Study Analysis With Different Deck Slab In MNB Using Ansys Software

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Abstract- *The structural performance of bridge deck slab systems is strongly influenced by deck geometry, load transfer mechanism, stiffness distribution, and stress concentration under vehicular loading. The present study investigates the comparative behaviour of different deck slab configurations in an MNB bridge using ANSYS finite element software. Three bridge deck systems are considered: RCC T-beam bridge, rectangular box girder bridge, and trapezoidal box girder bridge. The models are analysed under IRC Class A and IRC Class AA loading conditions. The main response parameters considered in the study are shrinkage, equivalent creep, normal creep, shear creep, equivalent stress, normal stress, and shear stress. The bridge models are developed with identical span and width conditions to obtain a rational comparison between the selected deck slab systems. The results show that deck slab geometry has a considerable effect on stress distribution and time-dependent deformation behaviour. Under Class A loading, the trapezoidal box girder bridge shows higher shrinkage, creep, equivalent stress, and shear stress compared with the rectangular box girder and RCC T-beam bridge. Under Class AA loading, the trapezoidal box girder still shows higher shrinkage and creep, while the rectangular box girder shows higher equivalent stress and shear stress. The study confirms that ANSYS-based finite element modelling is effective for understanding bridge deck behaviour and for selecting a suitable bridge deck configuration during the preliminary and analytical design stage.*

Keywords: ANSYS, MNB Bridge, Deck Slab, RCC T-Beam, Rectangular Box Girder, Trapezoidal Box Girder, IRC Loading, Finite Element Analysis, Creep, Shrinkage, Stress Analysis.

I. INTRODUCTION

Bridges are among the most important components of transportation infrastructure because they provide continuity to road networks, reduce travel distance, support economic movement, and ensure safe passage over rivers, valleys, rail crossings, and other obstacles. In bridge engineering, the deck slab and girder system form the main load-carrying component of the superstructure. The bridge deck receives vehicular load directly and transfers it to the supporting girders, bearings, piers, and foundations. Therefore, the behaviour of the deck slab has a direct influence on overall bridge safety, serviceability, stiffness, durability, and long-term structural performance. For medium-span bridges, different structural forms such as RCC T-beam bridges, rectangular box girder bridges, and trapezoidal box girder bridges are commonly adopted depending on span, traffic loading, construction method, economy, torsional demand, and serviceability requirements.

RCC T-beam bridges are conventional and widely used bridge systems because of their simple geometry, ease of construction, and economic suitability for moderate spans. In a T-beam bridge, the slab and beam act monolithically, where the slab functions as the compression flange and the beam web resists shear and bending action. This system is easy to construct and analyse, but its torsional stiffness and transverse load distribution capacity may be limited when compared with box girder systems. In contrast, box girder bridges are structurally efficient because their closed-cell or hollow section provides higher torsional rigidity, better load distribution, and improved stiffness-to-weight ratio. Rectangular box girders are commonly used due to their simple geometry and ease of modelling, whereas trapezoidal box girders are preferred in several practical bridge applications because of their better aesthetic form, efficient load path, and suitability for wide bridge decks.

The selection of a suitable bridge deck system is not only a matter of strength but also a matter of long-term performance. In reinforced and prestressed concrete bridges, time-dependent effects such as creep and shrinkage play an important role in structural response. Shrinkage occurs due to the loss of moisture from hardened concrete and may cause additional deformation and stress redistribution. Creep occurs when concrete undergoes gradual deformation under sustained loading. In bridge decks, these effects become important because the structure is continuously subjected to self-weight, wearing coat, vehicular load, and environmental actions. Along with creep and shrinkage, stress parameters such as equivalent stress, normal stress, and shear stress are also important for identifying critical zones and comparing structural efficiency.

Traditional analytical methods are useful for preliminary design, but they often simplify the three-dimensional behaviour of bridge deck systems. Such methods may not fully capture local stress concentration, load dispersion, boundary condition effects, and the influence of complex girder geometry. Finite element analysis provides a more detailed approach by dividing the bridge into small elements and solving the structural response numerically. ANSYS is one of the most widely used finite element software tools for modelling, meshing, applying boundary conditions, applying loads, and obtaining structural responses such as deformation, stress, strain, creep, and shrinkage. Several recent studies have used finite element modelling to analyse box girder bridge behaviour under Indian loading conditions, skewness, curvature, vibration, railway loading, prestress effects, and strengthening requirements. For example, Agarwal, Pal and Mehta studied skew RC box-girder bridges using finite element modelling under IRC loading, while Shaikh and Nallasivam developed an ANSYS-based model for box-girder bridge analysis under Indian railway loading.

The present study focuses on the finite element analysis of different deck slab configurations in an MNB bridge using ANSYS software. The selected configurations include RCC T-beam bridge, rectangular box girder bridge, and trapezoidal box girder bridge. These models are analysed under IRC Class A and IRC Class AA loading conditions. The comparison is based on shrinkage, equivalent creep, normal creep, shear creep, equivalent stress, normal stress, and shear stress. The main purpose of this work is to identify how the change in deck slab/girder configuration affects the structural response of the bridge. The study is useful for researchers and design engineers because it provides a direct comparison between conventional RCC T-beam and box girder systems using the same modelling platform and loading conditions.

The novelty of the study lies in the comparative evaluation of three bridge deck slab systems using ANSYS with both stress-based and time-dependent response parameters. Many existing studies focus mainly on bending moment, deflection, shear force, or modal response of box girder bridges. However, the present work compares creep, shrinkage, and stress behaviour together for RCC T-beam, rectangular box girder, and trapezoidal box girder bridge models. This gives a clearer understanding of how deck geometry affects both immediate and long-term bridge behaviour. Therefore, the study contributes to the performance-based selection of bridge deck slab systems for MNB bridge applications.

