International Research Journal of Innovations in Engineering and Technology (IRJIET)

ISSN (online): 2581-3048

Volume 10, Issue 7, pp 8-16, July-2026

https://doi.org/10.47001/IRJIET/2026.107002

Investigation of Bridge Serviceability and Strength Using Integrated Static and Dynamic Approaches

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Abstract - **The load-bearing capacity of bridges is critical to their structural integrity and longevity. In this work this capability is assessed using an integrated method combining computational calculations and experimental testing, with focus on static and dynamic loading situations. The numerical part relies on finite element modelling (FEM) to simulate the behaviour of bridges under different load situations, investigating characteristics such as stress distribution, deflection patterns, and modal frequencies. Experimental validation is performed using static load application and dynamic excitation methods, such as impact hammer testing and ambient vibration monitoring. The combination of these alternative methodologies offers a thorough view of structural response, pinpointing important failure causes and serviceability constraints.**

Static response characteristics, e.g. deformation and strain behaviour, are determined under a controlled loading regime to define the immediate structural responses. Dynamic metrics like frequency response and energy dissipation ratios are analysed to evaluate sustained performance and to identify underlying defects. The reliability of the evaluation is enhanced when the computational predictions agree with the experimental observations. Any differences are corrected via model calibration, therefore enhancing the accuracy of the future predictions. The study evidences the need for the use of both analytical and physical testing techniques for a comprehensive evaluation of the capacity, so as to improve the safety of infrastructure management and the operational efficiency.

The results show that dynamic assessment complements static evaluation by revealing small structural alterations that static testing alone may ignore. The suggested framework provides a realistic way for engineers to improve the prediction of load-bearing capacity and enable informed maintenance and retrofitting choices. This study promotes bridge evaluation procedures and contributes to sustainable infrastructure development via hazard avoidance and the effective allocation of resources. This is especially true for the aging bridge fleet, where accurate assessment of capacity is critical to prolonging the remaining service life.

Keywords: Bridge Load-Carrying Capacity, Static Load Test, Dynamic Load Test, Finite Element Modelling, Natural Frequency, IRC Loading.

I. INTRODUCTION

The load-carrying capacity of a bridge is a direct measure of its resistance against live loads and is important for future planning in terms of traffic volume, higher loads, and maintenance, assuring public safety (Ko and Kim, 2023). Bridges are important constructions for spanning physical obstacles such as rivers, valleys, roads or railroads and are integral components of transportation systems, improving connection within an area and facilitating the flow of people, goods and services. Their failure may result in a massive loss of life and economic fallout (Cook, 2014). Bridge capacity valuation is done in two essential lifecycle stages. Stage I is the design and construction stage where the bridge capacity is evaluated in the latest condition and according to the code. Stage II is the operation and maintenance stage where the bridge capacity is deteriorated due to weather, traffic and aging and should be monitored. Stage II values are especially important after significant occurrences such as earthquakes or floods and before to restoration efforts. Research shows that 80.30% of bridge collapses in India during 1997-2017 were due to natural calamities & good structural health monitoring & prompt appraisal may considerably decrease such failures (Garg *et al.*, 2023).

A condition evaluation was performed on a wrought iron bridge and static and dynamic load testing were carried out. Field results were confirmed by finite element modelling. For testing, a six-axle locomotive with an axle load of 13.16 tons was employed. Displacement, strain, and acceleration were recorded on crucial parts under many loading conditions. Bridge degradation and fatigue life are studied. Validated models support capacity under high load situations. It is shown that retrofitting costs were much less than new construction. Padgett et al. (2010) highlighted that maintenance and repair add up to lifetime costs; nonetheless, they pointed out the detrimental consequences of extreme

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events on structural durability. Static load testing as per IRC SP 51:2015 includes placement of focused loads or vehicles to produce maximum bending moments and measurement of deflection, stresses and fracture breadth. However, static testing is time consuming, costly and causes traffic disruption. Managing equipment in distant places is a big difficulty. Dynamic load testing offers techniques for quick capacity evaluation to overcome these restrictions. The comparison of the two approaches enhances the valuation methods, quality of maintenance procedures and testing techniques for safer and more trustworthy bridge infrastructure.

