Earthquake Engineering, Tenth World Conference © 1992 Balkema, Rotterdam. ISBN 90 5410 060 5

A method for evaluating earthquake resistant behaviour of bridge

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ABSTRACT: In this paper, a method is proposed for evaluating earthquake resistant behaviour of bridge based on system analysis. It comprises three steps. First, the assessment of seismic hazard for site of bridge is obtained to be considered the seismicity in spatical nonuniform and time nonstationarity by probability method of seismic hazard analysis. Then, the dynamic character of bridge is determined based on the earthquake excitation and dynamic prototype tests to be identified the space action of the whole bridge need be considered or not for built the reasonable calculating mathematical model of bridge, Finally, the earthquake resistant behaviour is evaluated through system analysis in which included the risk level of bridge site to be identified according to type and importance of bridge and calculation analysis of soil-bridge interaction and liquefaction etc. using proposed method to evaluating earthquake resistant behaviour of bridge is with accurate estimation and reliability than usual method.

1 INTRODUCTION

Correctly estimating the earthquake resistant behaviour of bridge is very important project for safety operating to ensure the vital traffic pass unimpeded during earthquake excitation. Generally, aseismic design code is used as the usual method to provided for evaluation earthquake resistant behaviour of bridge in which the design ground motion parameters and evaluating calculation method of bridge are key factors to affect the evaluating results of bridge. Using the usual method it could be either underestimated or overestimated the earthquake resistant capability due to adopt the design ground motion parameters can not be reflected the local site condition, regional seismology and geology as well as seismicity around the bridge site Chozen the mathematical model from the code for evaluating earthquake resistant behaviour of bridge is also not better to conform the dynamic behaviour of bridge during earthquake. If the design ground motion parameters for bridge site is underestimated, it is existing hidden danger, and is overestimated, it enhance unnecessary strengthening cost. Comparison the affection evaluation results of two key factors are shown that the error of evaluating results is induced by design ground motion parameters more than mathematical model for dynamic analysis of bridge. (Zhang Xue-Liang,(1988)). Therefore, the usual method can be only used as generally estimating earthquake resistant capacity for the ordinary bridge. In order to ensure safety operating of important bridge during earthquake excitation. At first, we ought to correctly estimate the design ground motion of bridge site, based on probability method of seismic hazard analysis. Then, the dynamic analysis calculation model is built based on the earthquake excitation or dynamic tests, Finally the system analysis method is proposed in this paper for evaluating earthquake resistant capacity of bridge. Using this proposed is with accurate estimation and reliability than using usual method.

2 SEISMIC HAZARD ANALYSIS

The probability method of seismic hazard analysis is used to determine the rock peak acceleration with a certain annual probability of exceedance of the site of bridge. It is as criterion of bridge risk level for assessment seismic hazard of the site of bridge. In order to increase reliability, it is need to consider various factors influencing the seismic force on structures such as seismology-geology, seismicity, propagation path, local site conditions etc. It comprises three steps as following.

2.1 Identification potential seismic sources. Considering a region with a radius of 320 KM around centre of the site of bridge, the active faults, deep rupture, seismicity, correlation between active faults and destructive earthquake and the seismicity character of basins structures etc. are used to identify the regions of potential seismic source. According to contribution dergee of regions of potential seismic source formed seismic hazard for the site, it may be divided three subareas within the range of 320 KM. Distance from 30 KM to site is as emphasis area, 30 to 100 KM is as secondary area, large than 100 KM is as general area. Three subareas of various degree are with various degree investigation on the correlation between active faults and seismicity. Because, the major contribution source formed seismic hazard for the site are usually in potential seismic source of emphasis area in which the active faults and seismicity must be investigated deeply for identification the regions of potential seismic source as possible as unique. (Zhang Xue-Liang, Yan Xin-Yu, 1990). The contribution formed seismic hazard for the site is weakness in general area in which are promised to identify several set of potential seismic sources, it may be disposed to use the method of weighted coefficient value (Zhang Xue-Liang, Yan Xin-Yu,(1987) and Zhang Xue-Liang (1988)). Using this principle and method within the regional site, we may be distinguished primary and secondary and need to do for emphasis feild geological work which occupation radio of cost is large in seismic hazard analysis, it is not only increasing reliability but also enhancing ratio of benefit-cost.

2.2 Seismicity parameters

Seismicity parameters of potential seismic sources are important factors to affect the seismic hazard assessment for the site of bridge such as reflecting the ratio of large and small earthquakes, annual occurrence rate and maximum magnitude. The occurred position of large earthquake is limited in range as possible as small through the identification potential seismic sources and its seismicity parameters, according seismogeological and seismicity data in usual probability method of seismic hazard analysis, it is used to be considered the seismicity in spacial nonuniform and time nonstationarity. Supposed occurrent earthquake is with equal probability in same potential seismic source, then may be denoted to use the uniform poisson model. It is idea that annual occurrence rate is only one in each potential seismic source in which is induced risk for low estimated large earthquake. For the porpose is that contribution of seismic hazard analysis for the site is not low estimated on high magnitude, the seismicity is considered in spatial nonuniform and time nonstationarity which is simplified to dispose as uniform and stationarity as following steps.

