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Seismic Reliability of Highway Bridges: A Meta Analysis of the Researches

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Abstract. Since bridges are one critical element of highway transportation, it is crucial to analyze seismic reliability of bridge to assess safety and serviceability to highway systems. Seismic reliability analysis is an efficient area of research that needs more input from engineers. The Seismic Reliability of a structure can be described as a probabilistic measure to assess the safety of a structure. Reliability assessment techniques are constructive tools for describing the potential of a structure to function in definite condition intended for an explicit point. The reliability assessment of bridges is useful for seismic retrofitting decisions and functionality of highway systems. The paper intends to study the existing seismic reliability assessment techniques.

Keywords: reliability assessment, reliability index, seismic loads.

1 Introduction

Seismic reliability of the bridge structure is essential in assessing the sustainability of bridge structures **(Wei Wang. et al, 2020)**. With bridges covering a substantial part of the highway network, the possibility of encountering a ground motion heightens within seismic prone regions **(Qing Zeng. et al, 2015)**. A huge quantity of bridges within the side has been damaged in the past due to heavy ground motions **(Ghosh S. et al, 2018)**. **(Legeron, et al 2014)** reliability of the transportation system is essential for constant progress of modern-day society. Bridges are important part of transportation globally. In recent decade the traffic volume have increased considerably. Various cases of bridge fail took place in Italy and a firm amount of fatalities and financial losses were count **(Cosenza. et al, 2021)**. The vehicular load on the bridge is erratic, so it is almost impossible to predict the accurate load. **(Y L Xu, et al 2003)**To meet the growing economic and social needs for safer and more efficient vehicles, many road bridges have been built around the world Bridges contribute to the increase in daily traffic due to the growing social, economic and recreational needs of the population. Traffic, weight and speed of (road) vehicles across bridges are also increasing radically **(Y L Xu. et al 2003).** Hence, plenty of well-being assessment on the bridge structure is essential to reduce disastrous failure and service ability tribulations (**Yangguang Yuan. et al, 2017)**. The functionality of the bridges is endangered due to natural disaster i.e. earthquakes, aging, wear etc. On the other hand, there are numerous literature devoted solely to the reliability of bridges under load or their susceptibility only to seismic hazards **(Nielson. et al, 2007)**[123456]. An ounce of research has focused on considering the live loads and earthquake simultaneously. Enormous quantity of study on seismic response of bridge alienated from moving vehicle, as well on the dynamic interaction of vehicles with bridges without taking into account earthquakes or other external forces has been done. In contrast, research into the simultaneous effects of earthquakes and vehicle dynamics is still limited. Seismic response of an interacting highway overpass bridge-vehicle structure during restrained earthquakes was investigated, and it was concluded that treating the vehicle as an additional stationary mass improves the bridge's seismic response **(Kim, et al 2011)**. Similar research on the interaction of railway bridges has highlighted the significance of the effect of ground wave propagation on the safety of railway vehicles traveling over a long span bridge during earthquakes **(Xia. et al, 2006)**. **(Dimitrakopoulos. et al, 2014)** The Author proposed an active analysis method for Vehicle Bridge Interaction **(Leonardo. et al, 2011)** system taking into account different types of bridge and vehicle. The seismic investigation of the bridge structure has become influential tool for assessing the susceptibility of bridge in seismic prone areas. Traditionally, seismic susceptibility model for bridge investigated, effect of ground movement hazards only on the susceptibility of the bridge and system components. Merely researchers have extended this idea to assess the susceptibility of the bridges to compound threat. Research efforts have been made over the times of yore decades to widen new methods for the evaluation, analysis, and managing of existing bridges **(Zlatko Savor. et al, 2014).** Thorough knowledge is required to determine the performance of a structure. A prominent example of such tribula-

tions is the assessment of structural damage after earthquakes of varying intensity.

2 Reliability Assessment

(Hurtado J. E. et al, 2010) Reliability is a probabilistic measure to assess the safety of a structure. Reliability assessment techniques are constructive tools in describing the potential of a structure to function in definite condition intended to work under firm situations for a precise instance. Many methods for seismic reliability assessment were proposed by researchers which are classified into two major groups; analytic and synthetic method **(Moustafa Moufid Kassem. et al, 2020)**.