II. LITERATURE REVIEW

Agarwal, Pal and Mehta (2020) investigated simply supported single-cell skew reinforced concrete box-girder bridges under IRC Class A loading using a finite element modelling approach. The abstract of their study indicates that the numerical model was developed and validated with an existing benchmark before carrying out a mesh convergence study. Their work showed that skewness significantly changes bending moment, shear force and support reaction distribution, making ordinary straight-bridge assumptions unsafe for skewed bridge decks. Agarwal et al. (2020) examined the combined influence of skewness and curvature on reinforced concrete box-girder bridge behaviour. Their abstract reported that curve angle and skew angle jointly affect deflection, design moments and reaction distribution, and these effects cannot be predicted by simple addition of individual skew and curvature effects. Shaikh and Nallasivam (2022) developed an ANSYS-based finite element model of a box-girder bridge with a ballastless sub-track system under Indian railway vehicle loading. Their study abstract focused on symmetric and unsymmetric loading conditions and evaluated static response parameters such as deflection, bending stress and load distribution, proving the usefulness of ANSYS for complex box-girder behaviour. Agarwal et al. (2022) carried out free vibration analysis of simply supported reinforced concrete box-girder bridges using finite element analysis. Their abstract highlighted the effect of straight, skew, curved and skew-curved configurations on natural frequency and mode shapes, confirming that dynamic characteristics must be considered along with static response. Yuan et al. (2022) analysed the working performance of large-curvature prestressed concrete box girder bridges. Their abstract focused on mechanical behaviour, torsional action and stress state of curved prestressed box girders and showed that box girders possess high torsional stiffness but may develop stress concentration under large curvature and eccentric traffic loading. These five studies collectively show that finite element modelling is essential for accurate bridge deck evaluation because geometry, loading pattern, curvature, skewness and torsional behaviour strongly affect structural response.

Agarwal, Pal and Mehta (2023) presented a finite element analysis of reinforced concrete curved box-girder bridges using CSiBridge. Their abstract stated that single-cell RC curved box girders were analysed under dead load and Indian Roads Congress live load, and the modelling approach was validated before obtaining design forces. The study showed that curvature significantly affects bending moment, shear force and deflection, supporting the need for three-dimensional bridge modelling. Agarwal et al. (2023) performed a parametric study on prestressed skewed box-girder bridges considering dead load, live load and prestress effects. Their abstract explained that Indian standard loading, skew angle and prestressing action influence reaction distribution, force demand and serviceability response, while also identifying a research gap in prestressed skewed box-girder bridges under Indian loading. Wang et al. (2023) studied seismic vulnerability and fragility of long-span prestressed concrete continuous girder bridges. Their abstract used nonlinear seismic assessment concepts and fragility curves to evaluate damage states, showing that pier-girder interaction, stiffness and seismic demand are important for bridge safety. Li et al. (2024) investigated insufficient transverse connectivity in prestressed concrete box girder bridges and evaluated strengthening measures for improving structural behaviour. Their abstract noted that prestressed concrete box girders are widely used for 20 m to 40 m urban viaduct and highway spans because of high stiffness, integrity and construction efficiency. Nguyen et al. (2025) studied optimization techniques for box girder bridge widening by adding reinforcing ribs and struts. Their abstract demonstrated that local strengthening and cross-sectional modification improve capacity, stiffness, stress distribution and service performance. Bozza et al. (2026) conducted diagnostic seismic analysis of an in-service curved prestressed concrete box girder bridge with a mid-span hinge. Their abstract emphasized the need for diagnostic modelling, modal behaviour study and seismic assessment of complex bridge systems. These studies support the present ANSYS-based comparison of RCC T-beam, rectangular box girder and trapezoidal box girder bridge systems because bridge geometry, transverse stiffness, prestressing, dynamic behaviour and seismic response directly influence deck slab performance.

III. RESEARCH GAP

From the reviewed literature, it is observed that most previous studies have focused on the finite element analysis of box-girder bridges by considering parameters such as skewness, curvature, prestressing, vibration, transverse connectivity, widening, and seismic vulnerability. Several researchers analysed curved, skewed, and prestressed box-girder bridges under IRC or railway loading conditions; however, these studies mainly concentrated on individual bridge forms rather than a direct comparison of different deck slab configurations. Limited research is available on the comparative behaviour of RCC T-beam bridge, rectangular box girder bridge, and trapezoidal box girder bridge under similar loading, material properties, span, and boundary conditions. Moreover, most studies focused on deflection, bending moment, shear force, natural frequency, or seismic response, while fewer studies considered combined parameters such as shrinkage, equivalent creep, normal creep, shear creep, equivalent stress, normal stress, and shear stress. Therefore, the present study fills this gap by comparing different MNB bridge deck slab systems using ANSYS finite element analysis.

IV. MATERIALS AND METHODOLOGY

The methodology adopted in the present study is based on finite element modelling and comparative structural analysis of three MNB bridge deck configurations. The bridge systems considered are RCC T-beam bridge, rectangular box girder bridge, and trapezoidal box girder bridge. These models are selected because they represent commonly used bridge superstructure systems. The RCC T-beam bridge represents a conventional deck slab-girder arrangement, while the rectangular and trapezoidal box girder bridges represent hollow girder systems with improved stiffness and load distribution characteristics. The comparison between these three systems helps in understanding the effect of deck geometry on structural response.

