International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 11 Issue: 04 | Apr 2024 www.irjet.net p-ISSN: 2395-0072

IMPROVEMENT OF THE LONG SPAN BRIDGE AFTER FIBER REINFORCED POLYMER JACKETING WITH LATERAL LOAD

Laraib Ahmad[1], Mr. Ushendra Kumar[2]

[1]*Master of Technology, Civil Engineering, Lucknow Institute of Technology, Lucknow, India*
[2]*Head of Department, Department of Civil Engineering, Lucknow Institute of Technology, Lucknow, India*

***

Abstract - *Long-span bridges represent vital components of infrastructure, encountering diverse environmental and operational exigencies over their operational lifespan. This scholarly review scrutinizes the efficacy of Fiber Reinforced Polymer (FRP) jacketing as a means to augment the performance of long-span bridges when subjected to lateral loads. Synthesizing extant literature, the review evaluates the structural behavior, performance enhancement, and longevity of long-span bridges retrofitted with FRP jackets. The examination delineates the fundamental mechanisms underlying FRP jacketing, elucidating its capacity to bolster the flexural strength, stiffness, and ductility of bridge elements. Moreover, the discussion encompasses the impact of lateral loads, such as wind, seismic events, and vibrations induced by traffic, on the behavior of long-span bridges reinforced with FRP jackets. Emphasis is placed on the importance of meticulous design, material selection, and construction methodologies to ensure the efficacy and enduring resilience of FRP retrofitting solutions. Case studies spanning diverse geographic regions and bridge typologies are analyzed to underscore the practical application and performance of FRP jacketing under lateral loading conditions. The review also confronts challenges and constraints associated with FRP retrofitting, including issues of adhesion, environmental degradation, and the imperative for sustained maintenance. Through its comprehensive examination, this review furnishes valuable insights into the optimization of long-span bridge performance via FRP jacketing under lateral loading circumstances, thereby providing guidance for researchers, engineers, and practitioners engaged in bridge retrofitting and maintenance endeavors.Long-span bridges are vital components of transportation infrastructure due to their vast lengths and intricate structural designs. However, their susceptibility to seismic forces makes it crucial to conduct a thorough seismic study to ensure their resilience and safety during earthquake occurrences. This study delves into the various facets of seismic analysis for long-span bridges, including Static analysis, adherence to seismic design guidelines, and the important role of Fibre Reinforced Polymer (FRP) jacketing. The research explores seismic retrofitting techniques (FRP Jacketing) for existing structures and emphasizes the significance of understanding the behavior of specific bridge components and materials under seismic loads. The use of advanced technical methods such as energy dissipation devices and seismic isolation bearings is also covered in the study to enhance the seismic resilience of long-span bridges. By shedding light on the complex dynamics of these iconic structures and providing valuable recommendations for seismic design and retrofitting, this research advances the field of structural engineering. Ultimately, it ensures the safety and functionality of long-span bridges in seismically active areas or zones with high levels of seismic activity. In analyzing two models of a bridge using parameters like lateral force on the bridge, natural period, maximum displacement of the bridge, overturning moment on the bridge, mode shape, and self-weight of the bridge; we can gain further insight into how these structures behave under different conditions. This knowledge can inform better design choices that improve safety measures against potential damage from earthquakes. Long-span bridges play a crucial role in modern transportation infrastructure. Their unique designs require careful consideration when it comes to ensuring their resilience against earthquakes. Through comprehensive studies like this one that examine various aspects like static analysis and FRP jacketing retrofitting techniques alongside advanced technical methods such as energy dissipation devices or isolation bearings; we can make informed decisions that keep these structures safe while advancing our understanding of structural engineering as a whole.*

Key Words: Long-span bridges, Seismic analysis, Seismic design codes, Seismic retrofitting, Transportation infrastructure, FRP Jacketing, ETABS.

