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# ENGINEERING INSTRUCTION

NEW YORK STATE DEPARTMENT OF TRANSPORTATION

SUBJECT: SEISMIC CRITERIA
BRIDGE REHABILITATION PROJECTS

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This Engineering Instruction establishes an interim seismic design policy for bridges programmed for rehabilitation. The interim policy has been established in accordance with the expected levels of seismic activity in New York State.

## INTERIM SEISMIC POLICY CONCERNING BRIDGES PROGRAMMED FOR REHABILITATION

Effective immediately, it shall be the policy of the Department to evaluate the seismic failure vulnerability of bridges programmed for rehabilitation, to assess options and costs of seismic retrofit measures, and to incorporate into the rehabilitation plans those retrofit measures deemed warranted to eliminate or mitigate such failure vulnerability.

The Regional Director will determine the need for and/or the extent of seismic retrofit to be incorporated into each rehabilitation project after careful consideration of this interim policy.

Included in this interim policy are guidelines for determining when seismic retrofit is warranted and what actions should be considered. These guidelines are based on:

- Current understanding of seismic activity in the Northeastern United States.
- Current seismic design specifications.
- Seismic retrofit experience of others.
- Ongoing seismic retrofit procedure development.

The guidelines will be periodically updated to reflect advances in any of these areas.

HC 157b (1/84)

The determination of seismic forces and their effect on existing structures is an inexact science, at the present time, requiring reliance on the designer's judgement and ability to assess structural behavior. Presently, there are no specifications or design requirements which clearly establish whether or not seismic retrofit is required. Therefore, these guidelines are presented with the understanding that the individual designer determining the need for seismic retrofit will understand the nature of seismic forces, the probable response of structural elements, and the degree of structural vulnerability.

This policy recognizes that strengthening existing bridges to the same earthquake resistance as currently required of new bridges is not always practical or cost effective. It is, therefore, the intent of this policy to upgrade elements to be retrofitted to "new bridge" seismic criteria where feasible.

**CRITERIA FOR PLANNING SEISMIC RETROFIT**

The seismic retrofit activities will be planned using the following criteria:

- Seismicity of Site: This is indicated by location of the project on the Seismic Performance Category (SPC) map (see Fig. 1) and also by the geotechnic characteristics of the particular foundation support system.

- Functional Importance: Bridges on or over highways which are critical to maintain essential services (e.g. fire and police), regional movement of goods and services (e.g. connects commercial centers), acceptable traffic flow (eg. those serving major traffic generators) etc. should be recognized as "functionally important" bridges and given high seismic priority.

  As a minimum,"functionally important" bridges should include all those that carry or cross major highways, such as interstates, expressways and major arterials. Other bridges on routes that are important to regional or local well being should also be included, at the Regional Director's discretion.

° Structure Type and Details: Certain bridge types (e.g. multiple simple spans), or details (e.g. high rocker bearings) which are more vulnerable to earthquake damage should be evaluated for seismic retrofit work based on the probable severity of damage and its impact on serviceability of the bridge.

° Rehabilitation Project Scope: The nature and extent of scheduled rehabilitation work can influence the decision to include or defer the recommended seismic retrofit activities.

Rehabilitation work can be classified as major or minor rehabilitation. Minor rehabilitations address non-structural repair or improvement of certain bridge elements, and include such work as concrete surface repair, deck overlays, joint and bearing restoration, secondary member steel repair and minor repair to primary steel members. Major rehabilitations involve structural repair or replacement of primary bridge elements, and include work such as pier and pier cap beam replacement, deck replacement, superstructure replacement, bridge widenings and primary member replacement or strengthening. (Simple restoration of steel members by cover plating with H.S. bolts can usually be considered minor repair.)

