Bridges & Earthquakes

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Introduction

Lifelines in general are excluded from the provisions of AS1170.4 and the question must then be asked,

`Do we have no guidance for designing lifelines?'

Insofar as bridges are concerned some guidance has been provided in Australian bridge design codes since at least 1965. The 1965 Edition of the NAASRA Highway Bridge Design Specification provided a formula to calculate earthquake lateral force EQ as

$$EQ = C \times D$$

where D = dead load of structure
C = coefficient depending on founding conditions

It was noted that the value of `C' may be increased by the engineer at his discretion in the light of local seismic records. It was also noted that all details should be designed to prevent displacement due to earthquake with special attention being given to bearings. In this context `displacement', is equivalent to `falling off'.

Unfortunately the section on earthquake forces was introduced with the words `In regions where earthquakes of significant intensity may occur, provision shall be made to accommodate lateral forces from these earthquakes...'. It was commonly thought that earthquakes of significant intensity did not occur in Australia so the section was not applied in design.

The 1970 edition of the Bridge Design Specification had essentially the same wording as the 1965 edition.

The 1976 edition modified the lateral force expression to

$$EQ = KCD \text{ (min } 0.02\text{ D)}$$

The coefficient `C' was now a function of the structure stiffness and `K' represented the ability of the structure to absorb energy. An increase of 50% in force was applied to structures founded in weak deep soil.

Reference was made to seismic zoning studies and the work of the National Committee on Earthquake Engineering to determine whether earthquake design forces were to be applied. Aspects requiring particular attention were stated more explicitly than in the earlier editions.

The 1992 edition of the Austroads Bridge Code makes explicit reference to AS2121 for zoning and uses the same expression as AS2121 to calculate horizontal earthquake force, with the zone factor modified for a 2000 year average recurrence interval.

It is seen then that guidance has existed for earthquake design of bridges in Australia for many years but that even the most recent Bridge Design Code (1992) is already out of date. The balance of this paper discusses aspects of bridge design that need special consideration based on performance in previous earthquakes and outlines an approach to calculating earthquake forces in tune with AS1170.4.

Bridge damage

In a simplistic sense it may be stated that most earthquake damage to bridges is related to inadequate detailing. While design for earthquake forces cannot be ignored it is the author's contention that careful, thoughtful detailing is more productive than careless, thoughtless design for a force.

A relatively common form of damage is where the superstructure falls off the supporting structure. This was evident in Niigata in 1964 with the Showa bridge, Madang in 1970 where several bridges collapsed on their roller bearings, San Fernando in 1971 and Northridge in 1994.

An original concern with bridges was to cater for movements due to temperature changes and details provided for this did not always cater for relative movements induced during earthquakes.

The Austroads Code covers this in Section 2.13.5.1 with words such as `restraining devices shall be provided with the specific aim of preventing dislodgment of the superstructure from the support structure'.

Failure of columns in compression where the longitudinal bars are not adequately confined (as is common in Australian construction) is another common failure cause evident at San Fernando, Northridge and other earthquakes. The Austroads Code addresses this aspect in Section 2.13.5.3 as follows, `special attention should be given to the detailing of concrete members bearing in mind the manner in which earthquake-induced energy will be dissipated and the desirability of avoiding brittle failures'.

Subsidence of approach embankments is another form of distress during an earthquake. It has occurred in many earthquakes including Madang in 1970 and San Fernando in 1971. A secondary effect of this can be to impose large forces on abutments, wing walls, etc., leading to structural failures. The Austroads Code covers this in section 2.13.5.2 with the words `consideration shall be given to the effects of excessive settlement of approach embankments and allowances made for increased earth pressures on earth retaining structures', Densification of the underlying material and better compaction of the embankment helps ameliorate this effect.

Liquefaction of granular soils can occur when they are subjected to earthquakes of sufficient duration and intensity. This leads to loss of support for piers and approach

embankments. Densification may be appropriate for the approaches and piles need to found in material that will maintain support during such an event.
The Austroads Code addresses this aspect also in Section 2.13.5.2, as follows:

> `This possibility of soil liquefaction should be investigated where saturated sandy soils within 10 m of ground surface have a SPT value of 10 or less'.

It has been argued that raking piles should be avoided because of the large forces generated on headstocks and the limited ductility of the pile configuration. The argument is based, at least in part, on performance in Alaska 1964 and Madang 1970. A counter argument is that the resulting cracking and distress was caused by the failure to detail for the resulting forces rather than any inherent shortcomings of a raking pile system since similar damage was caused in some cases where the piles were vertical.

Current approach to design

For the immediate future a reasonable approach to designing bridges for earthquakes in Australia would be as follows:

- Obtain acceleration coefficient from the information in AS1170.4 with `a' factored to reflect a 2000 recurrence interval for bridges as against a 500 year interval in AS1170.4. An appropriate factor for this might be 2.

- Obtain values of R_f for the bridge type from ATC6 `Seismic Design Guidelines for bridges'.

- Obtain the earthquake base shear force from Clause 6.2.2 of AS1170.4 noting that the importance factor and the period may be obtained from the 1992 Austroads Code.

- Design and detail the bridge for this force and other provisions of the Austroads Code.

Additional guidance may be obtained from New Zealand and Papua New Guinea documents listed in the references and from the Australian Earthquake Engineering Manual.

Continual reading about failures in earthquakes will add to one's experience but care is needed in interpretation.

Conclusions

The following conclusions may be drawn:

- Even though AS1170.4 excludes bridges from its provisions, there is ample guidance available for design purposes in the literature.

- Austroads Bridge Design Code, in conjunction with AS1170.4 and ATC6, addresses modes of failure and calculation of forces.

- Detailing is critical - think detailing and not simply forces.

- All design actions should be catered for. Do not become obsessed with one to the exclusion of others.

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He has developed seismic design criteria for structures designed in Australia, Papua New Guinea, Solomon Islands and other Pacific countries.

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