COMPARISON BETWEEN JANPANESE SPECIFICATION AND AASHTO 1998 SPECIFICATION IN SESMIC DESIGN

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Abstract: *Japan has much experience in seismic design. This article analyses the difference between AASHTO 1998 and Japanese Specification in seismic design; contributes to conclusion for applying of Japanese Specification for construction projects in Vietnam.*

Keywords: *Acceleration coefficient; Standard acceleration response spectrum; Elastic response coefficients*

I. INTRODUCTION

Recently, there are many projects in Vietnam that applied design seismic. Transport construction projects mainly apply Specification for Highway bridge 22TCN 272-05 belongs Ministry of Transport (refered to AASHTO 1998). Building construction projects mainly apply Specification for Design of structures for earthquake resistance TCXDVN 375-2006 (referred to EUROCODE 8). Both of Specifications use “Acceleration coefficient A” or “The map of seismogenic zones and maximum seismic intensity” published by Institute of Geophysics belong Vietnamese Academy of Science and Technology for seismic design. In addition, Japan, that has been suffered many earthquake damages, has much experience in seismic design. Question under investigation for Vietnamese engineer as well as Japanese engineer is ability of apply Japanese Specification for Seismic design of construction projects in Vietnam. This article analyses the difference between AASHTO 1998 and Japanese Specification in seismic design; contribute to conclusion for applying of Japanese Specification for construction projects in Vietnam.

II. COMPARISON OF SOME FACTORS EFFECT ON EARTHQUAKE LOAD IN AASHTO 1998 AND JAPANESE SPECIFICATION

	AASHTO 1998	**Japanese Specification**
Earthquake loads	Seismic loads assumed to act in any lateral direction.	Seismic load is inertia force that shall be calculated in terms of the natural of each design vibration unit.

	Earthquake loads shall be taken to be horizontal force effects on the basis of the elastic response coefficient, Csm and the equivalent weight of the superstructure, and adjusted by the response modification factor, R. The elastic seismic force effects on each of the principal axes of a component resulting from analyses in the two perpendicular directions shall be combined to form two load cases as follows: 100 percent of the absolute value of the force effects in one of the perpendicular directions combined with 30 percent of the absolute value of the force effects in the second perpendicular direction, and 100 percent of the absolute value of the force effects in the second perpendicular direction combined with 30 percent of the absolute value of the force effects in the first perpendicular direction. Load combination in sesimic design = Permanal loads + 1/2 Live load + Water Pressure + Friction Load + Earthquake effect	Inertia forces shall be generally considered in two directions perpendicular to each other. It can be assumed that the inertia forces in the two orthogonal directions, i.e. the longitudinal and transverse directions to the bridge axis. Inertia force shall be defined as the horizontal force equal to the product of the weight of a structure and the design horizontal seismic coefficient and be considered acting on the structure in the detection of the inertia force of a design vibration unit. Load combination in sesimic design = Primary load + Earthquake effect (= Permanal load + Water Pressure + Friction Load + Earthquake effect) - Earthquake effects (EQ): (1) Inertia force due to an earthquake (2) Earth pressure during earthquake (3) Hydrodynamic pressure during earthquake (4)Effect of liquefaction and liquefaction-induced ground flow (5) Ground displacement during earthquake
Calculation formula for earthquake force by statically method	$EQ=W.C_{sm}/R$ EQ: Earthquake force (kN) W: Weigh of structure (kN) C_{sm}: Elastic response coefficient. R: Response modification factor.	$H=W.k_{hco}.C_{z}.C_{s}$ H: Earthquake force (kN) W: Weigh of structure (kN) k_{hco}: Standard value of the design horizontal seismic coefficient. C_Z: Modification factor for zone. C_S: Force reduction factor.

