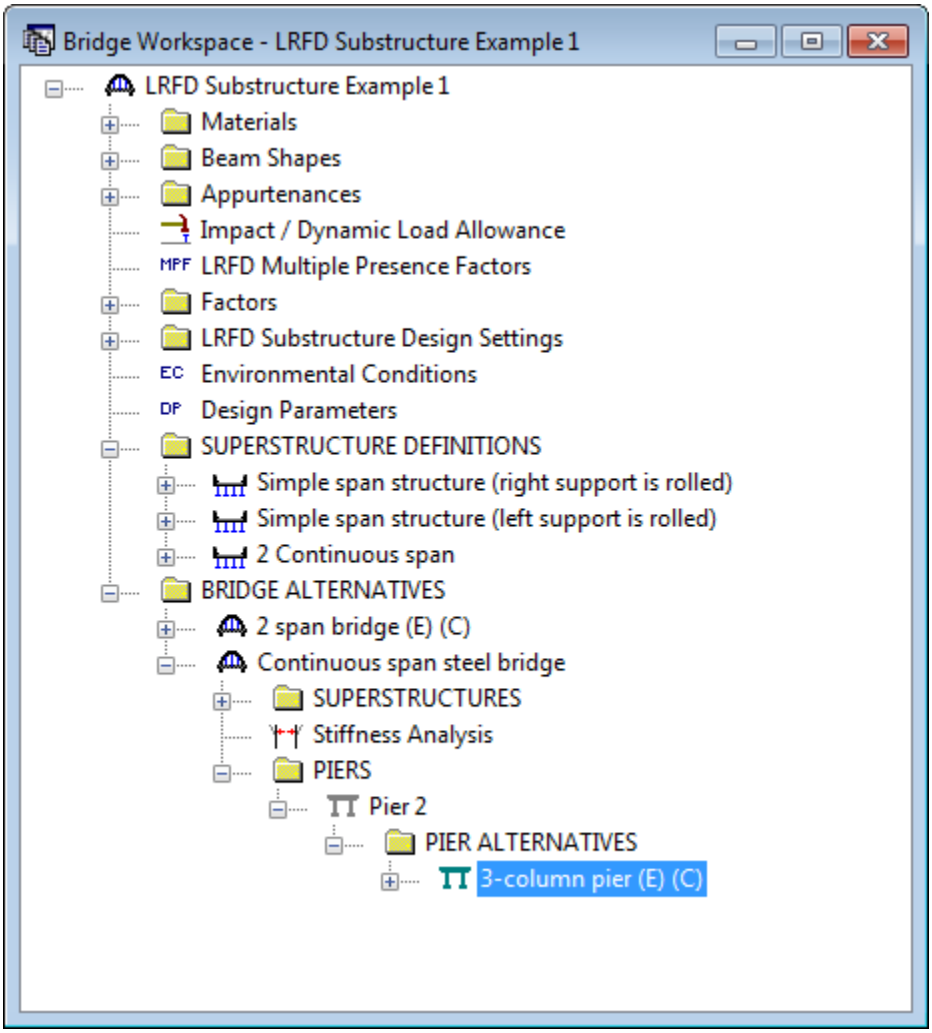
Topics Covered

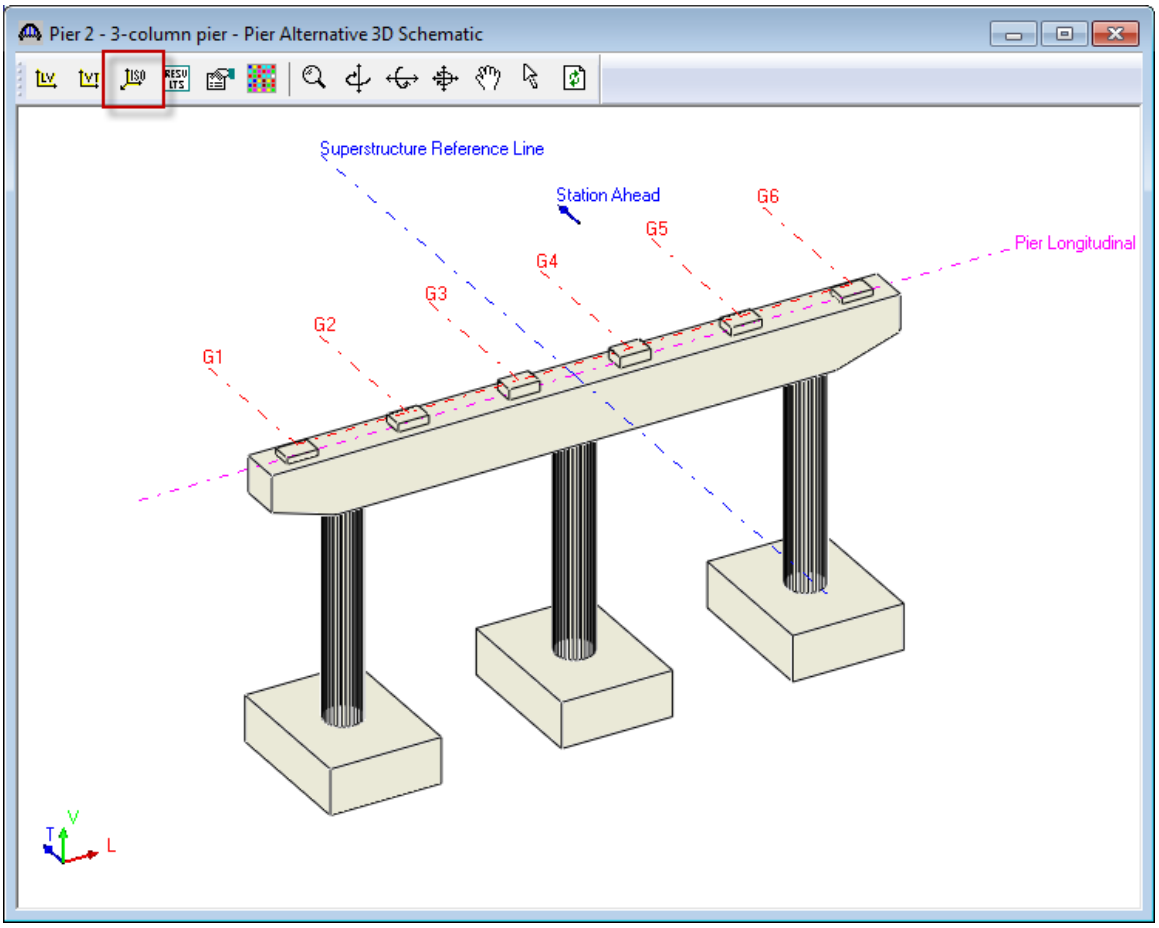
- 3 column frame pier
- Moment magnification analysis

This example uses the pier in BID 20, LRFD Substructure Example 1 in the sample database. Expand the Bridge Workspace tree to show the pier alternative.