Dynamic load tests analyse the structural integrity and dynamic behaviour of structures under simulated real-world situations, evaluating factors such as amplitude, frequency, impact coefficients, mode shapes and static characteristics. Dynamic loads are applied by hydraulic actuators, instrumented vehicles, impact drop weights or modal hammers. The methods include instrumented vehicle testing at different speeds, controlled impact testing and ambient vibration testing using ordinary traffic to identify natural frequencies (Laura *et al.*, 2020; Gatti, 2019; Samali *et al.*, 2007; Baisthakur and Chakraborty, 2021). Instrumentation includes accelerometers for acceleration measurement, strain gauges for stress distribution measurement, displacement sensors such as LVDTs and IDTs for deformation measurement, data acquisition systems for signal collection and analysis, environmental sensors for monitoring wind and seismic activities, high speed cameras for capturing visual response and GPS receivers for tracking the spatial displacement. IRC SP:51-2015 provides for dynamic load testing however no particular Indian standards are available. The IRC acceptance criteria states that the observed deflections and strains should be equal or less than the predicted values. The theoretical deflection should be between span/1500 and span/1000. Crack widths should not exceed 0.30 mm for mild exposure and 0.20 mm for extreme conditions. The minimum 24 hours deflection recovery percentages are given for different types of bridges.

Objectives

- Evaluate DLT feasibility as an alternative to SLT for bridge capacity assessment.
- Develop numerical models simulating static and dynamic bridge responses for performance quantification.
- Extract dynamic parameters from available static test literature data.
- Formulate a dynamic-parameter-based methodology for capacity determination from simulation data.

II. LITERATURE REVIEW

Song *et al.* (2025) computationally assessed failure of aging reinforced cement T-beam bridges under repeated stress conditions. The deflection at the mid-point was evaluated in the experiment under applied pressures providing vital insight on the structural behaviour of decaying bridge infrastructure. The researchers modelled the gradual degradation processes taking place in aging bridges under cyclic loading regimes using sophisticated finite element modelling techniques. The selected approach tested the material deterioration with time, which is vital to understand the long-term performance of existing bridge structures. The results indicated the influence of repeated loading cycles in developing structural fatigue and eventual failure in reinforced concrete T-beams. This study contributes significantly to the domain by developing computational frameworks that might predict remaining service life of aging bridges, allowing for proactive maintenance planning. The technique developed in this work provides engineers with a valuable tool to analyse bridge scenarios without considerable field testing.

Shaikh and Nallasivam, (2024) Shaikh and Nallasivam used ANSYS software for static analysis of a cement hollow-beam bridge with unballasted track layout using computational techniques to analyses deformation and internal pressures. The Assessment has been done as per Indian railway standards for compliance to national design criteria. The authors developed detailed finite element models that can efficiently simulate the geometry and material properties of the hollow-beam design for diverse loading scenarios. The stress distribution pattern and deformation characteristics of the bridge deck were investigated under train loads. The computer procedure enabled parametric studies to be carried out to study the influence of design factors on the structural response. The results are of importance to engineers who are constructing railway bridges with unballasted track systems and provide crucial advice on proper modelling approaches. The study methodology demonstrated the effectiveness of ANSYS in analysing complex bridge structures.

De Angelis and Pecce (2023) carried out a model study of a bridge using comprehensive static and dynamic load data Demonstrating the synergistic advantages of integrating both approaches. They studied a bridge created by Morandi in the 1950s in Benevento, with complicated architectural features and peculiar support conditions. Digital models were refined and the gap between experimental and computational results was minimized and reliability of structural evaluations was increased. The dynamic testing demonstrated linear behaviour and seismic performance, whereas the static tests indicated nonlinear serviceability responses. The vertical restrictions, stiffness and the structural modifications were shown to be considerable. Results demonstrated structural linearity for both test methods and proved they were complementary for comprehensive bridge assessment. The procedure is

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technically correct and precise in measuring to deliver accurate architectural insights. The results of this study add significantly to our knowledge of how combined static-dynamic approaches may provide a complete structural evaluation.

Wang *et al.* (2022) put out a way to investigate dynamic forces with genuine force distribution patterns for speedy evaluation of bridge capacity. This novel technique utilizes the traversing force testing to determine the force distribution profile of structures and value criteria based on the ratios of the peak magnitude and the integrated area of empirical and theoretical distribution curves. Numerical validation of the three typical deterioration scenarios demonstrated a high connection with the classical static assessment criteria. 6 vehicles of 350 KN were used for the static test and the dynamic force test in the field validation. The maximum variations were found to be quantitatively just 1.5% and 2.2% from ordinary stationary benchmarks in field situations. The results showed that the proposed technique could achieve better accuracy and efficiency than current methods in medium span crossing testing. This technique considerably saves the testing time and price and assures excellent dependability. The suggested approach is a viable alternative to classical load testing for regular bridge assessment.

Sun, Siringoringo, and Fujino (2021) suggested an effective method to assess the weight-bearing capacity of beam-based crossings, taking into account the deformations induced by the movement of cars. The framework includes three main stages: real-time deformation monitoring during assessment of truck transit by radar, production of the impact trajectory graph and evaluation of stationary weight created displacement. The capacity assessment is based on the AASHTO handbook. The reliability of the technique was verified by the digital simulation of a 3D computer model of a typical beam flyover under transport loads, taking into account the effect of transport mass, velocity and route texture on the deformation precision. Empirical assessment was performed using a basic supported tensioned concrete beam bridge to prove the feasibility and economic viability of the technology.