<table>
<tr>
<td>Basic value of earthquake load</td>
<td>
<p>Acceleration coefficient A: Determined by the national earthquake ground motion map used in the existing AASHTO provisions, that is a probabilistic map of peak ground acceleration (PGA) on rock which was developed by the U.S Geological Survey (USGS, 1990). The map provides contours of PGA for probability of exceedance (PE) of 10% in 50 years, which is approximately 15% PE in the 75 years design life of tipycal highway bridge.</p>
<p><i>Table 1</i> <i>Acceleration coefficient</i></p>
<table>
<tr><th>Acceleration coefficient</th><th>Seismic zone</th><th>MSK - 64 class</th></tr>
<tr><td>A ≤ 0.09</td><td>1</td><td>Class ≤ 6,5</td></tr>
<tr><td>0.09 < A ≤ 0.19</td><td>2</td><td>6,5 < Class ≤ 7,5</td></tr>
<tr><td>0.19 < A < 0,29</td><td>3</td><td>7,5 < Class ≤ 8</td></tr>
<tr><td>A≥0,29</td><td>4</td><td>Class > 8</td></tr>
</table>
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<td>
<p>Standard acceleration response spectrum S_0 : obtained from strong motion records with 394 components observed at the ground surface in Japan, with these results modified to account for the characteristics of past earthquake damage, vibration properties of the ground, and other engineering evaluation.</p>
<p><i>Table 2</i> <i>Standard acceleration response spectrum S_0</i></p>
<table>
<tr><th>Ground type</th><th colspan="3">S_{IIO} (gal) with natural period T(s)</th></tr>
<tr><td>I</td><td>T<0,3
$S_{IIO}=4.436T^{2/3}$</td><td>0,3≤T≤0,7
$S_{IIO}=2.000$</td><td>0,7<T
$S_{IIO}=1.104/T^{5/3}$</td></tr>
<tr><td>II</td><td>T<0,4
$S_{IIO}=3.224T^{2/3}$</td><td>0,4≤T≤1,2
$S_{IIO}=1.750$</td><td>1,2<T
$S_{IIO}=2.371/T^{5/3}$</td></tr>
<tr><td>III</td><td>T<0,5
$S_{IIO}=2.381T^{2/3}$</td><td>0,5≤T≤1,5
$S_{IIO}=1.500$</td><td>1,5<T
$S_{IIO}=2.948/T^{5/3}$</td></tr>
</table>
</td>
</tr>
<tr>
<td>Factor depend on seismic zone</td>
<td><p>There is no modification factor for zone, acceleration coefficient is classified according to 4 seismic zones, that are A ≤ 0.09; 0.09 < A ≤ 0.19; 0.19 < A < 0.29; A≥0.29 corresponding to zone 1, 2, 3, 4</p></td>
<td>
<p>Modification factor for zone C_Z is 1.0; 0.85; 0.7 corresponding to zone A, B, C to correct the acceleration response spectrum S_0, that applied for the bridge in large scale earthquake may happen</p>
<p>There are 3 zones following the regional classification map. The regional classification of earthquake ground motion complied by the Ministry of Construction. This map has been prepared by examining the results of studied published so far concerning the seismic risk in Japan, to obtain practical applicable regional characteristics of seismic risk and also comprehensively examining together with practical applicable data on the earthquake occurring at inland active faults.</p>
</td>
</tr>
</table>

<table>
<tr>
<td>Factor depending on natural period T and soil profile</td>
<td>
Elastic Seismic Response Coefficient C_{sm}

$$C_{sm} = \frac{1,2AS}{T_m^{2/3}} \leq 2,5A$$

T_m: Period of vibration of the m th mode (s)
A: Acceleration coefficient
S: Site coefficient specified

For soil profiles III and IV, and for modes other than the fundamental mode that have periods less than 0.3s: $C_{sm} = A(0.8 + 4.0\ T_m)$

If the period of vibration for any mode exceeds 4.0 s: $C_{sm} = \frac{3AS}{T_m^{4/3}}$

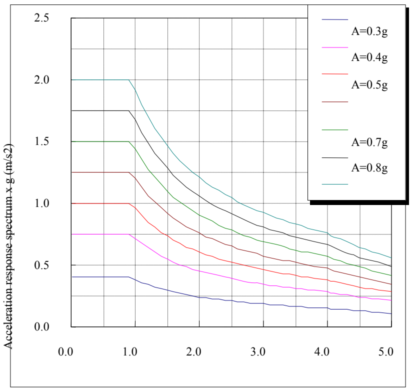

Figure 1. *Acceleration response spectrum C_{sm}*
</td>
<td>
Standard value of the design horizontal seismic coefficient k_{hco}

k_{hc0}=f(T, S) as Table 3:

Table 3. *Standard value of the design horizontal seismic coefficient k_{hco}*

<table>
<tr><td>Ground type</td><td colspan="3">k_{hco} , value in term of natural period T (s)</td></tr>
<tr><td>I</td><td>T<0,3
$k_{hcO}=4.46T^{2/3}$</td><td>0,3≤T≤0,7
$k_{hcO}=2.0$</td><td>0,7<T
$k_{hcO}=1.24/T^{-4/3}$</td></tr>
<tr><td>II</td><td>T<0,4
$k_{hcO}=3.22T^{2/3}$</td><td>0,4≤T≤1,2
$k_{hcO}=1.75$</td><td>1,2<T
$k_{hcO}=2.23/T^{-4/3}$</td></tr>
<tr><td>III</td><td>T<0,5
$k_{hcO}=2.38T^{2/3}$</td><td>0,5≤T≤1,5
$k_{hcO}=1.50$</td><td>1,5<T
$k_{hcO}=2.57/T^{-4/3}$</td></tr>
</table>

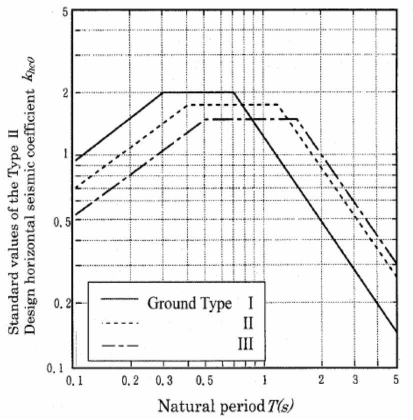

Figure 2*. Standard value of the design horizontal seismic coefficient k_{hco}*
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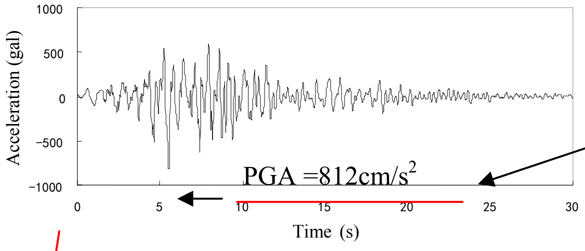
III. ANALYSIS CONSIDERATION METHOD OF DESIGN SEISMIC FORCE IN AASHTO 1998 AND JAPANESE SPECIFICATION

3.1. Consideration method of design seismic force in Japanese Specification

Japanese Specification do not use acceleration coefficient A or PGA, then design by acceleration response spectrum base on acceleration strong motion records actually obtained at ground surface (obtained from earthquake happening in Japan such as Hyogo-ken Nanbu earthquake of 1995 or disaster of large scale earthquake in Kanto). The procedure of seismic design is as follow:

a. Records actually obtained at ground surface

For example, during the Hyogo-ken Nanbu earthquake of 1995, the high acceleration was recorded at Kobe Maritime Meteorological Observatory

