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COMPARATIVE ANALYSIS AND DESIGN OF BRIDGE WITH UNEQUAL PIER LENGTH AND VARYING SPAN LENGTH

Saurabh Thokane[1], Dr. Vinesh Thorat[2]

[1] Department of Civil Engineering G H RAISONI COLLEGE OF ENGINEERING AND MANAGEMENT PUNE

[2] Associate Professor , Department Of Civil Engineering G H Raisoni College Of Engineering And Management Pune

Abstract: A comparative analysis and design methodology are presented in this study for bridges featuring varying span lengths and unequal pier lengths. Simulations using the Finite Element (FE) method are employed to evaluate the efficacy of structures subjected to various loading conditions. The study examines the distribution of loads, bending moments, and deflections along the bridge deck using displacement-based and force-based methodologies. Furthermore, optimization methods are utilized to improve the efficacy of the structure through the substitution of solid sections with porous sections that combine solid and solid components. An examination is carried out to compare conventional and proposed design methodologies, with an emphasis on factors such as construction feasibility, cost effectiveness, and structural integrity. Insights for enhanced design strategies for bridges with unequal pier lengths and varying span lengths are provided by the findings.

Keywords: - Bridges, Pier, T-beam girder, Box girder, Bridge design, Unequal pier lengths, span lengths.

I. INTRODUCTION

A bridge is an engineering construction utilised to traverse a physical impediment, including a ravine, road, or body of water, without obstructing the passage beneath. They are integral elements of a transportation network and serve crucial functions in the realm of disaster management. Bridge structures are typically comprised of a reduced number of elements, thereby reducing redundancy. Due to their asymmetrical design, which includes span lengths, pier heights that vary, and occasionally vertical curvature and skew in the superstructure, bridge structures are exceptionally susceptible to damage in the event of significant earthquakes. Mountainous areas provide optimal conditions for the construction of multispan continuous bridges featuring piers of unequal height. This is due to the fact that such edifices can negotiate wide, precipitous valleys. When aesthetic considerations impact the height of bridge piers, lesser piers with identical cross section diameters attract greater seismic inertia forces than their towering counterparts. This is especially true when fixed constraints are imposed between the superstructure and substructure, such as monolithic connections or fixed bearings. Due to the excessively attracted seismic forces, brittle shear failure in shorter foundations may result from transverse reinforcement of columns lacking sufficient detail. Despite the prevalence of ductile flexural responses, shorter piers continue to be subjected to greater ductility requirements; as a result, a greater preponderance of flexural damage will occur in these more rigid piers. By conducting extensive quivering table experiments, it was determined that shorter piers in a network of bridges are more vulnerable to seismic activity in comparison to towering piers. Furthermore, irregular pier configurations in multiple frame bridges with unequal height piers frequently cause adjacent frames to move out of phase; consequently, intermediate expansion joints are among the most susceptible components to seismic activity. Typically, an increase in the relative pier heights would lead to a concomitant rise in the altitudinal irregularity, thereby inevitably increasing the bridge's susceptibility. To ensure that conventional frame bridges with unequal-height piers exhibit a balanced seismic response, specific requirements regarding the relative rigidity of the piers are recommended. The stipulation is that the effective rigidity ratio must be a minimum of 0.5 and 0.75, respectively, between any two bends or adjacent bends within a frame. Multiple potential consequences are delineated in the codes for non-compliance with the balanced stiffness recommendation. The factors mentioned above include an uneven distribution of inelasticity across the entire structure, heightened column torsion caused by the rigid-body superstructure's rotation, and increased damage concentrated in more rigid components. In order to satisfy the balanced rigidity requirement, the protocols additionally comprise a collection of methods for modifying the relative stiffness of the piers. These techniques consist of integrating isolation bearings and dampers, modifying the height of the effective columns via isolation enclosures or lower footings, and modulating the ratios of longitudinal and cross-sectional reinforcement to the columns, among others. Clearly, a reduction in the cross-sectional area of shorter structures can lead to a decrease in the seismic forces that are attracted to them, thereby increasing their flexibility. Nevertheless, this methodology undermines the aesthetical integrity of the structures and diminishes their vertical carrying capacity. Although it is feasible to enhance the seismic resistance of shorter foundations through the application of outer jacketing or reinforcement quantity increases, doing so will inevitably lead to increased attracted inertia forces due to the heightened rigidity.

1.1 BRIDGES WITH UNEQUAL PIER LENGTHS AND VARYING SPAN LENGTHS

Bridges characterised by irregular pier lengths and span lengths present a unique challenge in the field of structural engineering, necessitating meticulous examination of their complex behaviour when subjected to diverse loading scenarios. The construction of the bridge becomes asymmetrical when the lengths of the piers are uneven, with one pier being higher or shorter than the others. This might affect the bridge deck's overall stability and structural integrity by causing an uneven distribution of forces and moments. Contrarily, varied span lengths result in variations in the spacing between the supports, which have an impact on the strength of the shear and bending moments felt by the bridge's various parts. In order to guarantee that the bridge can safely bear all predicted loads, including real traffic loads and environmental elements like wind and seismic occurrences, engineers must take these differences in pier heights and span lengths into consideration during the design process. Such bridges need intricate mathematical modelling and simulations for structural analysis in order to determine how these design characteristics impact the bridge's reaction to loads. In addition, cost and construction feasibility are important factors to take into account since the design has to be both structurally sound and feasible to construct within the allocated budget. To overcome these difficulties, novel design approaches are constantly being created with the goal of maximizing the effectiveness and safety of bridges with uneven pier and span lengths. In light of changing transportation demands, these initiatives help to develop bridge engineering and open the door to more sustainable and resilient infrastructure solutions.

1.2 IMPORTANCE OF COMPARATIVE ANALYSIS IN BRIDGE ENGINEERING

By conducting comparative analysis, engineers are able to evaluate various design alternatives by taking into account safety, construction feasibility, structural performance, and durability. Engineers are capable of optimizing bridge designs through the process of making informed judgements by juxtaposing different design alternatives. An essential element of comparative analysis is the capacity to assess diverse bridge configurations, including those characterized by uneven pier lengths and fluctuating span lengths. By comparing the structural performance of bridges featuring unequal piers to those featuring equal piers, engineers can gain insights into the ways in which asymmetry affects load distribution, bending moments, and overall stability. The examination of bridges featuring varying span lengths in a similar fashion enables the determination of the optimal span configuration that preserves materials and complies with safety regulations. Furthermore, comparative analysis facilitates a comprehensive evaluation of the financial ramifications linked to various design alternatives. Engineers possess the ability to evaluate the expenses associated with construction, maintenance, and the entire life cycle of each design alternative. This facilitates the identification of the most economically viable option while maintaining structural soundness and ensuring safety. In addition to its application in infrastructure development, comparative analysis is a pivotal factor in promoting advancements and novelty in the domain of bridge engineering. This capability empowers engineers to gain insights from previous endeavors, discerning optimal methodologies and opportunities for enhancement. By conducting comparative analyses, novel design approaches and technologies may be created, thereby enhancing the durability, sustainability, and effectiveness of bridge structures.