1. Selection of Bridge Models and Study Approach

The present study is based on the comparative finite element analysis of different deck slab systems used in MNB bridge construction. For this purpose, three bridge configurations are selected: RCC T-beam bridge, rectangular box girder bridge, and trapezoidal box girder bridge. These three models are selected because they represent commonly used bridge superstructure systems in highway bridge construction. The RCC T-beam bridge represents a conventional deck slab and girder system, whereas rectangular and trapezoidal box girder bridges represent hollow-section bridge systems with better torsional stiffness and load distribution capacity. The main aim of selecting these three models is to understand how variation in deck slab and girder geometry affects the structural response of the bridge under similar loading and support conditions. The comparison is carried out using ANSYS software, which helps in evaluating deformation-related and stress-related parameters more accurately than simplified manual methods. The study mainly focuses on shrinkage, equivalent creep, normal creep, shear creep, equivalent stress, normal stress, and shear stress as the major response parameters.

2. Geometrical Modelling of Bridge Deck Systems

The geometrical modelling of all bridge systems is carried out by using the dimensions provided in the study data. The rectangular box girder bridge is modelled with a span of 40 m, bridge width of 9 m, top slab thickness of 0.250 m, bottom slab thickness of 0.200 m, rib thickness of 0.200 m, total depth of 2 m, and hollow box width of 2.850 m. The trapezoidal box girder bridge is also considered with a span of 40 m and bridge width of 9 m, but its geometry differs in terms of top slab thickness, bottom slab thickness, and hollow section width. It has a top slab thickness of 0.300 m, bottom slab thickness of 0.210 m, rib thickness of 0.200 m, total depth of 2 m, hollow box width of 4.250 m, and bottom hollow width of 3.465 m. The RCC T-beam bridge is modelled with a span of 40 m, width of 9 m, total depth of 2 m, average slab thickness of 0.800 m, T-beam width of 0.400 m, and T-beam depth of 1.200 m. These models are prepared in three-dimensional form in ANSYS so that the actual load transfer mechanism and stress distribution can be studied effectively.

3. Material Properties and Finite Element Idealization

After defining the bridge geometry, material properties are assigned to all three bridge models. Concrete is considered as the main structural material. The density of concrete is taken as 2500 kg/m³, Young's modulus as 30000 MPa, Poisson's ratio as 0.18, bulk modulus as 15625000000 Pa, shear modulus as 12711864406.7797 Pa, tensile ultimate strength as 5000000 Pa, and compressive ultimate strength as 41000000 Pa. The same material properties are assigned to all bridge models so that the comparison remains focused on the effect of deck slab geometry rather than material variation. The finite element method is used for idealizing the bridge models because bridge deck systems have complex stress flow, load distribution, and boundary interaction. In ANSYS, the bridge geometry is divided into finite elements through meshing. Proper meshing helps in capturing local stress concentration, deformation behaviour, and response variation in the slab, girder, web, and hollow section regions. Therefore, finite element idealization forms the main analytical base of the present methodology.

4. Loading and Boundary Conditions

The bridge models are analysed under different loading conditions as per bridge design requirements. Dead load is considered from the self-weight of structural components such as deck slab, girder, ribs, wearing coat, and other permanent elements. Live load is applied as per Indian Roads Congress provisions. In this study, IRC Class A and IRC Class AA loading conditions are considered for comparing the response of all three bridge models. IRC Class AA loading is generally used for important bridges such as national highways and state highways, while IRC Class A loading is used for permanent road bridges. Impact load is also considered because moving vehicles create dynamic effects due to vibration and transfer of wheel loads on the bridge deck. The impact factor is applied according to IRC provisions. In addition, seismic loading is considered conceptually because bridges located in earthquake-prone regions must resist horizontal forces proportional to structural weight. Boundary conditions are applied at the support locations in ANSYS to restrain rigid body motion and represent the actual support behaviour of the bridge. These loading and boundary conditions are kept comparable for all three models to obtain a fair performance comparison.

5. Analysis Procedure and Result Extraction in ANSYS

After completing modelling, material assignment, meshing, boundary condition application, and load application, the bridge models are analysed in ANSYS. The analysis is performed to determine the structural response of RCC T-beam bridge, rectangular box girder bridge, and trapezoidal box girder bridge under IRC Class A and IRC Class AA loading. The major output parameters extracted from ANSYS include shrinkage, equivalent creep, normal creep, shear creep, equivalent stress, normal stress, and shear stress. Shrinkage and creep parameters are important for understanding the long-term deformation behaviour of concrete bridge decks, whereas equivalent stress, normal stress, and shear stress help in identifying critical stress zones and load-carrying behaviour. The results obtained from all three models are arranged in tabular and graphical form for direct comparison. The model showing maximum and minimum values for each parameter is identified. Based on this comparison, the suitability of each deck slab system is evaluated in terms of deformation control, stress distribution, stiffness behaviour, and overall structural performance.

6. Comparative Evaluation of Bridge Deck Performance

The final stage of the methodology involves comparative evaluation of all bridge deck configurations. The RCC T-beam bridge, rectangular box girder bridge, and trapezoidal box girder bridge are compared separately for IRC Class A and IRC Class AA loading conditions. This comparison helps in understanding how each deck slab system behaves under different traffic load intensities. The rectangular box girder is evaluated for its ability to control stress through its closed hollow section, while the trapezoidal box girder is assessed for its wider hollow geometry and load distribution behaviour. The RCC T-beam bridge is evaluated as a conventional and economical system. The final comparison is not based on only one response parameter but on a combined assessment of shrinkage, creep, equivalent stress, normal stress, and shear stress. This systematic evaluation helps in identifying the most suitable deck slab configuration for MNB bridge applications using ANSYS finite element analysis.