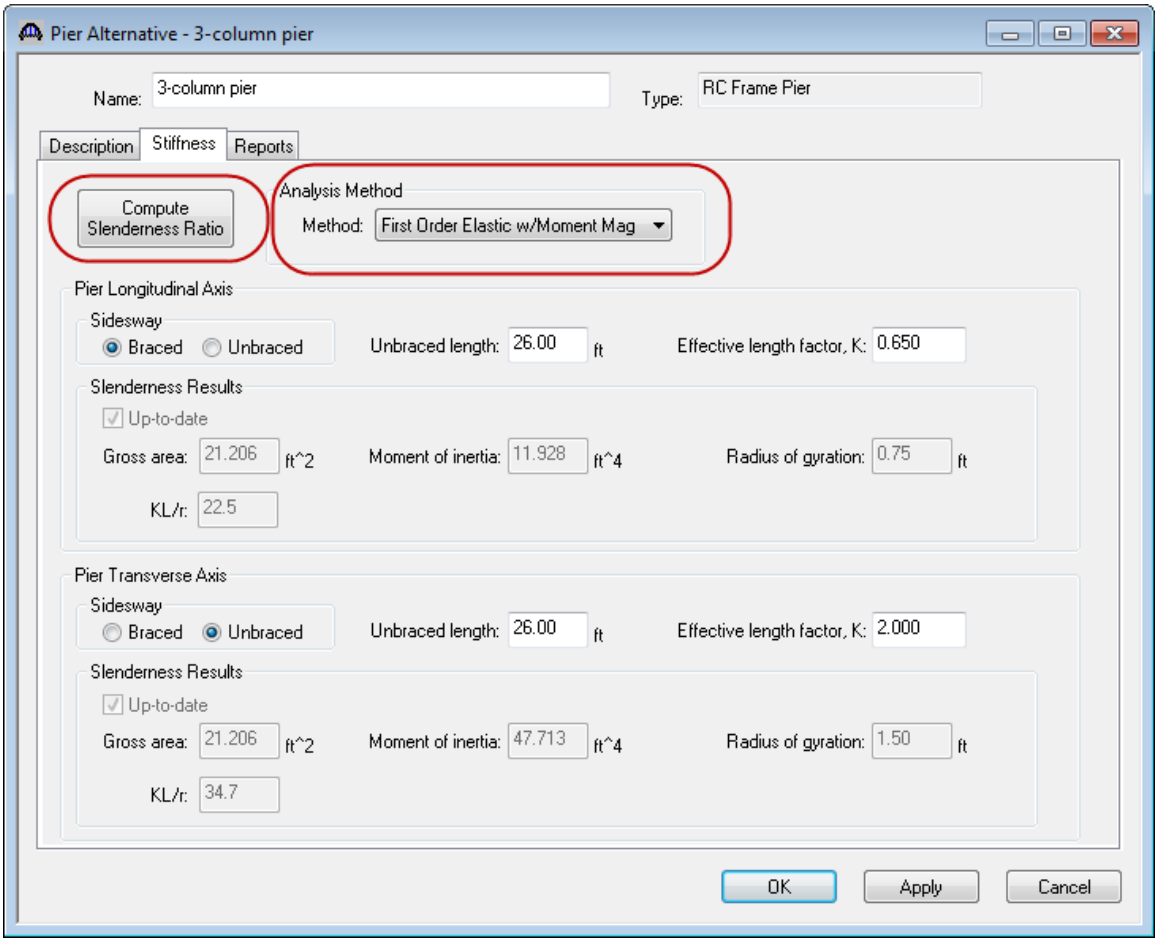


Click on the 3D Schematic button in the button bar.

The isometric schematic of this pier is shown below after pressing the iso button:



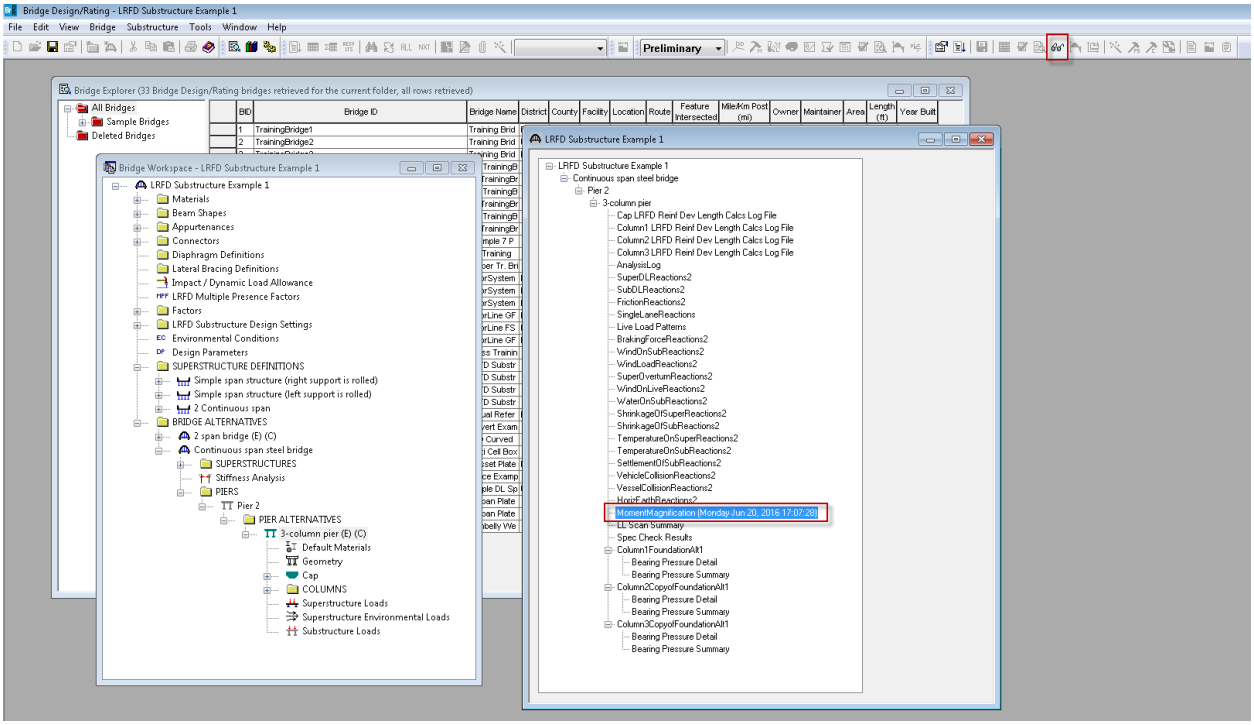
Open the Pier Alternative: Stiffness tab. Click the 'Compute Slenderness Ratio' button and BrD will compute the Kl/r ratios that you can use to determine the effect of slenderness as per AASHTO LRFD Article 5.7.4.3.



In this example, we should consider moment magnification to account for the effects of slenderness. Launch a spec check of the pier from the Substructure toolbar.

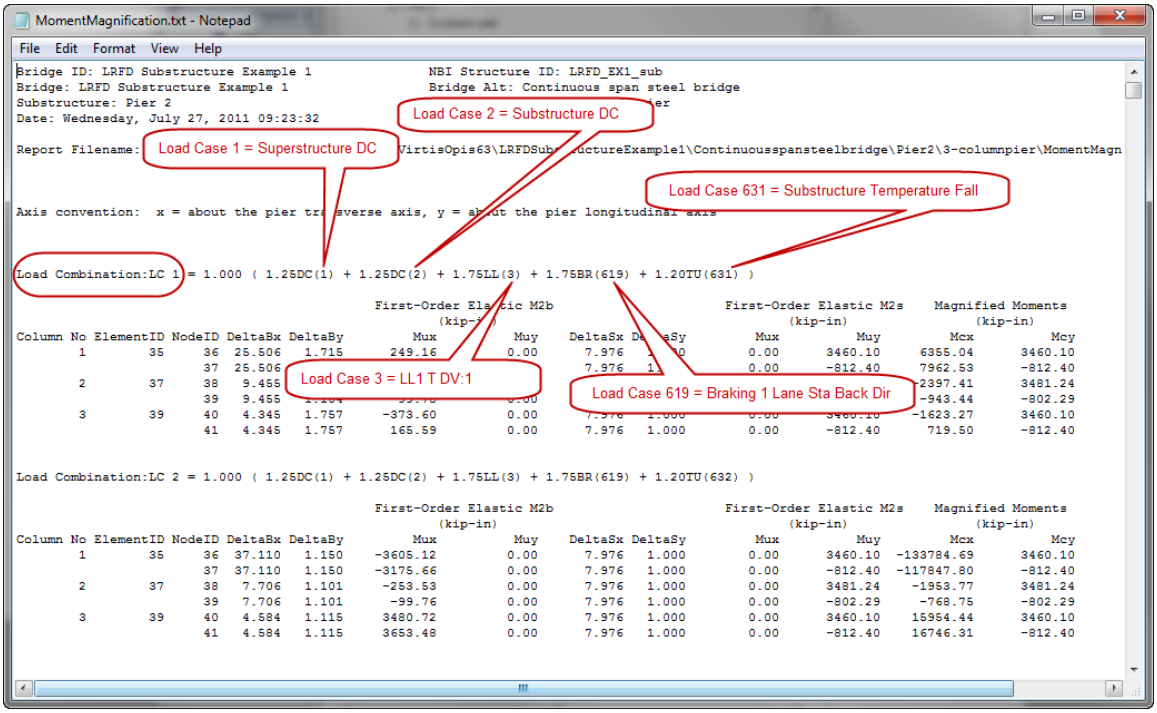
The program will first compute the elastic moments on the pier, then compute moment magnification factors and then compute the magnified moments. The magnified moments are then used in specification articles.