1.HISTORY

Throughout history, the practice of jacketing bridge structures has evolved in tandem with advancements in engineering and construction materials. Initially, with the use of materials like stone, wood, and later iron, repairs were localized, focusing on replacing damaged components rather than reinforcing entire structures. However, the emergence of steel in the late 19th century allowed for longer and more ambitious bridge designs, prompting the need for jacketing to address issues such as corrosion and fatigue. Steel jackets were employed to strengthen vulnerable areas and support sections experiencing excessive loads. As concrete became a primary construction material in the early 20th century, jacketing techniques adapted to reinforce concrete elements, often involving the application of additional layers of concrete or steel reinforcement. Over time, advancements in materials science introduced specialized materials like fiber-reinforced polymers (FRP), offering lightweight yet high-strength solutions for jacketing. Today, jacketing remains a common practice for rehabilitating aging bridges and strengthening structures to meet modern demands, with engineers utilizing advanced computational modeling and analysis tools to design tailored solutions for specific needs.

Figure-1: Concept of Jacketing

2. IMPORTANCE IN TRANSPORTATION INFRASTRUCTURE

Jacketing plays a crucial role in maintaining the integrity and functionality of transportation infrastructure, particularly bridges. As key components of road and railway networks, bridges facilitate the movement of people, goods, and services. Ensuring the structural stability and safety of these bridges is paramount for maintaining uninterrupted transportation flow and safeguarding public safety. Jacketing techniques allow engineers to address various challenges faced by aging bridges, including deterioration due to environmental factors, increased traffic loads, and evolving design standards. By reinforcing vulnerable sections and repairing damage, jacketing extends the service life of bridges, reducing the need for costly replacements and minimizing disruptions to transportation networks. Moreover, jacketing enables bridges to adapt to changing usage patterns and accommodate future growth in traffic volume and vehicle types. In essence, the application of jacketing in transportation infrastructure enhances resilience, longevity, and efficiency, thereby supporting sustainable economic development and ensuring safe and reliable mobility for communities.

3.FIBER REINFORCED POLYMER (FRP) JACKETING

Fiber Reinforced Polymer (FRP) jacketing has revolutionized the rehabilitation and reinforcement of bridge structures, offering a versatile and durable solution to address various challenges faced by aging infrastructure. Composed of high-strength fibers embedded in a polymer matrix, FRP materials provide exceptional strength-to-weight ratio, significantly lighter than traditional materials like steel or concrete. This characteristic not only simplifies handling during installation but also imposes minimal additional load on the bridge. Furthermore, FRP exhibits remarkable resistance to corrosion, a critical factor in prolonging the service life of bridges exposed to harsh environmental conditions. Its flexibility allows for tailored solutions, fitting the unique geometry and needs of each structure. Moreover, FRP jacketing enables rapid installation and curing, minimizing disruption to traffic and reducing overall construction time. In essence, FRP jacketing offers a cost-effective, sustainable, and efficient method to enhance the structural integrity and longevity of transportation infrastructure, ensuring safe and reliable mobility for communities.