## GUIDELINES FOR SEISMIC RETROFIT MEASURES

Considering the above criteria, the following guidelines should be employed in determining the extent and implementation of seismic retrofit work:

I. SPC "A" Bridges:

These bridges, in general, will not require seismic retrofit. However, for functionally important bridges programmed for major rehabilitation, it may be prudent to consider incorporating certain seismic resistant details, if they are compatible with other work in the contract. For instance, consider replacing high steel rocker-type expansion bearings with elastomeric types, if extensive bearing and/or pedestal restoration work is already required due to deterioration

Consider providing continuity at piers supporting simple spans, if major bearing/pedestal work is being done, or if deck replacement is contemplated. Cable restraints should also be considered at those piers if the available support length is inadequate and a continuity retrofit will not be done. Compatibility of the seismic retrofit work with other intended work will make the seismic actions more cost effective.

The area of the state included in SPC "A" is shown in Figure 1.

II. <u>SPC "B" Bridges:</u>

For SPC "B" bridges, the recommended retrofit actions are the following:

1. Replace high steel rocker bearings with elastomeric type bearings. Replace or retrofit companion fixed bearings. Replace low steel sliding bearings on "functionally important" structures, and on structures requiring bearing restoration work. Low steel fixed bearings which are in good condition may be kept or replaced as conditions warrant. Exceptions may be made to this general guideline when bridges are extremely wide, with many stringers in cross section, or when spans are continuous over several supports, and bearings are functioning properly and in good condition.

   Fixed or expansion high steel bearings supporting non-redundant elements, either superstructure or substructure (pier caps), should always be replaced.

2. Provide continuity at piers for multiple simple span bridges. When conditions permit the preferred method is to retrofit beams at piers by splicing for continuity. Where that is not feasible, cable restrainers or other connecting devices should be added.

3. Widen bridge seats where appropriate. (See Art. 3.21.3.3.(7) of the NYSDOT Bridge Design Specifications.)

4. Add lateral restraint systems at substructures.

Areas of the State included in SPC "B" are shown in Figure 1.

<u>For "Functionally Important" bridges in SPC "B"</u>, seismic retrofit work should be included in the first scheduled general rehabilitation activity for the structure. "Functionally important" SPC "B" bridges with concrete columns should also be evaluated for column reinforcement details. Although existing column reinforcement details generally will not meet new seismic criteria, it is anticipated that only in a few instances will the deficiency be significant enough to warrant retrofit action. In those instances, retrofit procedures such as those shown in the Appendix should be followed.

<u>For other SPC "B" bridges</u>, the seismic retrofit work described above should be included in the next scheduled <u>major</u> rehabilitation work. <u>Minor</u> rehabilitation contracts should include as much of the seismic retrofit work as can be accommodated by project cost and compatibility of activities. At a minimum, cable restraints or continuity at piers (where necessary) and lateral restraint systems should be included. Bridges with high steel rocker bearings should be scheduled for follow-up retrofit activity, if necessary.

III. <u>SPC "A" AND SPC "B" Bridges with Special Conditions:</u> Certain bridge types or bridge details are particularly sensitive to seismic forces. When such conditions are identified on bridges programmed for rehabilitation, it would be prudent to consider additional retrofit measures or structure replacement. The location (SPC area) and "functional importance" of the structure should be key considerations in this decision. The following conditions are particularly sensitive to seismic forces:

- Single or individual column pier supports.
- High, slender pier columns (where slenderness ratio exceeds 60).
- Large skews, generally in excess of 45°, with substandard support lengths. (Sec Art 3.21.3.3(7) of the NYSDOT Bridge Design Specifications).
- Severe curvature, where subtended arc angle exceeds 75°.

- Unusual geometry causing portions of the structure to be significantly different in stiffness than the main structure, or which results in unusual support or framing details.
- Hinges or seated connections in suspended superstructures.
- Non load-path redundant superstructures.

Bridges incorporating any of the above details or conditions should be evaluated for seismic vulnerability . Appendix A provides guidance for performing such an evaluation, and is based on criteria and information presented in the FHWA report

"Seismic Retrofitting Guidelines for Highway Bridges", (FHWA/RD-83/007).

