Section 38 - Seismic Design and Retrofit

38.1 History of Seismic Activity In New Jersey

In a Report published under the caption "Earthquake History of the United States" the United States has been divided into nine regions. New Jersey falls in the Eastern Region, an area that covers the Central Appalachian seismic region. Earthquakes that have occurred in New Jersey, of intensity equal to V or greater on the Modified Mercalli Intensity scale, are listed below.

Location	**Date**	**Intensity MM Scale**	**Magnitude Richter Scale**
Newark	September 1, 1895	VI	5.0
Asbury Park	June 1, 1927	VII	5.0
Trenton	January 24,1933	V	4.0
Central NJ	August 22, 1922	V	4.0
Salem County	November 14, 1939	V	4.0
West Central NJ	March 23, 1957	VI	5.0
NJ – PA	December 27,1961	V	4.0
Southern NJ	December 10, 1968	V	4.0

38.2 General Criteria

The AASHTO "*Guide Specifications for LRFD Seismic Bridge Design*" (referred to as AASHTO Guide Specifications hereafter), which establishes a "displacement based" seismic design philosophy, shall be used for the seismic design of bridges in New Jersey.

All bridge structures in New Jersey shall initially be considered to be "standard", that is "non-critical" and "non-essential". Bridges shall be designed for the "life safety" performance objective considering a seismic hazard corresponding to a 7% probability of exceedance in 75 years (approximately 1,000 year return period).

However, consideration for increasing the Bridge Importance category is permitted. This consideration shall strictly be based on social/survival and security/defense factoring of the bridge structure's location. That is, if social/survival or security/defense importance factors of the bridge structure's location clearly indicate the location's critical nature, then increasing the Importance Category may be considered.

Approval for increasing the Importance Category/Performance Level shall be obtained from the Manager, Structural Engineering.

The foundation supporting a bridge structure shall be designed to not experience damage in an earthquake event.

Site-specific ground motion response analyses are required for Site Class F soils.

The following criteria are provided to address seismic designs:

38.3 Methods of Analysis

Based on the *AASHTO Guide Specifications*, the Seismic Design Category (SDC) shall be identified for seismic design of new bridges. The selection of seismic analysis and design procedures shall be based on the SDC.

38.3.1 Seismic Analysis. The seismic analysis and design shall meet the minimum requirements for the identified SDC (A, B, C, D). The analysis may depend upon the following criteria:

- Dead weight of the structure
- Ground motion (acceleration coefficient)
- Type of soil
- Fundamental period of vibration
- Importance classification

38.3.2 Single Span Bridges. Single span bridges do not require a detailed seismic modeling regardless of the Seismic Design Category (SDC). The design requirements may be limited to provision of minimum support lengths and connection forces.

a. Adequate support lengths shall be provided in both the transverse and longitudinal directions.

b. Consideration of connection forces between the bridge span and the abutment seats shall be designed both longitudinally and transversely to resist horizontal seismic force, following the *AASHTO Guide Specifications*.

   The connection forces are based on the assumption that a single span bridge is very stiff and that a short fundamental period of response will occur. Other types of single span bridges, such as trusses, need additional precaution by the Designer.

38.3.3 Load Factors for Seismic Design

In evaluating a bridge structure's history, a significant traffic count should warrant an increase to the live load factor for Extreme Event I load combination. The live load factor, 0.5, listed for an Extreme Event II load combination, may be used. A Designer should use his/her engineering judgment in assessing the traffic count in applying the increase.

38.3.4 Higher Bridge Importance/Performance Category.

As stated above, the seismic Importance Category may be increased to that of "Critical" or "Operational" Performance Level. When this increase is approved on a project by project basis, the following methods may be used.

A. For "Operational" performance objective in a higher design earthquake event considered based on Subsection 38.2, the design criteria are being developed. The Designer may contact the Manager, Structural Engineering, on project by project basis.

B. Using a design earthquake event higher than 1,000 years return period in the *AASHTO Guide Specification*, the seismic design category (SDC) may be increased and seismic analysis procedure level is hence upgraded. AASHTO *Guide Specifications* shall be used for the seismic design at this SDC.

