Journal of Civil Engineering and Environmental Technology
p-ISSN: 2349-8404; e-ISSN: 2349-879X; Volume 3, Issue 9; October-December, 2016, pp. 801-804

http://www.krishisanskriti.org/Publication.html

Seismic Risk Analysis of RCC Bridge Pier

Vidushi Chauhan

Student of M.tech Earthquake Engineering, Jamia Millia Islamia, New Delhi, India
E-mail: vidushi@gmail.com

Abstract—*The consequences of seismic hazards may be very disastrous for the society and therefore proper decision making is very essential. The determination of* ***seismic risk*** *is the foundation for risk mitigation, decision-making, and a key step in risk management In this regard, the seismic risk assessment of an existing RCC bridge using hazard curve is presented here. The bridge taken for study is a metro bridge in DELHI located on the river Yamuna at about 85m downstream of Okhla Barrage (KALINDI KUNJ). As pier is considered to be the most important part of any bridge which responds inelastically under earthquake excitation hence the study mainly focusses on pier number 2 whose total height is 15.60 and diameter 2.2m .The method is based on PSHA analysis.it is extensively used to investigate the probability of different seismic hazard levels at a particular geographical location, and in past 20-25 years probabilistic approaches have attracted increasing attention in earthquake engineering and much research has been carried out nowadays to develop more efficient methods. First the basic theory is illustrated followed by the procedure to evaluate the seismic risk. Nonlinear Time history (IS Code compatible for Hard soil) analysis for different PGA values is being carried out, then the probability that the structural seismic demand will exceed the corresponding ground motion is calculated using seismic hazard curve. The results obtained are presented in the following sections*

1. INTRODUCTION

India had experienced a no. of world's greatest earthquakes in past years most of which have been of magnitude more than 7.0 on Richter scale. Of these Dec 26, 2004 Indian Ocean earthquake, which killed 15000 people in India was the third deadliest earthquake in the history of world. More than 50% of the country is considered as prone to damaging earthquakes. The Kashmir region, the western and central Himalayas, north and east Bihar are the areas with highest risk zones (zone 5) region of the country that suffers earthquake of magnitude more than 8.0. Bridges are potentially one of the seismically vulnerable structures in the highway system. These often provide a link to earthquake prone areas as seen in the Bhuj earthquake and hence, have vital post disaster operations. Therefore, they must remain functional after the seismic event is over to provide relief. Bridges are also called as the lifeline structures because they serve during emergency. Damage to bridges causes huge loss to life and property. Hence, they need to be designed in such a way that they are least damaged during any natural calamity. During earthquake large amount of energy is transferred from ground to the structure therefore, we need to design bridges in such a way that they dissipate large amount of energy. In bridges piers are designed to bear the damage unlike in buildings where strong column weak beam philosophy is adopted for design. Most of the damage in the past earthquake has occurred at columns as it follows weak column behaviour. Another factor which comes into play is the seismic risk analysis which is defined as the risk of damage from earthquake to a structure. The determination of **seismic risk** is the foundation for risk mitigation decision-making, a key step in risk management. A building located in a region of high seismic hazard is at lower risk if it is built to sound seismic engineering principles. On the other hand, a building located in a region with a history of minor seismicity, in a brick building located on fill subject to liquefaction can be as high or at higher risk. There are many literatures (e.g., IITM-SERC Manual, 2005) available that presents step-by-step procedures to evaluate multistoried buildings. This procedure follows nonlinear static (pushover) analysis as per FEMA 356. The attention for existing bridges is comparatively less. In order to address the problem; the present work aims to carry out the seismic risk analysis of a RCC bridge.