Magalhães, Cunha and Caetano (2020) monitored the vibration on the “Infante D. Henrique” structure, a new extended span arched concrete bridge over the Douro River in Porto, Portugal. Before the installation of the sensor, physical and computational tests on the observational setup were conducted and documented. The results are given and analysed using customized Matlab programs for the Assessment of data delivered via online. By the Ambient Oscillation Examinations, the resonance property could be determined objectively, which was also consistently detected close to the values of the real-time monitoring system. The recognized methods include the automated detection of the structure’s intrinsic oscillation frequencies using Spectral Range Dissection, a web-based method that enables seeing the first twelve resonant modes. This feature can only be achieved by combining the greatest data gathering equipment with the most powerful computing algorithms. The research shows the efficacy of long-term dynamic monitoring for the assessment of the bridge performance.

Liu *et al.* (2019) explored the reliability assessment of the deflection limit state of a simply supported bridge based on the vibration data and dynamic Bayesian network inference. The purpose of the research was to explore the deformation patterns as a key indication of a structure's capacity to withstand various loads, for instance, car traffic loads. The authors developed a system for the evaluation of bridge deflection dependability using modern probabilistic methods integrating vibration data with Bayesian network Assessment. The methodology used uncertainty quantification to improve the accuracy of forecasts of the structural performance under operational conditions. The suggested technique is verified by utilizing field measurements of instrumented bridges. The study has shown that dynamic response data may be used for the evaluation of serviceability limit condition, as an alternative to traditional static load testing techniques. The dynamic Bayesian network technique made it possible to update the reliability decisions on a continuous basis as new monitoring data became available. This paper is an essential contribution for the development of probabilistic frameworks for bridge condition evaluation using vibration-based approaches.

III. METHODOLOGY

Validation of the Numerical Model and Convergence Study

The process starts with the creation and validation of the three-dimensional finite element model of the reinforced concrete T-beam bridge by utilizing ANSYS software. The validation procedure was carried out by comparing the numerical findings with data available in the literature for a bridge with 15 m span. For M25 reinforced concrete young modulus 2.5 x 1010 N/m2, density 2500 kg/m3 and Poisson ratio 0.18 were used for the model parameters. The IRC Class AA tracked vehicle is chosen as the reference live load for validation. We completed detailed mesh convergence research to optimise the element size for computing efficiency and accuracy. The convergence study was performed for mesh sizes between 500 mm and 200 mm and the moving load was placed at 1200 mm from the curb. Results showed convergence at mesh size of 200 mm with a model of 81,892 nodes and 19,188 elements. The validation showed a

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percentage error of 3.84% between the ANSYS findings (7.56 mm deflection) and the literature reference (7.28 mm deflection), which confirmed the appropriateness of the numerical model for the further parametric studies.