V. RESULTS AND DISCUSSION

The ANSYS results are discussed for two loading conditions: IRC Class A and IRC Class AA. The comparison is made between rectangular box girder bridge, trapezoidal box girder bridge, and RCC T-beam bridge. The results are taken from the ANSYS output data available in the project file.

RCC Bridge-Class A

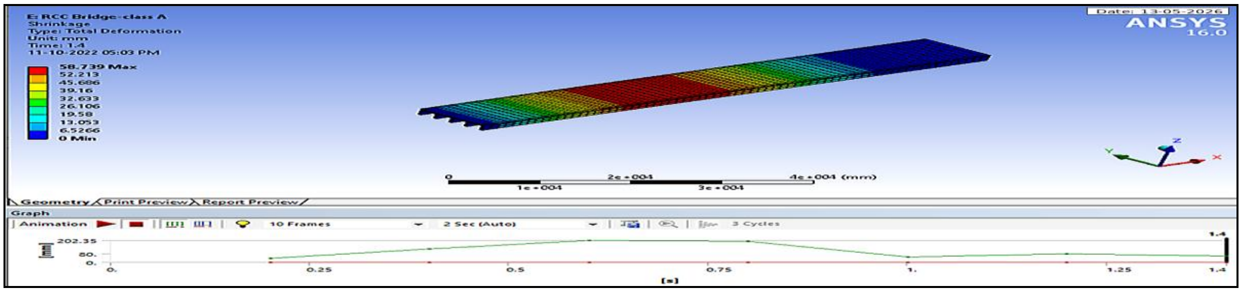


Fig 1. Shrinkage

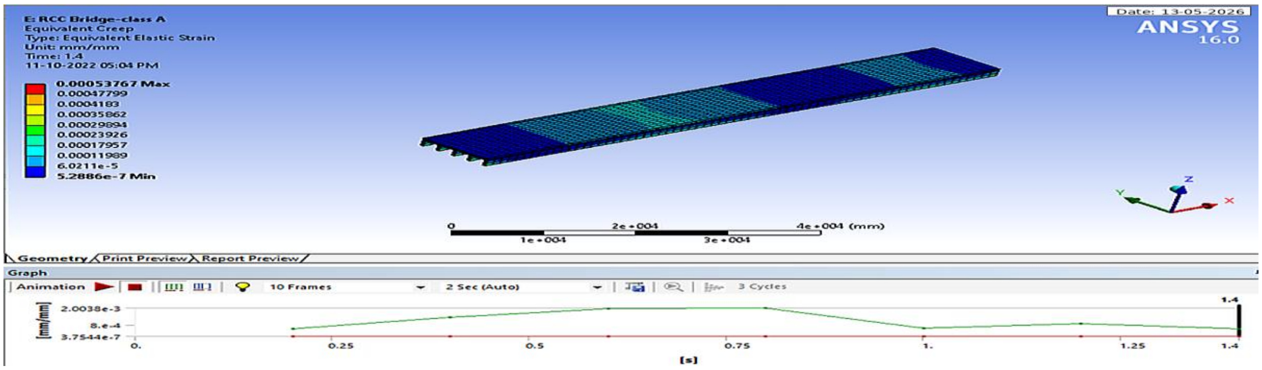


Fig 2. Equivalent Creep

