SEISMIC DESIGN OF BRIDGES

SECTION 12

STRENGTHENING OF BRIDGES FOR SEISMIC LOADS

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12.1 INTRODUCTION

Traditionally, bridge controlling authorities have not regarded the seismic resistance of existing bridges as a significant criterion, compared with capacity for live load. The preference is to carry the risk, and face the possible repair costs when the time comes. However, it is relevant to consider the seismic risk in comparison with other risks and several techniques are available. Cost-benefit analysis is one but it is admittedly difficult to define criteria for analysis, since a number of the benefits are not very easily measured in monetary terms. It is easier to determine relative priorities for strengthening among a specific group of bridges, and methods have been published for doing this[12.1, 12.2, 12.3].

It is not necessary to strengthen every bridge to full design criteria. There will be many cases where some small attention to detail will significantly improve the performance.

12.2 RELATIVE IMPORTANCE OF BRIDGES FOR STRENGTHENING

Points which should be considered in evaluating the importance of a bridge (refer to Clause 1.3) and in setting priorities for strengthening include:

(a) The existence of an alternative route.

(b) The existence of services carried by or passing under the bridge.

(c) The existence of buildings under or nearby which could be damaged in the event of a collapse.

(d) The expected remaining economic life of the bridge.

(e) The cost and the benefit derived from strengthening to various proportions of the design loading.

(f) The availability of suitable temporary bridging or modes of transport not requiring bridging.

(g) The likely needs of the region and the necessity for the region to be reinstated quickly after a severe earthquake.

(h) The need to facilitate movements of emergency forces to and from the stricken region.

(i) The need to upgrade the strength of the bridge for reasons other than seismic capacity; e.g. live loads, flood loads, alignment.

12.3 STRENGTHENING CRITERIA

12.3.1 Design Earthquake

The design earthquake for strengthening should preferably be the same as that defined in Section 2, where the design life is taken as the remaining economic life of the strengthened bridge, and the earthquake return period is determined as a function of the importance of the bridge as provided for in Clause 1.3.5.

Alternatively, if the basic foundation elements are weak, and not easily strengthened, it may be necessary to design for a smaller percentage of the design load, on the basis that any improvement will still be an advantage.

12.3.2 Structural Design

As far as is practical the principles of capacity design should be followed in accordance with Section 3. Seismic details should be appropriate to the load level chosen for the strengthening and be in accordance with Clauses 12.3.3 (a) to (d) and other relevant Sections of this document.

Weak points of the structure should be identified and strengthened if this is technically and economically feasible. Designers should be aware that the strengthening of one or even several elements of a structure will not necessarily improve its overall capacity to resist an earthquake if other critical elements or details remain inadequate. A thorough understanding of the structure is necessary for adequate design of the strengthening.

12.3.3 Design Details

The range of techniques for strengthening is wide[12.4]. The appropriate method of strengthening will depend on the specific requirements for the bridge which should be determined after adequate site inspection, review of design calculations, construction drawings and analysis. In some cases dynamic analysis may be desirable. (Refer to Section 10).

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If a large number of bridges have to be evaluated in a short time it may be necessary to group the different bridge types and develop standard solutions for each type.

Specific measures which will generally lead to significant enhancement of seismic resistance are:

(a) Improvement to linkage bolts or cables and tiebacks and seating at joints in the superstructure and renewal of sliding bearings which may have ceased to function. Renewal of bearings may improve the seismic response of the structure and control the distribution of loads between supports.

(b) Improvement to the ductility of the substructure by the addition of suitable confining reinforcement or the addition of energy absorbing devices.

(c) Improvement to the strength of the substructure and foundations. Weak piers or foundations may be improved by the provision of carefully located prestressed tendons.

(d) Improvements to the stability of approaches.

12.4 REFERENCES:

12.1 Longinow, A., Cooper, J.D., Bergmann, E., "Selection of Critical Bridges for Retrofitting", Journal of ASCE Vol 105 No. TCl, April 1979.

12.2 Longinow, A., Robinson, R.R., Chu, K.H., "Retrofitting of Existing Highway Bridges Subjected to Seismic Loading - Analytical Considerations", ATC-6, paper llb.

12.3 Ohashi, M., Fijii, T., Kuribayashi, E., Tazaki, T., "Inspection and Retrofitting of Earthquake Resistant Vulnerability of Highway Bridges - Japanese Approach", ATC-6, paper llc.

12.4 Dengenkolb, O.H., "Retrofitting of Existing Highway Bridges Subject to Seismic Loading - Practical Considerations", ATC-6, paper lla.