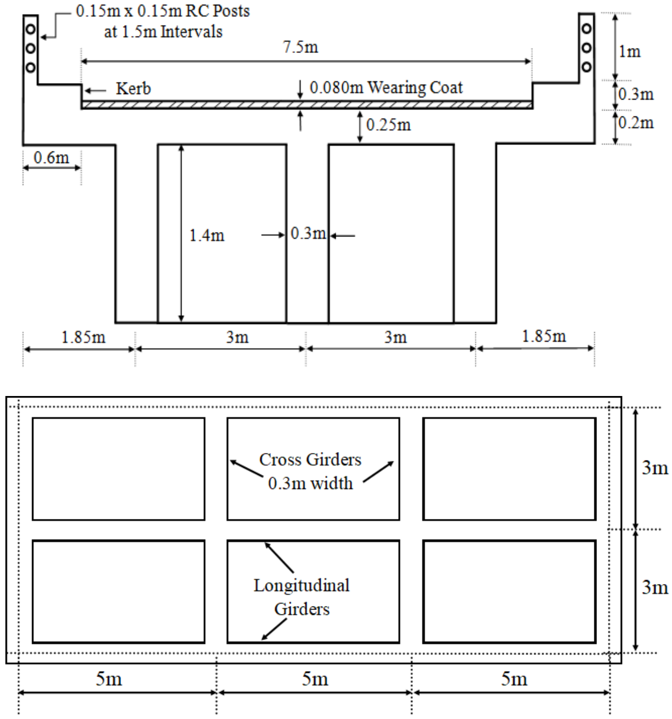

Figure 1: T-Beam and Slab Bridge-Deck for 15m of span used for validation

Modelling of the bridge and transient load set-up

The bridge model used for the inquiry is simply supported with hinge support at the left end and roller support at the right end. The overall span length is 16.3 meters. The geometry was modelled in AutoCAD and then loaded into ANSYS Workbench under transient structural analysis system. The structural discretization used SOLID65 elements, which are elements for reinforced concrete structures. The different components were meshed using different strategies, using triangular (tetrahedral in 3D) meshing for the wearing coat section and rectangular (hexahedral in 3D) meshing for the cross girders, deck and longitudinal girders. The reinforced concrete was modeled using the following material properties: Young's modulus 3.162×10^{10} N/m², density 2500 kg/m³ and Poisson's ratio 0.18. The dead load was the normal gravity acceleration (9.81 m/s²) and the live load was the IRC Class AA tracked vehicle for the different eccentric sites. The transient analysis is carried out with step end time of 1.2 sec and time increments of 0.2 sec. The moving load is made to travel on eccentric paths from 1200 mm to 2300 mm from the curb with an increment of 100 mm to study the effect of load eccentricity on the parameters of structural response.

Advanced Analysis of Prestressed Concrete Bridges Using ABAQUS

The approach is extended for a detailed study of Prestressed Concrete (PSC) bridge in Mirzapur, India, data being given by CSIR-CRRI. The bridge span under consideration (P3-P4) has an effective span of 28.2 m and a variable girder shape over its length, including tapered sections with thickness ranging from 0.77 m to 0.15 m to 0.77 m. The bridge features include a slab depth of 0.2m, slab width of 8.45m, girder spacing of 4.76m and girder depth of 1.85m. The numerical modeling was done in ABAQUS software using linear geometric order C3D8R hexahedral elements. The study was based on a reduced geometry without the effects of prestressing while retaining other structural characteristics. Material characteristics taken were concrete density 2500 x 10 6 ton/mm 3 , modulus of elasticity 27386 N/mm 2 and Poisson's ratio 0.2. The finite element mesh was made up of 5618 nodes and 2445 elements with varied mesh sizes of 400 mm for the deck, 200 mm for cross girders and 600 mm for longitudinal girders. The model was validated by comparing the vertical deflection under self-weight with the findings of CRRI research. The results are in good correlation with a difference of just 0.29% (16.39 mm in ABAQUS and 16.35 mm in CRRI study).

Implementation of Moving Load and Parametric Study

The moving load implementation in both ANSYS and ABAQUS used fortran based DLOAD subroutines to specify the vehicle movement across the bridge. The Class AA tracked vehicle load was at different eccentricities from 1200 mm to 2300 mm from the curb in the ANSYS model to see the changes in maximum total deformation, equivalent stress and equivalent strain. The time history analysis of the moving load progression determined the longitudinal location of the vehicle for maximum response parameters. The investigation also noted the time period at which the greatest values occurred and the locations of the vehicle along the bridge span. The ABAQUS study considered four different IRC loading situations. These are: Class AA tracked load, Class AA wheeled load, Class A wheeled load (2-lane) and 70R wheeled load. The Class A and 70R wheel loads were studied for both eccentric and symmetric loading circumstances. The vehicle was driven at a speed of 28.2 m/sec for a bridge span travel duration of 1 second to find the critical load instances the greatest vertical deflection responses were studied. The load location at maximum deflection was estimated by the formula $Zp = Vt$ where V is velocity and t is time. Such a detailed parametric study helps engineers to assess the structural behaviour for different moving load situations, thereby helping informed design choices and proactive maintenance of aging bridge infrastructure.

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IV. RESULT AND DISCUSSION

Static Load Test and Analysis

The loading method for the static load test was created as per Indian Road Congress (IRC) criteria, particularly IRC-6:2017, which specifies hypothetical design vehicles for bridge structures in India. The major aim was to locate loaded trucks across the bridge spans such that the maximum bending moment in the outer girder is identical with that due to the standard design live load on the roadway after the recommendations given in para-6 of IRC Special Publication No. 37. The loading scheme for bridge P3-P4 has been designed by CSIR-CRRI using RM Bridge V11 software for numerical modelling under simply supported boundary conditions. The concrete grade was obtained as M30 from the results of Non-Destructive Testing (NDT). Multiple load situations as per IRC-6:2017 were investigated to estimate the theoretical maximum bending moment and deflection in the span girder. The result of study shows that the 70R Wheeled One Lane eccentric loading condition is the critical design values with the theoretical maximum bending moment of 4232 kN-m and maximum deflection of -16.9032 mm. The specific IRC design vehicles are not readily accessible during field testing. Hence, a similar commercial vehicle loading method was designed. The final loading scheme was 42 tonne and 62 tonne commercial vehicles with a total theoretical maximum bending moment of 4285 kN-m and deflection of -17.2806 mm, which were quite near to the design IRC loading requirements.

