DEVELOPMENT OF EARTHQUAKE RESISTANT DESIGN GUIDELINES FOR BRIDGES IN SRI LANKA

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Degree of Master of Science in Structural Engineering Design

Department of Civil Engineering

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DECLARATION

I declare that this is my own work and this thesis does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgment is made in the text.

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The above candidate has carried out research for the master dissertation under my supervision. I confirm that the declaration made above by the student is true and correct.

Name of the supervisor: Prof. C.S. Lewangamage

……………………………. …………………………

Signature of the supervisor Date

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Abstract

Sri Lanka is an island located on the Indo-Australian tectonic plate and the location of the country is far away from the plate boundary where inter-plate earthquakes are possible to occur. However, there are earthquake records during the recent past which have considerable magnitude. Moreover, intraplate earthquake risk is there which is possible to occur without prior warning. Therefore, Sri Lanka is no longer be considered safe from seismic threats.

With the increasing demand to improve the road network in the country, it is necessary to reconstruct existing bridge structures. However, there are no seismic design guidelines to use for bridge design procedure in Sri Lanka.

This study is therefore aims to formulate earthquake-resistant design guidelines for bridges in Sri Lanka. For the purpose of formulating the design guideline, bridge classification into three different important classes is proposed based on the relevant classifications in similar codes such as EN 1998-2:2005 , IS 1893-3:2014 and AS 5100.2-2004. Important factors and return periods are proposed based on the guideline given in EN 1998-1:2004. Further, Elastic response spectrums for rock or hard soil are selected based on the available response spectrum for Sri Lanka. However, there is no response spectrum defined for medium soil and soft soil. Therefore, it is proposed to use the response spectrum available in IS 1893-1:2002 for medium and soft soil since soil and rock types are more similar when both countries lie on the same tectonic plate.

This study proposed a seismic analysis approach for bridges using either EN 1998-2:2005 or AS 5100.2-2004. Moreover, suitable design parameters such as peak ground acceleration values are proposed to select according to the available national data.

There are three case studies carried out to illustrate the use of developed guidelines for seismic analysis of bridges in Sri Lanka. Three Case studies were carried out for bridges in the category of important class I, important class II and important class III by using the design codes of AS 5100.2-2004, IS 1893-3:2014, and EN 1998-2:2005. For case study 1, base shear values were calculated using the static lateral force method of analysis and three different design codes provided different results of 50kN, 51kN, and 36kN. For case studies 2 and 3, static analysis was carried out using selected three design codes, and response spectrum analysis was carried out according to EN 1998-2:2005 using the response spectrum defined for rock or hard soil of Sri Lanka. Base shear values of the static analysis results provide different values for three design codes. However, a comparison of the results of response spectrum analysis and fundamental mode method of analysis for Eurocode 8-part2 as the basis of analysis, provided similar fundamental period values and base shear values for both methods.
Results of the case studies illustrate that when the design basis is Eurocode 8-Part 2, it provides an average or lower result of base shear value. Since Eurocode 8 provides an opportunity to use it with national choices, it is more suitable to use EN 1998-2:2005 with a national annex for bridge design. Therefore, a developed guideline with national parameters can be used for the seismic design of bridges in Sri Lanka.

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List of Abbreviations

q - Behavior factor

η - Damping correction factor with a reference value of η = 1 for 5% viscous damping,

d_{es} - d_{Ed} for decks connected monolithically or through fixed bearing

h - Depth of cross section

DBE - Design Basis Earthquake

d_g - Design ground displacement in accordance with EC8-1 Cl. 3.2.2.4 $= 0{,}025.a_g.S.T_C.T_D$

d_E - Design seismic displacement in accordance with 2.3.6.1. EC8-2

L_s - Distance from the plastic hinge to point of zero moment

L_g - Distance beyond which the ground motions may be considered as completely uncorrelated.

d_T - Displacement due to thermal movements

d_{eg} - Effective displacement of the two parts due to spatial variations of the seismic ground displacement.

L_{eff} - Effective length of deck, taken as the distance from the deck joint in question to the nearest full connection of the deck to the substructure.

d_{es} - Effective seismic displacement of the support due to the deformation of the structures

Se(T) - Elastic response spectrum

EC - Eurocode

t - Exposure period

Ƴ - Importance Factor

d_G - Long term displacement due to permanent & quasi-permanent actions

T_B - Lower limit of the period of the constant spectral acceleration branch

MCE - Maximum Considered Earthquake

l_m - Minimum support length ensuring the safe transmission of the vertical reaction, but no less than 400mm

T_n - Natural Period

PGA	-	Peak Ground Acceleration
a_g	-	Peak Ground acceleration value
P	-	Probability of exceedance
a_{gR}	-	Reference peak ground acceleration
T_{LR}	-	Reference return period
T_L	-	Return Period
R	-	Risk Factor
α_s	-	Shear Span ratio
S	-	Soil factor
$S_{a/g}$	-	Spectral Acceleration
SPT	-	Standard penetration test
M_s	-	Surface wave magnitude
ULS	-	Ultimate Limit State
T_c	-	Upper limit of the period of the constant spectral acceleration branch
T_D	-	Value defining the beginning of the constant displacement response range of the spectrum
T	-	Vibration period of a linear single-degree-of-freedom system