RCC Bridge-Class AA

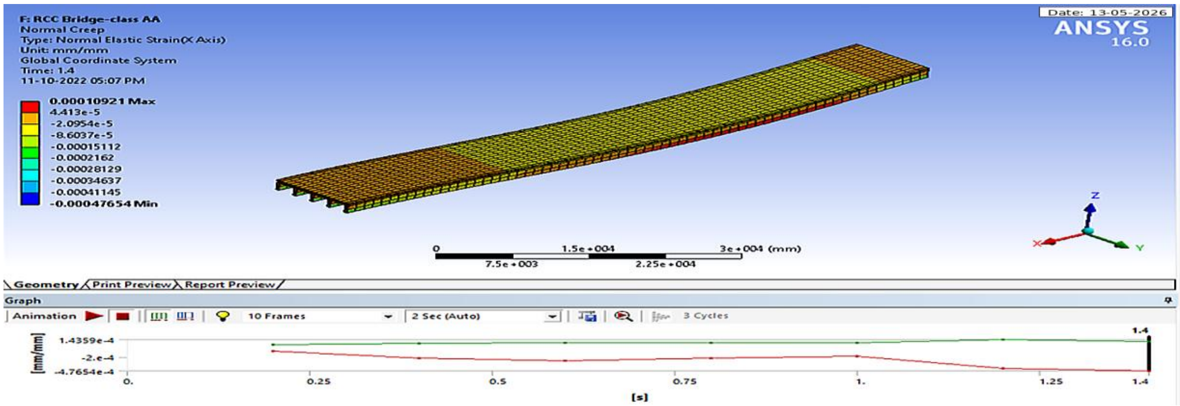


Fig 3. Normal Creep

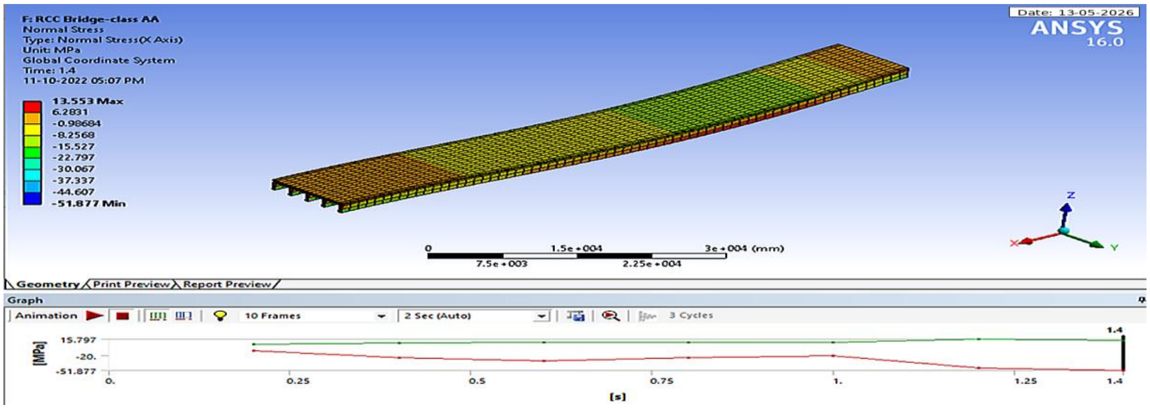


Fig 4. Normal Stress

Rectangular Box Girder Bridge-Class A

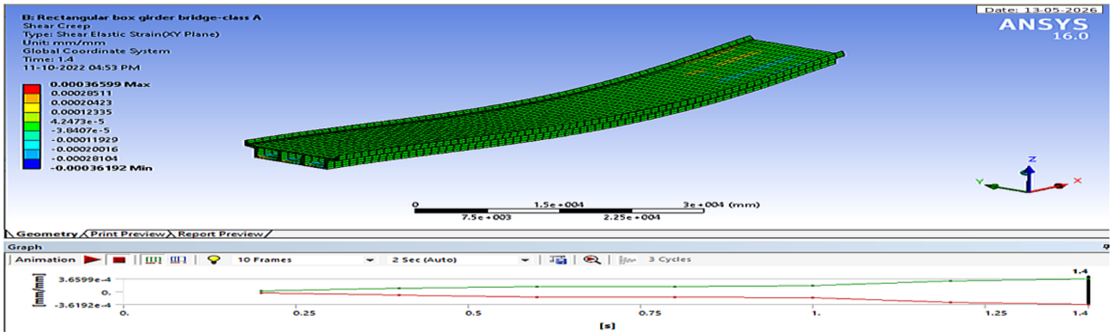


Fig 5. Shear Creep

Trapezoidal Box Girder Bridge-Class A

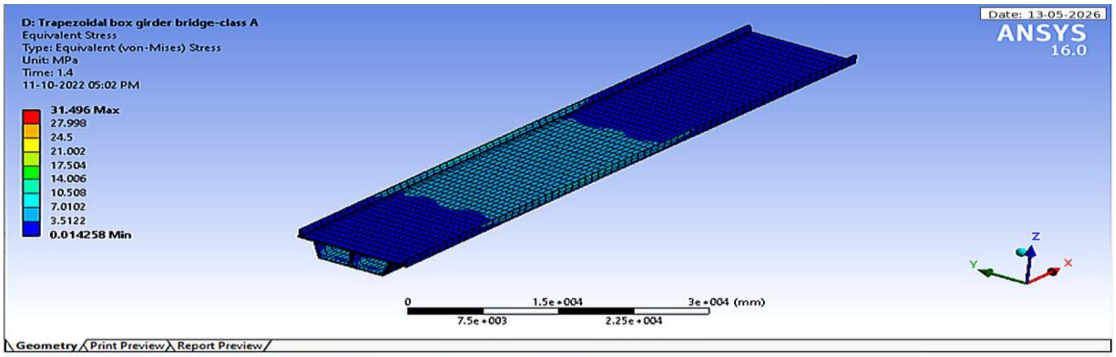


Fig 6. Equivalent Stress

Trapezoidal Box Girder Bridge-Class Aa

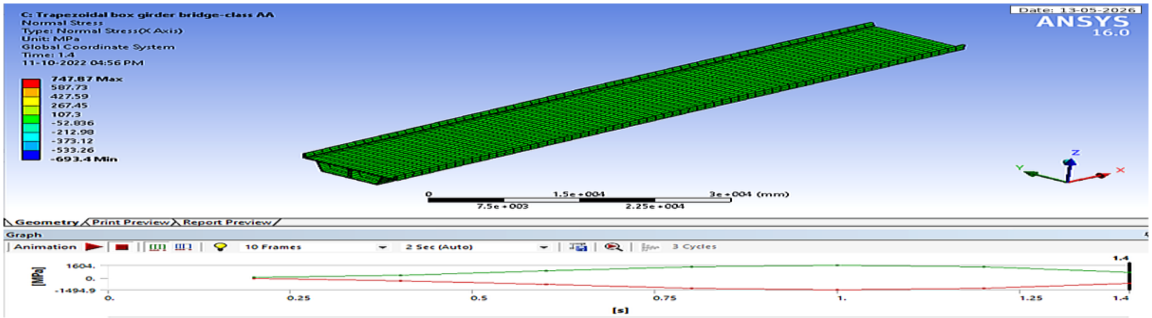
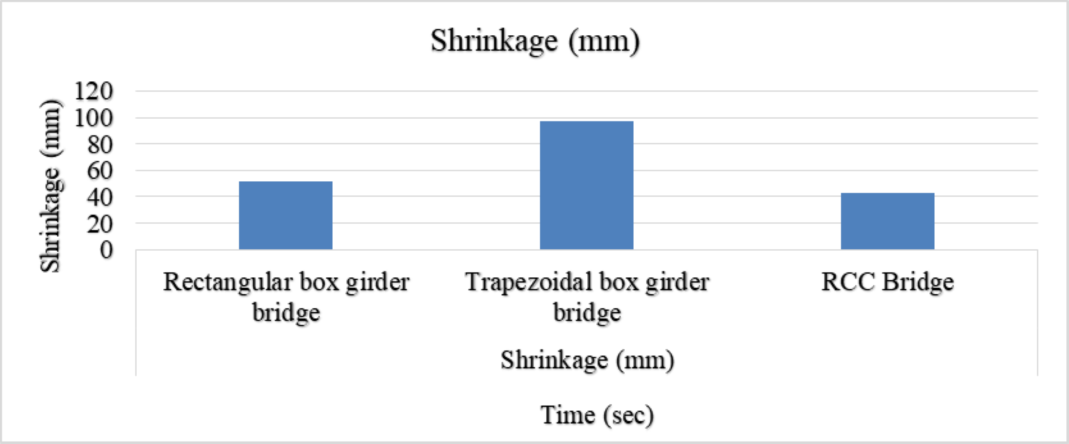