Table 1: Weight of Loaded Trucks for Load Testing of Span P3-P4

Vehicle No.	Type of Truck Three/four Axles	Load on			Total Weight of loaded Truck (kg)
		Front one Axle (Kg)	Front two Axle (Kg)	Rear two Axle (Kg)	
1.	Three	10500	NA	31500	42000
2.	Four	NA	18500	43500	62000
The total weight of all the above trucks				1040000 kg Say104 ton	

Table 2: Deflection Data during load test of Span P3-P4

Loading Stage	Average Temp (°C)	Mid-Span Girderu/s (G2)	Mid-Span Girderd/s (G1)
Dial Gauge No.		D-2	D-1
Initial Reading-R1	32.5	0	0
Final Deflection after 3 hours of loading R3	29.55	-5.35	-23.06/17.28
Residual Deflection after 30 minutes of unloading - R5	31.1	-0.5	0.04
Parentage recovery [(R3-R1)*100/(R5-R1)]		90.7%	100.2%

MIDAS Civil Section Properties and Modelling Method

The bridge was modelled numerically using MIDAS CIVIL 2024 V1.1 software instead of ABAQUS used in the previous chapter, primarily to allow for the direct extraction of bending moment values that could not be acquired from the ABAQUS output. The prestressing tendons were purposefully neglected in the modelling since the structural reaction parameters such as bending moment and deflection are largely dependent on the mass, modulus of elasticity and the section moment of inertia. Dynamic assessment is influenced heavily by the modulus of elasticity, which is a changeable attribute. The bridge was simulated as simply supported boundary condition by using M30 grade concrete with isotropic material qualities as per Indian Standards. The girder sections were characterized according to a cross-sectional area, effective shear areas, torsional resistance and area moments of inertia around both axes. The validation was performed to confirm numerical correctness before continuing with the analysis.

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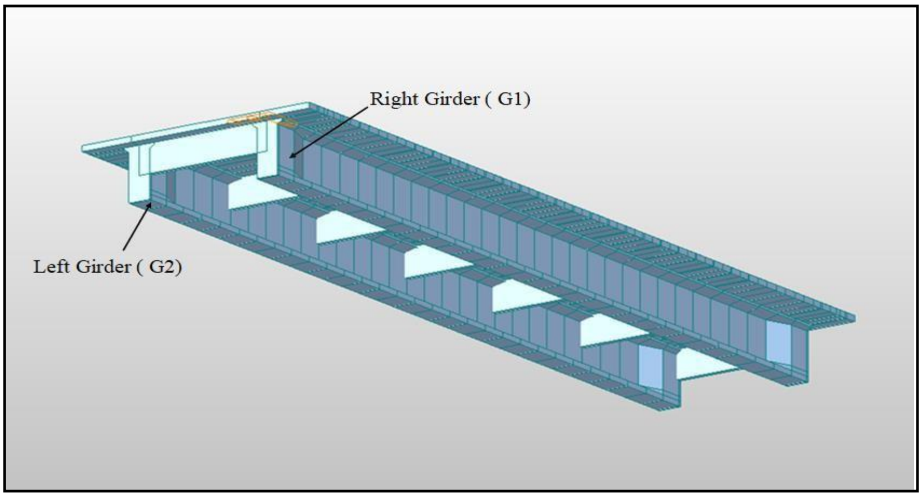
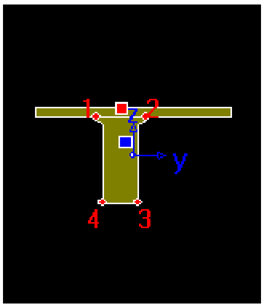
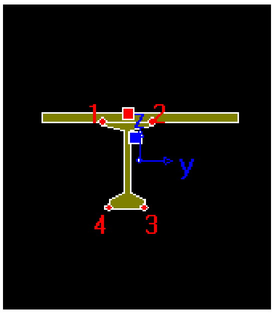


Figure 2: 3D view of Bridge in Midas Civil 2024 V1.1

Table 3: Section Properties of left end girder (G2)

Properties	End-Section	Mid- Section
C/Sal Area (A)	$2.3095 \times 10^{6} mm^{2}$	$1.3981 \times 10^{6} mm^{2}$
Effective Shear Area (Asy)	$7.9559 \times 10^{5} mm^{2}$	$7.2876 \times 10^{5} mm^{2}$
Effective Shear Area (Asz)	$1.2242 \times 10^{6} mm^{2}$	$2.7551 \times 10^{5} mm^{2}$
Torsional Resistance (Ixx)	$2.2852 \times 10^{11} mm^{4}$	$2.3418 \times 10^{10} mm^{4}$
Area Moment of Inertia (Iyy)	$9.7536 \times 10^{11} mm^{4}$	$6.5072 \times 10^{11} mm^{4}$
Area Moment of Inertia (Izz)	$1.3740 \times 10^{12} mm^{4}$	$1.3011 \times 10^{12} mm^{4}$
Geometry		