It should be noted that only a few SPC "A" bridges, incorporating the conditions noted above, will be candidates for extensive analysis or retrofit actions. However, the presence of these conditions should be acknowledged and considered in the project scoping phase.

Retrofitting existing bridge elements will be done in accordance with current NYSDOT seismic design policy whenever feasible. However, seismic evaluations and seismic element analysis may be based on the actual rock acceleration coefficient attributable to the bridge site. (See Fig. 2.)

## IV. Retrofit Costs:

The cost of retrofitting structures will vary significantly based on the type and extent of needed work, as well as site conditions. In determining seismic retrofit actions, it may be appropriate, in some cases, to limit immediate retrofit action with a pre-determined cost ceiling, while deferring remaining less critical actions to a future project. As a guideline, a cost increase for seismic retrofit in the range of 10-15% is considered appropriate, with 15% being typical for projects with costs of less than $2 million. Where certain bridges are judged to be highly vulnerable based on the previously noted criteria, cost increases in excess of 15% may be warranted to guarantee the structural integrity of the bridge.

In making a decision to defer work based on initial cost, the Regional Director should recognize the benefits of performing the seismic retrofit work now in conjunction with other proposed rehabilitation work. Further, in some instances, the need for major seismic retrofit may indicate that replacement rather than rehabilitation is more cost effective therefore the more appropriate action. A Regional Director's decision to defer seismic retrofit work for SPC "B" bridges should preferably be made with concurrence of the Deputy Chief Engineer (Structures). The basis for that decision should be documented in the project file, with copy to the DCE(s). Should the DCE(s) not concur with the Regional Director's decision, the DCE(s) reserves the right to appeal that decision, if in his/her opinion it presents a significant threat to the safety of the structure.

This **INTERIM SEISMIC POLICY CONCERNING BRIDGES PROGRAMMED FOR REHABILITATION** will be in effect until further notice.

Questions concerning this Engineering Instruction should be directed to the Structures Division.