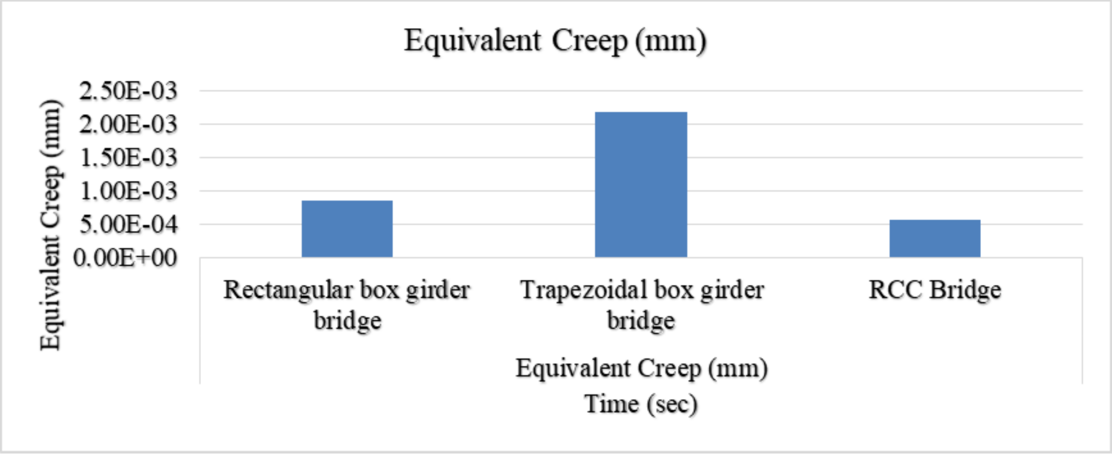
Fig 7. Normal Stress

GRAPHICAL RESULTS



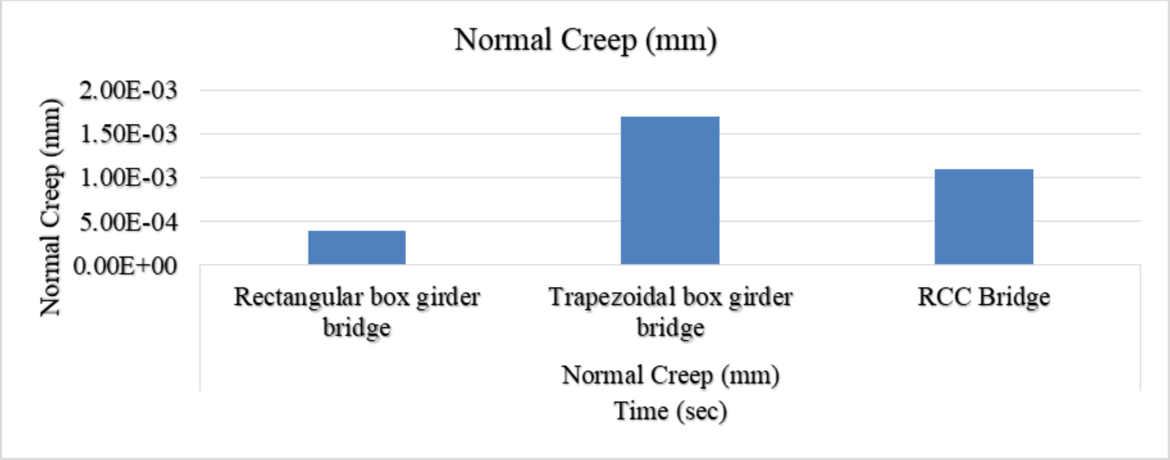
Graph 1 Shrinkage (mm)

The contraction of a hardened concrete mixture owing to the loss of capillary water is known as shrinkage. The total shrinkage of the rectangular box girder bridge, the Trapezoidal box girder bridge, and the RCC Bridge is shown in the table above, with 120 being the maximum span of the Trapezoidal box girder bridge in comparison to the rectangular box girder bridge and RCC Bridge.

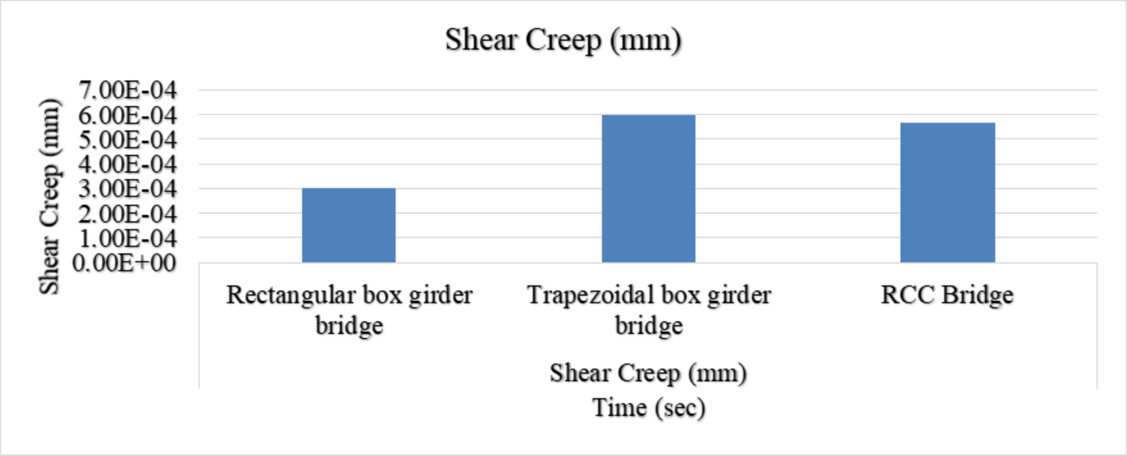


Graph 2 Equivalent Creep (mm)