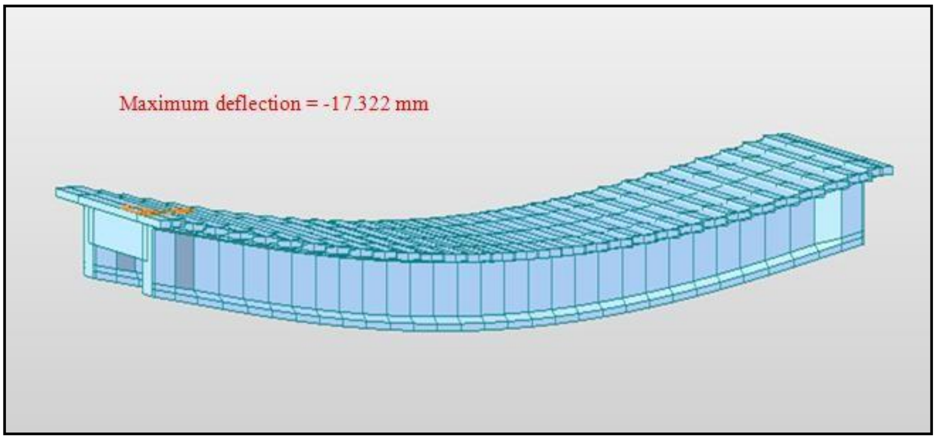


Figure 3: Deflected shape of the bridge in 3D under self-weight

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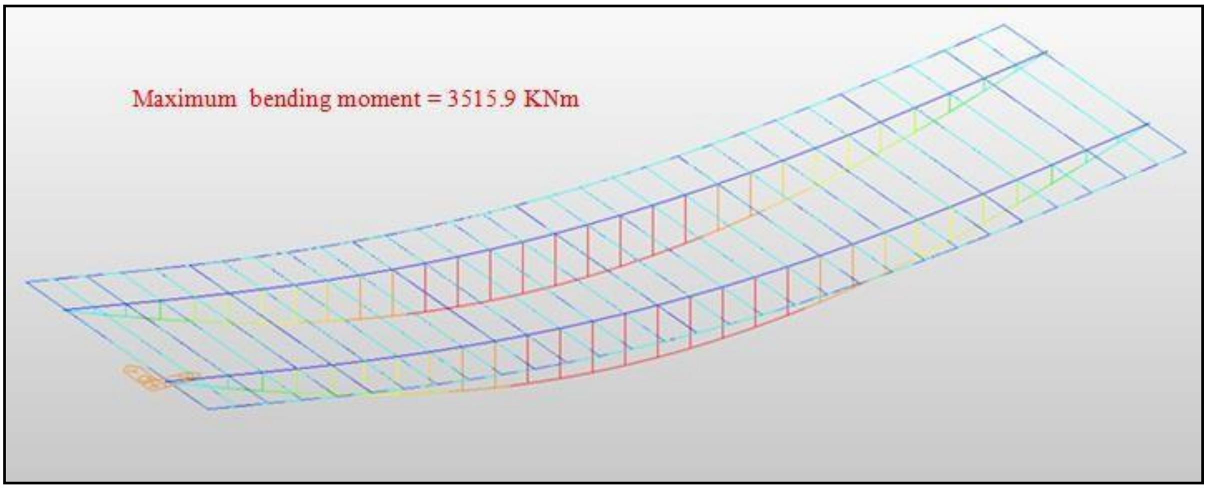

Figure 4: Bending moment diagram of girders under self-weight

Numerical Model Updating

The numerical model updating procedure was performed to align the dynamic load-carrying capacity with the static load-carrying capacity of the bridge. A parametric study was conducted to achieve the desired natural frequency by varying three key parameters that influence structural properties: material property (elastic modulus), boundary conditions, and moment of inertia. The boundary conditions were maintained as simply supported while the elastic modulus was varied corresponding to concrete grades M20 through M60, and the moment of inertia was reduced incrementally from 100% to 60% of the ideal value to account for potential cracking and deterioration.

The frequency analysis revealed that the target frequency of 3.376 Hz was achieved with 65.1% of the ideal moment of inertia and M30 grade concrete modulus. Using this updated frequency, the recalculated dynamic load-carrying capacity became 113.05 tons, which closely matches the static load-carrying capacity of 113.15 tons. This successful correlation verifies that the flexural capacity derived from dynamic characteristics aligns with the capacity obtained from inspection, confirming consistent structural integrity across both analytical and experimental approaches.

