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SEISMIC ANALYSIS OF LONG SPAN BRIDGE AND EXTERNAL SUBSTRUCTURE RETROFITING TECHNOLOGIES

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Abstract - *Long-span bridges, integral to transportation infrastructure, require meticulous seismic analysis to ensure their resilience and safety in the face of earthquake forces. This thesis delves into the multifaceted realm of seismic analysis for these iconic structures, addressing critical aspects such as static analysis, adherence to seismic design guidelines, and the pivotal role of Fiber Reinforced Polymer (FRP) jacketing. The research explores seismic retrofitting techniques, specifically focusing on FRP jacketing for existing structures, emphasizing the imperative understanding of the behavior of bridge components and materials under seismic loads.*

The study also investigates the application of cutting-edge technical approaches, including energy dissipation devices and seismic isolation bearings, aimed at bolstering the seismic resilience of long-span bridges. By shedding light on the intricate dynamics of these renowned structures, the research provides valuable insights and recommendations for seismic design and retrofitting. Such contributions serve to advance the field of structural engineering, ultimately ensuring the safety and functionality of long-span bridges in seismically active areas, particularly those falling within seismic zone five.

The project further conducts a comparative analysis of two bridge models, utilizing seismic parameters such as lateral force, natural period, maximum displacement, overturning moment, mode shape, and self-weight. This comprehensive examination contributes to a deeper understanding of the seismic performance of long-span bridges, paving the way for more robust and resilient infrastructure in earthquake-prone regions.

***Key Words*: Bridge, Seismic Analysis of Bridge, Long Span Bridge, Retrofitting, Retrofitting of Bridge, Fiber Reinforced Polymer (FRP) jacketing.**

1.INTRODUCTION

Bridges serve as indispensable infrastructural lifelines, overcoming natural obstacles like rivers and valleys to facilitate the efficient movement of people, vehicles, and goods. Smith (2005) underscores their pivotal role in transforming the geographical accessibility of isolated land masses, promoting economic development and communication. Jones (2010) extends this narrative, highlighting the broader impact of bridges in enhancing trade and contributing to regional growth. Within this landscape of bridge engineering, long-span bridges emerge as distinctive marvels, showcasing human ingenuity in conquering challenging terrains (Brown, 2018). This thesis delves into the multifaceted significance of long-span bridges, examining their role in creating efficient transportation routes, reducing travel times, and fostering cross-cultural interactions. By bridging historical insights with contemporary perspectives, the research aims to contribute to the comprehensive understanding of how these structures shape accessibility, connectivity, and integration across diverse landscapes.

1.1 Long-Span Bridges as Engineering Marvels

Within the realm of bridge engineering, long-span bridges emerge as particularly captivating structures. Brown (2018) highlights their unique contributions, showcasing human creativity in conquering challenging terrains. These bridges, characterized by their extended reach, exemplify the evolution of engineering prowess over time.

Long-span bridges stand as awe-inspiring engineering marvels, pushing the boundaries of structural design and defying the constraints of geography. These extraordinary feats of engineering demonstrate the ingenuity and technical prowess of human achievement. What sets long-span bridges apart is their ability to traverse vast expanses, spanning across rivers, valleys, or deep ravines with unparalleled grace and strength. The sheer magnitude of these structures, often characterized by expansive spans and intricate designs, captivates not only engineers and architects but the general public as well. These bridges represent the pinnacle of technological advancement, showcasing the application of cutting-edge materials and innovative construction techniques. As symbols of human aspiration, long-span bridges not only provide essential transportation links but also serve as iconic landmarks that symbolize progress, connectivity, and the indomitable spirit of overcoming physical challenges.

The common types of earthquake damages of bridges in India are briefly described below.

1. Damanganga river bridge collapsed (2003): it was 300 m long bridge over Damanganga river ,90m collapsed portion of the bridge was without column . due to improper maintenance and soil movements ,bridge got collapsed.

2. Bihar bridge collapsed on train(2006): 150 yr old bridge due to poor maintenance this accident took place. At the day of tragedy ,vibration transferred by train cause pillar to shake.

3. Darjeeling bridge collapsed (2011): bridge got weakened by magnitude of 6.9 earthquake & large no, of people gather on it.

4. Vivekananda flyover (2016): This was the under construction failure of bridge of 150m due to continuous traffic movement.

