PENNDOT e-Notification

Bureau of Design
Engineering Computing Management Division

PENNDOT

BRADD No. 003 March 18, 2005	**Seismic Shear Force Calculation Error**

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The calculation of the Seismic Shear Force in BRADD is incorrect, as is the documentation of this calculation shown in the BRADD User Manual Section 3.4.2.

Based on limited testing, it appears that the calculated seismic shear force is very conservatively overestimated at the expansion end, but is underestimated and thus not conservative at the fixed end.

BRADD will be corrected for this problem as a part of the next release of BRADD, currently scheduled for summer 2005.

The correction for this problem will be made as per the revised Section 3.4.2 of the BRADD Users Manual documented on the following pages.

Please direct any questions to:

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3.4.2 Seismic Forces

3.4.2.1 Theoretical Design Criteria

For single span bridges, seismic forces are those shear forces used to design the dowels, anchor bolts, shear blocks, and cheek walls.

A combination of orthogonal seismic shear forces is used to account for the directional uncertainty of earthquake motions and the simultaneous occurrence of earthquake forces in two perpendicular directions. The perpendicular axes are the longitudinal and transverse axes of the bridge. For curved bridges, the longitudinal axis is a chord connecting the two abutments.

The orthogonal seismic shear forces along the longitudinal and transverse axes of the bridge at each abutment (fixed and expansion) are calculated as follows:

Fixed End

$$LSFL = AC * SC * TSSDL$$
$$LSFT = 0.0$$

$$TSFL = 0.0$$
$$TSFT = \frac{AC * SC * TSSDL}{2}$$

BRADD

No. 003

March 18, 2005

Seismic Shear Force Calculation Error

NO LONGER APPLICABLE - RESOLVED BY BRADD v3.1.1.0

For bridges in seismic zone I (as per LRFD Specifications Article 3.10.9.2), the force in the restrained directions shall not be less than 10 or 20 percent of the vertical reaction due to the tributary permanent load and the tributary live loads assumed to exist during an earthquake. As per DM-4 Article 3.4.1, $Y_{eq} = 0.0$, thus live load is not used in the Extreme Event I limit state.

If seismic zone I:

When AC < 0.025 and Soil Type I or Soil Type II:

$$LSFL = MAX((AC * SC * TSSDL),(0.1 * TSSDL))$$
$$LSFT = 0.0$$

$$TSFL = 0.0$$
$$TSFT = MAX\left(\left(\frac{AC * SC * TSSDL}{2}\right),\left(\frac{0.1 * TSSDL}{2}\right)\right)$$

Otherwise:

$$LSFL = MAX((AC * SC * TSSDL),(0.2 * TSSDL))$$
$$LSFT = 0.0$$

$$TSFL = 0.0$$
$$TSFT = MAX\left(\left(\frac{AC * SC * TSSDL}{2}\right),\left(\frac{0.2 * TSSDL}{2}\right)\right)$$

NO LONGER APPLICABLE - RESOLVED BY BRADD v3.1.1.0

<u>Expansion End</u>

$$LSFL = 0.0$$
$$LSFT = 0.0$$

$$TSFL = 0.0$$
$$TSFT = \frac{AC * SC * TSSDL}{2}$$

For bridges in seismic zone I (as per LRFD Specifications Article 3.10.9.2),), the force in the restrained directions shall not be less than 10 or 20 percent of the vertical reaction due to the tributary permanent load and the tributary live loads assumed to exist during an earthquake. As per DM-4 Article 3.4.1, Y_{eq} = 0.0, thus live load is not used in the Extreme Event I limit state.

If seismic zone I:

When AC < 0.025 and Soil Type I or Soil Type II:

$$LSFL = 0.0$$
$$LSFT = 0.0$$

$$TSFL = 0.0$$
$$TSFT = MAX\left(\left(\frac{AC * SC * TSSDL}{2}\right), \left(\frac{0.1 * TSSDL}{2}\right)\right)$$

Otherwise:

Seismic Shear Force Calculation Error

NO LONGER APPLICABLE - RESOLVED BY BRADD v3.1.1.0

$$LSFL = 0.0$$
$$LSFT = 0.0$$

$$TSFL = 0.0$$
$$TSFT = MAX\left(\left(\frac{AC * SC * TSSDL}{2}\right), \left(\frac{0.2 * TSSDL}{2}\right)\right)$$

where:

LSFL	= Longitudinal Seismic Shear Force based on an earthquake whose motion is along the longitudinal axis of the bridge
LSFT	= Transverse Seismic Shear Force based on an earthquake whose motion is along the longitudinal axis of the bridge
TSFL	= Longitudinal Seismic Shear Force based on an earthquake whose motion is along the transverse axis of the bridge
TSFT	= Transverse Seismic Shear Force based on an earthquake whose motion is along the transverse axis of the bridge
AC	= Acceleration Coefficient (0.15 for Zone 2; 0.09 or 0.05 for Zone 1; as per DM–4 Article 3.10.2)
SC	= Site coefficient (As per LRFD Specifications, Articles 3.10.9.1 and 3.10.5.1)
TSSDL	= Total Span Superstructure Dead Load (all dead loads applied to the superstructure, including future wearing surface) (kip (kN))
R	= Response Modification Factor, 1.0 (as per DM–4 Article 3.10.7.1, the response modification factor should not be applied to simple span structures. Therefore BRADD sets this value to 1.0)

BRADD
No. 003
March 18, 2005

Seismic Shear Force Calculation Error

NO LONGER APPLICABLE - RESOLVED BY BRADD v3.1.1.0

Longitudinal Seismic Shear Forces are forces acting along the longitudinal axis of the bridge, and Transverse Seismic Shear Forces are forces acting along the transverse axis of the bridge.

In order to combine these orthogonal seismic shear forces, the above components must be combined into two load cases, as per Article 3.10.8 of the LRFD Specifications. The equations for determining these load cases are as follows:

Fixed End

Load Case #1

$$
\begin{aligned}
LSF &= LSFL + (0.3 * TSFL) \\
&= LSFL
\end{aligned}
$$

$$
\begin{aligned}
TSF &= LSFT + (0.3 * TSFT) \\
&= 0.3 * TSFT \\
&= 0.15 * LSFL
\end{aligned}
$$

Load Case #2

$$
\begin{aligned}
LSF &= (0.3 * LSFL) + TSFL \\
&= 0.3 * LSFL
\end{aligned}
$$

$$
\begin{aligned}
TSF &= (0.3 * LSFT) + TSFT \\
&= TSFT \\
&= 0.5 * LSFL
\end{aligned}
$$

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<u>Expansion End</u>

Load Case #1

$$LSF = LSFL + (0.3 * TSFL)$$
$$= 0.0$$

$$TSF = LSFT + (0.3 * TSFT)$$
$$= 0.3 * TSFT$$

Load Case #2

$$LSF = (0.3 * LSFL) + TSFL$$
$$= 0.0$$

$$TSF = (0.3 * LSFT) + TSFT$$
$$= TSFT$$

where:

LSF = Orthogonal Seismic Shear Force along the longitudinal axis of the bridge

TSF = Orthogonal Seismic Shear Force along the transverse axis of the bridge

The actual resultant seismic shear force at each abutment is calculated based on the combination of the orthogonal seismic shear forces for the two load cases presented in Article 3.10.8 of the LRFD Specifications.

NO LONGER APPLICABLE, RESOLVED BY BRADD v3.1.1.0

Fixed End

Load Case #1

$$
\begin{aligned}
SF &= \sqrt{LSF^{2} + TSF^{2}} \\
&= \sqrt{LSFL^{2} + (0.15 * LSFL)^{2}} \\
&= \sqrt{LSFL^{2} + 0.0225 * LSFL^{2}} \\
&= \sqrt{1.0225 * LSFL^{2}}
\end{aligned}
$$

Load Case #2

$$
\begin{aligned}
SF &= \sqrt{LSF^{2} + TSF^{2}} \\
&= \sqrt{(0.3 * LSFL)^{2} + (0.5 * LSFL)^{2}} \\
&= \sqrt{0.09 * LSFL^{2} + 0.25 * LSFL^{2}} \\
&= \sqrt{0.34 * LSFL^{2}}
\end{aligned}
$$

Thus, Load Case #1 controls.

