An analysis on the consequences of even mild seismic activity on RCC bridges

[1]Bhukya Shanker, [2]Mallikarjun Yadav Pilli, [3]Racha Konda Dhanalakshmi, [4]Korra Revanth
[1,2,3]Assistant Professor, [4]Student, [1,2,3,4]Department of Civil Engineering , Siddhartha Institute of Engineering and Technology, Hyderabad, India.

ABSTRACT
The vital link in any nation's lifeblood is its bridges. The public's anxiety over earthquake damage to transportation infrastructure has grown as a result of the highway network's quick expansion and growing dependence on it. Because to the potential for significant damage to bridges exposed to earthquakes, it is imperative that existing bridges be seismically evaluated, especially those that were either not constructed to withstand earthquake effects or were only moderately designed to do so.
Key words: The Response Spectrum, Time-History Analysis Methods, Pushover analysis and finite element method.

INTRODUCTION
The vital link in any nation's lifeblood is its bridges. The public's anxiety over earthquake damage to transportation infrastructure has grown as a result of the highway network's quick expansion and growing dependence on it. The need for seismic evaluation of existing bridges is driven by the prospect of significant damage to bridges that are vulnerable to earthquakes, especially those that have either been constructed without concern for earthquake effects or with minimal earthquake-resistance consideration.
It has been said that the San Fernando earthquake of 1971 marked a significant turning point in the advancement of seismic research and design considerations for bridges. After that, in recent years several procedures for non-linear static and dynamic analysis of structures have been developed. These methods differ in respect to accuracy, simplicity, transparency, and clarity of theoretical background. The principal objective of modeling andanalysis tools is the quantification of the seismic response of bridges in terms of structural displacement, member forces and deformations. This quantification is required for both the seismic design of new bridgesand seismic assessment of existing bridges. For the sizing and detailing of new bridges, modeling and analysis tools are used primarily to determine the seismic demand in the form of required member forces and deformations, whereas for the seismic vulnerability assessment of existing bridges the emphasis is on the available deformation and strength capacity quantification.

Seismic failure of bridge.

LITERATURE REVIEW
Jane L.et.al (1993) explained behavior of two-span continuous bridge under truck axle loading. The simulatedtruck axle loads were applied on the test bridge on one, two, and three lanes to maximize positive moment at 0.4 L and negative moment at 1.0 L. the results of the study show that finite element analysis

most accurately predicted the bridge behavior under the truck axle loading. The AASTHO and NCHRP analysis methods gave inaccurate results, since the loads were applied away from the supports.

Hyo-Gyoung Kwak et.al (2001) this study deals with the control of cracking at interior supports of continuous pre-cast pre-stressed concrete ŽPCS. Girder bridges. Since PCS-girder bridges are constructed by placing in-situ concrete decks on the PCS-girders at time intervals, the differences in material properties and age at loading between the deck and girder lead to time-dependent material behaviours. In addition, the continuous deck by providing a negative moment connection at interior supports, also causes the transverse cracking of the concrete deck at interior supports. In that way, cracking at interior supports is predicted with the analytical model introduced in the companion paper. Based on the ACI model, the ultimate shrinkage strain is expressed as a function of concrete slump and the relative humidity while the other remaining factors such as unit weight of cement and air content are assumed, in accordance with the typical values in mixed concrete. Finally, field recommendations in terms of concrete slump and relative humidity are suggested to minimize early transverse cracking of concrete decks at interior supports.

Hyung-Keun Ryu et.al (2004) In order to apply precast decks to continuous composite bridges, several experiments and analytical studies were performed. From many previous studies, design criteria for crack controls in transverse joints of prefabricated slabs were confirmed. These considerations were needed for serviceability. The bridges which satisfy service limit states, also, should be evaluated for ultimate strengths to define limit states. In this paper, experimental and analytical studies of two-span continuous composite bridges with open box girder section were conducted. Cracking, yielding and ultimate loads were evaluated and compared with the test results for design of continuous composite bridges with precast decks. To evaluate yielding loads of continuous bridges, an uncracked section method considering moment redistribution which isdefined in EUROCODE 4, was considered. In calculation of ultimate strengths, full or partial shear connection and sectional classes which were defined in EUROCODE or AASHTO LRFD specifications were considered. Also, through numerical analysis considering material nonlinearities, moment–curvature relationship andmoment redistributions were estimated.