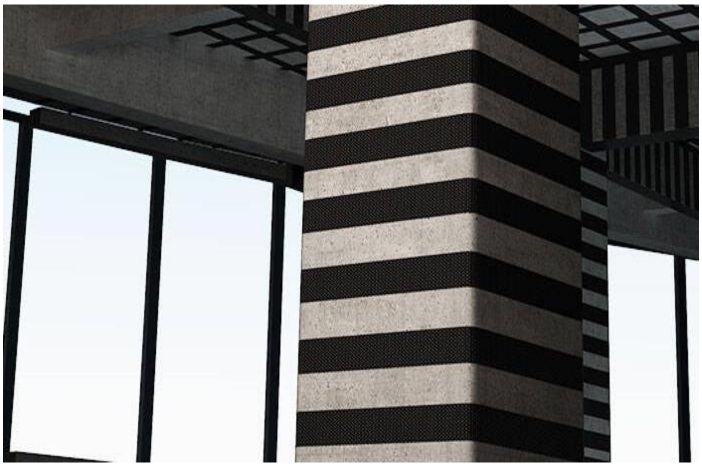


Figure-2: Jacketing of the Bridge

3.1.APPLICATION OF FRP IN BRIDGE STRENGTHENING

Fiber Reinforced Polymer (FRP) materials have found extensive application in strengthening bridge structures, offering a versatile and effective solution to address various structural deficiencies and extend the service life of aging infrastructure. One prominent application of FRP in bridge strengthening involves externally bonded reinforcement, where FRP sheets or strips are bonded to the surface of concrete elements such as beams, columns, or decks. This method enhances the flexural and shear capacity of the bridge components, allowing them to withstand increased loads and mitigate the effects of deterioration or damage. Additionally, FRP materials can be used to wrap or jacket existing structural members, providing confinement and enhancing their resistance to axial and lateral forces. The lightweight and high-strength properties of FRP make it particularly suitable for strengthening bridges without significantly increasing dead loads or altering the original aesthetics of the structure. Moreover, FRP offers excellent corrosion resistance, making it ideal for bridges exposed to aggressive environmental conditions, such as marine or industrial environments. By providing targeted reinforcement to critical areas and extending the service life of bridge components, FRP contributes to the safety, reliability, and longevity of transportation infrastructure, ultimately ensuring uninterrupted mobility for communities.

3.2.IMPORTANCE OF LATERAL LOAD IN BRIDGE ENGINEERING

Lateral loads in bridge engineering are crucial factors that significantly influence the design, analysis, and performance of bridge structures. These horizontal forces, stemming from sources like wind, seismic activity, and dynamic vehicle loads, exert pressure on the bridge deck and superstructure. The consideration of lateral loads is paramount in ensuring the structural integrity and stability of bridges, particularly in mitigating the risk of instability or failure. For instance, strong winds can induce structural vibrations or oscillations, potentially leading to collapse if not adequately accounted for in the design. Similarly, seismic events can subject bridges to lateral displacements and accelerations, necessitating robust structural design to withstand such forces. Furthermore, understanding the dynamic response of bridges to lateral loads is crucial for optimizing their performance and ensuring user comfort and safety. Engineers must integrate lateral load considerations into the geometric and aesthetic design of bridges to minimize aerodynamic effects, enhance stability, and improve resilience against external forces. Overall, accounting for lateral loads is essential for creating structurally sound, resilient, and safe bridge infrastructure that can withstand diverse environmental and operational conditions, ultimately facilitating efficient transportation networks.

3.3.JACKETING OF BRIDGE

Jacketing of bridges is a vital process in civil engineering aimed at strengthening and prolonging the lifespan of existing bridge structures. This method involves the application of additional materials or components to reinforce vulnerable areas, address structural deficiencies, or accommodate increased load demands. Typically initiated after a thorough structural assessment, jacketing solutions are customized to the specific condition and requirements of each bridge. Common jacketing techniques include steel, concrete, and fiber reinforced polymer (FRP) jacketing, each offering unique advantages such as increased strength, durability, and corrosion resistance. Whether it's repairing deteriorated concrete decks, reinforcing steel beams, or enhancing overall structural performance, jacketing plays a crucial role in maintaining the safety, reliability, and longevity of bridge infrastructure. By implementing jacketing solutions, engineers can effectively extend the service life of bridges, minimize maintenance costs, and ensure the uninterrupted flow of transportation networks for communities.

4.EFFECTS OF LATERAL LOADS ON BRIDGE BEHAVIOR

Lateral loads exert significant influence on the behavior of bridge structures, impacting their stability, dynamics, and overall performance. These horizontal forces, originating from sources such as wind, seismic activity, and vehicular movements, induce various responses within bridge components and systems. Wind, for instance, can cause lateral displacements and vibrations in bridge decks and superstructures, potentially compromising their stability if not adequately accounted for in design. Moreover, wind-induced aerodynamic effects like vortex shedding and buffeting can lead to dynamic instabilities and structural fatigue, necessitating careful consideration of aerodynamic design measures. In seismic regions, lateral loads from earthquakes subject bridges to dynamic displacements and accelerations, requiring robust seismic design strategies to ensure structural resilience and safety. Additionally, lateral loads influence the dynamic response of bridges, affecting factors such as natural frequencies and mode shapes. Engineers must employ appropriate design and reinforcement techniques to mitigate the effects of lateral loads, ensuring the structural integrity and safety of bridge infrastructure under diverse loading conditions. By understanding and addressing these effects, engineers can develop resilient bridge designs that withstand lateral forces and ensure reliable transportation networks for communities.