A report showing the moment magnification calculations can be found in the Analysis Output window.

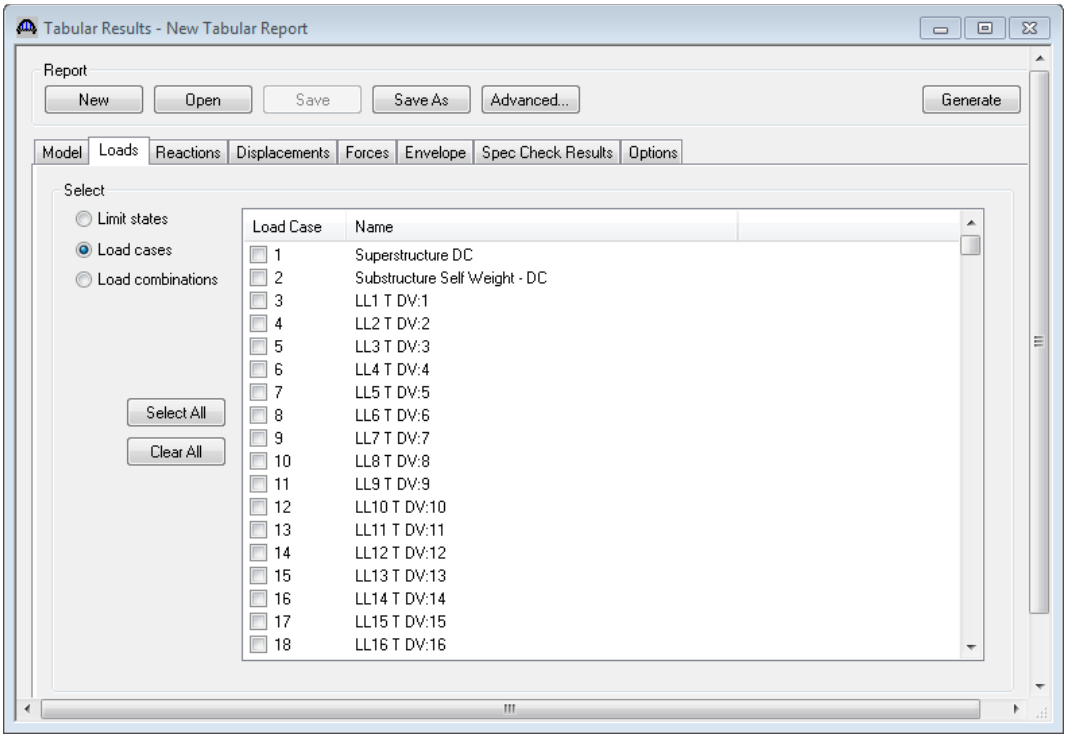


This report contains the elastic moments, the moment magnification factors and the resulting magnified moments for each load combination.