1.3 PROBLEM STATEMENTS AND MODELLING

Effective span lengths for the three-span varying structure prototype bridge (Figure 1) are twenty-eight metres, twenty-eight metres, and twenty-eight metres. In the shape of a T, the superstructure is comprised of five precast restrained concrete girders. These girders span two intermediate piers of unequal height and two end seat-type abutments.The loads considered in the analysis are the self-weight (DL) of the bridge and a live load (LL) of IRC Class 1100kN.568 tonnes constitute the superstructure mass of a single span; this mass is constituted of the girders, pavement, and guardrails. Cap beams are affixed to the double-column bowed structures that comprise the bridge foundations. These are the effective heights of the shorter and taller piers: 5 metres and 14 metres, respectively. On geological strata, extended piling foundations of increased dimensions provide support for the pier structures. The longitudinal reinforcement possesses a design value of 400 MPa for tensile yield strength, while the pier columns are made of concrete and have a design value of 26.8 MPa for compressive strength. Exterior concrete shear keys are manufactured on both sides of the cap beams and abutments to prevent transverse displacement. In order to streamline the construction procedure, a 3 cm initial design separation between shear keys and girders has been eliminated. The T-shaped girders of the intermediate pier are reinforced with rubber bearings that have been laminated, whereas the end abutments are ornamented with bearings made of polytetrafluoroethylene (PTFE). As an expedient measure in construction, it is customary to insert laminated rubber bearings without any reinforcing material directly between the superstructure and substructure. By implementing this methodology, the bearings are rendered susceptible to displacement in the midst of severe seismic incidents. The determination of the shear rigidity, which is an essential mechanical characteristic of laminated rubber bearings, is possible by employing the shear modulus. The prototype bridge's finite element numerical models (Figure 2) are produced by employing Open Sees, an open-source dynamic simulation application. Elastic beam elements are utilised to represent the T-girders and diaphragms situated within the superstructure. The fundamental premise underlying the operation of these elements is that they retain an elastic state in the face of seismic excitations. To ensure an accurate depiction of the inelastic properties exhibited by critical load-transmitting components, including pier columns and cap beams, steel reinforcing bars are employed in conjunction with fibre elements. The nonlinear properties demonstrated by both confined and unconfined concrete are a result of this amalgamation. To simulate the behaviour of steel reinforcement, exposed areas are reinforced with reinforcing steel material. The tensile strength in tension is assumed to be 200 GPa and the elastic modulus is 410 MPa in this formulation. Additionally, it is determined that the strain at maximum strength is 0.15 MPa, whereas the maximum strength is quantified at 525 MPa. Due to the immobile constraints imposed at the pier column foundations, the influence of soil-structure interaction is omitted from this analysis. In order to simulate the seismic sliding characteristics of laminated rubber and PTFE bearings, sliding elements are implemented. In order to facilitate construction, non-seismic laminated rubber bearings are often not attached to the superstructure or substructure. This characteristic significantly amplifies the susceptibility of the bearing to displacement during periods of intense seismic activity. To produce exterior shear key models that exhibit sacrificial properties, progressive incorporation of multilinear hysteretics components is employed to reduce the strength. By means of integrating a gap element that replicates the compressive interaction between the shear keys and the girders, the shear key model is transformed into a compressive-only composition. A prospective retrofitting approach for the prototype bridge might entail substituting the conventional shear keys with ductile steel dampers. To replicate the seismic characteristics of steel dampers, the present investigation incorporates a bilinear hysteretic component to account for strain hardening.

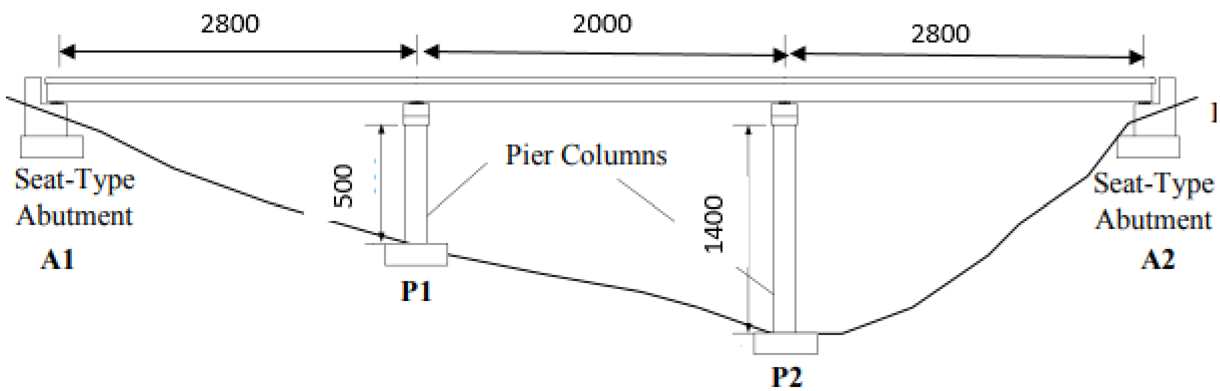


fig. 1. bridge prototype: a three-span varying bridge with unequal height piers (unit: cm)