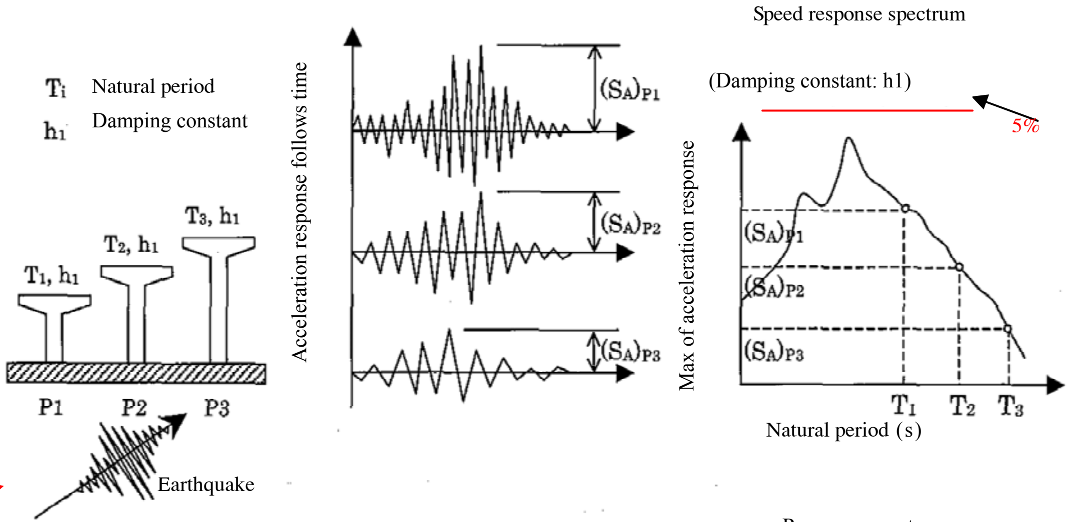


Japanese does not use this value directly

__Figure 3.__ Acceleration recorded during the Hyogo-ken Nanbu earthquake of 1995

b. Calculate acceleration response spectrum of structure

Act the obtained acceleration on structure having different natural period and establish acceleration response spectrum of the structure.



a. Damping constant not changed; Natural period changed

b. Response follows time history

c. Response spectrum

__Fifure 4.__ Steps of establishment of acceleration response spectrum of the structure

c. Calculate acceleration response spectrum of structure for each ground type

Base on 3 ground types, establish acceleration response spectrum of structure for each ground type

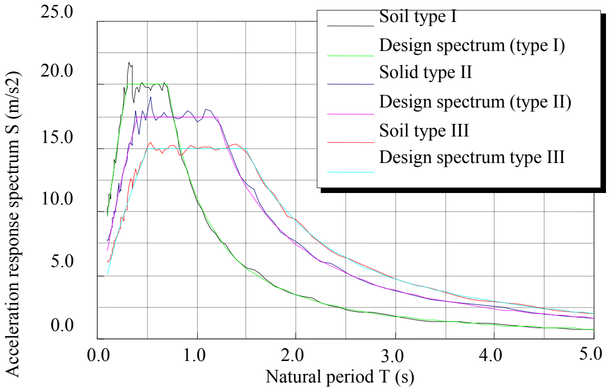


Figure 5. *Acceleration response spectrum of structure for each ground type*

d. Calculate standard value of design horizontal seismic coefficient

Standard value of design horizontal seismic coefficient for each natural period established by modification of acceleration response spectrum of ground motion through damping constant for each natural period

$$k_{h0} = \frac{S(T,h)}{g}$$

Therefore, acceleration response spectrum and standard value of design horizontal seismic coefficient are little different as below figure 6:

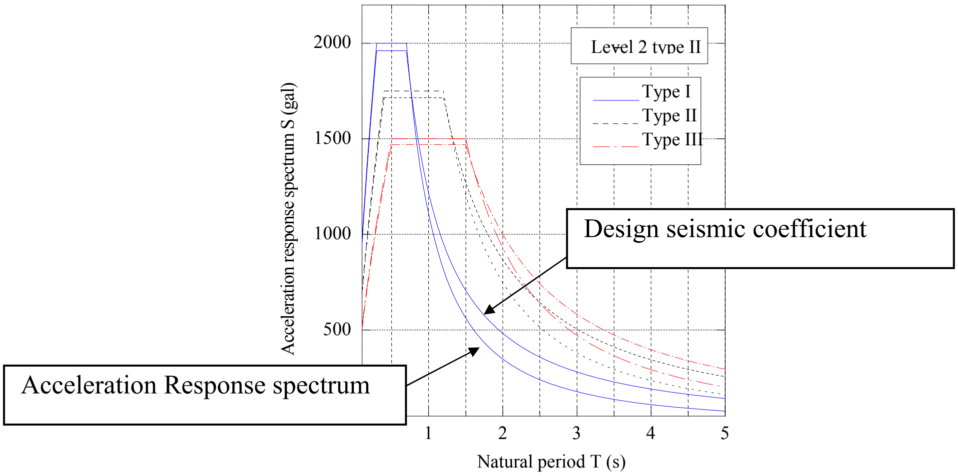


Figure 6. *Acceleration response spectrum and Standard value of design horizontal seismic coefficient*