Equivalent Creep (mm) Trapezoidal box girder bridge 2.50E-03, Rectangular box girder bridge 5.055E-04, and RCC Bridge 0.00E+00 are illustrated in the graph above. Trapezoidal box girder bridge has the greatest span.

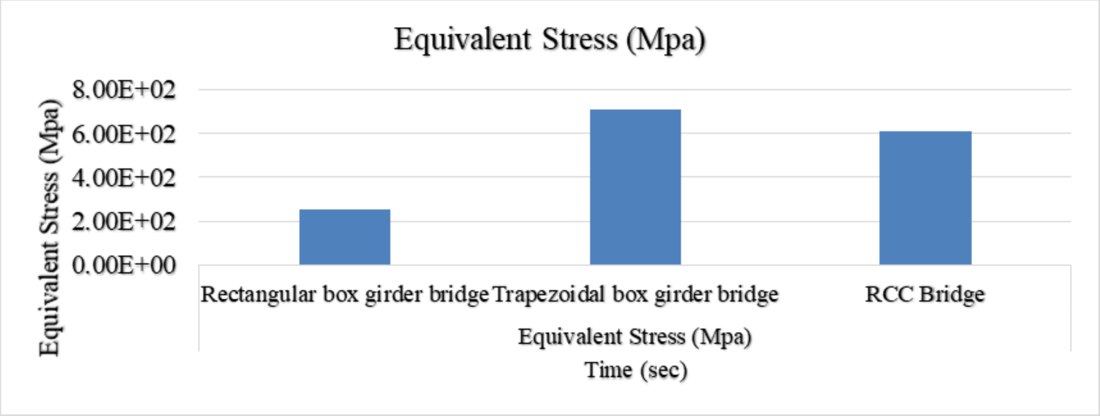


Graph 3 Normal Creep (mm)



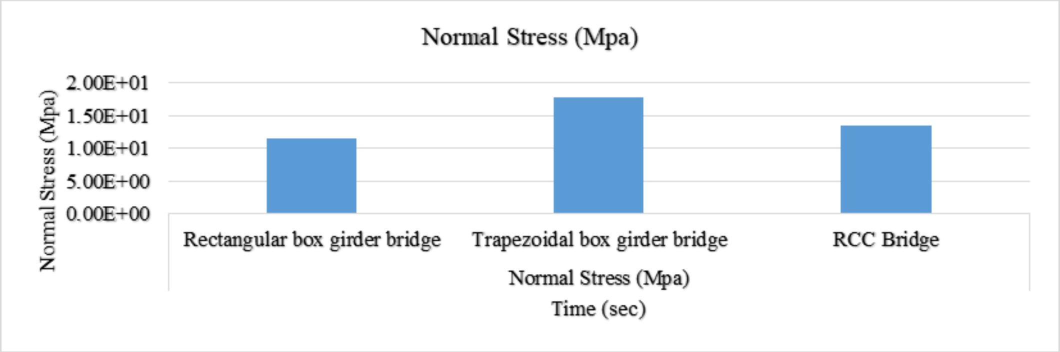
Graph 4. Shear Creep (mm)

Trapezoidal box girder bridge has a larger shear creep (mm) than RCC Bridge and Rectangular box girder bridge, which is 6.00E-04, as indicated in the graph above.



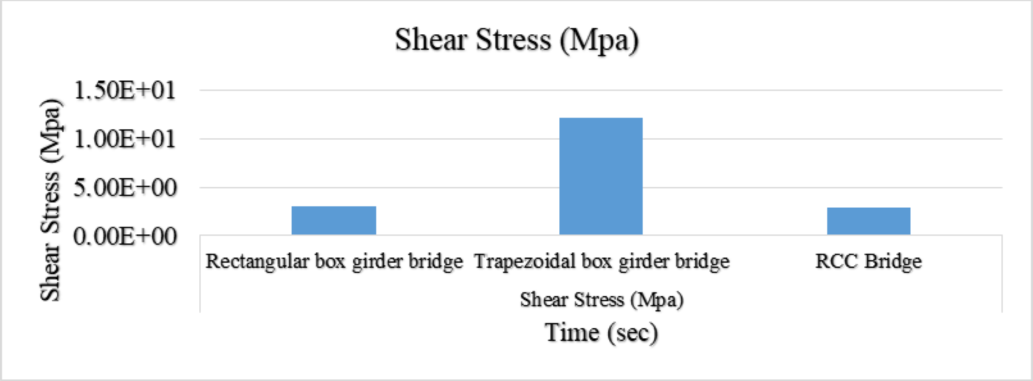
Graph 4. Equivalent Stress (Mpa)

Equivalent stress (von Mises stress, unit: MPa) distributions for deflection rates a v = 0.25/sec (left column) and b v = 250/sec (right column). The maximum span of a trapezoidal box girder bridge, as depicted in the above graph for the equivalent stress (Mpa), is 7.00E+02, while the minimum span of a rectangular box girder bridge is 2.00E+02.