X.Q. Zhu, S.S. Law (2005) a method based on modal superposition and regularisation technique is developed to identify moving loads on an elastically supported multi-span continuous bridge deck. The effects of different influencing parameters, such as the measuring noise, sampling rate, vertical and rotational stiffness, and the travelling velocity of the moving loads, are studied. Numerical simulations show that the method can identify accurately the moving loads on the bridge supported by elastic bearings using different types of measured responses. The stiffness of the bearing should be large relative to the stiffness of the bridge deck. Measured acceleration gives better results than those from strains, and the number of vibration modes used in the identification should exceed the highest frequency of the excitation forces for an accurate identification.

Tommy H.T. Chan et al. (2006) A method to identify moving forces on a continuous bridge has been developed in this paper. The bridge is modelled as a Bernoulli–Euler beam and the boundary value problem of the beam is solved to get the exact mode shape functions of the vibrating beam with intermediate supports. As the number of spans of the bridge increases, the identification accuracy decreases and at the same time more execution time is needed to finish one case study. To minimize this problem, a method has been developed to identify moving forces on a selected span of interest from the continuous bridge. The Singular Value Decomposition (SVD) of the coefficient matrix of the over determined equation is used in the solution. To evaluate the method, simulations of two moving forces on a continuous bridge and on one selected span from the continuous bridge are studied. White noise is added to the simulated bending moment and acceleration responses to study the effect of noise in moving forces identification problem for different numbers and arrangements of sensors. The results obtained from the simulation study show that the method is effective in identifying moving forces and acceptable results can be obtained.

Francis E. et al. (2007) this paper traces the international evolution of mathematical theory and construction processes that affected the design, construction, and use of continuous truss bridges in the United States. It covers the evolution from intuitive designs in wood and iron of the early 19^{th} century to the mathematically rigorous designs of long-span continuous steel trusses in the late 19th and early 20th centuries.

Akbar Vasseghi (2008) this paper presents a simple reinforcement method which changes the failure mechanism of the continuous girder from local buckling to formation of plastic hinges at the interior supports and mid-span. Such a change in failure mechanism greatly improves the strength and ductility of the superstructure. In this method the compressive portion of the web near the interior support is braced against local buckling by bolting pairs of stiff bracing elements on opposite sides of the web. The bracing elements prevent local buckling failure of the support section and create a section which can rotate in elastically at plastic moment allowing the second hinge to form at mid-span. The bracing elements may be plates or longitudinal stiffeners which should be designed to remain elastic while the section undergoes plastic deformation. The behaviour of plate girders which are reinforced by such bracing elements is studied using nonlinear finite element analyses.

Charles D. et al. (2008) in this paper, An increasing number of bridges are being designed with continuous spans instead of simple spans. By reducing the number of joints in a bridge, the traveling public receives a better riding surface and corrosion caused by leaking joints can be reduced. Also, redundancy is created when the system is made continuous, producing a tougher structure. However, a continuous system is more complicated to design and secondary restraint moments due to creep, shrinkage, and thermal effects can develop at the connection. This paper presents results from an experimental study done to monitor the earlyage restraint moments that develop in a two-span continuous system made of full-depth precast concrete bulb tee girders. The restraint moments observed were compared to the predicted restraint moments using the RMCalc program. The observed restraint moments were significantly lower than predicted by the program. Expansion of the deck during curing, which is generally not considered in the predictions, significantly influenced the early age restraint moments. A simplified model to predict the restraint moments considering thermal effects is proposed.

Robert K. Dowell (2009) in this paper, a new method is presented that gives exact member-end-moments for continuous beams and bridge structures, without the need to distribute moments back and forth as in moment distribution or to set up and solve simultaneous equations, as with the stiffness method. It is anticipated thatthe primary application of the proposed method will be to spot-check computer results.

