
</tr>
<tr>
<td>5</td>
<td>P13</td>
<td>HS20-44 or HS20-44L</td>
</tr>
<tr>
<td>6</td>
<td>P13</td>
<td>HS20-44 or HS20-44L</td>
</tr>
<tr>
<td>7</td>
<td>P13</td>
<td>HS20-44 or HS20-44L</td>
</tr>
<tr>
<td>8</td>
<td>HS20-44 or HS20-44L</td>
<td>P13</td>
</tr>
<tr>
<td>9</td>
<td>P13</td>
<td>HS20-44 or HS20-44L</td>
</tr>
<tr>
<td>10</td>
<td>P13</td>
<td>HS20-44 or HS20-44L</td>
</tr>
<tr>
<td>11</td>
<td>HS20-44 or HS20-44L</td>
<td>P13</td>
</tr>
<tr>
<td>12</td>
<td>HS20-44 or HS20-44L</td>
<td>P13</td>
</tr>
<tr>
<td>13</td>
<td>P13</td>
<td>HS20-44 or HS20-44L</td>
</tr>
<tr>
<td>14</td>
<td>HS20-44 or HS20-44L</td>
<td>P13</td>
</tr>
<tr>
<td>15</td>
<td>HS20-44 or HS20-44L</td>
<td>P13</td>
</tr>
<tr>
<td>16</td>
<td>HS20-44 or HS20-44L</td>
<td>P13</td>
</tr>
</tbody>
</table>
axles and wheels for each axle, independent influence lines are required and automatically generated for each longitudinal wheel line. Because of such multiple influence lines for a single permit vehicle, the vehicle and the center of the vehicle must correspond to a particular moving load case. As such if a permit vehicle is to be loaded along the bridge in question at different transverse positions, additional moving load cases corresponding to the transverse positions need to be created. A permit vehicle and standard vehicles can not be used together in a single moving load case. If a permit vehicle and standard vehicles need to be placed on the bridge simultaneously, a load case for the permit load and a load case for the standard vehicles need to be created, and their results are subsequently combined. Because a permit vehicle is defined on the basis of a specific vehicle, its loading is not affected by the signs of influence lines for the wheel lines. For loading a permit vehicle, the Exact method in Figure 2.86 is used.

![Figure 2.86 Data input for Moving load case using Permit Vehicle](image)

*Figure 2.86 Data input for Moving load case using Permit Vehicle*