Note: Upper line is Standard value of design horizontal seismic coefficient
Under line is Acceleration response spectrum

e. Actual calculation

In static design, calculate standard value of design horizontal seismic coefficient (k_{hco}) follow above steps, then multiply with below factors for getting design horizontal seismic coefficient (khc) for design.

Factor for zone: Base on probability of earthquake occurring in zone C_z= 0,7~1,0

Factor for structure's property: Base on plasticity of structure's component $C_S \frac{1}{\sqrt{2\mu - 1}}$ with μ allowable ductility ratio, about 0.45

Factor for damping: Base on damping method such as isolation bearing shoe C_E=0.7~1.0

Factor for modification of dynamic: Base on relative difference between superstructure and substructure C_m=1.2

3.2. Consideration method of design seismic force in AASHTO 1998

a. Decide acceleration coefficient

Acceleration coefficient in AASHTO 1998 is "peak of ground acceleration (PGA)" or "maximum value of ground acceleration" considering return period or probability of exceedance (PE), it looks seismic coefficient in seismic design

Decide acceleration coefficient from hazard map considering to zone's properties and return period or probability of exceedance

Table 5. *Acceleration coefficient*

Zone	Acceleration coefficient
1	$A \leq 0.09$
2	$0.09 < A \leq 0.19$
3	$0.19 < A < 0.29$
4	$0.29 < A$

b. Calculate elastic seismic response coefficient Csm (or response acceleration of structure)

Response acceleration of structure for its natural period Tm established by modification of acceleration coefficient through site coefficient S

$$C_{sm} = \frac{1.2AS}{T_m^{\;2/3}} \le 2.5A \;\square\; C_{sm} = A(0.8 + 4.0T_m)\,,C_{sm} = \frac{3AS}{T_m^{\;4/3}}$$

For soil type III, IV and T < 0.3 For T > 4.0

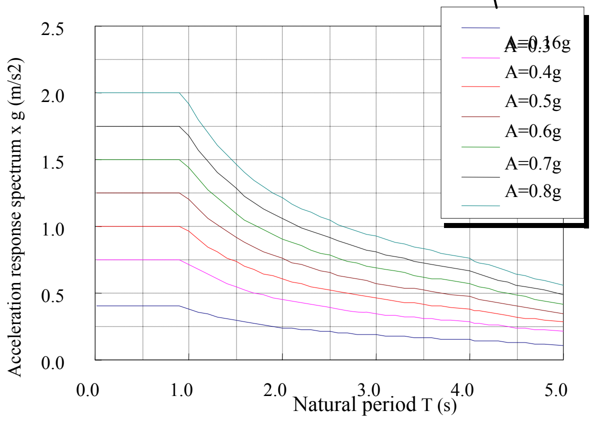


Figure 7. *Acceleration response spectrum* C_{sm}

c. Actual calculation

In static design, calculate response acceleration of structure (C_{sm})follow above steps, then consider to below factors for getting C_{sm} for design.

Factor for structure's properties: Base on plasticity of structure's component R= 0.8～5.0

Factor for damping: Base on damping method such as isolation bearing shoe B= 0.8～2.0

3.3. Basic different between ASHTO1998 and Japanese Specification in seismic design

Both of acceleration coefficient of AASHTO 1998 and standard value of design horizontal seismic coefficient of Japanese Specification give similar result, however start point and procedure to the result of both are different.

a. Start point and procedure to the result of both are different

Japanese Specification

Obtained acceleration in the past → Acceleration response spectrum S → Consider to modification factor for standard value of design horizontal seismic coefficient khco

AASHTO 1998

Acceleration coefficient A or PGA considering return period → Acceleration response spectrum C_{sm} → Consider to modification factor for elastic seismic response coefficient C_{sm}