5.METHODOLOGY

In order to evaluate the load analysis of two models, a methodology was devised which involved utilizing software as well as adhering to the Indian Standard Code. This approach allowed for a comprehensive examination of the models, ensuring that all aspects related to load analysis were thoroughly analyzed. By incorporating these techniques, a more accurate and reliable assessment could be made regarding the performance and structural integrity of each model. Overall, this methodology proved to be highly effective in providing valuable insights into the load analysis of both models.

5.1.Software Used for Modeling

Computers and Structures, Inc. (CSI) has developed the ETABS (Extended Three-dimensional Analysis of Building Systems), a robust program for structural analysis and design. Tailored to meet the needs of structural engineers, it simplifies the creation of intricate three-dimensional models, supports diverse structural components, and conducts thorough static, dynamic, and nonlinear analyses. It seamlessly integrates with other CSI tools while providing an intuitive user interface that streamlines design compliance with regulations and standards. In engineering and construction industries, ETABS is an indispensable tool that ensures optimal safety in structures throughout the entire design and analysis process [7]. This is achieved through graphical representations as well as comprehensive reports that facilitate effective visualization of findings. The research utilized version 17 of ETABS Software which was instrumental in updating Indian Standard Code for Seismic Research or IS Code 1893 part-1:2016.

5.2.Method Used for Analysis of Models

Static analysis is a crucial technique used to evaluate two models created using the ETABS program. Model analysis can be carried out in two distinct ways, namely Static Analysis and Dynamic Analysis, as per Indian Standard Code 1893 part-1:2016. For earthquake-resistant design, Equivalent Static Analysis is employed following IS Code 1893 Part 1:2016. This strategy involves seismic forces being treated as static loads distributed at each floor level, thereby minimizing dynamic complexities. To compute design seismic forces, certain elements like the Response Reduction Factor (R), Importance Factor (I), and Zone Factor (Z) must be taken into account according to the code. The I factor indicates the importance of the structure, while the R factor considers energy dissipation and ductility. Additionally, the Z factor accounts for seismicity in the region. The code prescribes a systematic process that involves computing seismic base shear and force distribution throughout the structure's height. It also highlights the significance of site-specific response spectra when necessary [8]. In order to implement this technique effectively in seismic design projects, it is essential for engineers to collaborate with experienced structural engineers and keep up-to-date with any revisions made to the code.

5.3.Dynamic Analysis of the Model

In this study project, our team utilized dynamic analysis techniques, with a particular focus on Time History Analysis (THA), which follows the standards set out in IS 1893 Part 1. Dynamic analysis is a systematic approach used to assess how a structure responds to external pressures that change over time, such as earthquakes or other forces that vary with time. THA involves applying a load pattern that varies over time to the structure, thereby replicating dynamic circumstances observed in the real world. IS 1893 Part 1 is a seismic design code that provides detailed instructions and methods for conducting dynamic analysis to evaluate the seismic behavior of structures. The goal of our study was to gain insights into how structures behave under dynamic loading conditions, specifically seismic stresses. By utilizing THA in compliance with IS 1893 Part 1, we were able to conduct comprehensive analyses of structural responses to different stresses over time. This enabled us to create robust and earthquake-resistant structural designs that can withstand dynamic loading conditions. Our use of IS 1893 Part 1 ensured that our dynamic analysis adhered to recognized industry norms, thus enhancing the dependability and trustworthiness of our study results. In conducting our analyses, we used ElCENTRO data for two models of a bridge. This data was obtained from the ETABS software library and allowed us to conduct accurate and reliable analyses of the bridge's response under seismic stresses. Overall, this study demonstrates the importance of utilizing dynamic analysis techniques like THA in accordance with industry standards for creating earthquake-resistant structural designs.

5.4.Indian Standard Code for load

The research work at hand delves into the various Indian standard codes that are utilized for load case. Specifically, the Indian Standard Code 875 part-1 is employed for the self-weight of the bridge, while Indian Roads Congress 6:2017 serves as the go-to code for vehicle load and considers vehicles with Tracked Vehicle 70R [9] (Tracked) Vehicle characteristics. Lastly, the seismic load is determined by way of the Indian Standard Code 1893 part-1:2016. These codes play an integral role in ensuring that structures are designed and built in accordance with safety standards and regulations, thereby safeguarding both people and property alike.