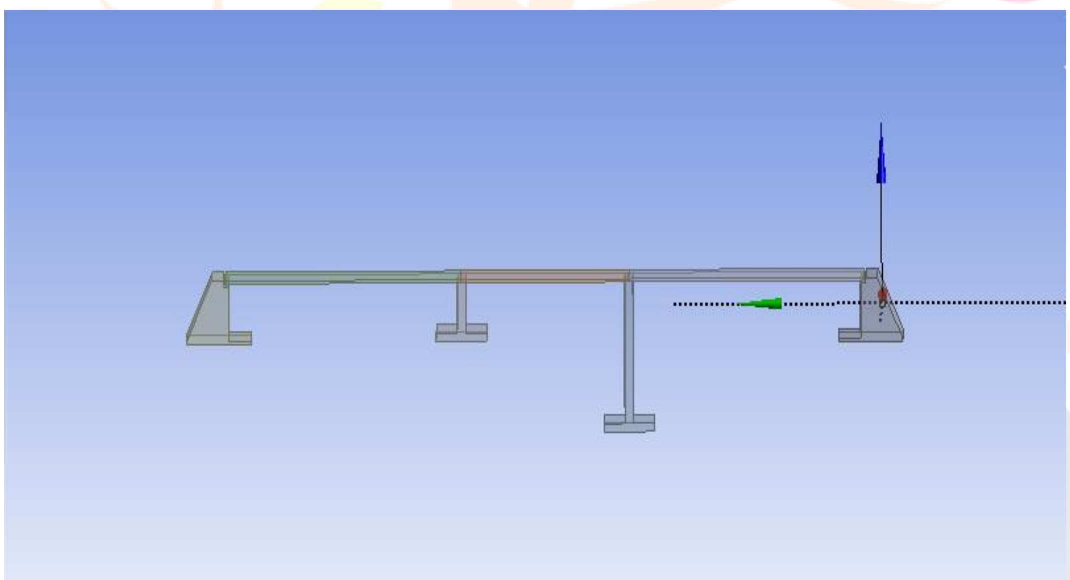


fig. 2 model

II LITERATURE REVIEW

Zhanfei Wang et.al (2021) The seismic response of steel tubular bridge foundations integrated into a five-span continuous girder bridge system was assessed. An analysis is undertaken to compare partially concrete-filled steel tubular (PCFST) and hollow steel tubular (HST) structures when subjected to varying eccentricities of the ground and superstructure. The findings indicate that the eccentricity of the superstructure significantly increases the transverse displacement of HST piers, whereas its effect on the longitudinal displacement is negligible. Yield strength is achieved in HST foundations via the mechanisms of local fracturing and tension concentration. On the contrary, PCFST foundations demonstrate restrained buckling as a result of the substantial enhancements in ductility and bearing capacity induced by the concrete in-fill. The results obtained from this study indicate that the incorporation of PCFST foundations has the potential to improve the seismic performance of the bridge system. **Jawalkar, Prof. G.C. et.al (2021)** examines the buckling phenomenon, referred to as the 'P∇' effect, that occurs in thin members under axial load and biaxial bending conditions. This phenomenon is characterised by excessive bending moments and yielding at the sites of maximum deflection. Using beam column theory, the study intends to develop a bending moment equation and assess the performance of bridge supports featuring hollow and solid circular sections. Optimisation entails the substitution of solid sections with solid-porous section combinations, while adhering to specified constraints. A comparative analysis is conducted to evaluate the effects of axial, longitudinal, and transverse forces on piers. Piers are conceptualised as columns subject to axial load and biaxial moment. In order to obtain precise force calculations that account for the collapse effect, second order analysis is required. **Nailiang Xiang et.al (2020)** In mountainous regions where multispan continuous bridges with unequal height structures are prevalent, seismic response is emphasised. For earthquake protection, exterior concrete shear keys are typically employed; however, this practice may result in atypical seismic reactions and substantial rotations of the superstructure. Substituting yielding steel dampers for shear keys would result in more consistent movement of the superstructure and more equitable seismic loads on the substructure, according to the study. By employing deterministic and probabilistic dynamic analyses, the efficacy of this design approach is verified, thereby guaranteeing that these bridges will exhibit a consistent and equitable seismic performance. **M. A. Hoque et.al (2020)** When examining multispan bridges with unequal pier heights, an analysis was conducted to compare displacement-based seismic design (DBD) and force-based seismic design (FBD). Using acceleration and displacement response spectra, a comparison is made between the conventional FBD method and the DBD method, which incorporates direct displacement-based (DDBD) and alternative-to-direct displacement-based (ADBD) approaches. The findings suggest that DBD techniques yield more minimal base incisions compared to FBD techniques. Specifically, ADBD techniques generate more condensed member sections while implementing a conservative design strategy. This investigation contributes to the body of knowledge concerning seismic design methodologies for multispan bridges incorporating irregularities. **Denis DAVI (2014)** compared structural analysis methods, including force-based and displacement-based modal spectral analysis, push-over analysis, and non-linear dynamic time-history analysis, from Eurocode 8-2 and the bridge seismic design literature. A theoretical 306-meter-long prestressed concrete deck bridge with reinforced concrete piers situated in a high seismic zone in France is the subject of the methodologies utilised in this study. Furthermore, it establishes a distinction between Eurocode 8-2 and the previous French seismic regulations known as "AFPS92" and puts forth suggestions for improving Eurocode 8-2 by employing theoretical and practical analogies.**Gopal Adhikari et.al (2010)** The effectiveness of the direct displacement-based seismic design (DDBD) technique, originally developed for bridges with short to moderate spans, was evaluated in relation to straight long span bridges featuring unique attributes like elevated piers, irregular spans, and heights. The results indicate that the current DDBD method exhibits a reduced ability to precisely capture displacement and base shear demands when compared to nonlinear dynamic analysis. An extension based on improved mechanics is suggested, which incorporates pier mass into the estimation of base shear demand and a modal combination rule into the estimation of displacement demand; parametric studies have validated this extension. Furthermore, this innovative approach offers engineers the ability to modify the strength distribution at potential plastic hinge locations. **Mohammad Abbas et.al (2015)** The seismic behaviour of a multiframe concrete box-girder viaduct that displays a spectrum of altitudinal irregularities (ranging from highly irregular to regular) can be assessed through the utilisation of fragility curves. Anxious conditions that emerge during catastrophes and are exacerbated by irregular topographical features and long span junctions are the subject of this study. Comprehensive nonlinear time-history analyses conducted on three-dimensional finite-element models demonstrate that the degree of altitudinal irregularity increases proportionally with the instability of the bridge. Component fragility parameters, which incorporate uncertainties associated with materials, structural geometries, and earthquake impacts, have identified the unseating of the in-span hinge location as the element with the highest susceptibility. **Hossein Rezaei et.al (2019)** The effects of hammering and irregularity on concrete box-girder bridges with varying altitudinal irregularities were investigated by employing probabilistic seismic assessment. The objective of this research is to examine the impact of pressure on seat-type abutments and in-span hinges of multi-frame bridges. This inquiry takes into account various factors, including variations in materials, geometries of structures, and seismic activity. The inquiries encompass an analysis of the impact of gap size on engineering demand parameters (EDPs), a comparison of pounding force across bridge irregularities of varying degrees, and an examination of the correlations between pounding force and earthquake parameters. The research calculates the likelihood that a striking incident will not occur in bridges that are not continuous, as well as examines the consequences of such an occurrence on neighbouring bridge segments. The findings underscore the substantial influence that the magnitude of the gap exerts on the passive deformation, impacting force, and base shear of abutments. The correlation between gap size and EDPs is nevertheless attenuated by substructure irregularities. The correlation between pounding force and structural/seismic parameters is assessed in the study's conclusion, with particular attention given to the influence of adjacent frame period ratios on earthquake type and pounding probability. **Athanasios Agalianos et.al (2017)** utilised two swaying isolation concepts to investigate the seismic performance of a flyover bridge situated on the Attiki Odos motorway in Athens, Greece: (a) rocking pier-footing assemblies on soil and (b) rocking piers on foundations. A 5-span system is analysed in relation to conventionally designed bridges, with a focus on surface foundations in deep clay. For static pushover and non-linear dynamic analyses involving 20 selected ground motions that exceed design levels, 3D numerical models are utilised. In five out of ten instances, the conventional system fails, whereas the swaying piers design endures with only minor deformations in eight out of ten. Even greater safety margins are observed for rocking footings, which endure any circumstance with enhanced durability and diminished structural damage. Conversely, stress concentrations at the bases of swaying foundations indicate the necessity for specialised design, in contrast to rocking footings which experience increased settlements but no residual rotations. **M. Shahria Alam et.al (2019)** This study examined the feasibility of retrofitting energy dissipation devices onto a pre-existing bridge that had lead rubber bearings (LRBs) for reinforcement. The objective was to reduce the displacement hazards that are commonly associated with period elongation. Yielding steel cables (YSCs), friction dampers (FDs), viscous dampers (VDs), and superelastic shape memory alloy cables (SMAs) are all examples of retrofit measures. Fault sensitivity analyses are utilised to assess the efficacy of isolation bearing damage prevention measures in bridge structures in order to mitigate the risk of further injury. The findings indicate that SMAs exhibit greater effectiveness in reducing residual superstructure displacement and improving recentering performance when compared to FDs, VDs, and YSCs.