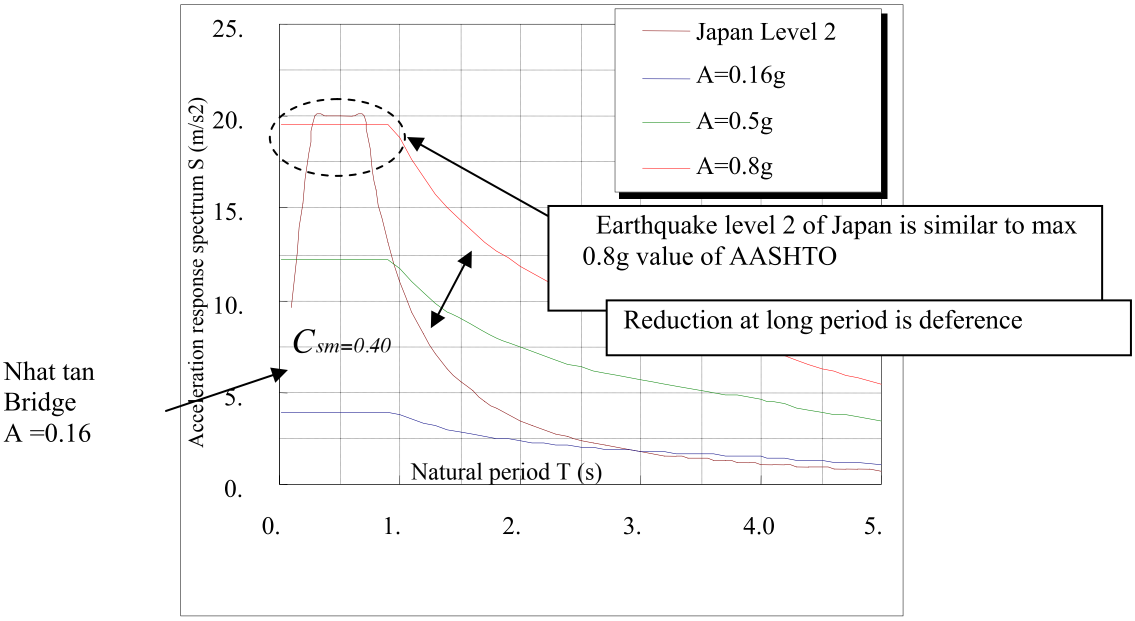
b. Result of acceleration response spectrum

Both Specifications give curves of Acceleration response spectrum; the comment is given base on graph:

Maximum value of acceleration response spectrum of both Specification concentrate to similar value of natural period

Value of maximum acceleration response spectrum of level 2 earthquake of Japanese Specification is similar to value of maximum acceleration response spectrum of acceleration coefficient A=0.8 of AASHTO 1998

Reduction slope of acceleration response spectrum at long natural period of Japanese Specification is more sloping than AASHTO 1998



Earthquake level 2 of Japan is similar to max 0.8g value of AASHTO

Reduction at long period is deference

Nhat tan
Bridge
A =0.16

Figure 8. *Curves of acceleration response spectrum of AASHTO 1998 and Japanese Specification*

IV. COMMENTS

Each Specification has own back ground and composes each design procedure by own philosofy. Therefore, basically we cannot use two design Specifications with mixed way in one project, namely each equation, table, etc. are not like subroutines in Specification for aplying.

Comparison between two Specifications is necessary to more understand each back ground and philosophy. Base on above comparisons, the comment is proposed that we cannot use acceleration coefficient A of AASHTO 1998 for seismic design according to Japanese Specification. However in the case of applying the Japanese Specification to carry out seismic design for projects in Vietnam, that have only acceleration coefficient, in limited range we can use Elastic seismic response coefficient C_{sm} of AASHTO 1998 replacing for factor of $k_{hco}.C_Z$ for seismic design according to Japanese Specification.

If possible, comparison between results of the existing bridges, which carried out by two Specifications of seismic design, will give us more detail comment about the difference between two Specifications in Seismic design

References

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