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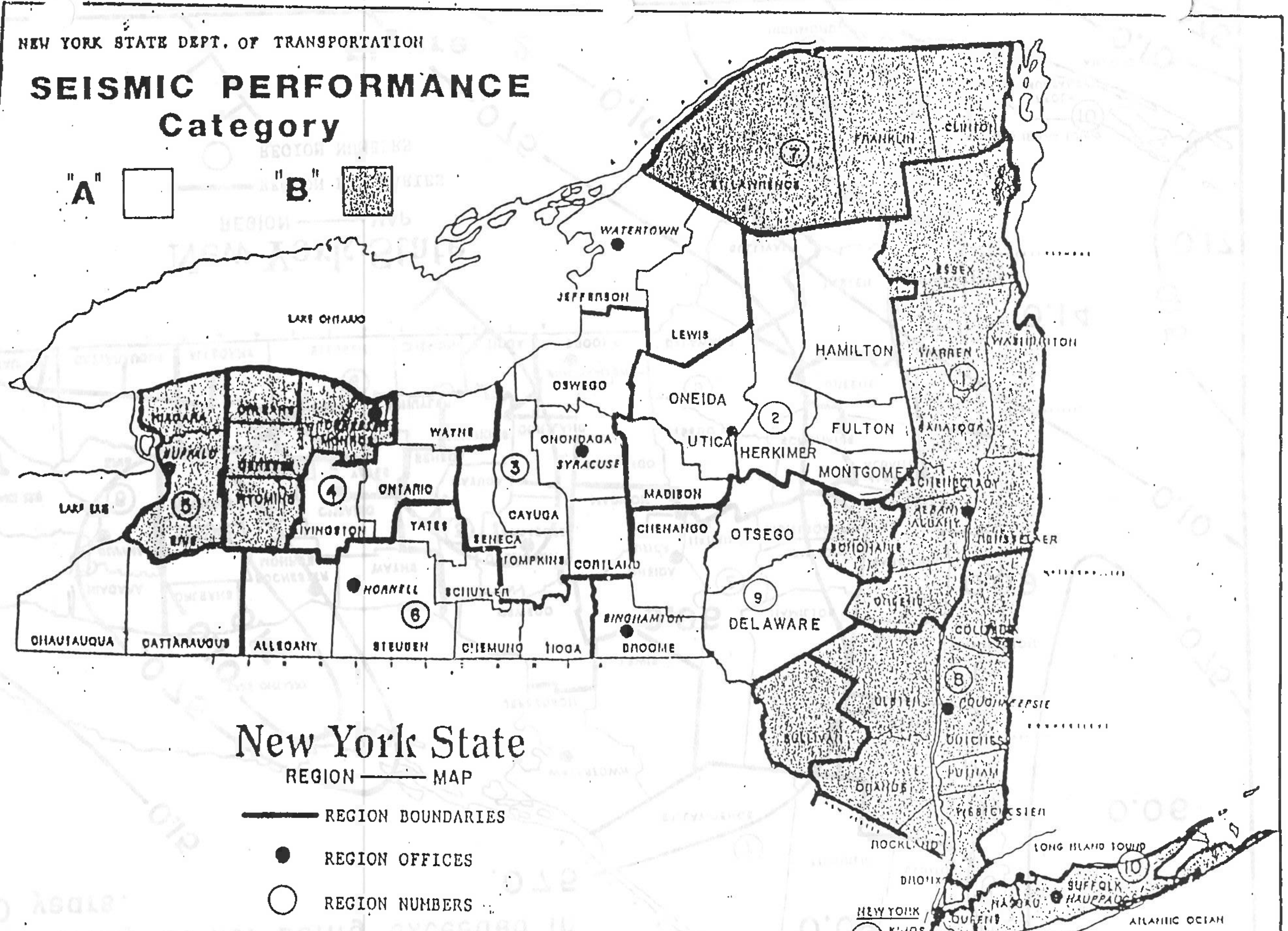
NEW YORK STATE DEPT. OF TRANSPORTATION
SEISMIC PERFORMANCE
Category
"A"
"B"
New York State
REGION —— MAP
REGION BOUNDARIES
REGION OFFICES
REGION NUMBERS
REVISED 8/92
LAKE ONTARIO
LAKE ERIE
LONG ISLAND SOUND
ATLANTIC OCEAN
WATERTOWN
JEFFERSON
LEWIS
HAMILTON
WARREN
WASHINGTON
ESSEX
FRANKLIN
CLINTON
ST. LAWRENCE
OSWEGO
ONEIDA
UTICA
HERKIMER
FULTON
MONTGOMERY
SCHENECTADY
ALBANY
RENSSELAER
ONONDAGA
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MADISON
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WAYNE
ONTARIO
YATES
SENECA
CAYUGA
TOMPKINS
CORTLAND
BINGHAMTON
BROOME
TIOGA
CHEMUNG
SCHUYLER
STEUBEN
HORNELL
ALLEGANY
CATTARAUGUS
CHAUTAUQUA
ERIE
BUFFALO
NIAGARA
WYOMING
LIVINGSTON
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**Figure 1**

Map of Rock Acceleration (A) with 90% probability of not being exceeded in 50 years.