1. The seismicity level is changed with time in the range of statistical region of earthquakes and according the maximum seismicity tendeney in the future to determine the b value, annual average occurrence rate and maximum magnitude.

2. According to probability density function of earthquake space for each potential seismic source of magnitude grade, the annual average occurrence rate of magnitude grade of each earthquake can be obtained within statistical area of each earthquake to be determined the potential seismic sources and its maximum magnitude.

3. The lower bound magnitude is usually adopted as 4.0, the maximum magnitude of historical seismic sources is increased by 0.5 to give the upper bound magnitude (Zhang Xue-Liang, chief editor, 1987), except in region where a maximum magnitude of 8.0 or above has already been measured, since the accumulation of strain energy has already been released in these area.

2.3 Attenuation relation of ground motion

Various choice of attenuation relation of ground motion lead to large variation for seismic hazard assessment of the site of bridge in seismic hazard analysis, selection of realistic attenuation relation is one of the very important project inseismic hazard analysis. In order to enhance reliability and correctness, the attenuation relation is proposed based on seismic hazard analysis that is obtained to comprise two steps. First, a preliminary choice is made of the attenuation formula of ground motion or seismic intensity, based on the parameters given for various regions of potential seismic sources considering the seismological and geological condition, the major regions of potential seismic source are identified by comparing the annual exceedance probability for each contribution source in seismic hazard analysis. Then according to the maximum magnitude of regions of potential seismic source and distance from the major regions of potential seismic source to site, the attenuation formulas of ground motion are statistically obtained by selecting ground motion data with similar magnitude, hypocentral distance and seismological and geological conditions in the regional area.

2.4 Seismic hazard assessment

Using these parameters as stated above and considering seismicity in spacial nonstationary, contribution of seismic hazard of each region of potential seismic source for site of bridge can be obtained to use segment poisson model. According to segment poisson model and full probability theory, a probability of exceeding of specified rock peak acceleration of ground motion or intensity can be obtained. Suggested 50 and 100 years exceeding probability 0.1 and 0.02 is as risk level of nonstructural element and structural for important bridge respectively (Zhang Xue-Liang, Yan Xin-Yu 1990).

3 GROUND MOTION PARAMETERS

Artifical ground motion are generated using a nonstationary random process model, then the design ground motion parameters for bridge site are obtained by the wave motion analysis using the testing data of dynamic behaviour of soil layers in the bridge site

3.1 Site spectra and shape function

According to the major potential seismic sources with maximum magnitude and distance from the site, the site spectra are constructed to choose the data of ground motion with similar maximum magnitude of major potential seismic sources, hypocentral distance from the major source to site and seismological and geological conditions to be considered (Zhang Xue-Liang, (1987)).

The shape function of the ground motion is obtained by statistial analysis from ground motion data for the major potential seismic sources using values appropriate for the maximum magnitude and the distance from the site.

3.2 Artifical ground motion

For the shape of an artifical acceleragram on rock to achieve similitude with natural ground motion, it is generated to match the target spectra and corresponding shape function of ground motion, thus achieving required amplitudes, frequencies and duration. The technique is to use a nonstationary random process model (Zhang Xue-Liang, (1987), Zhang Xue-Liang, Yan Xin-Yu, (1986)).

3.3 Design ground motion parameters

The design ground motion parameters at surface for every boring of bridge site are obtained from the average values of calculating results of the seismic responses of soil layers. The seismic responses of soil layers are got by shearing wave model using the testing data of dynamic behaviour of soil layers in the bridge site in which the rock ground motion is as imput at the base rock surface.

4 DYNAMIC CHARACTER

Correction determination dynamic character of bridge is very important investigation project for built appropriate calculating mathematical model to estimate earthquake resistant capacity of bridge. The dynamic character of bridge structures can be obtained from the dynamic prototype test using the vibration generator as a shaking source and vehicle induced vibration or ambient vibration as a random sources. A set of strong motion acceleragraphs were located on some important bridge to hunt the strong motion records during earthquake excitation. The dynamic character of bridge can also be obtained by analysis these strong motion records (Zhang Xue-Liang, Yan Xin-Yu, (1984)). Bridge vibration behaviour with spatial action or not during earthquake excitation can be identified through investigation dynamic charater of bridge, then it may be built the calculating mathematical model of bridge with reflecting bridge vibration character during earthquake excitation.