Table 4: Frequency of the bridge for varying E&I Target f=3.376 Hz

E, Iyy and frequency										
		E1	E2	E3	E4	E5	E6	E7	E8	E9
		M20	**M25**	**M30**	**M35**	**M40**	**M45**	**M50**	**M55**	**M60**
Iyy1	**60%**	2.9334	3.1017	3.2457	3.3738	3.4880	3.5920	3.6873	3.7764	3.8580
Iyy2	**65%**	3.0497	3.2237	3.3738	3.5063	3.6245	3.7327	3.8329	3.9246	4.0112
Iyy3	**70%**	3.4965	3.3411	3.4965	3.6337	3.7566	3.8685	3.9714	4.0667	4.1563
Iyy4	**75%**	3.2669	3.4542	3.6140	3.7566	3.8835	3.9984	4.1051	4.2034	4.2955
Iyy5	**80%**	3.3693	3.5625	3.7272	3.8745	4.0048	4.1237	4.2337	4.3365	4.4307
Iyy6	**85%**	3.4686	3.6670	3.8373	3.9872	4.1220	4.2463	4.3592	4.4623	4.5600
Iyy7	**90%**	3.5638	3.7679	3.9432	4.0984	4.2355	4.3630	4.4783	4.5851	4.6860
Iyy8	**95%**	3.6563	3.8655	4.0453	4.2034	4.3459	4.4763	4.5956	4.7059	4.8077
Iyy9	**100%**	3.7467	3.9620	4.1459	4.3085	4.4543	4.5851	4.7081	4.8216	4.9261

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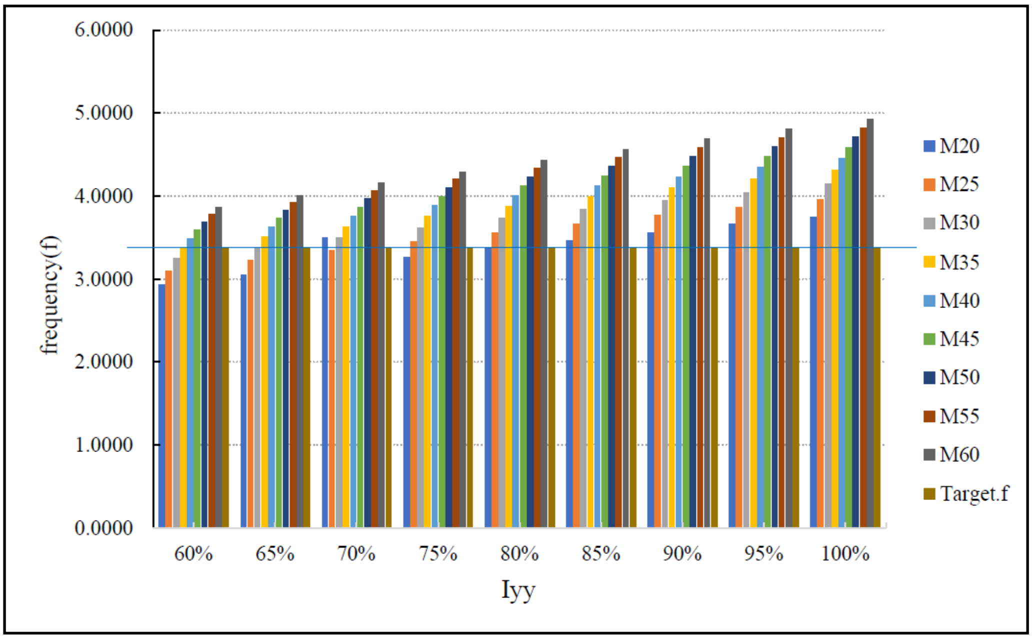

Figure 5: Graph illustrating frequency (fn') **for varying I&E**

V. CONCLUSION

The numerical study of the finite element analysis of a concrete bridge subjected to IRC Class-AA tracked moving load, shows a constant reduction in structural response parameters with the increasing of the eccentricity of the moving load path from the kerb. The overall deformation, ultimate equivalent stress and ultimate equivalent strain all reduce as the load path changes from the eccentric 1200mm position to the symmetric 2300mm position. Specifically, the percentage decrease of eventual total deformation is 13.76%, although the comparable stress and the equivalent strain are both reduced by 9.48% throughout the same range of eccentricity. The critical response values are at 1200mm of eccentric position, including 8.06 mm of total deformation, 51.63 MPa of equivalent stress and 0.00163 of equivalent strain. Furthermore, the analysis of various IRC moving load cases such as Class AA tracked, Class AA wheeled, Class A wheeled and 70R wheeled loads under eccentric and symmetric conditions indicate that the 2-lane Class A wheeled vehicle with eccentric loading produces the maximum deflection of -16.02mm and hence it is the most critical load case for the bridge under study.