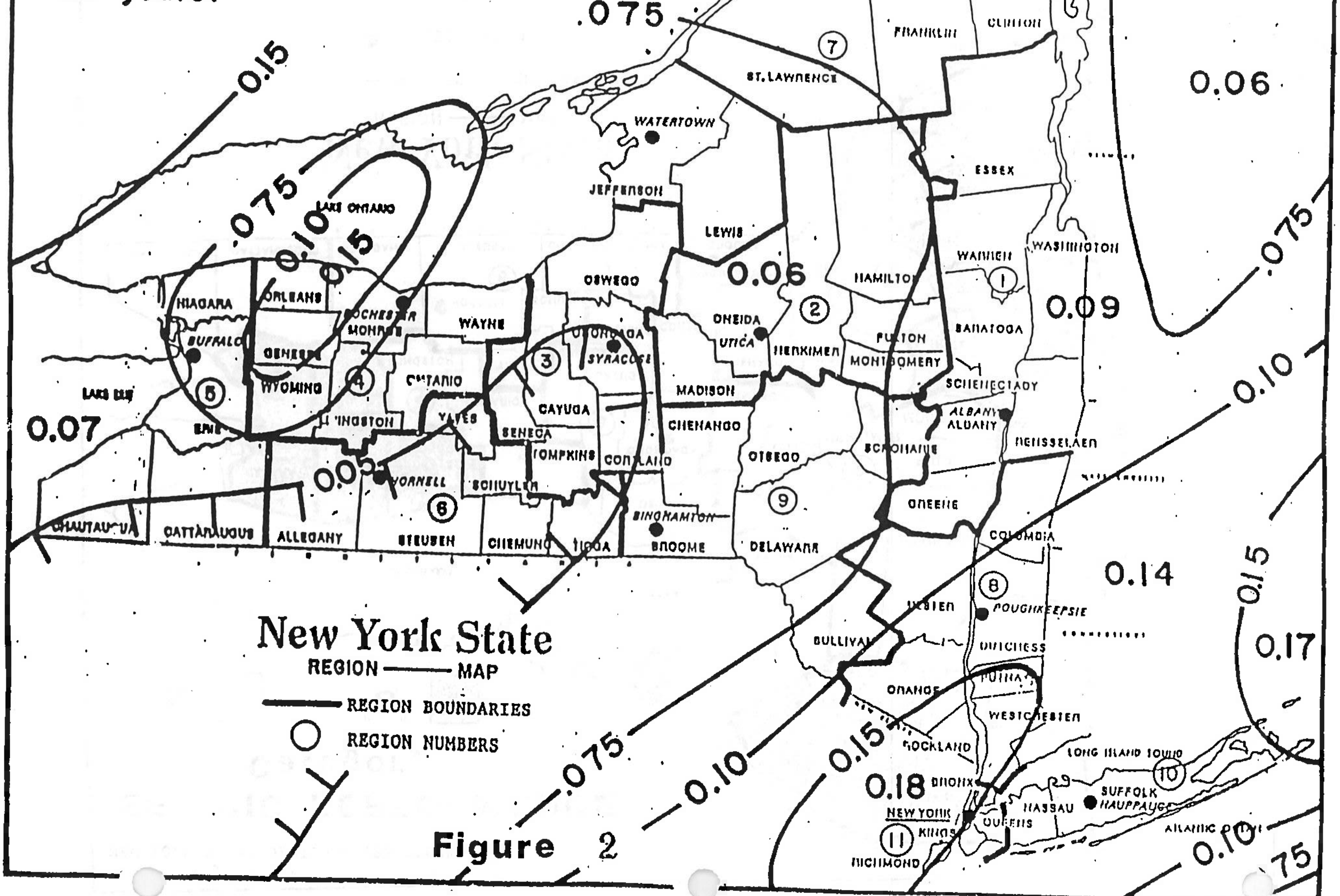



Figure 2

## APPENDIX "A"

## SEISMIC EVALUATION PROCEDURE

The detailed seismic evaluation of a bridge should be performed in two phases. The first phase is a quantitative evaluation of individual bridge components using the analysis procedures outlined in current AASHTO Specifications for Seismic Design of Bridges and Art. 3.21 of the New York State Design Spec. for Highway Bridges. The resulting forces and displacements (referred to as demands) should be compared with the ultimate force and displacement capacities of respective components. A capacity/demand ratio is then calculated for each potential mode of failure in the critical components. This ratio represents the portion of the design earthquake that each of the components is capable of resisting.

The second phase of evaluation is an assessment of the influence of failure in each component with insufficient capacity to resist the design earthquake. Consideration should be given to retrofitting substandard components if their failure will result in bridge collapse. In the case of certain essential bridges, the loss of function may also warrant the consideration of retrofitting.