5.5.Details View of Model

There are two model created in the ETABS Software, where one model is without FRP jacketing and other one is with FRP Jacketing. The Plan, Elevation, and 3D View of each model are given below:

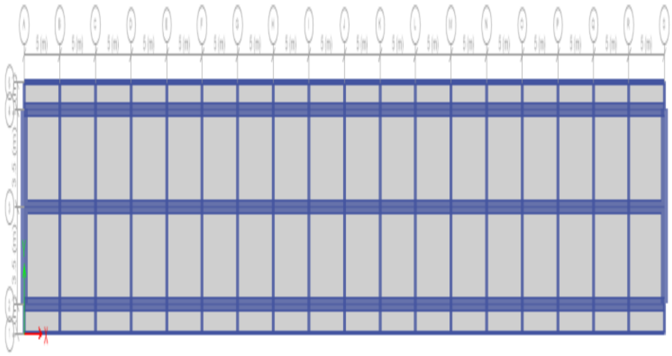


Figure-3: Plan View of the First Model.

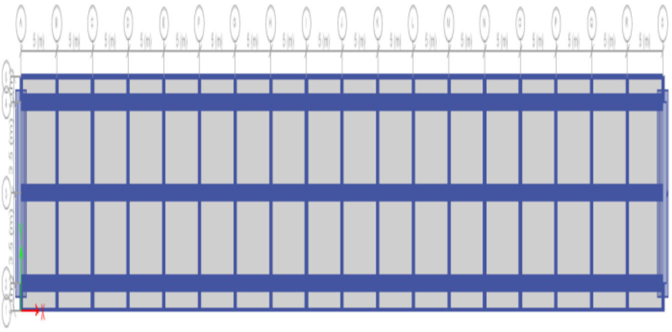


Figure-4: Plan View of the Second Model.

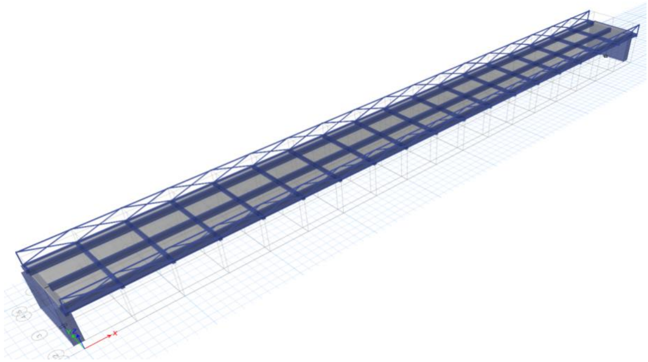


Figure-5: 3D View of the first Model.

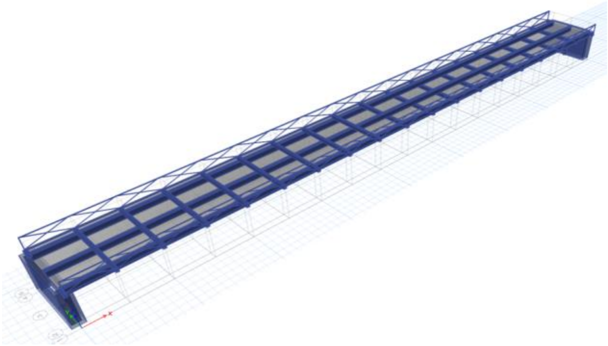


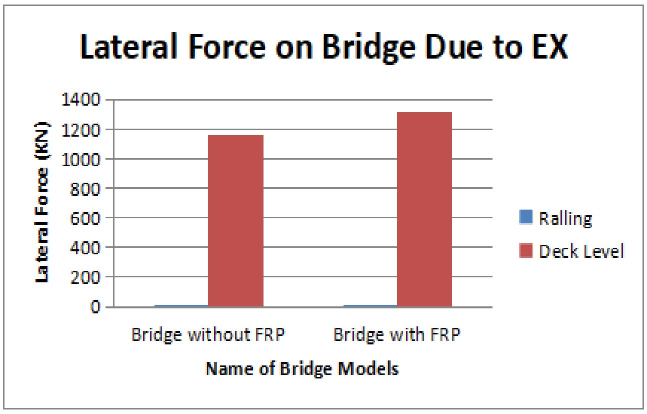
Figure-6: 3D View of the Second Model.