III. METHODOLOGY

Finite-Element Methods

The comparative analysis and design of bridges featuring unequal pier lengths and varying span lengths is accomplished through the application of Finite Element (FE) method simulations, which evaluate the structural performance across a range of conditions.

Commencing with the intricate geometric challenges posed by uneven span lengths and pier heights, comprehensive three-dimensional finite element models of the bridge are constructed. The material properties of the bridge elements are set by standards and design specifications. The bridge models are subjected to rigorous loading conditions, such as seismic loads, environmental loads, and live loads, during numerical simulations conducted with FE software. A comparative evaluation of the efficacy of force-based and displacement-based approaches in capturing the bridge's response to the specified pressures is conducted. The examination of load distribution, bending moments, shear forces, and deflections along the bridge deck is possible when employing the FE method on bridges with unequal pier lengths. Comprehensive parametric studies are conducted to analyse the impact of unequal pier heights on the structural response. Additionally, the finite element models permit the evaluation of various design scenarios, including the optimization of cross-sectional areas through the substitution of solid sections with porous sections in combination, as long as the deviations from allowable limits are kept to a minimum. While assuring safety and cost-effectiveness, this optimization procedure seeks to enhance structural efficiency. Moreover, for bridges with unequal pier lengths and varying span lengths, the FE method enables a comparative analysis of conventional design approaches and hypothesized methodologies. This tasks involves assessing the structural performance, cost efficiency, and construction feasibility of various design approaches to determine their efficacy.

Dead Load Analysis

Physically, the dead load response can be calculated by taking into account the dead load imposed by the superstructure (Brace, Stomach, and Deck piece). Similarly, longitudinal moments are calculated by duplicating responses with the longitudinal irregularity, which represents the distance between the bearing and the centerline of the jetty. SIDL (wearing a garment and impact barrier) and the response on each bearing caused by Superimposed Dead Load, suspenders, midsection, and deck piece are determined independently.

Impact Load

Impact load refers to the dynamic effect that occurs when the locomotive is in motion and the live load is periodically shifted from one wheel to another, resulting in vertical oscillation. The product of the active load and the impact factor (i) yields the impact load.

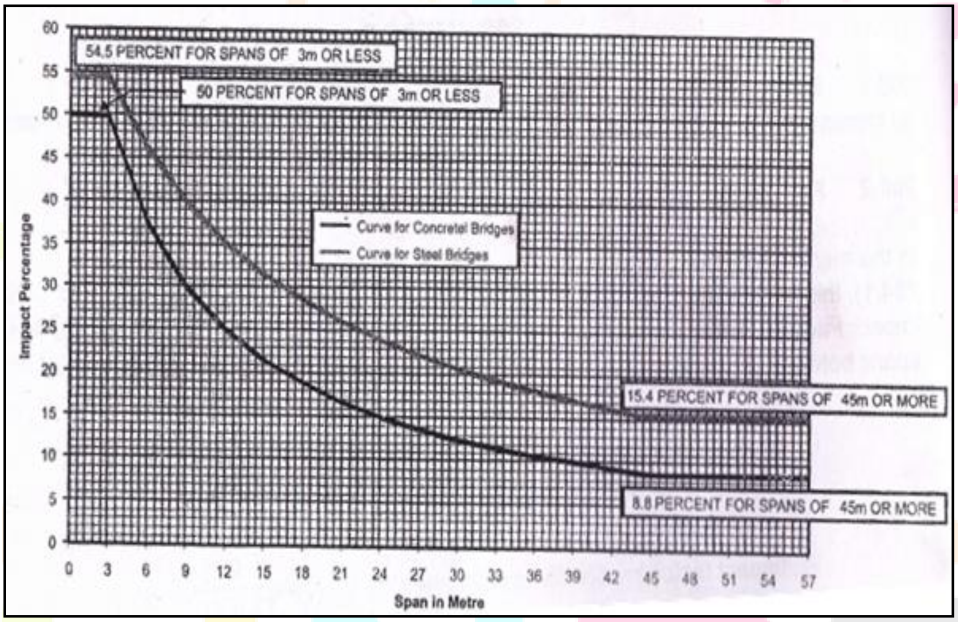


fig 3 impact percentage curve for highway bridges for irc class a and irc class b loadings.