2. DESCRIPTION OF STUDY CASE

The bridge taken for study is a metro bridge in DELHI located on the river Yamuna at about 85m downstream of Okhla Barrage (KALINDI KUNJ). The river bed is sandy . The total length of the bridge consists of 14 spans with each span of 41m and piers with height P1=7.67m, P2=P3=P4….P14 = 15.60m and P15= 6.092m. The superstructure consists of PSC box girder deck section and RC slab supported on I- section girders (beams) while the substructure consists of piers and pile foundation with well surrounding the piles. As pier is considered to be the most important part of any bridge which responds inelastically under earthquake excitation hence the study mainly focusses on pier number 2 whose total height is 15.60 and diameter 2.2m with circular cross section, pier cap dimensions are 3x4.1x1.4 (m) and the bearings (POT-PTFE type) dimension are 1x1x0.330 (m) .The design of bearings shall confirm to IRC: 83- Part3. All bearings are designed for minimum horizontal force as 10% of vertical load. The bridge lies in seismic zone 4 with seismic zone factor 0.24g. This region is considered to be prone to seismic activity, hence the bridge is considered to be important as per IITK-RDSO guidelines (2010) with importance factor of 1.5, Moreover metro is the lifeline of the National Capital, therefore the proper functioning of this bridge under seismic loading is very necessary for the safety of people as well as from other aspects as its malfunctioning will disturb the activities of this area.

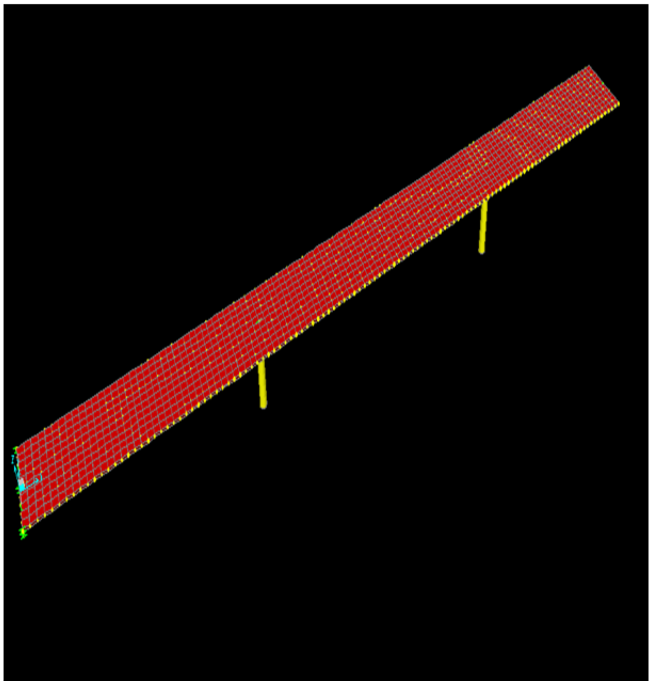

Fig. 1: Snapshot of bridge model from SAP2000

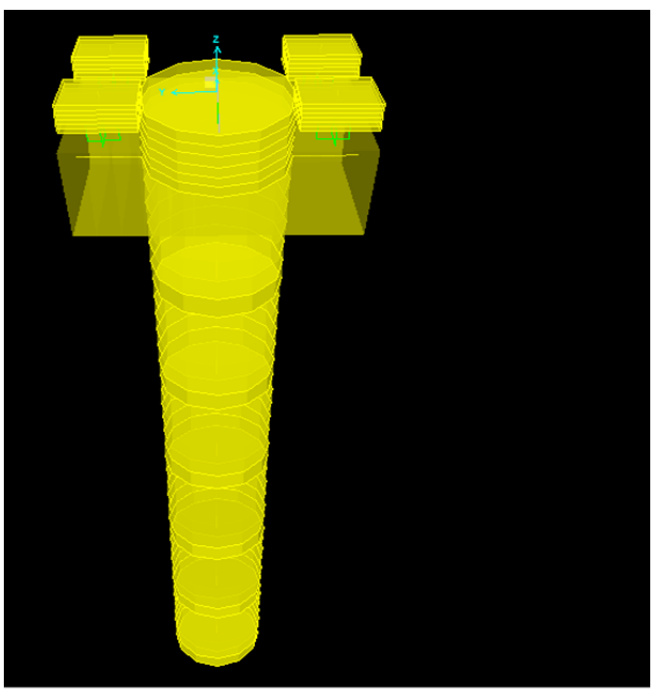

Fig. 2: Model of pier from SAP2000

3. SEISMIC RISK

1) Seismic risk at a site is similar in concept to that of a probabilistic seismic hazard determined for a site. Seismic risk is defined as the probability that a ground motion X_s that is equal to or greater than a specified value X_1 will occur during a certain period (usually one year) at the site of interest, that is, $P(X_s \geq X_1)$, or it can be defined by the return period T_{x1}, which is inverse of $P(X_s \geq X_1)$. The study of seismic risk requires:

a) Geotectonic information that provides estimates for the source mechanism parameters such as focal depth, orientation of the causative fault rupture, and the earthquake magnitude;

b) Historical seismicity presented in the form of a recurrence relationship, which allows the development of the probability distribution of the magnitude of an earthquake and contains information related to the relative seismic activity of the region;

c) A set of attenuation relationships relating the ground motion parameters at any site to the source magnitude and epicentral distance.

2) The seismic risk of a structure is usually defined as the annual probability of failure $P_{f,}$ which can be expressed as

$$\mathbf{P_f = P_r\{D>C|1\ YEAR\}}$$

Where D is a measure of yearly maximum demand on the structure and C is measure of capacity of the structure. The term failure does not necessarily mean the collapse of structure but it refers more generally to the exceedance of a predefined performance level. Risk is defined by four parameters:

i) Probability
ii) Level of severity
iii) Time period
iv) Location

Seismic risk depends not only on seismic hazard and exposure conditions but also on the models i.e. time independent (Poisson model) and time dependent ones that could be used to describe the occurrence of earthquakes. High seismic hazard does not necessarily mean high seismic risk and vice-versa. For egg. There are high seismic hazards in California deserts but low seismic risk due to low exposures (buildings and people), on the other hand seismic risk could be high in countries like Pakistan, Iran because of high exposure even though the hazard could be moderate. The different models will result in different risk estimates.

4. SEISMIC HAZARD CURVE

Hazard and Risk are two fundamentally different concepts. In general hazard is a phenomena that has potential to cause harm. Risk on the other hand is the probability (chance) of harm if something is vulnerable to hazard. In quantitative terms, a hazard is defined by three parameters:

i) A level of hazard
ii) Its occurrence frequency
iii) location

Seismic hazard curves can be obtained for individual source zones and combined to express the aggregate hazard at a particular site. The basic concept of the computations required for development of seismic hazard curves is fairly simple. The probability of exceeding a particular value, y*, of a ground parameter, Y, is calculated for one possible earthquake at one possible source location and then multiplied by the probability that, that particular magnitude earthquake would occur at that particular location. The process is then repeated for all possible magnitudes and locations with the probabilities of each summed. Since the actual hazard curve for the region is not available, it is assumed that the seismic hazard curve shown in (Fig. 3) is valid for the site.

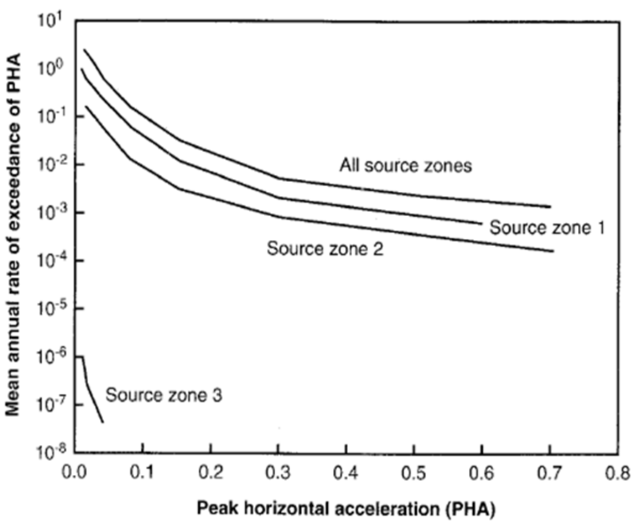

Fig. 3: Seismic Hazard curve

5. RESULTS

Time history analysis (Hard soil i.e. type 1) for different PGA values is being carried outand the probability that the structural seismic demand will exceed the corresponding ground motion parameter (PGA) is calculated using seismic hazard curve (Fig.3).From the results shown above in (table 1) it can be observed that The AnnualProbability of Exceedance (Mean annual rate of exceedance) is higher for smaller PGAvalues and it decreases as we move to higher values of ground motion parameter. FurtherMean annual rate of exceedance of smaller earthquakes is greater than largerearthquakes because it has been found that earthquakes of higher magnitude (PGA) donot occur frequently, the reciprocal of annual rate of exceedance is known as return period of earthquakes exceeding that magnitude.