There are three areas where local failure may occur and where component's capacity/demand ratios should be calculated. These are:

- Bearings and connections to superstructure and sub structure.
- Columns - connections, confinement and splices.
- Support length at the bridge seat.

Computations of Capacity/Demand Ratios

$$\Gamma = (R_c - \Sigma Q_i)/Q_{EQ}$$

where

$\Gamma$ = Capacity/Demand Ratio

$R_c$ = Nominal ultimate displacement or force capacity for the structural component being evaluated.

$\Sigma Q_i$ = Sum of the displacement or force demands for loads other than earthquake which are included in the group loading defined in the current AASHTO (Guide) Specifications for Seismic Design of Bridges (Chapter 4) and EI 90-8 (Figure 3)

$Q_{EQ}$ = Displacement or force demand for design earthquake loading at the site.

Capacity/demand ratios should be calculated at the nominal ultimate capacity without the use of capacity (strength) reduction factors ($\phi$) so as to obtain a more realistic estimate of the as-built capacity of the members.

The demands are obtained either from minimum specified values in the case of bearings and support lengths at the bridge seat or from an elastic analysis of the bridge, in the case of pier columns. The analysis procedures and design loads required to calculate the demands are identical to that required for a new bridge, including the combination of forces in orthogonal directions.

Displacement Capacity/Demand Ratio for Support Length:

The displacement C/D ratio should be calculated for bearings when movement can occur due to the absence of restraint in a horizontal direction (Method 1). When displacement limiting devices, such as restrainers, are provided, C/D ratio for both displacement and force should be calculated (Method 2).

Method 1 (no restrainers provided)

Capacity/demand ratio $r_{bd} = N(c)/N(d)$

where

N(c) = Lateral support length provided. The length is measured from the end of the bridge seat (pedestal) normal to the centerline of the beam (girder) at the centerline of the bearing.

N(c) = Longitudinal support length provided, considering the effect of temperature, shrinkage and creep shortening. The length is measured normal to the bridge seat (pedestal) from centerline of the beam (girder) end.

N(d) = Minimum support length as defined in New York State specification for Highway Bridges under Art. 3.21 (NY)

<u>Method 2</u> (with restrainers)

Capacity/demand ratio $r_{bd} = \dfrac{\Delta_{s(c)} - \Delta_{i(d)}}{\Delta_{eq(d)}}$

where

$\Delta_{s(c)}$ = Allowable movement of the expansion joint or bearing.

$\Delta_{i(d)}$ = Maximum possible movement resulting from temperature, shrinkage and creep shortening. Usually the temperature effects need to be considered.

$\Delta_{eq(d)}$ = Maximum relative displacement due to earthquake loading, computed by seismic analysis of the bridge.

Force Capacity/Demand Ratio for Bearings:

The force C/D ratio for bearings and restrainers (if provided), are evaluated as follows: $r_{bf} = V_{b(c)} / V_{b(d)}$

where

$V_{b(c)}$ = Nominal ultimate capacity of the component in the direction under consideration

$V_b(d)$ = Seismic force acting on the bearing (or restrainer.) This force is the elastic force determined from an analysis multiplied by 1.25. The minimum bearing force demand of 0.19 x (DL + LL) is used when an analysis is not performed, or when it exceeds the force demand obtained from an analysis.

<u>Capacity/Demand Ratios for Reinforced Concrete Pier Columns:</u>

a) Shear failure in the column. Determine the elastic shear demand from seismic analysis:

$$V_e(d) = \sqrt{V^2_{Long.} + V^2_{Trans.}}$$

Calculate initial and final shear capacities,

$$V_i(c) \text{ and } V_f(c)$$

Initial column shear capacity $V_i(c)$ is based on the contribution of the concrete and the transverse reinforcement.

$$V_i(c) = 2\sqrt{f'_c} \cdot A_g + A_{tr} \cdot f_y \cdot d/s$$

Final column shear capacity is based on the contribution of the transverse reinforcement.