The impact factors for different bridges for different types of moving loads are given in the Table 3.1 as shown below

table 1. impact factor (i)

Bridge	Loading	Span	Type of Vehicle	Impact factor (i)
Highway RC bridges according to IRC regulations	IRC class AA loading	(i) Spans less than 9 m.	(a) Tracked vehicle	25% for spans up to 5m linearly reducing to 10% for span of 9m.
			(b) Wheeled vehicle	25%
		(ii) Spans 9 m or more	(a) Tracked vehicle	10% up to a span of 40m & in accordance with the curve in Fig 3.4 for spans in excess of 40m
			(b) Wheeled vehicle	25% for span up to 12m & in accordance with the curve in Fig 3.4 for spans in excess of 12m
	IRC class A loading and IRC class B loading	Spans between 3 m and 45 m	(a) Wheeled vehicle	$\frac{4.5}{6 + L}$ L- Span in meters

ABOUT SOFTWARE (ANSYS)

As a simulation technique, the finite element method (FEM) is widely utilised to forecast the physical properties of structures and systems. In the engineering sciences, where analytical solutions for the preponderance of daily problems are typically unavailable, numerical methods such as FEM have been devised to solve the problem's governing equations. Extensive research has been conducted over the past three decades in the domain of numerical modelling, empowering contemporary engineers to execute simulations that closely resemble reality. In the field of structural mechanics, modelling standard operating conditions now includes nonlinear material behaviour, large deformations, and contact problems. At present, simulations of models with millions of degrees of freedom are feasible, as the hardware industry's rapid advancements have led to the development of more powerful processors and reduced memory expenses. The finite element solution, from a mathematical standpoint, invariably provides an approximation of the numerical solution to the problem under consideration. Engineers are not always tasked with the straightforward ability to determine whether a given solution is excellent or poor. It is readily feasible to validate any finite element result in the presence of experimental or analytical data. Nevertheless, in order to reliably forecast structural behaviour without conducting experiments, it is essential for every user of a finite element programme to possess a fundamental understanding of the finite element method as a whole. Furthermore, it is imperative that he possesses a foundational understanding of the implemented software in order to assess the suitability of the selected components and algorithms. The objective of this article is to present a comprehensive examination of ANSYS's capability to produce precise finite element analysis outcomes. We demonstrate numerous ANSYS features and, whenever feasible, what has already been implemented in the ANSYS Workbench.

MATERIALS PROPERTIES

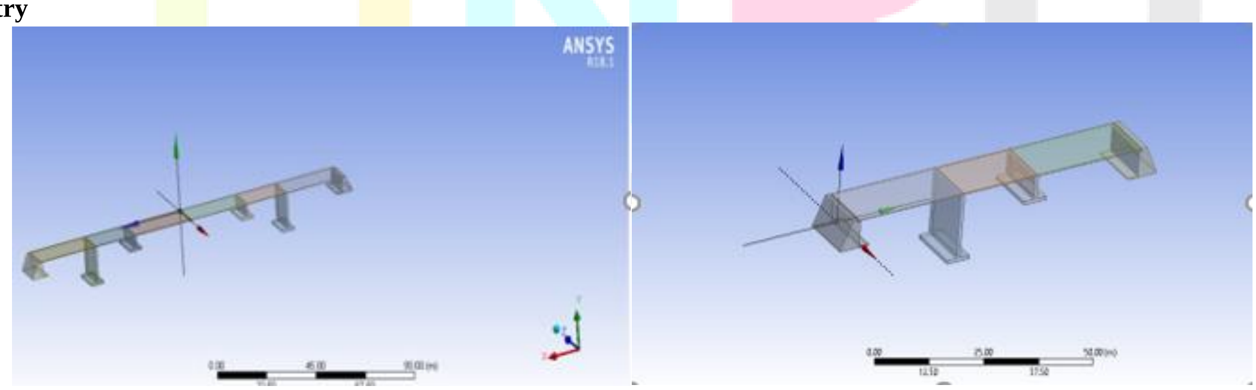
table no. 2 material properties

Sr.No.	Material	Property	Value
1	Structural steel	Yield stress f_{sy} (MPa)	265
		Ultimate strength f_{su}(MPa)	410
		Young's modulus *Es*(MPa)	205×10^3
		Poisson's ratio µ	0.3
		Ultimate tensile strain e_t	0.25
2	Reinforcing bar	Yield stress f_{sy} (MPa)	250
		Ultimate strength f_{su} (MPa)	350
		Young's modulus Es(MPa)	200×10^3
		Poisson's ratio µ	0.3
		Ultimate tensile strain e_t	0.25
3	Concrete	Compressive strength f_{sc}(MPa)	42.5
		Tensile strength f_{sy}(MPa)	3.553
		Young's modulus E_c(MPa)	32920
		Poisson's ratio µ	0.15
		Ultimate compressive strain e_s	0.045

IV RESULTS AND ANALYSIS

IRC CLASS AA LOADING 1100kN

Geometry



model 1 **model 2**

fig 4. geometry

boundary condition

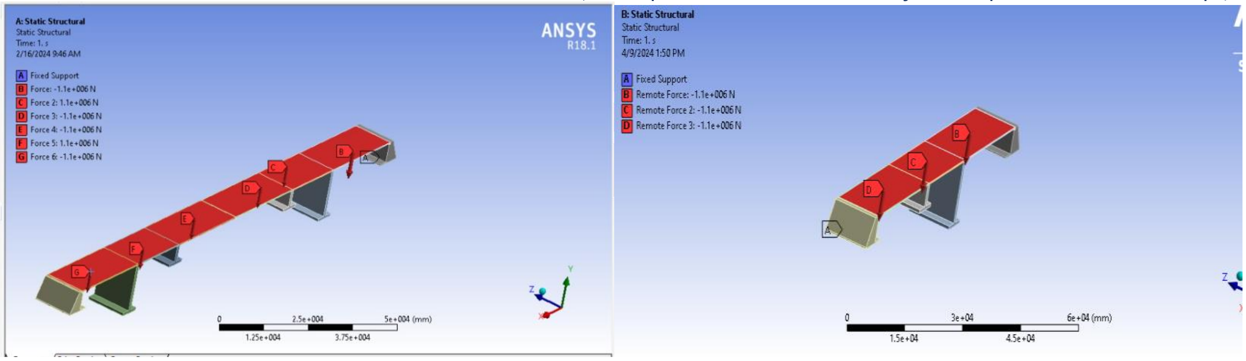


fig 5. boundary condition

the fig 5 show the loads applied on the bridge (dl) and a live load (ll) of irc class 1100kn.on the bridge span.

