

Literature review of methods for earthquake analysis



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CHAPTER 2

2. REVIEW OF LITERATURE

2. 1 INTRODUCTION

Earthquakes result from the sudden movement of tectonic plates in the earth's crust. The movement takes place at fault lines, and the energy released is transmitted through the earth in the form of waves that causes ground motion many miles from the epicenter. Regions adjacent to active fault lines are the most prone to experience earthquake. As the ground moves, inertia tends to keep structure in place, resulting in the imposition of displacements and forces that can have catastrophic results. The purpose of the seismic design is to proportion structures so that they can withstand the displacements and the forces induced by the ground motion. Seismic design has emphasised the effects of horizontal ground motion, because the horizontal components of an earthquake usually exceed the vertical component and because structures are usually much stiffer and stronger in response to vertical loads than they are in response to horizontal loads.

Any learning process has different components through which learning takes place. School learning may be based on book knowledge, theoretical explanations and study, but most people learn more from real examples and learning by doing. Seeing is also much more educative than just reading, reason for which the illustration of a topic is of great importance to the learning process. Analysing post earthquake pictures does vividly teach about what designs were faulty and why. Unfortunately, that cannot be said from the structures that were not damaged because from the outside little

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can be seen. Only the study of the drawings and calculations can determine why a certain structure did not fail, and while neighbouring structure were damaged or totally collapsed. In particular those constructions that are at the point of total failure are interesting because they present themselves as a freeze frame during the process of collapsing.

Earthquake engineers in recent years have emphasized the need for performance-based seismic analysis. An essential element in many seismic evaluations is the determination of ultimate inelastic response of the structure. Performance-based methods require reasonable estimates of inelastic deformation or damage in structures which are better quantities to assess damage than stress or forces. The performance based analysis is based on quantifying the deformation of the members and the bridge structure as a whole, under the lateral forces of an earthquake of a certain level of seismic hazard. Existing codes are based on elastic analysis which has no measure of the deformation capability of members of bridges. The performance based analysis gives the analyst more choice of 'performance' of the bridges as compared to the limit states of collapse and serviceability in a design based on limit state method.

Flexibility of soil causes lengthening of lateral natural period due to overall decrease in lateral stiffness of the structural system. Such lengthening of lateral natural period may considerably alter the seismic response of the building frames resting on isolated foundation.

Considerable amount of works have been carried out in the above said areas by researchers. In the present work, a few literatures related to these areas are reviewed and reported.

2. 2 CODAL PROVISIONS FOR PERFORMANCE BASED ANALYSIS

The FEMA-273 (1997) document provides technically sound and acceptable guidelines for the seismic rehabilitation of buildings. The guidelines for the Seismic Rehabilitation of Buildings are intended to serve as a ready tool for design professionals, a reference document for building regulatory officials, and a foundation for the future development and implementation of building code provisions and standards. This document provides different Seismic performance levels of buildings for structural and Non-structural components in detail. It also gives different analysis procedures used for Seismic rehabilitation of buildings.

The FEMA-349 (2000) action plan presents a rational and cost effective approach by which building stakeholders: owners, financial institutions, engineers, architects, contractors, researchers, the public and governing agencies, will be able to move to a performance based design and evaluation system. The plan recognizes that there is a strong demand from stakeholder groups for more reliable, quantifiable and practical means to control building damage. It also recognizes that there is not a focused understanding among these groups as to how these goals can be obtained. This Plan describes how performance based seismic design guidelines can be developed and used to achieve these goals. It engages each of the groups in the development of

these guidelines, by which future building design will become more efficient and reliable.

The FEMA-356 (2000) standard is intended to serve as a nationally applicable tool for design professionals, code officials, and building owners undertaking the seismic rehabilitation of existing buildings. The procedures contained in this standard are specifically applicable to the rehabilitation of existing buildings and are, in general, more appropriate for that purpose than are new building codes. Advancement of present-generation performance-based seismic design procedures is widely recognized in the earthquake engineering community as an essential next step in the nation's drive to develop resilient, loss-resistant communities.

FEMA 445 (2006) program plan offers a step-by-step, task-oriented program that will develop next-generation performance-based seismic design procedures and guidelines for structural and nonstructural components in new and existing buildings. This program plan is a refinement and extension of two earlier FEMA plans: FEMA 273 Performance-Based Seismic Design of Buildings - an Action Plan, which was prepared by the Earthquake Engineering Research Center, University of California at Berkeley in 1997, and FEMA 349 Action Plan for Performance Based Seismic Design, which was prepared by the Earthquake Engineering Research Institute in 2000. The state of practice for performance-based assessment, performance-based design of new buildings, and performance-based upgrades of existing buildings will all be significantly advanced under this Program Plan.