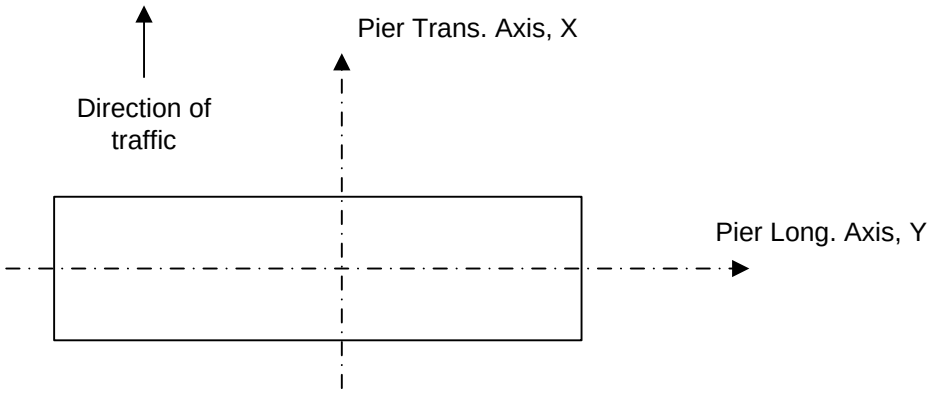
Load Combination 1 is composed of the following load cases.



The load case descriptions can be found in the Tabular Results window for the Pier Alternative. First press on the "New" button, and then click on the "Load Cases" radio button. By scrolling down the window, the many load cases can be reviewed.



The following axis convention is used:



Plan View of Column

MomentMagnification.txt - Notepad

File Edit Format View Help

```
Bridge ID: LRFD Substructure Example 1              NBI Structure ID: LRFD_EX1_sub
Bridge: LRFD Substructure Example 1                 Bridge Alt: Continuous span steel bridge
Substructure: Pier 2                                Substructure Alt: 3-column pier
Date: Wednesday, July 27, 2011 09:23:32

Report Filename: C:\ProgramData\beta                tructur                    umnpier\MomentMagn
```

M2b: Elastic moment due to loads that don't cause sidesway. DL, LL, Substructure TU & SH

M2s: Elastic moment due to loads that do cause sidesway. Braking, Wind, Water, Superstructure TU & SH

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Axis convention:  x = about the pier transverse axis, y = ab    the pier longitudinal axis


Load Combination:LC 1 = 1.000 ( 1.25DC(1) + 1.25DC(2) + 1.75    (3) + 1.75BR(619) + 1.20TU(631) )

                                    First-Order Elastic M2b                    First-Order Elastic M2s    Magnified Moments
                                             (kip-in)                                  (kip-in)              (kip-in)
Column No ElementID NodeID DeltaBx DeltaBy       Mux         Muy    DeltaSx DeltaSy       Mux         Muy         Mcx         Mcy
       1        35     36  25.506   1.715    249.16        0.00      7.976   1.000      0.00     3460.10     6355.04     3460.10
                      37  25.506   1.715    312.18        0.00      7.976   1.000      0.00     -812.40     7962.53     -812.40
       2        37     38   9.455   1.104   -253.55        0.00      7.976   1.000      0.00     3481.24    -2397.41     3481.24
                      39   9.455   1.104    -99.78        0.00      7.976   1.000      0.00     -802.29     -943.44     -802.29
       3        39     40   4.345   1.757   -373.60        0.00      7.976   1.000      0.00     3460.10    -1623.27     3460.10
                      41   4.345   1.757    165.59        0.00      7.976   1.000      0.00     -812.40      719.50     -812.40


Load Combination:LC 2 = 1.000 ( 1.25DC(1) + 1.25DC(2) + 1.75LL(3) + 1.75BR(619) + 1.20TU(632) )