5. Morbi bridge collapsed (2022): Due to poor maintenance slab of bridge got break just after 10days of repair.

1.2 FRP JACKETING OF LONG SPAN BRIDGE

Long-span bridges with fiber-reinforced polymer (FRP) jacketing use composite materials to improve the bridge's structural integrity and longevity. To provide the current bridge components more strength and protection, FRP materials—typically composed of fibers like carbon, glass, or aramid contained in a polymer matrix—are employed to wrap or jacket them. This approach is often used to reinforce and renovate aging infrastructure [4]. A thorough evaluation of the bridge's condition and structural needs usually marks the start of the procedure. FRP jacketing is a viable option if the bridge has to support larger weights or exhibits symptoms of degradation. Before the FRP materials are added, the old structure is cleaned and sometimes repaired to make it ready for use. Long-span bridges benefit from the high strength-to-weight ratio, longevity, and resistance to corrosion that come with FRP jacketing. When compared to more conventional rehabilitation techniques, the application procedure for these materials is often speedier and less disruptive. Additionally, these materials may be tailored to the unique requirements of the bridge. Furthermore, the bridge's seismic.

Fig-1: Long Span Bridge

2. LITERATURE REVIEW

[1] Chao ma ,kai li Volume 142 December (2023), 105435 "Seismic performance of underground structures improved by using PET FRP retrofitting central columns" This paper proposed applying Polyethylene Terephthalate Fiber-reinforced Polymer (PET FRP) to enhance the lateral deformation capacity of the central columns of underground structures and then improve the seismic capacity of the overall structures. It can be concluded After calibrating the numerical models with the seismic tests on the RC columns retrofitted by PET FRP, 3D numerical models of underground structures and surrounding soils were built and the seismic response of underground structures subjected to multiple horizontal and vertical ground motions.

[2] kh YifanWang1and Lihui Yin (2022) "Seismic Vulnerability of High-Pier and Long-Span Bridges Based on Improved IMK Resilience Model" This paper combines the improved IMK resilience model to study the seismic vulnerability of high-pier and long-span bridges. Moreover, this paper obtains the parameter calculation model based on the regression analysis of PEER's 255 column specimen data. The experimental research shows that the seismic vulnerability research model of high-pier and long-span bridges based on the improved IMK restoring force model has a certain analytical effect. Through the analysis and research on the seismic damage evolution and vulnerability of the bridge structure, it is possible to evaluate the seismic performance of the bridge, provide a basis for the seismic design of the bridge, provide a theoretical basis for the assessment of bridge damage after the earthquake, and provide a certain theoretical basis for post-disaster decision-makers to formulate emergency plans for earthquake resistance and disaster reduction.

[3] Praveen Kumar Nigam, Saleem Akhtar Volume 45, Part 7, (2021) "Retrofitting practices in various categories of RCC structures" In this proposed paper, operational evaluation of retrofitting practices has been discussed for residential, commercial, industrial and educational buildings and massive structures like buildings and dams. The paper conclude a critical analysis of the methodologies used to test retrofits to thermal efficiency of existing occupied buildings. Best practice strategies were developed by identifying guidelines.

[4] Chunwei Zhang (2021) "The advancement of seismic isolation and energy dissipation mechanisms based on friction" In this paper the historical development and practical implementation of structural base isolation systems that work on the principle of friction are discussed in the light of analytical, numerical, and experimental studies carried out by researchers. Various parameters such as sliding velocity, surface temperature, axial pressure, vertical excitation along with near-field and far-field excitations that influence the overall performance of the isolation system have been explored. This paper conclude that friction-based isolation systems are favored, which are adequately effective in reducing the acceleration response with limited sliding displacement, cost-effective, easy to design and install is been concluded.

[5] Zhijun Fu, Rui Gao (2020) "Probabilistic Seismic Resilience-Based Cost–Benefit Analysis for Bridge Retrofit Assessment" In this paper explores a probabilistic resilience-based cost–benefit model that can be used to identify the best retrofit measures for bridges. In the model, the increase in resilience is considered to be the benefit of seismic retrofit. A bridge functionality assessment model is also proposed to evaluate resilience. The functionality is estimated based on the appropriate seismic loss and exponential recovery function models. In this paper it is been concluded that the 90% confidence intervals of resilience-based cost–benefit ratios estimated from random sampling also indicate the high cost-effectiveness of seat extenders and elastomeric isolation bearings to enhance bridge performance.

[6] Anjani Kumar Shukla, P. R. Maiti & Gopal Rai Journal of Failure Analysis and Prevention volume 20, pages895–911 (2020) "Retrofitting of Damage Rail Bridge Girder and Its Performance Evaluation" In this Paper, retrofitting of a 59-year-old prestressed bridge of Indian railway at Ratlam has been executed in which multiple vertical cracks visualized in tension zone and surface deterioration were observed. In this Paper, retrofitting of a 59-year-old prestressed bridge of Indian railway at Ratlam has been executed in which multiple vertical cracks visualized in tension zone and surface deterioration were observed.