Valter Carvelli (2010) this paper presents the results of an experimental campaign on four full scale concrete bridge deck specimens reinforced with GFRP bars that were designed, constructed and tested to resist cyclic moving loads. Two hydraulic jacks were used to simulate moving concentrated loads. After the cycles, the load was increased to static failure. The slabs reinforced with GFRP bars showed a better fatigue performance compared to the requests of the European codes.

Wen-Wei Wang et al. (2010) this paper presents a post-tensioned negative moment connection technique is proposed to strengthen old multiple spans simply supported T-section reinforced concrete (RC) girders. In this technique, old concrete is removed from girder ends and flanges, a diaphragm is placed between the two adjacent girder ends over the interior support and negative moment steel strands are installed in new cast-in-place concrete and post-tensioned to make continuity. A total of six two-span simply supported T-section RC girders were cast and five of them strengthened using the provision of the proposed post-tensioned negative moment connections. Both laboratory tests and nonlinear finite element (FE) analysis were conducted to investigate the structural performance of the strengthened RC girders. The moment redistribution in the strengthened continuous RC girders was also measured and is discussed. It is shown that the proposed post- tensioned moment connection technique can reliably transfer the negative moment over the support and markedly increase member stiffness and the load-carrying capacity of existing multiple span simply supported RC girders. The validity of the FE analysis was also demonstrated through comparisons with experimental results.

METHODS OF ANALYSIS

Linear Static Procedure (LSP)

Under the Linear Static Procedure (LSP), design seismic forces, their distribution over the bridge, and the corresponding internal forces and system displacements are determined using a linearly elastic, static analysis. In the LSP, the RC bridge is modeled with linearly-elastic stiffness and equivalent viscous damping that approximate values expected for loading to near the yield point. Design earthquake demands for the LSP are represented by static lateral forces whose sum is equal to the pseudo lateral load.

Linear Dynamic Procedure (LDP)

Under the Linear Dynamic Procedure (LDP), design seismic forces, their distribution over the bridge, and the corresponding internal forces and system displacements are determined using a linearly elastic, dynamic analysis. The basis, modeling approaches, and acceptance criteria of the LDP are similar to those for the LSP. The main exception is that the response calculations are carried out using either modal spectral analysis or Time-History Analysis. Modal spectral analysis is carried out using linearly-elastic response spectra that are not modified to account for anticipated nonlinear response. The LDP includes two analysis methods,

1. The Response Spectrum and
2. Time-History Analysis Methods.

The Response Spectrum Method uses peak modal responses calculated from dynamic analysis of a mathematical model. Only those modes contributing significantly to the response need to be considered. Modal responses are combined using rational methods to estimate total bridge response quantities. The Time- History Method (also termed Response-History Analysis) involves a time-step-by-time-step evaluation of bridge response, using discretized recorded or synthetic earthquake records as base motion input.

PUSHOVER ANALYSIS

A pushover analysis is a nonlinear static procedure wherein monotonically increasing lateral loads are applied to the structure till a target displacement is achieved or the structure is unable to resist further loads. A pushover analysis is a series of incremental static analyses carried out to develop a capacity curve for the bridge. Based on the capacity curve, a target displacement which is an estimate of the displacement that the design earthquake will produce on the bridge is determined. The extent of damage experienced by the bridge at this target displacement is considered representative of the damage experienced by the bridge when subjected to design level ground shaking. The recent trend in seismic codes is oriented to a simplified mechanical approach in order to assess bridges. The role of non-linear equivalent static (pushover) analyses is being more and more recognized as a practical tool for the evaluation of the seismic response of structures. Pushover analyses are therefore increasingly being considered within modern seismic codes, both for design of new structures and for assessment of existing ones.