total deformation

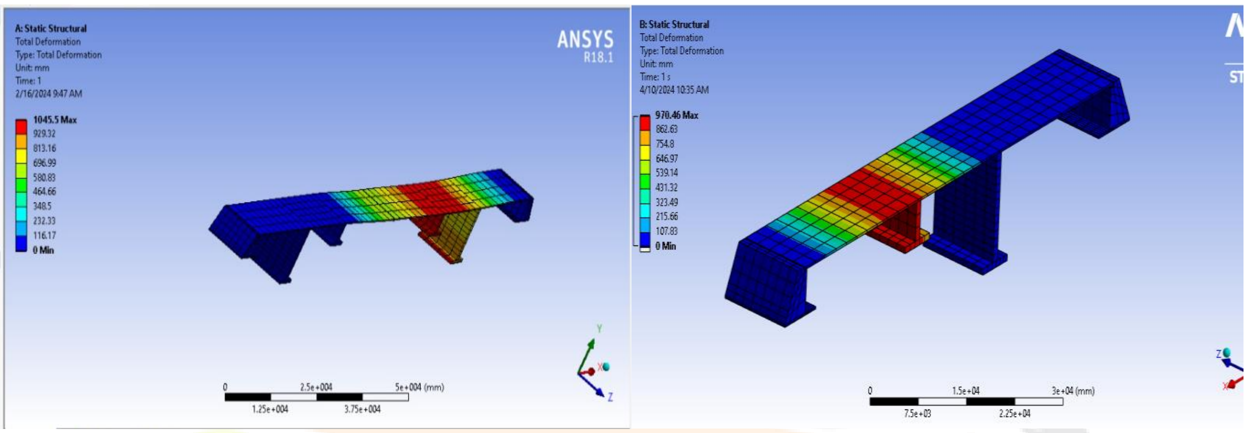


fig 6. total deformation

normal elastic strain

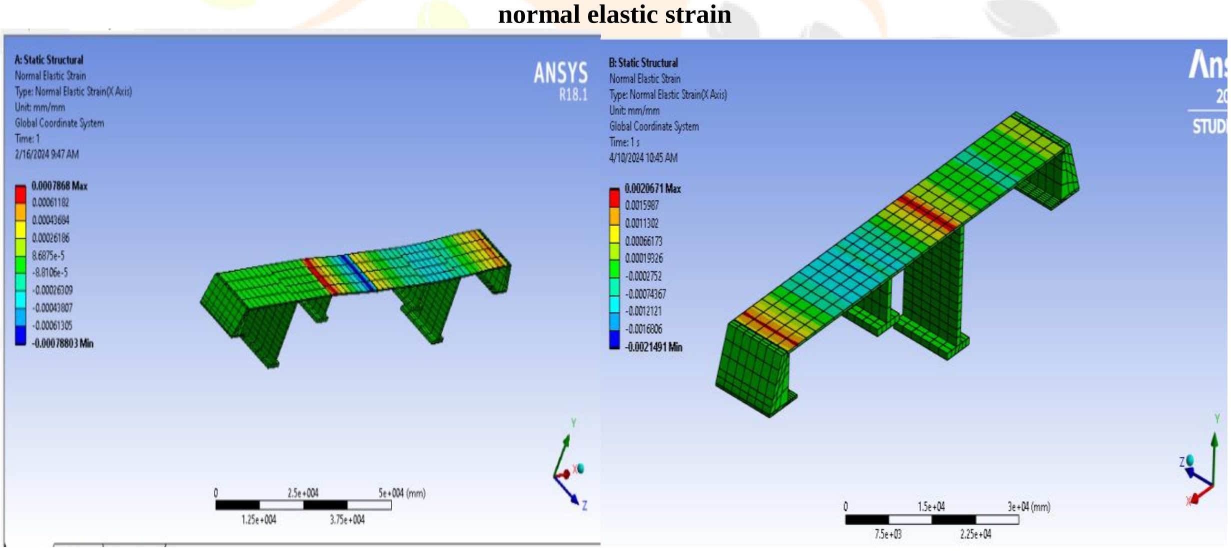


fig 7. normal elastic strain

shear stress

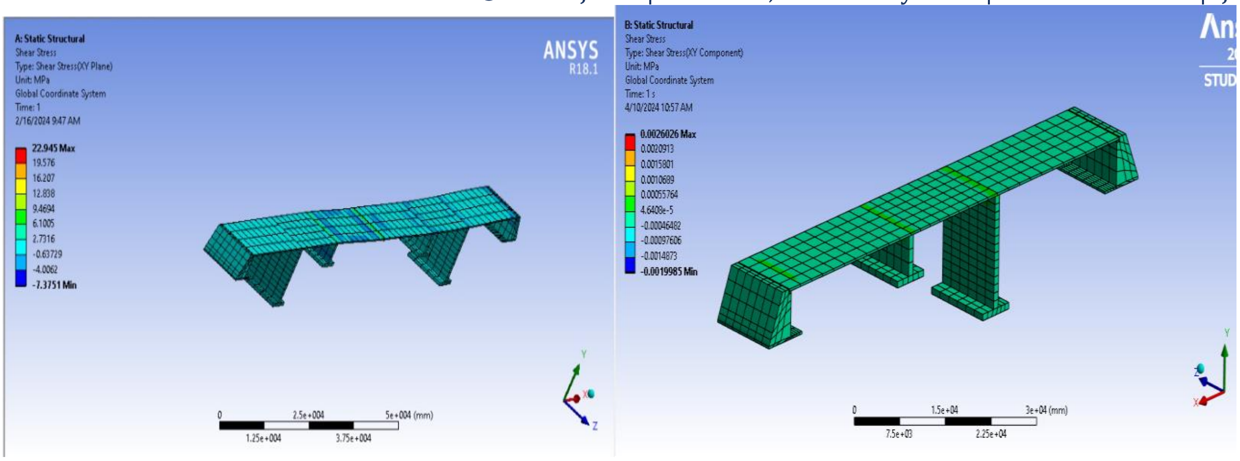
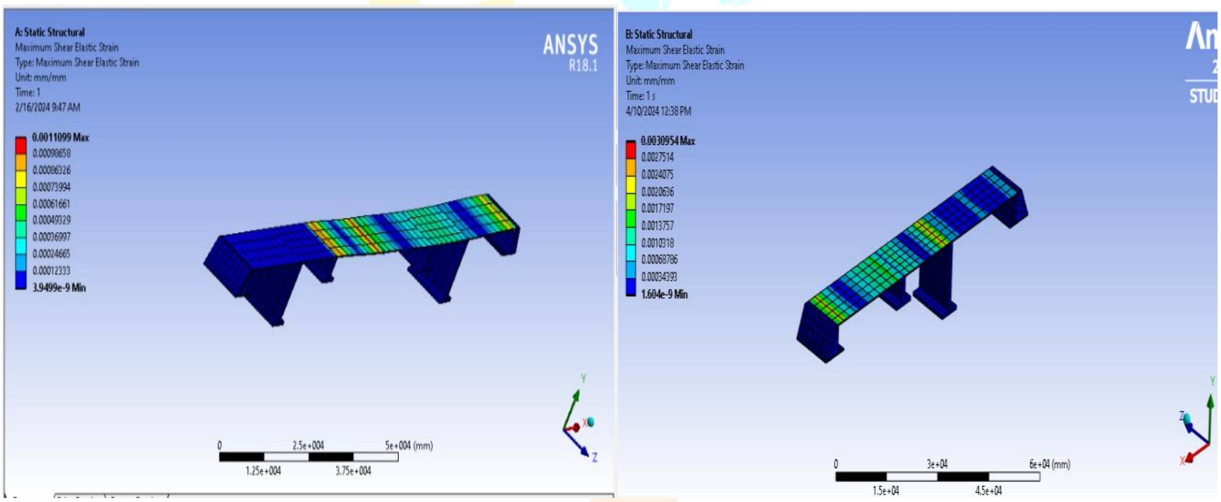
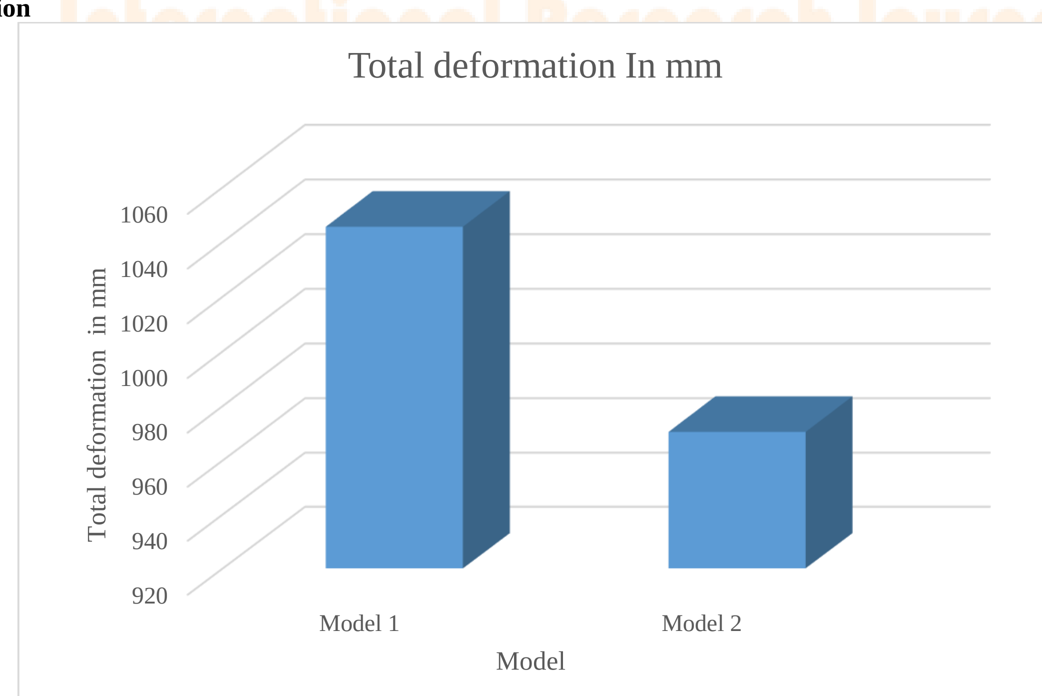


fig 8. shear stress

maximum shear elastic strain



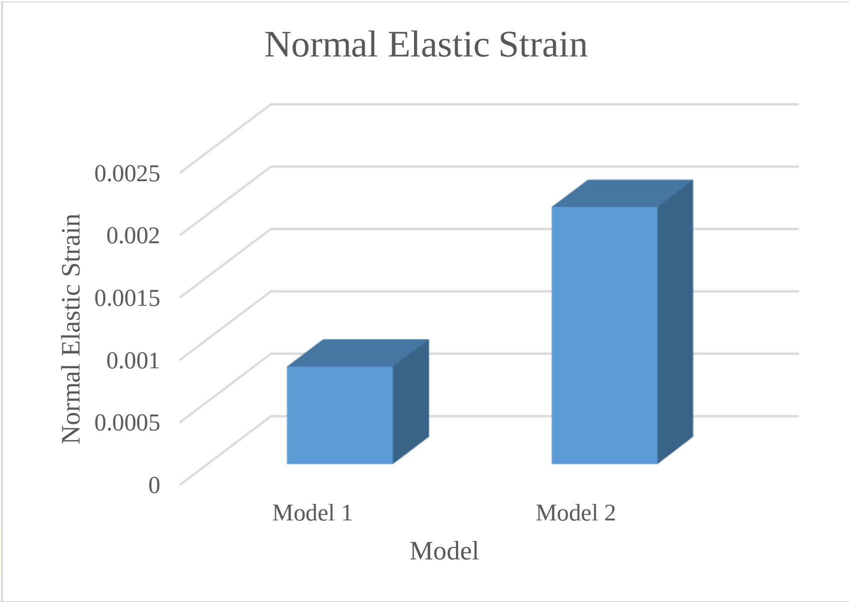
Results
Total Deformation



Interpretation

The graph show "Total Deformation in mm" data for Model 1 (1045.5) and Model 2 (970.46) suggests varying degrees of structural displacement. Model 1 exhibits a greater deformation of 1045.5 mm, indicating potential stress or load factors affecting its integrity. On the other hand, Model 2 shows a lower deformation of 970.46 mm, possibly implying better resilience to applied forces. This comparison could signify the effectiveness of design modifications or material differences between the two models. Engineers may use this data to refine designs for optimal performance, ensuring structures withstand expected loads with minimal deformation for safety and durability.