[7] Sivaganesh Selvaraj, Mahendrakumar Madhavan Journal of Constructional Steel Research Volume 167, April 2020 "Retrofitting of steel beams using low-modulus carbon fiber reinforced polymer laminates" In this paper the reliability study based on the limited test results also indicates that the suggested elastic strain design limit state is reliable been discussed here. An experimental and analytical investigation retrofitting of steel beams using low modulus CFRP has been presented. Unlike the existing methodologies (ultimate stress and ultimate strain design limit states) that are typically employed for design of strengthening of steel members using high modulus CFRP ($E_{CFRP} > ES_{teel}$), a conservative design limit state has been presented specifically for the use of low modulus CFRP ($E_{CFRP} < ES_{teel}$) as a potential alternative.

[8] Teng Tong, Siqi Yuan, (2019) "Seismic retrofitting of rectangular bridge piers using ultra-high performance fiber reinforced concrete jackets" In this research paper, the focus of study is directed towards the performance of two jacketing techniques i.e; steel reinforced concrete jacket and fiber reinforced concrete jacket . Model was consider and gave responses of ductility and cumulative energy dissipation. With the help of this paper we have understood that FRP, strengthening work shows the remarkable results. The overall cracked area reduces to 1/5th of total cracked area and crack width reduces to its minimum value. Overall deflection also reaches to the lowest possible value . Analysis of these strengthening methods shows that the FRP strengthening is more efficient and feasible solution than the steel plate strengthening.

[9] M. Karan kumar, S. Sujith, G. Karthikeyan Volume 07-Issue 06 (2019) "Structural Rehabilitation and Strengthening of Column using Micro Concrete and Additional Reinforcement" In this paper they adopt reinforced concrete jacketing method. It involves adding a new layer of micro concrete with reinforcement, closely spaced ties and also a suitable bonding agent (Nitozinc Primer) is used for the monolithic action between the old concrete and newly pore (Micro concrete). In this paper it is advisable to monitor the building health periodically if any future expansion or live load increase by taking a professional opinion. Non- destructive testing should be carried out if buildings found deteriorated and damaged over time.

[10] Associate Professor, Dept. of Civil and Environmental Engineering, Amir Kabir University of Technology, Tehran, Iran (2008) "Structural Performance of Retrofitting Bridge Deck Slabs using CFRP Strips" In this paper the study evaluates the force-deformation responses of retrofitted bridge deck panels under cycling loading up to the failure. The numerical analysis is carried out for analyzing cracking behavior . In this paper the study evaluates the force-deformation responses of retrofitted bridge deck panels under cycling loading up to the failure. The numerical analysis is carried out for analyzing cracking behavior.

2.2 PROBLEM STATEMENT

A Comparative analysis of two type of structure before and after retrofitting of long span bridge.

A bridge of span is 90m, which is beam bridge type of structure that lies in earthquake zone V which is the most active region in the India. and the consideration of load is 60 Tonne of weight. Calculation of deflection, moments, frequency and Various analysis like dynamic, structural, cost benefit will be done and serviceability check will be given. Also plotting fatigue curve of both structures.

2.3 OBJECTIVES OF THE STUDY

This objective of the study is to investigate the seismic resilience of long-span bridges, with a specific focus on crucial aspects.

1. Perform comprehensive study of large-scale bridges subjected to different loading scenarios, with a particular focus on seismic forces.
2. Assess adherence to seismic design guidelines to verify conformity with seismic design standards for the purpose of ensuring safety and resilience.
3. The purpose of FRP jacketing is to analyze its application in seismic retrofitting to improve resilience by using Fiber Reinforced Polymer (FRP) materials.
4. Technical Approaches: Investigate sophisticated methodologies, such as energy dissipation devices and seismic isolation bearings, to enhance the ability to withstand seismic events.
5. Comparative Analysis: Conduct an analysis of two bridge models, specifically examining seismic factors in order to enhance comprehension of seismic performance.
6. Integrate historical insights with modern viewpoints to comprehend the importance of long-span bridges in influencing accessibility, connectivity, and integration across various landscapes.

The study intends to enhance the field of structural engineering by fulfilling these objectives. It seeks to provide valuable insights for seismic design and retrofitting, with a special focus on seismic zone five.

2.3 METHODOLOGY

In the methodology section, we will study the method used for analysis of these two models, the software used for creating and analyzing of thesis model, the Indian Standard Code used for dead load, vehicle load, seismic load, etc.

1. **ETABS Software:** Computers and Structures, Inc. (CSI) has created ETABS (Extended Three-dimensional Analysis of Building Systems), a powerful structural analysis and design program. Designed with structural engineers in mind, it facilitates the production of intricate three-dimensional models, accommodates a range of structural components, and performs thorough static, dynamic, and nonlinear analysis.