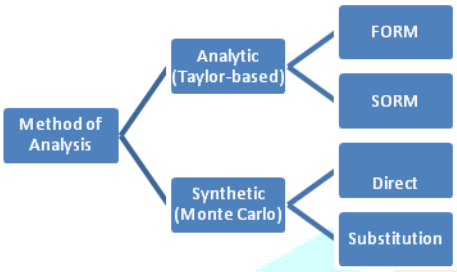

Fig-2.1 Methods of Analysis

Consideration should be given to various sources of design uncertainty. Reliability analysis techniques provide a basis for reasonably considering these uncertainties. Types of Reliability Analysis are as follows: First Order Reliability Method (FORM) and Second Order Reliability Method (SORM).These techniques are used to propose and investigate the bridge structures. The aim is to obtain in providing serviceability and safety during the structural lifespan.

3 Literature Review

Numerous works have been carried out on the basis of the assessment of the seismic reliability of the bridge structures. A review of some of the literature is briefly presented, summarizing the work carried out by various academics and researchers on influence of ground motion on seismic reliability of bridge structures.

(Leonardo Duenas-Osorio. et al, 2011) This piece proceed towards in a combinable proposal grounded on including arguments that unambiguously compute all probable configurations of bridge section failure. Author proposed a closed-form combination technique to compute all probable behavior in which bridge elements can cease to function within and across limit states. The explanations for limit state bridge level fault events have evolve from failure of a key component of bridge as a model of entire bridge structure to crumple of one of various components. Bridges under construction and modernization conditions are used to demonstrate the calculation in seismic loads and significance of projected reliability method. **(Simon, et al 2017)** the fragility evaluation of the 30 tested configurations indicates that, huge joints of integrated precast multi girder & Slab Bridge are possible to go through harm; whilst crumble is initiate through pier shear failure will occur in maximum situations. Longer precast multi girder bridges making use of each elastomeric bearing and monolithic joints are extraordinarily susceptible, and pier shear failure takes place previous to every other factor harm with excessive possibility. Evaluating the reliability indices of bridge, implies improved overall performance with traditional bearings, whilst generally sure slab bridge and longer precast multi girder bridge with elastomeric bearing have inferior behaviour. It is made acknowledged that an excessive reliability stage may be attained with a unique design with monolithic joints on abutments, and traditional repair and loses bearings in longitudinal & transverse routes on the piers, respectively. By evaluating the intensity-primarily based trendy assessment technique to the reliability evaluation outcomes as in line with the Euro code 8. After investigating it can be concluded, the inadequate pier shear resistance is a normal hassle of numerous present bridges, well known example of the predicted seismic overall performance, and reliability degrees of ordinary non seismically structure bridge.

(Karthik C R. et al, 2018) this article presents the prediction of the most likely failure patterns of the yield lines for relatively wide composite bridge structures. The resulting otcome can be used to calculate the ultimate strength or the required ultimate strength moments in the design of single-span and continuous composite bridge structures. The outcome shows that the first-order reliability technique can be used in predicting the final failure load. The theoretical parameters for further testing of the existing bridge structures by first order reliability method, to conclude the reliability index and possibility of damage to structure were investigated. **(Hellebrandt. et al, 2014)** The Author developed a deterministic traffic load replica for small span bridge to provide as input for reliability calculation. The result of the replica is a maximum load distribution function can be used as a load variable in the probabilistic reliability study. In the analysis with the completely probabilistic computation and the site-specific load model, the structure fulfills the conditions with the reliability required in mostly cases, one that contains the site-specific load.

(Viet-Hung Truong, et al 2017) The Hypercube Enhanced Importance Sampling method was developed for the reliability investigation of cable-stayed bridges by incorporating enhanced hypercube sampling and efficient forward sampling. Technique improvement comes from advanced practical analysis, performing structural analysis, and improved hypercube sampling. Sampling is effective in solving the reliability analysis. Practical Advanced Analysis Method Enhanced Hypercube Sampling Effective significance sampling can accurately determine the likelihood of structural failure and the sample count compared to (a) Monte Carlo simulation, (b) significance sampling (c) Latin hypercube (d) Subset simulation method. Mainly three mathematical cases and two steel frames are presented to demonstrate the precision and effectiveness of enhanced hypercube sampling. This technique is applied to the cable bridge. The reliability sensitivity of the bridge was examined.