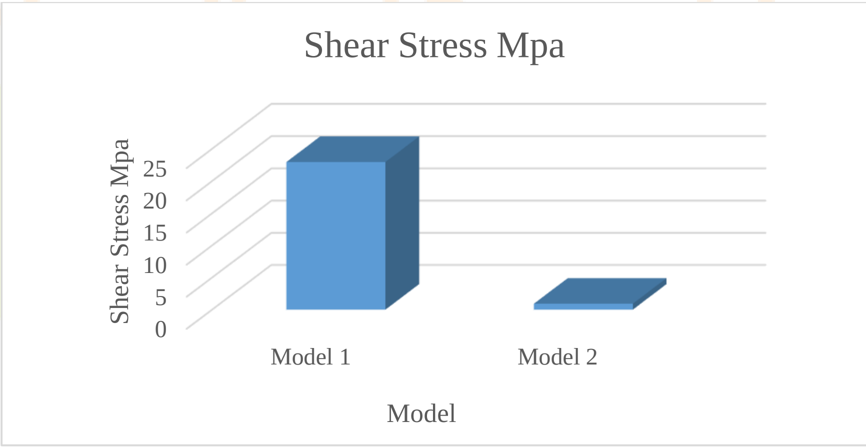
Normal Elastic Strain



Interpretation

The graph show "Normal Elastic Strain" values for Model 1 (0.00078) and Model 2 (0.00206) reveal insights into their material behavior under stress. Model 1's lower strain of 0.00078 suggests it undergoes less deformation per unit of force, indicating higher stiffness and potentially more brittle behavior. Conversely, Model 2's higher strain of 0.00206 implies greater elasticity, deforming more under similar forces. Engineers could infer that Model 1 might be suitable for applications where minimal deformation is crucial, like load-bearing structures. In contrast, Model 2's higher strain might be advantageous for applications requiring flexibility, such as certain types of machinery or components subject to dynamic loads.

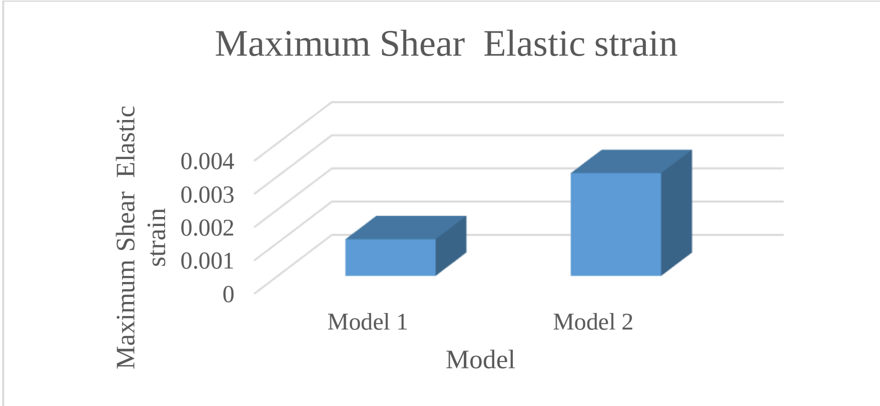
Shear Stress



Interpretation

The graph show "Shear Stress Mpa " values for Model 1 (22.945) and Model 2 (0.9212) offer significant insights into their material behavior under applied forces. Model 1's higher shear stress of 22.945 suggests it experiences greater resistance to shearing forces, indicating a stiffer and potentially more robust material. This could make Model 1 suitable for applications where withstanding shear loads is critical, such as structural components in buildings or bridges. On the other hand, Model 2's lower shear stress of 0.9212 indicates it deforms more readily under shear forces, implying a more ductile material. This characteristic could be advantageous in applications where some deformation without failure is desired, such as in certain manufacturing processes or product designs requiring flexibility.

Maximum principal elastic strain



Interpretation

The graph show "Maximum Shear Elastic Strain" values for Model 1 (0.0011) and Model 2 (0.00309) provide crucial insights into their material properties under shear stress. Model 1's lower strain of 0.0011 indicates it undergoes less deformation per unit of applied shear force, suggesting higher stiffness and resistance to shearing. This characteristic could be advantageous for applications where minimal deformation is critical, such as in load-bearing structures. Conversely, Model 2's higher strain of 0.00309 suggests it deforms more under similar shear forces, indicating greater elasticity and flexibility. This property might be beneficial in applications requiring materials to absorb energy through deformation, such as in certain types of machinery or shock-absorbing components.

CONCLUSION

In summary, the examination and design investigation of bridges featuring differing span lengths and unequal pier lengths have yielded significant knowledge regarding the enhancement of the structural functionality of these structures. The simulations utilising the Finite Element (FE) method facilitated a comprehensive examination of the distribution of loads, bending moments, and deflections along the bridge deck in response to various loading conditions. The comparison shed light on the advantages and disadvantages of force-based and displacement-based methods, thus guiding the selection of appropriate design methodologies. The outcomes of the comparative analysis and design of bridges featuring varying span lengths and disparate pier lengths provide significant insights into the operational characteristics of Model 1 and Model 2. The data on "Total Deformation in mm" indicates that Model 1 experienced a greater deformation of 1045.5 mm compared to Model 2's 970.46 mm. This suggests potential stress or load factors affecting Model 1's integrity, while Model 2 exhibits better resilience to applied forces. The "Normal Elastic Strain" values show Model 1's lower strain of 0.00078, indicating higher stiffness, while Model 2's higher strain of 0.00206 implies greater elasticity. Shear stress analysis reveals Model 1's higher resistance to shearing forces (22.945), suitable for load-bearing applications, while Model 2's lower shear stress (0.9212) suggests a more ductile material. Additionally, the "Maximum Shear Elastic Strain" shows Model 1's stiffness (0.0011) versus Model 2's flexibility (0.00309) under shear forces. Engineers can utilize these findings to refine designs for optimal performance, ensuring safety, durability, and suitability for specific applications like load-bearing structures or machinery components requiring flexibility.

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