The dynamic load-carrying capacity (DLCC) was computed as 170.49 tonnes using an experimental deflection of 23.06 mm and a numerical frequency of 4.145 Hz, which is considerably higher than the static load-carrying capacity (SLCC) of 113.15 tonnes for the 70R wheeled vehicle with impact. The difference is because mathematical models consider ideal conditions while real bridges undergo fluctuations in material stiffness, support conditions and sectional properties with the passage of time owing to ageing and deterioration. To address this, parametric research altered these factors, leading to a redesigned model with a frequency of 3.376 Hz obtained by calibrated modulus of elasticity, 65.1% moment of inertia and simply supported boundaries. The recalculated DLCC of 113.05 tonnes is quite near to the CRRI's SLCC value of 113.15 tonnes. This confirms that flexural capacity from dynamic evaluation is in agreement with the experimental results. This verification proves the exigent need of calibrating numerical models to replicate actual bridge conditions, particularly for ageing infrastructure where structural deterioration has a considerable impact on load-capacity evaluations and maintenance planning decisions.

REFERENCES

[1] Abedin, M., y Basalo, F.J.D.C., Kiani, N., Mehrabi, A.B. and Nanni, A., 2022. Bridge load testing and damage evaluation using model updating method. *Engineering structures*, 252, p.113648.

[2] Baisthakur, S. and Chakraborty, A., 2021. Experimental verification for load rating of steel truss bridge using an improved Hamiltonian Monte Carlo-based Bayesian model updating. *Journal of Civil Structural Health Monitoring*, 11(4), pp.1093-1112.

[3] Benčat J and Kohár R (2018) Bridges Subjected to Dynamic Loading. Bridge Engineering. *InTech.* Available at: http://dx.doi.org/10.5772/intechopen.73193.

[4] Caglayan, B.O., Ozakgul, K. and Tezer, O., 2012. Valuation of a concrete arch bridge using static and

ISSN (online): 2581-3048
Volume 10, Issue 7, pp 8-16, July-2026
https://doi.org/10.47001/IRJIET/2026.107002

dynamic load tests. *Structural Engineering and Mechanics*, 41(1), pp.83- 94.

[5] Chen, W.F. and Duan, L., 2014. Substructure design. Bridge Engineering Handbook, *2nd edn. CRC Press, Taylor & Francis Group.*

[6] Cook, W., 2014. Bridge failure rates, consequences, and predictive trends. *Utah State University*.

[7] CRRI Report, 2019. Valuation and Rehabilitation Scheme for Shashti Bridge across Ganger River, *Mirzapur (CNP-2419).*

[8] De Angelis, A. and Pecce, M.R., 2023. Model valuation of a bridge by load and dynamic tests. *Engineering Structures*, 275, p.115282.

[9] Dissanayake, R. and Bandara, C.S., 2016. Retrofitting of damaged bridges–the sustainable solution. *International journal of urban sciences*, 20(sup1), pp.50-59.

[10] Garg, R.K., Chandra, S. and Kumar, A., 2022. Assessment of bridge failures in India from 1977 to 2017. *Structure and Infrastructure Engineering*, 18(3), pp.295-312.

[11] Gatti, M., 2019. Structural health monitoring of an operational bridge: A case study. *Engineering Structures*, 195, pp.200-209.

[12] Gupta, N., Kaushal, A.K. and Ranjan, R., 2023. Parametric study on reinforced concrete T-beam girder bridges. *Materials Today: Proceedings.*

[13] Indian Road Congress, 2010. IRC: SP:037-2010, Guidelines for Evaluation of Load Carrying Capacity of Bridges (First Revision). *New Delhi: Indian Road Congress*.

[14] Indian Road Congress, 2015. IRC: SP:51-2015, Guidelines for Load Testing of Bridges (First Revision). *New Delhi: Indian Road Congress*.

[15] Indian Road Congress, 2017. IRC:6-2017, Standard Specifications and Code of Practice for Road Bridges, Section-II Load and Combinations (Seventh Revision). *New Delhi: Indian Road Congress*.

[16] Islam, A.A., Jaroo, A.S. and Li, F., 2015. Bridge load rating using dynamic response. *Journal of Performance of Constructed Facilities*, 29(4), p.04014120.

[17] Ko, S.W. and Kim, J.K., 2023. A Framework for Evaluating the Load-Carrying Capacity of Bridges without Design Document Using an AI Technique. *Applied Sciences*, 13(3), p.1283.

[18] Laura, M., Francesco, C. and Antonio, F., 2020. Static and dynamic testing of highway bridges: A best practice example. *Journal of Civil Structural Health Monitoring*, 10(1), pp.43-56.

Citation of this Article:

Junaid Farooq, Dr. V.K Saini, & Dr. S.K Chandel. (2026). Investigation of Bridge Serviceability and Strength Using Integrated Static and Dynamic Approaches. *International Research Journal of Innovations in Engineering and Technology - IRJIET*, 10(7), 8-16. Article DOI https://doi.org/10.47001/IRJIET/2026.107002

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