2. **Method Used for Analysis of Models:** Static analysis is the technique used to analyze these two models, which were produced using the ETABS program. Model analysis may be done in two ways, according to Indian Standard Code 1893 part-1:2016: Static Analysis and Dynamic Analysis. Equivalent static analysis is used following IS Code 1893 Part 1:2016 for earthquake-resistant design. By considering seismic forces as static loads dispersed at each floor level, this strategy minimizes dynamic complications. To compute design seismic forces, the code requires taking into account elements like the Response Reduction Factor (R), Importance Factor (I), and Zone Factor (Z). The I factor indicates the significance of the structure, while the R factor takes energy dissipation and ductility into consideration. The region's seismicity is taken into account by the Z factor. A methodical process is prescribed by the code, which involves the computation of seismic base shear and force distribution throughout the height of the structure. When required, it highlights the significance of site-specific response spectra. When it comes to exact application in seismic design projects, engineers have to work with experienced structural engineers and follow the most recent revisions of the code.

3. **Indian Standard Code for load:** In this research work, there are several Indian standard codes used for load case, such as the Indian Standard Code 875 part-1 used for the self-weight of the bridge, and Indian Roads Congress 6:2017 used for the vehicle load and vehicle considered as Tracked Vehicle 70R [9] (Tracked) Vehicle. Indian Standard Code used for the seismic load is 1893 part-1:2016.

4. **Overview of Material Used:** In this research work, we have used different types of material in this long-span bridge. The details of the materials are given below in the table-1:

Table -1: Materials Used for Models Sample

Sr. No.	Material Name with Grade	Purpose in the Models
1	M35 Concrete	Main Girder and Supporting Girder
2	M50 Concrete	Used in the Abutment
3	HYSD415	Used as Lateral Bar in Abutment and Girder
4	HYSD500	Used as Main Bar in Abutment and Girder
5	Fe250 Steel	Railing of Bridge
6	Fe345 Steel	Side Supporting Girder below the Pedestrian

5. **Overview of Seismic Parameter Used:** In this research paper, we have selected the Indian Standard Code 1893 part1:2016 and selected the seismic zone fifth. The details of seismic details are given below in Table 2.

Table -2: Seismic Parameter

Sr. No.	Name of Seismic Parameter	Value
1	Seismic Zone (R)	0.36
2	Importance Factor (I)	1.5
3	Response Deduction Factor (R)	5.0
4	Soil Type	Medium Type

6. **Geometry of Bridge Models:** The details of the long-span bridge used in this research paper are given below in Table 3, such as the dimension of the abutment, the dimension of the main girder, etc.

Table -3: Geometry of the Bridge Models.

Sr. No.	Geometry of Bridge	Dimension
1	Dimension of the Abutment	1000 mm*7000 mm
2	Dimension of the Main Girder	450 mm*750 mm
3	Dimension of the Supporting Girder	300 mm*500 mm
4	Total Lane Width of Bridge	9000 mm
5	Total Span of the Bridge	90000 mm
6	Height of the Deck	6000 mm
7	Height of the Railing from the Deck	2000 mm
8	Distance between the Supporting Girder	5000 mm
9	Cross section of the Side Girder	I section
10	Cross section of the Railing	I section

7. **Fiber-reinforced polymer (FRP) jacketing:** In the second model, the abutment, main girder, and supporting girder are jacketed by the FRP [10]. The thickness of the Fiber Reinforced Polymer jacketing is different for the abutment, main girder, and supporting girder. The area of the FRP jacketing in the abutment is 0.5 sq m, the area of the FRP jacketing in the main girder is 0.0625 sq m, and area of the FRP jacketing in the supporting girder is 0.01 sq m.

3. CONCLUSION

In this Conclusion section , we will analyze the result after the static analysis of these two models by using the ETABS Software [11]. As we know here, we are doing the seismic analysis of the long-span bridge so the main parameters for the seismic analysis are base shear (lateral force due to earthquake on the bridge), fundamental period, maximum displacement of the bridge due to lateral load, maximum overturning moment, and mode shape of the bridge. In this paper we can conclude that the strength and stability of bridge are increased as compared to the bridge without fibre-reinforced polymer. That means if bridge has low strength , then after applying the FRP jacketing ,the stability and strength of bridge will be improved.

3.2 FUTURE SCOPE

The present work makes a notable contribution to the comprehension of seismic analysis and retrofitting methods for long-span bridges, with a specific focus on the importance of Fiber Reinforced Polymer (FRP) jacketing. In terms of future prospects, the research paves the way for various lines of investigation and expansion:

- Detailed Material Investigations
- Experimental Validation

- The thesis presents FRP jacketing as a retrofitting option, however further research can investigate optimization methodologies.
- Expanding on the environmental benefits of FRP materials, future research might perform thorough life-cycle studies to evaluate sustainability factors Integrating advanced technologies, such as artificial intelligence, machine learning, and smart sensors, into seismic analysis and retrofitting procedures shows great potential as technology continues to progress. These technologies have the potential to improve the real-time monitoring, adaptive reactions, and predictive maintenance of long-span bridges.

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