(Jianhui LI, et al 2012) This paper presents sensitivity and reliability exploration of self-anchored suspension bridge through a modern hybrid method recommended by author on the integration of the Latin Hypercube Sampling method. The procedure is assigned to assess the Bridge. The structural parameter & external loads are taken into account as random variables of a bridge structure. The study acknowledged various structural parameters & external load have a considerable effect on structural service ability and safety. **(Ghosh J. et al 2014)** fragility curve is derived for the significant position of the truck in which, probability of failure is conditioned by weight of the vehicle in question as well as by the intensity of the ground movement, thus representing the result of load of truck on seismic fragility of bridge. This area of fragility is convoluted with the vehicle weight distribution and the truck

occurrence probability to determine the conditional seismic reliability estimates of the traffic informed. The effects of traffic and seismic load have been well thought-out individually while assessing the reliability of the bridge. This document presents an outline for evaluating the seismic fragility and the load of bridges. Comprehensive probabilistic analyzes taking into account the deviation in bridge parameter, ground movement, load movement, and truck position are offered to extend bridge system, brittleness curves and to recognize truck positions that make the bridge vulnerable to earthquakes. The author proposed a methodology on a continuous multi span girder bridge. The structure can find preconfigured extensions to evaluate the combined effect of earthquakes and traffic loads on other bridge conditions as well as hazards; it can provide a basis for deriving load combinations based on increasing reliability in bridge design.

(Nabizadehdarabi, et al 2015) presented the utilization of existing data on bridge allows the improvement of endurance analysis apparatus that can present statistical information on reliability and failure rates at different ages of bridge. In this reading, the hypertabastic survival model was used to carry out analyses of bridge superstructure reliability along its failure rates in Wisconsin. The data was used for statistical analysis and parameter estimations for the survival model were gathered form NBI. Endurance time of steel and concrete superstructure was examined through hypertabastic accelerated failure time model with covariates set at their mean and median values. Like bridge ages, the reliability reduces and failure rate rises. Results indicate that both average daily traffic and utmost span length influence bridge survival time and failure rate drastically. Effects of escalating span length were considered for a fixed average daily traffic. Outcome showed that as there is an increase in maximum span length, the superstructures reliability reduces, and the failure rate increases. Results indicate that its reliability decrease whereas failure rate increases at fifty and seventy five years of age. The outcome for superstructures shows an almost linear relationship amongst reliability and average daily traffic at fifty years of age. A reliability analysis must be performed for the structural system to understand the contribution of redundancy. Reliability analysis is a very important approach to accessing the safety margin and probability of failure associated with structures designed using available design codes. Structure can be design to lessen the possibility of failure, but reducing the probability of failure further than the optimal level is not always economical. Further studies must be carried out to determine the optimum load and resistance factors and the corresponding level of safety.

(Yilmaz, 2021) In this paper, Reliability analysis statistically determines the probability of failure of a bridge. Existing specifications used a semi-probabilistic approach to calculate the reliability of the bridge and determine a threshold to maintain the safety of the bridge. The statistical models make the material properties of the transport system and the loading conditions more precise. Distributions were used to represent concrete and reinforcement. The normal distribution was used to simulate the payload and dead load on the bridge. Bridge collapse loads were determined and simulated using the limit analysis theory. Finally, the reliability of the bridge was determined. **(Bucher, et al 2020)** Therefore, they should be viewed as random variables to estimate structural security as an essential degradation system for reinforced concrete bridges, and bridge resistances were considered random variables, while weight in motion information is used for estimation of traffic load models. As an outcome of the investigation, the actual form of structure is reflected quantitatively. This work presents a complete probabilistic safety evaluation methodology of presented bridges and has been functional to finite element analysis and it is a constructive tool. The mechanism of the deterioration of CR structure was considered to be chloride induced corrosion of the reinforcing steel and the strength of bridge component, considered as random variables while the weight in motion data was used to evaluate presumptive traffic load model.

4 Conclusions

In this article, a thorough study of the developed methodologies, as well as the results of other studies, were carried out. The authors aimed to summarize the analytical methodologies that would encourage researchers to utilize them as a complete work guide and reference for their potential work.

There are a variety of methods to evaluate seismic reliability of bridges. The Monte-Carlo technique is an effective tool in assessing the seismic reliability of bridge structure. The exploration of the seismic response demonstrates its significance for designing the cyclic behaviour of the rigid joints & pounding between the bridge elements. The evaluation of seismic response suggests its significance for modeling cyclic behaviour of the monolithic joints and pounding among bridge components. The research recommend that monolithic joints with included precast multi girder and slab bridge be probable to go through harm whilst disintegrate is begin through pier shear failure in maximum case. Long precast multi girder bridge making use of each elastomeric bearings and monolithic joint are surprisingly susceptible, and pier shear collapse takes place earlier than some other element harm with excessive probability. An excessive-reliability degree may be accomplished with unique design by way of monolithic joints on the abutments and traditional repair and unfastened bearing within side of longitudinal and transverse guidelines on piers. The random variable correlation of bridge shape has a substantial effect on seismic reliability of excessive pier bridge.

Conflicts of Interest

"The authors declare no conflict of interest."

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