Table 1: Time history analysis results for different PGA values

PGA(g)	Base shear	Max. Displacement	Annual Probability of Exceedance(%)
0.05	956.24	0.013	80
0.08	1070.65	0.015	52
0 .10	1111	0.017	10
0.12	1465	0.020	9
0.16	1883	0.025	6.32
0.18	2115.78	0.029	5
0.24	2742	0.039	4.30
0.26	3056	0.042	3.88
0.36	3247.36	0.056	0.88
0.48	3936.92	0.075	0.64
0.52	4226.59	0.084	0.48

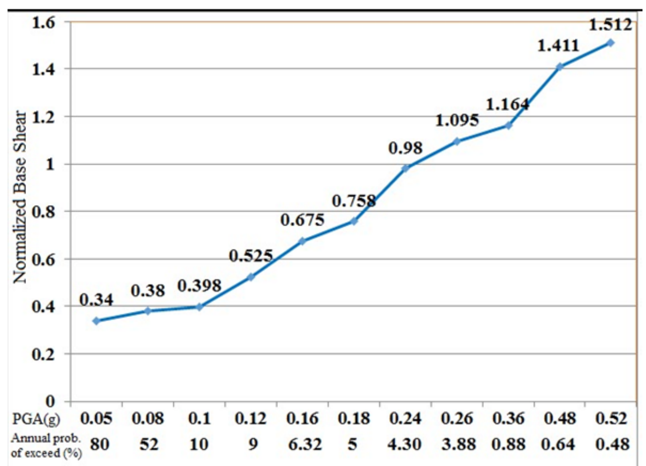

Fig. 4: Normalized base shear variation with PGA

$$\text{Normalizedbaseshear} = \frac{\text{value of base shear corresponding to a particular PGA value}}{\textit{Total load acting on the structure}}$$

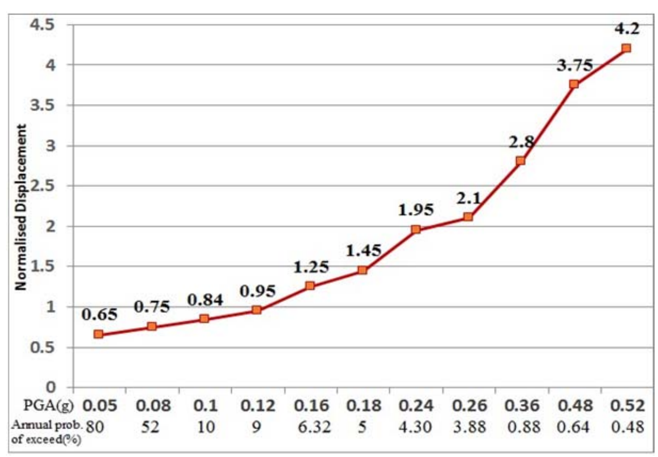

Fig. 5: Normalized displacement variation with PGA

Normalized displacement= $\frac{\text{value of displacement corresponding to a particular PGA value}}{\text{Threshold displacement}}$

Magnitude Probability distribution:

Using the Cornell equation al. (1979) given as:

$$\text{Ln PHA (gals)} = 6.74+0.859M-1.80\ln(R+25)$$

For different PGA values, using the relation given above the magnitude corresponding to these peak ground accelerations has been obtained. The distance from the source has been taken as 25km.From the above calculated values of annual probability of exceedance for these PGA values, a magnitude probability distribution histogram is plotted. From the graph (fig. 6) shown above it can be seen that the probability of exceedance decreases for higher magnitude values as it has been observed that earthquakes of higher magnitudes do not occur frequently