ATC-40 (1996) document provides a comprehensive, technically sound recommended methodology for the seismic evaluation and retrofit design of existing concrete buildings. Although it is not intended for the design of new buildings, the analytical procedures are applicable. The document applies to the overall structural system and its elements and components. The methodology used here is performance based: the evaluation and retrofit design criteria are expressed as performance objectives, which defines desired levels of seismic performance when the building is subjected to specified levels of seismic ground motion. Acceptable performance is measured by the level of structural and/or non-structural damage expected from the earthquake shaking. Damage is expressed in terms of post yield, inelastic deformation limits for various structural components and elements found in concrete buildings. The analytical procedure incorporated in the methodology accounts for post elastic deformations of the structure by using simplified nonlinear static analysis methods.

IRC 6 The object of the Standard Specifications and Code of Practice is to establish a common procedure for the design and construction of road bridges in India. This publication is meant to serve as a guide to both the design engineer and the construction engineer but compliance with the rules therein does not relieve them in any way of their responsibility for the stability and soundness of the structure designed and erected by them. The design and construction of road bridges require an extensive and thorough knowledge of the science and technique involved and should be entrusted only to specially qualified engineers with adequate practical experience in bridge engineering and capable of ensuring careful execution of work.

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IS 1893 (Part 3): 2002 The standard (Part 3) deals with the assessment of earthquake forces and design of new bridges on highways, railways, flyover bridges, pedestrian bridges, submersible bridges, utility bridges and aqueducts. The earthquake effect on retaining walls and bridge abutments are covered. The hydrodynamic effect of water on submerged substructure and method of assessment of liquefaction potential of soil is also included. The methodology of estimation of seismic forces given in the code can be employed for seismic evaluation of the existing bridges and retrofitting of such structures. This standard deals with the earthquake resistant design of regular bridges in which the seismic actions are mainly resisted at abutments or through flexure of piers, that is, bridges composed of vertical pier-foundation system supporting the deck structure with/without bearings. However for all special and major bridges, detailed dynamic studies should be undertaken. This standard does not deal with the construction features relating to earthquake resistant design of bridges.

- RESPONSE SPECTRUM ANALYSIS

Greg Griffin and M. Saiid Saiidi, have made a study to better understand the bridge response due to site response effect. Several methods are available to predict bridge response to incoherent ground motions, but are typically cost prohibitive to implement in standard bridge designs. To simplify the analysis and understand the pseudo-static displacement and acceleration behavior, they developed a response history computer model for a two degree of freedom (DOF) system. A super structure of a bridge is represented by shear beam connected both DOF. They used Superposition of the pseudo-static and acceleration response in order to determine the total

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DOF response. The site response effect was predicted by a SDOF, nonlinear ground response model. An iteration scheme using the Newton-Raphson method was implemented and it has been verified with an equivalent linear stiffness method. Later Parametric studies were conducted on different structure masses and shear beam stiffnesses. For varied soil depths at supports, they used three different earthquake ground motions. A stiffness parameter defined as Coupling Ratio (CR) varies from 0 (each DOF responds independently) to 1 (rigid body response) has been observed. Then the magnification factors were calculated as the ratio of the relative displacement at each DOF due to the incoherent ground motion to the uniform base motion response. They observed from the study that magnification factors could be used to account for ground motion incoherency by modifying the response of a two DOF system subjected to uniform base motion.

Said M. Allam and T. K. Datta , studied on response spectrum method of analysis for suspension bridges subjected to multicomponent, partially correlated stationary ground motion. This analysis conducted is based on the relationship between the power spectral density function and the response spectrum of the input ground motion and fundamentals of the frequency domain spectral analysis. They said that analysis duly takes into account the spatial correlation of ground motions between the supports, also the quasi-static component of the response, and the modal correlation between different modes of vibration. They have analyzed the suspension bridge under a set of important parametric variations to study (1) The comparison between the responses obtained by the response spectrum method of

analysis and the frequency domain spectral analysis; and (2) To investigate the behavior of suspension bridges under seismic excitation. The parameters defined in analysis include the spatial correlation of ground motion, the ratio between the three components of ground motion, the angle of incidence of the earthquake, the nature and number of modes considered in the analysis, and the nature of the power spectral density function of ground motion. They finally concluded that the response spectrum method of analysis provides a fair estimate of responses under parametric variations considered in the study.

- TIME HISTORY ANALYSIS

Yong Deng, a senior structural engineer has made a research on seismic issues over structures. He studied that Non-linear Time history Analysis simulates the structure behavior under severe Earthquake movement exactly than any other methods. In his paper, Non-linear time history analysis has been presented with one of the world famous project. Yerba Buena Island (YBI) West-Bound (WB) Ramps are portion of San Fransisco-Oakland Bay Bridge Project. The ramps are touched down to Yerba Buena Island from YBI WB widening by hinges. . This project is located at a 0. 627g Site Specific Response for Safety Evaluation Earthquake (SEE). YBI WB On-ramp is a highly horizontally Curved Bridge with radius of 38. 8 meters. He mentioned that Seismic behavior is very important for the project. In order to understand structural non-linear behavior, especially highly horizontally curved bridge behavior under severe earthquake events, YBI WB On-ramp stand-alone bridge is analyzed by non-linear time history analysis method. A analysis software SAP 2000 with Hilber-Hughes-Taylor α direct integration <https://assignbuster.com/literature-review-of-methods-for-earthquake-analysis/>