Pushover analysis is a static, nonlinear procedure in which the magnitude of the structural loading is incrementally increased in accordance with a certain predefined pattern. With the increase in the magnitude of the loading, weak links and failure modes of the structure are found. The loading is monotonic with the effects of the cyclic behavior and load reversals being estimated by using a modified monotonic force-deformation criteria and with damping approximations. Static pushover analysis is an attempt by the structural engineering profession to evaluate the real strength of the structure and it promises to be a useful and effective tool for performance based design.

The ATC-40 and FEMA-273 documents have developed modeling procedures, acceptance criteria and analysis procedures for pushover analysis. These documents define force-deformation criteria for hinges used in pushover analysis.

THE OBJECTIVE OF THE OF THE STUDY:

1. Modeling of sample Reinforced Concrete Bridges.
2. Comparative study of different methods of Non-linear seismic analysis for R.C. Bridges.

Conclusion:

As the previous sections mentioned, there is a need to evaluate the safety and stability of Reinforced Concrete Bridges, and there are technical limitations which are preventing this need from being met. The seismic performance of RC Bridges which essentially comprises of analysis methods when subjected to earthquake loading is to be studied in the current project.

REFERENCES

1. Krawinkler, H., Seneviratna, G. D. P. K. (1998) "Pros and Cons of a pushover analysis of seismic performance evaluation", Engng Structures, 20 (4-6), 452-464.
2. Isakovic, T., Fischinger, M., Kante, P. (2001) "Bridges: When is single mode seismic analysis adequate?", Proc. of the Institution of Civil Engineers Structures & Buildings; 149(4):1-9, Paper No. 12468.
3. Bracci, J. M., Kunnath, S. K., and Reinhorn, A. M. (1997) "Seismic performance and retrofit evaluation for reinforced concrete structures", ASCE, Journal of Structural Engng, 123 (1), 3–10.
4. Gupta B, Kunnath SK. Adaptive spectra-based pushover procedure for seismic evaluation of structures. Earthquake Spectra 2000; 16:367–392.
5. Pinho, R., Casarotti, C., and Antoniou, S. (2007) "A comparison of single-run pushover analysis techniques for seismic assessment of bridges", Engineering Structures, vol. 30, pp. 1335-1345.
6. Chiorean, Cosmin G.(2003), "Application Of Pushover Analysis On Reinforced Concrete Bridge Model", Research Report No. POCTI/36019/99.
7. Chung C. Fu and Hamed AlAyed, "Seismic Analysis of Bridges Using Displacement-Based Approach", Department of Civil & Environmental Engineering University of Maryland.
8. Pinho, R., Casarotti, C., and Antoniou, S. (2007) "A comparison of single -run pushover analysis techniques for seismic assessment of bridges", Engineering Structures, vol. 30, pp. 1335-1345.
9. Muljati, I and Warnitchai, P (2007) "A modal pushover analysis on multi-span concrete bridges to estimate inelastic seismic responses", Civil Engineering Dimension, Vol. 9, No. 1, 33–41.
10. Kappos A. J. , Paraskeva T.S. and Sextos A.G. (2010), "Modal Pushover analysis as a means for the seismic assessment of bridge structures", Proceedings of the 4th European Workshop on the Seismic behaviour of Irregular and Complex Structures, Thessaloniki, Greece, Paper No. 49.
11. Bernardo Frère,(2012), "Pushover Seismic Analysis of Bridge Structures", Departamento de Engenharia Civil, Arquitectura e Georrecursos, Instituto Superior Técnico, Technical University of Lisbon, Portugal.
12. Jingyao Zhang, Makoto Ohsaki and Atsushi Uchida (2008), "Equivalent Static Loads for Non liner seismic design of structures", The 14th World Conference on Earthquake Engineering October 12-17, 2008, Beijing, China.
13. Nasim K. Shatarat,(2012), "Effect of Plastic Hinge Properties in Nonlinear Analysis of Highway Bridges", Jordan Journal of Civil Engineering, Volume 6, No. 4, 2012.
14. N.K. Manjula, Praveen Nagarajan, T.M. Madhavan Pillai (2013), "A Comparison of Basic Pushover Methods", International Refereed Journal of Engineering and Science (IRJES) Volume 2, Issue 5(May 2013), PP. 14-19