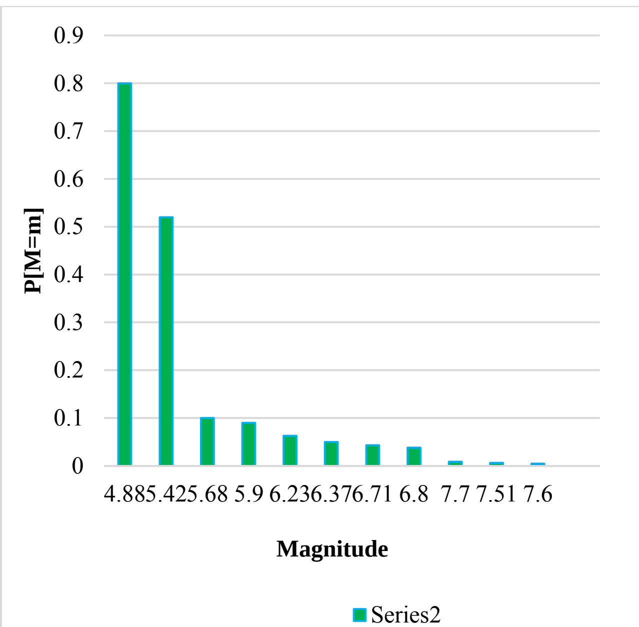

Fig 6: Graph between annual probability of exceedance and Magnitude

6. CONCLUSION

a) Using the seismic hazard curve (Fig.3), The Annual Probability of exceedance corresponding to different PGA values is calculated .from the table and magnitude probability histogram it can be seen that the seismic risk is high for lower PGA values and decreases for higher values of PGA. Further Mean annual rate of exceedance of smaller earthquakes is greater than larger earthquakes because it has been found that earthquakes of higher magnitude (PGA) do not occur frequently, the reciprocal of annual rate of exceedance is known as return period of earthquakes exceeding that magnitude.

b) With increasing PGA, the values of maximum base shear and maximum displacement increases, the maximum displacement, as obvious is obtained at the top of pier.

7. SCOPE OF THE STUDY:

The paper presents the seismic risk study carried out on a RCC bridge pier**.** The methodology can be applied for the study of different types of structures like buildings, steel structures as seismic risk is the most important parameter to judge the safety of these structures under earthquake excitations.

REFERENCES

[1] Ady Aviram, Kevin R. Mackie, Bozidar Stojadinovic, PEER Centre "Guidelines for Nonlinear Analysis of Bridge Structures in California

[2] A Lupoi, P.Franchin & M. Schotanus "Seismic risk evaluation of RC bridge structures" (2003).

[3] A.Rahai & M.Arezoumandi **.**Effect of vertical motion of earthquake on RC bridge pier

[4] D. Cardone, Giuseppe & M. Dolce " Seismic risk assessment of highway bridges"

[5] Gregory G. Deierlein, Andrei M. Reinhorn and Michael R. Willford, "Nonlinear Structural Analysis for Seismic Design", NIST GCR 10-917-5.

[6] IITK – RDSO Guidelines on Seismic Design of Railway Bridges, Research Design and State Organization, National Information Centre for Earthquake Engineering, Lucknow, 2010.

[7] IS 456, "Indian Code of Practice for Reinforced Concrete Structures Using Limit State", Bureau of Indian standards, New Delhi

[8] IS: 1893-2002 (Part 1), Criteria for Earthquake Resistant Design of Structures, Fifth Edition, Bureau of Indian Standards, 2002.

[9] IS: 1893-2002 (Part 3), Criteria for Earthquake Resistant Design of Structure, Fifth Edition, Bureau of Indian Standards, 2002

[10] M.G. Sfahani ,Hong guan & Yew chaye loo(2015)" Seismic reliability and risk assessment of structures based on fragility analysis"

[11] Miguel Arriagae Cunha (2011). **"**Seismic analysis of bridges"

[12] Rahul Leslie **"**The pushover analysis explained in its simplicity**".**

[13] Rajeev Sharma (2015) "Nonlinear static analysis of RC bridge".

[14] Sachin Kulkarni, U.N. Karadi (2014)" Case study of RC slab bridge using nonlinear analysis".

[15] Steven L. Kramer "Geotechnical earthquake engineering".

[16] T.K. Datta " seismic analysis of structures", John wiley and sons (Asia)