$$V_f(c) = A_{tr} \cdot f_y \cdot d/s$$

where

$A_{tr}$ = Area of transverse reinforcement

$A_g$ = gross area of column

Elastic Capacity/Demand ratio:

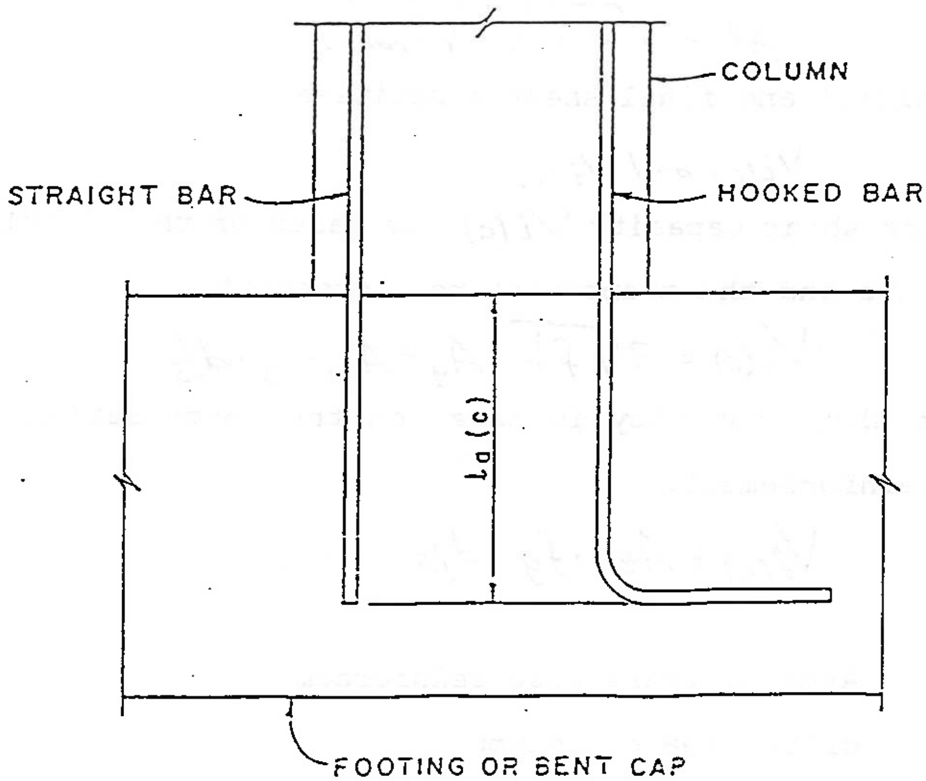
$$\gamma_{ecv} = \frac{V_i(c)}{V_e(d)}$$

b) Anchorage failure in the main Longitudinal Reinforcement of reinforced columns:

The pullout of longitudinal reinforcement can occur at the bent cap or at the footings.

Capacity/demand ratio of the anchorage longitudinal reinforcement is based on the effective development length provided and the reinforcing details at the anchorage. When 90° standard hooks are used, the required effective anchorage length in inches is:

$$\ell_a(d) = k_m \cdot 1200 d_b \cdot \frac{f_y}{60000\sqrt{f'_c}} > 15 d_b$$




EFFECTIVE ANCHORAGE LENGTH OF LONGITUDINAL REINFORCEMENT where

la(d)= Required effective anchorage length of longitudinal reinforcement.

la(c)= Effective anchorage length of longitudinal reinforcement.

km =0.7, for #11 bars or smaller, when side cover (normal to plane of the hook) is not less than 28 inches, and cover on bar extension beyond the hook is not less than 2 inches.

km =1.0, for all other cases.

db = Nominal bar diameter in inches

f'c = Concrete compression strength (psi)

fy = Yield strength of reinforcement (psi)

There are two methods for calculating the seismic capacity demand ratio for anchorage of the longitudinal reinforcement $(r_{ca})$ . These methods depend on the effective anchorage length provided and the reinforcement details.