                                    First-Order Elastic M2b                    First-Order Elastic M2s    Magnified Moments
                                             (kip-in)                                  (kip-in)              (kip-in)
Column No ElementID NodeID DeltaBx DeltaBy       Mux         Muy    DeltaSx DeltaSy       Mux         Muy         Mcx         Mcy
       1        35     36  37.110   1.150  -3605.12        0.00      7.976   1.000      0.00     3460.10  -133784.69     3460.10
                      37  37.110   1.150  -3175.66        0.00      7.976   1.000      0.00     -812.40  -117847.80     -812.40
       2        37     38   7.706   1.101   -253.53        0.00      7.976   1.000      0.00     3481.24    -1953.77     3481.24
                      39   7.706   1.101    -99.76        0.00      7.976   1.000      0.00     -802.29     -768.75     -802.29
       3        39     40   4.584   1.115   3480.72        0.00      7.976   1.000      0.00     3460.10    15954.44     3460.10
                      41   4.584   1.115   3653.48        0.00      7.976   1.000      0.00     -812.40    16746.31     -812.40
```

Deltabx and deltaby are computed based on the braced/unbraced selections the user makes on the Pier Alternative:Stiffness tab.

The magnified moments, Mcx and Mcy, are then used in the specification checks.

The following is a detailed description of the moment magnification process excerpted from the BrD Substructure Method of Solution manual:

First-Order Elastic Analysis using Moment-Magnification

Moment magnification takes into account the effects of deflection on force effects by using the approximate moment magnification adjustment method presented in AASHTO Article 4.5.3.2.2b. This method can be used for members with $K\ell_u/r$ less than 100.

$$M_c = \delta_b M_{2b} + \delta_s M_{2s} \qquad (4.5.3.2.2b\text{-}1)$$

M2b is the moment on compression member due to factored gravity loads that result in no appreciable sidesway calculated by conventional first-order elastic analysis. BrD substructure will assume that the following loads contribute to the M2b moment: DL of Superstructure, DL of Substructure, LL, Substructure Temperature, Substructure Shrinkage.

M2s is the moment on compression member due to factored lateral or gravity loads that results in sidesway, Δ, greater than lu/1500, calculated by conventional first-order elastic frame analysis. BrD substructure will assume that the following loads contribute to the M2s moment: Wind on Superstructure, Wind on Substructure, Water loads, Superstructure Temperature, Superstructure Shrinkage. The deflection produced by these loads will not be checked against the lu/1500 limit.

Moment magnification factors will be computed for both the longitudinal and transverse axes of the columns at each point of interest in the columns. Since the moment magnification factors are load dependent, they are computed for each load combination.

Article 4.5.3.2.2b gives equations to determine magnification factors, δ_b and δ_s. This article further states that δ_s shall be taken as 1.0 for members braced against sidesway.

The following equation is given for δ_b:

$$\delta_b = \frac{C_m}{1 - \frac{P_u}{\phi K P_e}} \geq 1.0 \qquad (4.5.3.2.2b\text{-}3)$$

φKis the stiffness reduction factor equal to 0.75 for concrete.

Article 4.5.3.2.2b gives an equation for C_m for members braced against sidesway and without transverse loads betweens supports. For all other cases, C_m shall be taken as 1.0. Since the columns on a pier typically experience transverse loads, BrD Substructure will assume Cm is 1.0.

The following equation is given for δs:

$$\delta_s = \frac{1}{1 - \frac{\sum P_u}{\phi_K \sum P_e}} \qquad (4.5.3.2.2b-4)$$

P_e is the Euler buckling load for the column. It is taken as:

$$P_e = \frac{\pi^2 EI}{(Kl_u)^2} \qquad (4.5.3.2.2b\text{-}5)$$

For concrete compression members, Article 5.7.4.3 also applies. That article specifies that the EI to use in the Euler buckling load computation shall be the larger of:

$$EI = \frac{\frac{E_c I_g}{5} + E_s I_s}{1 + \beta_d} \qquad (5.7.4.3\text{-}1)$$

$$EI = \frac{\frac{E_c I_g}{2.5}}{1 + \beta_d} \qquad (5.7.4.3\text{-}2)$$

For columns that do not have a constant cross section over their length, a weighted average EI will be computed. BrD does not include the reinforcement in the computation of EI.

β_d is the ratio of maximum factored permanent load moments to maximum factored total load moment, always positive. This value will be computed at each point of interest by dividing the factored moment due to dead loads by the total factored moment at that point.

In this analysis, the order of load application does not affect the analysis results. Superposition can be used to determine the force effects due to the load combinations. The computation and application of the moment magnification factors occurs during the computation of the LRFD combinations within the substructure module.