5 IDENTIFICATION LIQUEFACTION

Generally speaking, the beam bridge were usually built on the soft formation, hence it is constructed with the piles foundation in the bearing layer to enhance the bearing capacity. Due to existing deep alluvium layer, the design length of piles were not necessarily constructed on the rock according the design load of bridge. In these cases, it could be induced liquefaction of soil during earthquake excitation in the feild of bridge site with these deep alluvium and especially for deep alluvium with a sandwith of a soft deposite. The frictional force of the piles of beam bridge will be decreased and the brearing capacity of piles were also decreased up to the damage of bridge due to liquefaction of soil. Therefore the damage of beam bridge with piles foundation on deep alluvium layer induceded soil liquefaction is very important investigation project in the evaluating earthquake resistance capacity of bridge. At first, the degree and range of foundation liquefaction of bridge are identified, then the earthquake resistant capacity of bridge is estimated

5.1 Method of identification liquefaction

Identification liquefaction around the piles foundation of bridge is usually to use the method provided from an aseismic design code in China which is used the relation between the numbers of standard penetration and earthquake intensity to build the experience formula. Using this method provided from code can only be to rough estimate, it is not appropriate identification liquefaction of improtant bridge. Calculation analysis soil-pile-structure interaction is considered using finite element analysis to identify the liquefaction degree and range around the piles foundation of bridge in which three dimensional problem of nonlinear soil-pile-structure is simplified to dispose as a two dimensional plane strain problem of equivalent linear, it is with enough engineering precision. In order to get the reliability value in the identification liquefaction of bridge site, it is need to measure these data of dynamic behaviour of soil layers in the bridge site, such as shear wave velocity and the relation between dynamic shearing modulus, damping ratio and shearing strain etc.

5.2 Calculation analysis

At first, the bridge dynamic character is determind throught the vibration test to be understood the bridge appeared spatial vibration or not. If the space action of bridge structure need not be considered during earthquake excitation (Zhang Xue-Liang, (1984)). Then the soil-pile-bridge structure interaction may be simplified as a two dimension plane strain problem of equivalent nonlinear, it can be satisfied the engineering precision. In the calculation analysis, it will be noticed some key points to be considered as follows.

1. Imput rock ground motion parameters
According to importance of bridges, chozen 50 years or 100 years exceedance probability 0.1 or 0.05 are respectively as the various risk level of bridges for seismic hazard assessment. Then, based on the application of probability method of seismic hazard analysis, the rock ground motion parameters can be obtained using the non-stationary random model as the imput at base rock surface in which if the soil layers are very thickness, then, the imput position of soil layers is chozen the value of shearing wave velocity is large or equal than 500 M per sec. as imput of rock ground motion parameters for nonlinear analysis of soil-pile-bridge structure interaction.

2. Basic data
Beside the meterial elastoplastic behaviour of bridge structure, the dynamic behaviour of various soil type in boring soil layers were measured in the field of bridge site to get the shearing wave velocity, and were adopted the soil core to be built the relation between dynamic shearing moludus, damping ratio and shearing strain through the dynamic triaxial testing analysis of soil core. These basic data is key value for increasing the engineering precision and reliability in evaluating earthquake resistant behaviour of bridge.

3. Identifaction criterion of soil liquefaction
The maximum seismic shearing stress can be obtained along the depth of soil layer at arbitrary position under earthquake load. Then, the Seed identifaction formula is improved to be used to identify soil liquefaction in these cases, that is when the maximum shearing stress to be gotfrom the calculation analysis is large than liquefaction resistance strength, it is liquefaction (Liu Ying, Xie Jun-Fei, (1984)).

6 SYSTEM ANALYSIS

As discussed above, according to the calculating analysis steps, the earthquake resistant behaviour of bridges were evaluated to correctly give the range and depth of foundation liquefaction of bridge and to also estimate seismic resistance capacity and stability of bridge. Using the method of system analysis, at first, it is to identify the depth and range of liquefaction of soil layers of bridge foundation and its neighborhood field. If the bridge foundation is liquefaction, then, the strength and stability of bridge are evaluated according the liquefaction depth of foundation and its neighborhord field.

The system analysis method is used to evaluate earthquake resistant behaviour for Nanjing Yangtse River bridge approach. It is a beam bridge, the length of frictional piles are 23.5M. The overburden thickness is 48.8M. the high of concret frame bridge piers is 19M. soil layers of sandy silt, sandy soil and sand loam etc. are distrubution along the surface to rock. The risk level of approach bridge is adoped 100 years exceedance probability 0.05 to get rock peak acceleration 90.1 gal., based on seismic hazard analysis. It is as imput at base rock surface, the results of calculating analysis is shown that the bridge foundation is identified liquefaction. The liquefaction depth is 9M. The position of nearby the bridge piers is nonliquefaction due to squeeze soil by piles. The liquefaction depth and range is increasing with the increasing the distance from the position of nearby the bridge piers. The calculating analysis results are very valuable to provide for the design of strengthening bridge.

7 CONCLUSIONS

The system analysis method for evaluating earthquake resistant behaviour of bridge is based on seismic hazard analysis and calculating analysis soil-pile-bridge structure interaction, it is with accurate estimation and reliability more than usual method. Although using this method, it will be increased the cost for the field dynamic tests of nearby the bridge site and also enhanced amount of work, but it will get high engineering precision for accurate evaluation seismic resistance capacity, then it can be adopted appropriate measure to ensure the vital traffic pass unimpeded during earthquake excitation.

8 ACKNOWLEDGEMENT

The authous wish to thank the colleagues of Seismological Bureau of Jiangsu Province for their support in complete process of this paper.

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