6.RESULT AND ANALYSIS

In the upcoming section dedicated to result and analysis, we will carefully scrutinize and examine the outcome of our static analysis of two models. To carry out this task, we will make use of the highly sophisticated ETABS Software [11]. Our current focus is on conducting a seismic analysis of a long-span bridge. Therefore, it is essential to consider some critical parameters that play a vital role in determining the impact of an earthquake on the bridge. These parameters include base shear (which indicates the lateral force exerted by an earthquake on the bridge), fundamental period, and maximum displacement of the bridge caused by lateral load. By taking into account these crucial factors, we can gain valuable insights into how earthquakes may affect long-span bridges and devise effective strategies to mitigate any potential damage.

6.1.Lateral Load on the Bridge

Perpendicular horizontal forces acting on the longitudinal axis are commonly referred to as lateral loads when it comes to bridges. These types of forces can stem from various sources, such as wind gusts, earthquakes, and vehicle-induced pressure that push sideways. Engineers must take into account these lateral loads during the design phase in order to ensure structural stability, prevent collapse, and guarantee safe operation under multiple external pressures [12]. In this particular case, we have selected seismic lateral load on the bridge. The graph below illustrates the lateral force exerted on the bridge at load case EX where EX denotes seismic effect-related sideways pressure in X-direction.



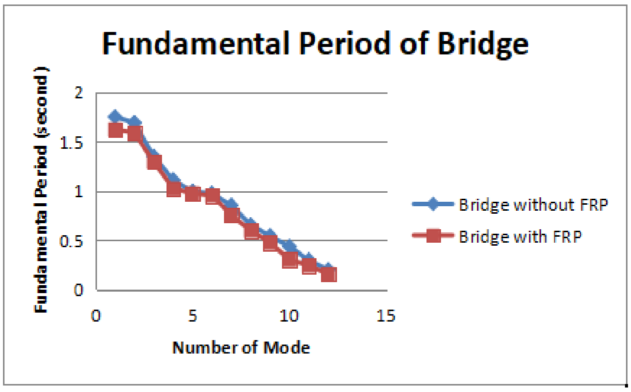
Graph 01: Lateral Force on the Bridge.

As we know concerning the Indian Standard Code 1893 part1:2016, the value of the lateral force increases by increasing the self-weight of the structure.

6.2.Fundamental Period of the Bridge

The bridge's fundamental period refers to the duration required for the bridge to complete one oscillation cycle caused by an earthquake. This essential period is determined through structural analysis and depends on various factors, such as the structure's geometry, material qualities, and boundary conditions [13]. As per the Indian Standard Code 1893 part 1:2016, it is recommended that this value should not fall below 0.05 seconds or exceed 2.0 seconds.

Below is a graph illustrating the fundamental periods of two models of the bridge.

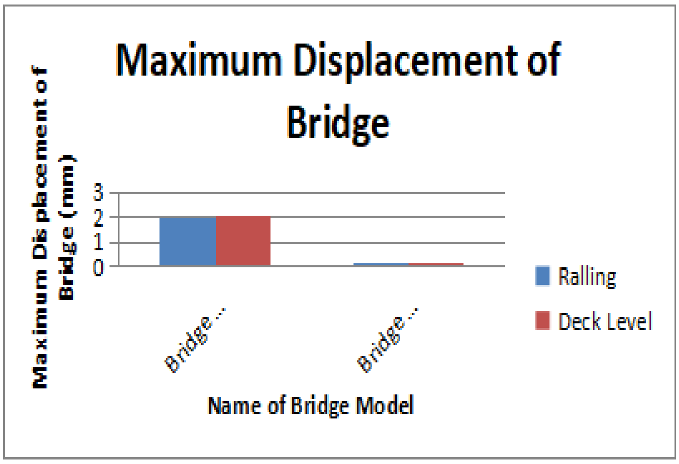


Graph 02: Fundamental Period of the Bridge Models

As we can see from Graph 02, the maximum value of the fundamental period is not greater than 2.0 seconds or not less than 0.05 seconds, which means that all these two models of the bridge are in safe condition.