Case A: If the effective development length provided is insufficient then the C/D ratio for anchorage of longitudinal reinforcement,

$$r_{ca} = \frac{l_{a(c)}}{l_{a(d)}} \cdot r_{ec}$$

Case B: If the effective development length is sufficient, that is, $l_{a(c)} \geq l_{a(d)}$ , the C/D ratio will depend on the reinforcing details at the anchorage. The six possible details and corresponding methods for calculating the C/D ratios are as follows:

Detail 1: When no flexural tensile reinforcement is present in the top of the footing and column bar development is by straight anchorage i.e., no hooks are present at the bottom of the footings,

$$r_{ca} = r_{ef}$$

Detail 2: When no flexural tensile reinforcement is present in the top of the footing and the column bars are anchored with 90° or greater standard hooks, bent away from the column towards the edges of the footing,

$$r_{ca} = 1.3\, r_{ef} \leq 1.0$$

Detail 3: When no flexural tensile reinforcement is present in the top of the footing and the column bars are anchored with 90° or greater standard hooks turned toward the vertical centerline of the column,

$$r_{ca} = 2\, r_{ef} \leq 1.0$$

Detail 4: When the top of the footing contains adequately anchored flexural tensile reinforcement so that $r_{ef}$ can be reliably computed from the flexural strength of the top reinforced footing section, and the column bar development is by straight anchorage only,

$$r_{ca} = 1.5\, r_{ef} \leq 1.0$$

unless soil overburden and/or pile anchorage is insufficient to overcome the negative moment capacity of the footing, in which case

$$r_{ca} = 1.0$$

Detail 5: When the top of the footing contains flexural reinforcement, as for the above detail, and the column bars have been provided with 90° standard hooks, the C/D ratio for anchorage should be taken as 1.0.

Detail 6: When the anchorage is in a bent cap, the C/D ratios for anchorage should be taken as 1.0.

Seismic Retrofitting Systems

Seismic retrofitting systems are designed to prevent collapse and/or severe structural damage of the bridge due to the following modes of failure:

1. Bearing failure
2. Loss of Support due to insufficient seat width
3. Pier column failures

Each retrofitting system selected must be evaluated to ensure that it does not transfer excessive force to other less-easily inspected and repaired components.

All retrofit components shall be designed to the standards listed here but, whenever possible, not less than the standards for the design of new structures. Reduced standards may be used when the use of full design standards is not practical or economically feasible and partial strengthening significantly reduces the risk of unacceptable damage.

Replacement of Bearings:

Certain types of bearings, such as steel rocker and low steel bearings have performed poorly during past earthquakes, because of their low resistance to horizontal loads. A possible retrofit measure in these cases is the replacement of the bearings with modern bearing types such as steel laminated elastomeric bearings (types E.L. or E. B.) or Multi-Rotational bearings (pot or disc design). Figures 1A and 2A show details of this retrofit scheme.

Bearing Restrainers:

Transverse and longitudinal restrainers are necessary in many cases to keep the superstructure from sliding off the bearings. Conditions that are particularly vulnerable include high concrete pedestals which serve as bearing seats for individual girders, bearing seats which are narrow and highly skewed, and in two girder bridges in which the transverse distance between the bearing and the edge of the seat is small.

The forces used to design transverse restrainers are generally determined from an analysis. The minimum transverse restrainer design capacity should be not less than that required to resist an equivalent horizontal static load of 1.25 times 19% of Dead Load plus Live Load Reaction. Transverse restrainer design capacity $\geq$ 1.25 x 0.19 x (D.L.R. + L. L. R.). (For retrofitting other than "important" bridges, values smaller than 19% may be used as long as the value is not less than the actual ground acceleration).

When two superstructure segments are tied together (figures 3A and 4A), the minimum restrainer capacity shall be the greater of the two capacities obtained by considering each section independently. Connection of the restrainer to the superstructure and/or