C. The following guidance may be followed for a seismic force analysis.

1. **The Mononobe-Okabe Method**. If warranted by the Bridge Importance designation, the Mononobe-Okabe Method, as defined in Section 11, Appendix A11 of the *AASHTO LRFD Bridge Design Specification*, may be used to analyze the effects of soil pressure on an earth retaining element. This method is an extension of Coulomb's method for analyzing soil pressure.

   With the use of this method, the following shall apply:

   - Backfill is assumed unsaturated so that liquefaction effects are negligible.
   - The backfill is assumed cohesion-less.
   - Seismically induced active and passive pressures will be considered.

2. **Load Combinations**. Extreme Event-I load combinations shall be applicable for a seismic analysis. Refer to the guidance provided in Section 3.4 of the *AASHTO LRFD Bridge Design Specifications*.

3. **Abutments**. Refer to the AASHTO Guide Specifications for seismic analysis and design. The abutments shall be designed for seismic forces from the superstructure in addition to the static earth pressure. Consider both the active and passive pressures.

   Also, refer to Subsection 15.3.11 of this Manual for additional guidance for integral abutment bridges.

4. **Liquefaction**. The potential for soil liquefaction and liquefaction related ground instability shall be investigated at relevant locations along project alignments. Effects of settlement of footings, loss in bearing capacity and increased lateral earth pressures shall be considered in the design of abutments, walls and footings.

5. **Seismic Slope Instability and Landslide**. The potential for seismic induced slope movements and landslide along the proposed alignment shall be investigated. Mitigation measures shall be incorporated in the design of abutments, walls and footings.

6. **FHWA Geotechnical Engineering Circular**. In addition to the *AASHTO LRFD Bridge Design Specifications*, the FHWA Geotechnical Engineering Circular No. 3 titled, "*Design Guidance: Geotechnical Earthquake Engineering for Highways*" may be referred to for guidance on seismic design.

38.4 Seismic Retrofit of Existing Highway Bridges

1. The seismic retrofit design of existing highway structures shall follow the guidelines of the FHWA publication titled "*Seismic Retrofitting Manual for Highway Structures: Part 1 - Bridges*", dated January, 2006.

   Based on the *Seismic Retrofitting Manual*, the Seismic Retrofit Category (SRC) shall be identified for seismic analysis of existing bridges, and hence retrofit requirements for this SRC can be established and analysis method can be selected.

2. As defined in Subsection 1.4.1 of the referenced *Seismic Retrofitting Manual*, the Performance Level (PL) for retrofitting bridges in New Jersey shall be initially assumed to be that of "Life Safety" (PL1).

   As defined in Subsection 1.4.3 of the referenced Retrofit Manual, the Bridge Importance Classification of bridges in New Jersey shall be initially that of "Standard".

If a Designer believes that the classification for a bridge structure, should be taken as "Essential" or a higher level, correspondence to support this belief should be directed to the Manager, Structural Engineering for concurrence.

The Earthquake Ground Motion Level shall be assumed to be that of "Upper Level (UL)" as defined in Subsection 1.4.2 of the *Seismic Retrofitting Manual*. The UL earthquake ground motion has a relatively low probability of exceedance (7% in 75 years/1,000 year return period) within the life of a bridge.

3. A Seismic Retrofit Report shall be prepared to provide a determination as to a bridge structure's eligibility for a seismic retrofit.

   a. A flow chart to provide guidance in determining if a bridge structure qualifies as a seismic retrofit candidate can be found as attached. The results of the analysis, performed in accordance with the flow chart, shall be provided in the Seismic Retrofit Report.

   b. In preparing the Seismic Retrofit Report, the following guidance shall be followed. Initially, seismic retrofitting of a bridge structure shall only be considered under the following conditions:

      - The planned work will involve widening of a deck by more than 30% of its deck area; or,
      - The planned work will involve an entire deck replacement; or,
      - The planned work will involve superstructure rehabilitation or replacement, major bearing seat area repairs, bearing repairs or bearing replacement.