6.3Maximum Displacement of Bridge

The displacement of a bridge refers to the movement of its upper level in relation to its base, which can be caused by various load scenarios such as weight, vehicle or pedestrian load. However, when it comes to analyzing seismic activity on long-span bridges, engineers focus on earthquake loads. One critical aspect of seismic design for bridges is determining their maximum displacement, which is influenced by factors such as seismic forces, material quality, and bridge shape. Engineers calculate the maximum displacement to ensure that the bridge can withstand seismic events without compromising its structural integrity. For instance, the chart below shows the maximum displacement of a bridge under earthquake load conditions in the X-direction. This information is crucial for designing safer and more resilient bridges that can withstand natural disasters and other unexpected events.



Graph-03: Maximum Displacement of the Bridge.

From Chart 03, we can see that the displacement of the bridge decreased due to applying the jacketing of Fiber Reinforced Polymer.

7.CONCLUSION

Upon analyzing the results of the ETABS software and static method analysis model for the bridge, we have come to several conclusions. Upon calculating the self-weight of both models, it was discovered that model-02, which included fiber-reinforced polymer jacketing on the abutment, main girder, and supporting girder experienced a 3.48 percent increase in self-weight compared to model-01 without any jacketing. Despite this increase, there was not a significant change in overall bridge weight.

Additionally, after analyzing both models using ETABS software, it was found that at railings level and deck level of the bridge lateral force increased by 0.06426% and 11.4223%, respectively in Model-02 as compared to Model-01 (bridge without FRP jacketing). Moreover fundamental period decreased by 7.4158% when FRP Jacketing is used on abutment ,main girder & supporting girders indicating its safety.

According to Indian Standard Code 1893 part-1:2016 standards state that maximum displacement should not exceed H/205 where H represents total height from base to top; thus given our total height of 8000 mm ,the displacement should be no greater than 32mm . However in Model -01,the maximum displacement measured only up to2.035mm whereas with application of FRP jacketing onto Bridge resulted in decrease by92..38 percent as compared to Model -01of Bridge..

REFERENCE

1. IRC: 6-2010 Standard Specifications and Code of Practice for Bridges Section II Load stresses, Indian Road Congress, 2010
2. IRC: 21-2000 Standard Specifications and Code of Practice for Bridges Section III,
3. N. Krishna Raju, "Design of bridges", Oxford & IBH publishing Co. Pvt. ltd, ISBN 81-204-0344-4
4. N. Krishna Raju, "Prestressed concrete", 2014, Mcgraw Hill Education Private Limited ISBN 81-204-0396-7.
5. D. Johnson Victor,1973, "Essentials of bridge engineering", Oxford & IBH publishing co. Pvt. ltd. ISBN 81-204-0396-7.
6. IS:456-2000 Indian Standard Code of Practice for Plain and Reinforced Concrete
7. Hellon G. Ogallob, Manoj K. Jhaa, ―A Quantitative Analysis of Sustainability and Green Transportation Initiatives in Highway Design and Maintenance‖ EWGT2013 – 16th Meeting of the EURO Working Group on Transportation vol.no.111 (2014) pp.1185 – 1194.
8. INyoman Sutarja, Ida Bagus Rai Widiarsa, ―Partial prestressed concrete slabs as an alternative for vehicle decks of steel truss bridges‖ The 5th International Conference of Euro Asia Civil Engineering Forum (EACEF-5) vol.no.125 pp. 974 – 978.
9. Khairmode A. S., Kulkarni D. B. ― Analysis of Prestressed Concrete Multi-cell Box Girder Curved Bridge‖ International Journal of Science and Research (IJSR) Volume 5 Issue 6, June 2016.
10. Klaudiusz Fross, Marek Salamak ―Bridges in Urban Planning and Architectural Culture‖ World Multidisciplinary Civil Engineering‖ vol.no. 161 (2016) PP.207 – 212.