Introduction

Australian Standard 5100.2, Clause 14.5 provides equations specifically for bridges (based very closely on and practically identical to Australian Standard on Earthquake Loads AS 1170.4 – 1993) to determine the horizontal design earthquake force, refer Equations 14.5.2(1) to (3).

AS 5100.2, Clause 14.1 states that AS 1170.4 is only to be used for specifically referred factors and that AS 1170.4 shall not be otherwise used for earthquake design of bridges.

AS 1170.4 has been updated with a 2007 edition. The equation in AS 1170.4 – 2007 is very different and uses new factors and hence the formulae and factors in AS 1170.4 are no longer directly compatible with those in the Bridge Design Code.

A review of the changes in AS 1170.4 is given below, and as an interim measure, a recommended approach as to how these changes may be incorporated into the Bridge Design Code until such time as it is formally updated to conform to the latest earthquake code.

Discussion and Qualifying Assumptions

1. **Acceleration Coefficient (a)** – AS 5100.2 Clause 14.3.3 states that ‘a’ shall be as specified in AS 1170.4. AS 1170.4 – 1993, Clause 2.3 gave maps based on geographic location to determine ‘a’. AS 1170.4 – 2007 has this same information but no longer refers to an acceleration coefficient. It is now called a Hazard Factor (Z) as per Clause 3.2. There is little change to values and therefore the name and symbol can be transposed.

2. **Site Factor (S)** – AS 5100.2, Clause 14.3.4 states that S shall be as specified in AS 1170.4. AS 1170.4 – 1993, Clause 2.4 gave tables based on soil profile to determine S with values between 0.67 for rock to 2.0 for soft soils. If the soil was not known it was recommended to use S = 1.5. AS 1170.4 – 2007, Clause 6.4 has introduced a spectral shape factor (C_h(T)) in the form of response spectra that varies depending on the fundamental natural period of the structure and on the sub-soil class. This would seem a refinement of the previous edition and the preferred approach is to use the spectral shape factor C_h(T) in the force formulae, which in effect incorporates and supersedes S.
3. Bridge Earthquake Design Category (BEDC) – AS 5100.2, Table 14.3.1 determines the BEDC based on the product of acceleration coefficient and site factor (aS). AS 1170.4 – 2007 does provide for the selection of earthquake design category (EDC), however, it does not deal clearly with bridge structures and as an interim solution it is recommended to retain the current BEDC Table 14.3.1 using the hazard factor (Z) as above but retain the site factor (S) from AS 5100.2, Clause 14.3.4. In determining the BEDC the probability factor (k_p) should not be applied. Thus, use ZS in Table 14.3.1 of AS 5100.2 to determine the BEDC.

4. Earthquake Design Coefficient (C) – AS 5100.2, Clause 14.5.4 calculates the earthquake design coefficient (C) as a function of the acceleration coefficient (a) and structure period of the first dominant mode of free vibration (T). AS 1170.4 – 2007 Clause 6.4, as with the Site Factor S, has incorporated C into a spectral shape factor (C_h(T)).

5. Structural Response Factor (R_f) – AS 5100.2 Clause 14.5.5 provides that the minimum value of R_f shall be given in Table 14.5.5. AS 1170.4 – 2007 does not use R_f. Instead, it uses new factors, the structural performance factor (S_p) and structural ductility factor (\mu) which when combined as \mu/S_p appears similar to R_f in AS 5100.2 with ranges from 2.6 to 6.0 compared to 3.0 to 6.0 respectively for likely bridge structures. It might be argued that there is a possibility that the lower range of the 2.6 \mu/S_p is more stringent than the 3.0 value and hence its use would be conservative. However, the 2.6 value only applies to ordinary moment-resisting steel and concrete frames; limited ductility concentrically braced steel frames; limited ductility concrete shear walls; timber frames; and close spaced reinforced masonry. These have limited application to bridges and hence AS 5100.2 Table 14.5.5 provides better guidance for the different structural bridge systems and it is proposed to retain R_f.

6. Importance factor – For AS 5100.2, Clause 14.5.3 the importance factor (I) shall be 1.00 for all structure types unless otherwise stated by the Road Authority.

7. Probability Factor (k_p) – AS 5100.2 is currently written for 500 year return interval earthquakes (refer AS 5100.2, Clause C14.3). However, the ultimate limit state philosophy of AS 5100 is to design for a 2000 year return interval and MRWA has required the probability to be converted using k_p = 1.8 as per AS 1170.0 – 2002, Table D1. AS 1170.4 – 2007 now incorporates k_p based on the annual probability of exceedance in Clause 3.1 with k_p = 1.7 for 1/2000. It is therefore recommended to use a k_p of 1.7.

**Action**

As an interim measure, until such time as the AS 5100.2 is amended to reflect the changes made to AS 1170.4, the horizontal earthquake force (H^*_u) shall be determined from the following equation:

\[ H^*_u = I \left( \frac{k_p Z \ C_h(T_1)}{R_f} \right) G_g \]

where
- I = importance factor as per AS 5100.2, Clause 14.5.3
- k_p = probability factor = 1.7 as per AS 1170.4 – 2007, Clause 3.1
- Z = hazard factor as per AS 1170.4 – 2007, Clause 3.2
- C_h(T_1) = spectral shape factor for the fundamental natural period as per AS 1170.4 – 2007, Clause 6.4
\[ R_f = \text{structural response factor as per AS 5100.2, Clause 14.5.5} \]
\[ G_g = \text{total unfactored dead load including superimposed dead load} \]

The AS 5100.2 lower limit of the horizontal design earthquake force should be retained. Thus using:

\[ H_u^* \geq 0.02 G_g \]

Note also that AS 1170.4 – 2007 has removed the requirement for considering vertical earthquake actions. It is appropriate that AS 5100 should align with this and as such AS 5100.2, Clause 14.5.6 can be removed.

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