      When an entire deck replacement is planned, the retrofit considerations may be limited to bridge seat modifications and bearing replacement.

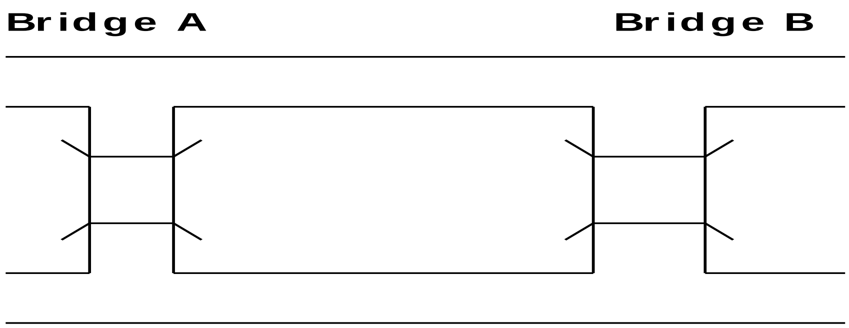
4. The Report should also include a study of a project to determine if retrofitting a bridge is a cost-effective measure. The following areas should be addressed:

   a. An investigation to determine the extent of retrofitting which may be required.

   b. Prior to making a detailed evaluation of the seismic capacity of the bridge structure, the relationship of the bridge structure to other bridge structures on the route system, that may also be damaged during an earthquake, shall be considered.

      1) Consider two bridge structures that have similar functions, such as bridge structures A and B in parallel as detailed herein. It is possible that retrofitting bridge structure A would be more economical or that bridge structure A is more seismically adequate.

      2) Accordingly, even though bridge structure A is not in the project scope and bridge structure B is, it would be more rational to retrofit bridge structure A than bridge structure B.



5. Several methods of seismic retrofit are outlined for bearings and expansion joints within the *FHWA Retrofit Manual* that is referenced above. Of these methods the following are recommended for consideration in order of preference based on the Seismic Retrofit Category (SRC). If applicable, a recommendation as to the proposed treatment of a bridge structure should be included in the Seismic Retrofit Report.
   a. Increase seat length, modify existing bearings and connections to resist seismic loads, or prevent toppling of existing bearings by installing longitudinal displacement stoppers.
   b. Longitudinal joint restraints and/ or shear keys as outlined in the *FHWA Retrofit Manual*.
   c. Bearing replacement with those type bearings described in Subsection 24.20 of this Manual. If conventional steel and elastomeric bearings are proposed to remain, typical modifications would include the following:

      i. Modifications to Steel Bearings

      - Increase size, number or embedment of anchor bolts.
      - Increase the outer diameter of the pin head.
      - Increase the width of the expansion rocker.
      - Increase the top and bottom dimension of the pintle detail for increased movement.

      ii. Modifications to Elastomeric Bearings

      - Secure bearing against horizontal and vertical movement.
      - Modify the plan area and/or thickness of the elastomeric bearing to reduce seismic forces to the substructure.

   The methods outlined above are recommended procedures and are not intended to restrict the ingenuity and creativity of the Design Engineer. Each bridge is different; therefore, retrofit procedures will be approved on a project by project basis by the Manager, Bureau of Structural Engineering.
6. If it is found through a seismic analysis that the substructure is in need of seismic retrofit, it will probably be economically advantageous to study bearing replacement as part of a retrofit.

38.5 Bearings

1. Refer to Section 24 of this Manual for guidance in providing bearing designs to meet seismic requirements.

2. The *AASHTO Guide Specifications for Seismic Isolation Design* shall be used for designing isolation bearings when they have been deemed necessary for accommodating seismic loads. These bearings have special performance characteristics, which will alter the dynamic response of a bridge.

38.6 Computer Software

For Single and multi-mode analysis standard computer programs such as SEISAB and STAAD-PRO may be used.

38.7 Flow Diagram For Retrofit

The following flow diagram may be used to assess the benefits of providing seismic retrofit improvements to a bridge on a project by project basis.

Additional Analysis Required for Existing Bridges Found in Planned Projects