Expansion End

Load Case #1

$$
\begin{aligned}
SF &= \sqrt{LSF^{2} + TSF^{2}} \\
&= \sqrt{0.0 + (0.3 * TSFT)^{2}} \\
&= \sqrt{0.09 * TSFT^{2}}
\end{aligned}
$$

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Load Case # 2

$$SF = \sqrt{LSF^2 + TSF^2}$$
$$= \sqrt{0.0 + TSFT^2}$$
$$= \sqrt{TSFT^2}$$

Thus, Load Case #2 controls.

where:

SF = Resultant Seismic Shear Force at the given abutment for the given load case (kip (kN))

3.4.2.2 BRADD Implementation

Seismic Force is considered an extreme limit state. The seismic forces are calculated based on the above equations, resulting in the following:

$$TSSDL = 2 * RX_{BEAM} * N_{BEAMS}$$

BRADD
No. 003
March 18, 2005

Seismic Shear Force Calculation Error

NO LONGER APPLICABLE - RESOLVED BY BRADD v3.1.1.0

Fixed End

$$SF\ (fixed) = \frac{\Upsilon_P * \sqrt{1.0225 * LSFL^2}}{R}$$

$$where:$$
$$LSFL = AC * SC * TSSDL$$

$$thus:$$

$$SF\ (fixed) = \frac{\Upsilon_p * \sqrt{1.0225 * (AC * SC * TSSDL)^2}}{R}$$

If seismic zone I:

When AC < 0.025 and Soil Type I or Soil Type II:

$$SF\ (fixed) = \frac{\Upsilon_p * \sqrt{1.0225 * (MAX\ ((AC * SC * TSSDL), (0.1 * TSSDL)))^2}}{R}$$

Otherwise:

$$SF\ (fixed) = \frac{\Upsilon_p * \sqrt{1.0225 * (MAX\ ((AC * SC * TSSDL), (0.2 * TSSDL)))^2}}{R}$$

NO LONGER APPLICABLE - RESOLVED BY BRADD v3.1.1.0

Expansion End

$$SF\ (Expansion) = \frac{\Upsilon_P * \sqrt{TSFT^2}}{R}$$

$$where:$$

$$TSFT = \frac{AC * SC * TSSDL}{2}$$

$$thus:$$

$$SF\ (Expansion) = \frac{\Upsilon_p * \sqrt{\left(\frac{AC * SC * TSSDL}{2}\right)^2}}{R}$$

If seismic zone I:

When AC < 0.025 and Soil Type I or Soil Type II:

$$SF\ (Expansion) = \frac{\Upsilon_p * \sqrt{\left(MAX\left(\left(\frac{AC * SC * TSSDL}{2}\right),\left(\frac{0.1 * TSSDL}{2}\right)\right)\right)^2}}{R}$$

Otherwise:

PENNDOT e-Notification

Bureau of Design
Engineering Computing Management Division

PENNDOT

BRADD
No. 003
March 18, 2005

Seismic Shear Force Calculation Error

NO LONGER APPLICABLE - RESOLVED BY BRADD v3.1.1.0

$$SF\,(Expansion\,) = \frac{Y_p * \sqrt{\left(MAX\left(\left(\frac{AC * SC * TSSDL}{2}\right),\left(\frac{0.2 * TSSDL}{2}\right)\right)\right)^2}}{R}$$

where:

RX_{BEAM}	= Maximum total dead load reaction from all beams
N_{BEAMS}	= Number of beams in superstructure
AC	= Acceleration Coefficient (0.15 for Zone 2; 0.09 or 0.05 for Zone 1, as per DM–4 Article 3.10.2)
SC	= Site Coefficient (as per LRFD Specifications, Articles 3.10.9.1 and 3.10.5.1)
TSSDL	= Total Span Superstructure Dead Load (all dead loads applied to the superstructure, including future wearing surface) (kip (kN))
R	= Response Modification Factor, 1.0 (as per DM–4 Article 3.10.7.1 the response modification factor should not be applied to simple span structures. Therefore BRADD sets this value to 1.0)
Y_p	= Load Factor (1.0 as per LRFD Specifications Article 3.4.1, Extreme Event I, EQ load)
SF	= Resultant Seismic Shear Force at the given abutment (kip (kN))

All seismic design calculations are performed from the design compute menu calculation routine. The seismic forces are outputted in the seismic design output file.