method is used for Non-linear Time History Analysis. Seismic Modeling is also discussed in this paper. Then he has used six sets of acceleration time histories for Non-linear Time History Analysis by SAP 2000. Also a program developed by University of California-Berkeley is used to verify Non-linear Time history Analysis accuracy in this paper. Site Specific Response Spectra ARS is also used for linear analysis and compared with results of Non-linear Time History Analysis and with the program developed by California-Berkeley University. Later the Non-linear push-over analysis is performed to determine the structural capacity and ductility under severe earthquake events. Finally, discrepancies between different program analyses are discussed and recommendations are presented.

R. K. Dowell, has studied on a new method for finding member forces for statically indeterminate bridge frames. He said that the unique aspect of this new method is that it produces exact member-end-moments for statically indeterminate bridge frames from simple closed-form equations, without the need to setup and solve a system of simultaneous equations, as required in the stiffness method. Also the result shows that new method is 1000 times faster than any of the currently available methods that depend on matrix manipulation. He presented the incremental form of the closed-form approach and nonlinear time-history results for a typical bridge frame subjected to earthquake loading are compared with the results obtained from stiffness method. Finally he concluded that new closed form approach is based on modified classical analysis techniques and is so fast and stable that bridge designers may now consider using nonlinear time-history analysis for the seismic design of typical highway bridge structures.

- PUSHOVER ANALYSIS

Mark R. Capron, he made a study on pushover based seismic evaluation of a 2, 164 m long bridge located near the New Madrid Seismic Zone in southeastern Missouri. His research includes the existing structure, and the substructure retrofitted with column jackets, cap-beam modifications, and seismic isolation bearings. The research shows that the existing structure has 30% to 40% of the displacement capacity required for the 500 year design level, and significantly less than required for the 1, 000 and 2, 500 year levels that retrofits can improve performance to the 500 year level and that isolation bearings can improve performance of the main spans.

Ima Muljati and Pennung Warnitchai, has studied the performance of Modal Pushover Analysis (MPA) in predicting the inelastic seismic response of multi-span concrete bridges. Considered bridge is subjected to lateral forces distributed proportionally over the span of the bridge in accordance to the product of mass and displaced shape. Later the bridge is pushed up to the target displacement determined from the peak displacement of the n^{th} mode inelastic Single Degree of Freedom System derived from Uncoupled Modal Response History Analysis. Then the peak response from each mode is combined using Square-Root of Sum-of-Square (SRSS) rule. Results shows that the use of SRSS rule is not appropriate in this bridge and the displaced pattern is shifted from the elastic shape due to yielding, Modal Pushover Analysis can predict well the total peak response of the bridge in inelastic range.

P. S. Lande and A. D. Yawale, they studied that the structures within elastic range have quiet high displacement & forces. Therefore it requires linear methods for analysis. He said that the bridge being a special type of structure requires higher load carrying capacity due to introduction of ductility in design requiring the design for lesser forces as compared to the forces obtained in elastic range. To evaluate the Non-linear behavior and consequent failure pattern in different components of the bridge, Pushover analysis is an effective tool. In his study, he deals with nonlinear pushover analysis at a specific bridge structure with elastic foundation in urban area. The procedure recommended in ATC 40 (Capacity Spectrum method) is adopted for analysis under various seismic demands. The hinge formations for expected performance level are recorded. The response parameter like base shear & roof displacement are studied. Performance point for bridge under consideration is determined.

Jasmin A. Gadhiya and Anuj K. Chandiwala, has made a study on pushover analysis of bridge after 2001 Gujarat Earthquake and 2005 Kashmir Earthquake, and said that there is a nation-wide attention to the seismic vulnerability assessment of existing important structures. There are so many literatures available on the seismic evaluation procedures of multi-storeyed buildings using pushover analysis. Its known that bridge is a very important structure in any country but there is no much effort available in literature for seismic evaluation of existing bridges. Bridges extends horizontally with its two ends restrained and that particular characteristic make the dynamic behavior of bridges different from building. Modal analysis of a 3D bridge model reveals that it has many closely spaced modes. Participating mass

ratio for the higher modes is very high. Therefore, pushover analysis with single load pattern may not yield correct results. In order to address this problem, the aim of their study was to carry out a seismic evaluation case study for an existing RC bridge using nonlinear static (pushover) analysis and upper bound push over analysis and suggest whichever is better to understand bridge structural behavior. They considered a 12-span existing RC bridge for the case study. Standard pushover analysis using FEMA 356 (2000) displacement coefficient method and an upper bound pushover analysis method is used to analyse the bridge in which they have considered higher mode effects. And they concluded that evaluation results presented show that the selected bridge does not have the capacity to meet any of the desired performance level.