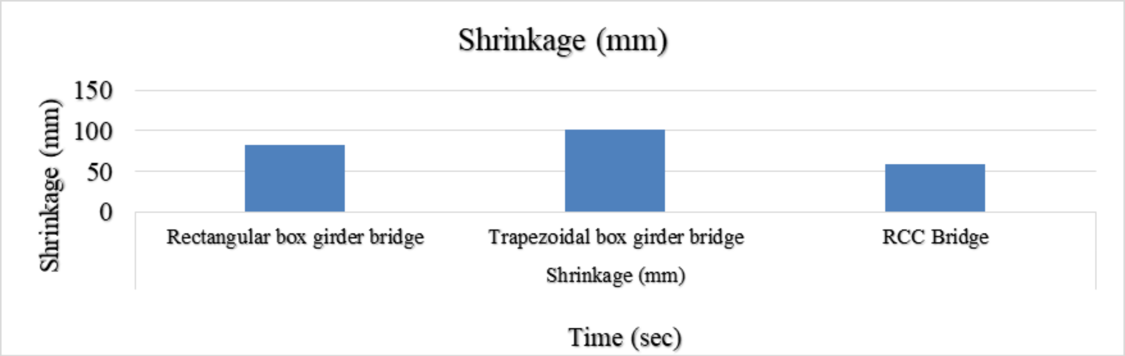
Graph 6. Normal Stress (Mpa)

At a point, the normal stresses on two mutually perpendicular planes are 120 MPa (Tensile) and 60 MPa (Bending) (Tensile) The maximum normal stress (Mpa) for a trapezoidal box girder bridge is 1.80E+01 more than for a rectangular box girder bridge and an RCC bridge, as seen in the graph above.



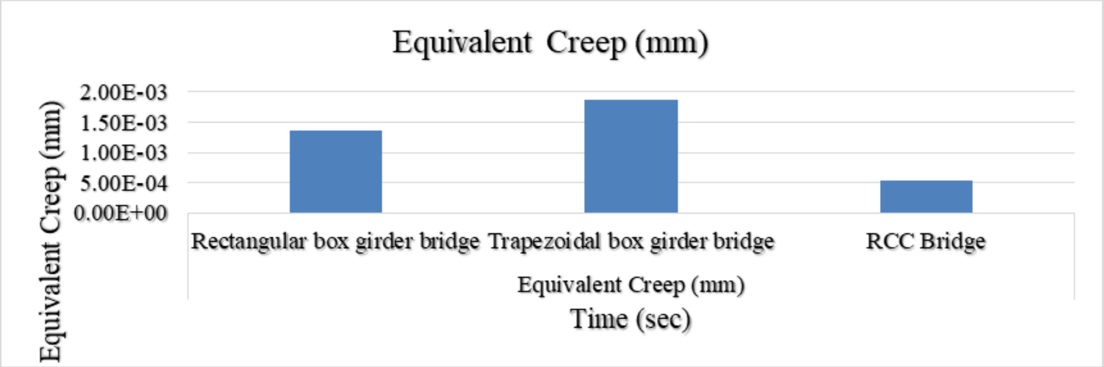
Graph 5. Shear Stress (Mpa)

Shear force (MPa) vs shear displacement (mm) for typical experiments According to the graph above, a trapezoidal box girder bridge has a maximum 1.20E+01 span when compared to a rectangular box girder bridge and an RCC bridge for shear stress (Mpa).



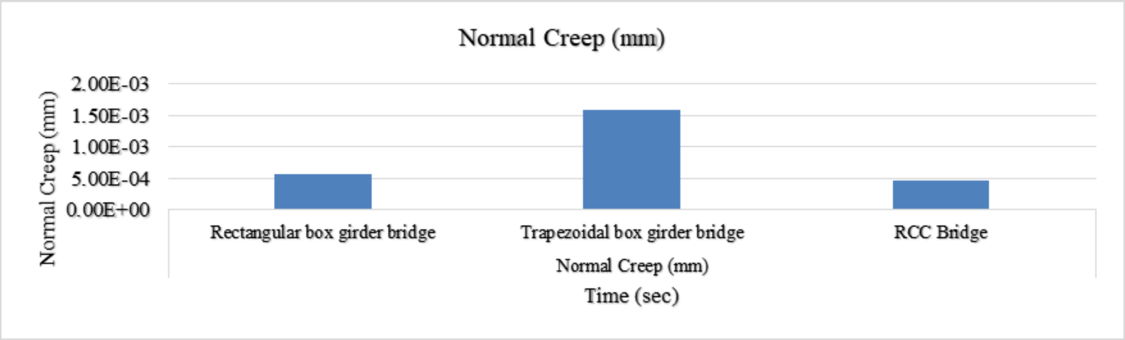
Graph 6. Shrinkage (mm)

Above table displays the total shrinkage of the rectangular box girder bridge, the Trapezoidal box girder bridge, and the RCC Bridge, with 120 being the maximum span of the Trapezoidal box girder bridge in comparison to the rectangular box girder bridge and the RCC Bridge. The discrepancy between a company's balance sheet inventory and its actual inventory is referred to as shrinkage.



Graph 7. Equivalent Creep (mm)

The graph above depicts the equivalent creep (mm) for trapezoidal box girder bridge 1.50E-03, rectangular box girder bridge 1.50E-04, and RCC Bridge 5.00E+00. The longest span is a trapezoidal box girder bridge.



Graph 8. Normal Creep (mm)

In general, materials with higher melting temperatures, lower diffusivity, & greater shear strength have greater creep resistance. The Trapezoidal box girder bridge has the highest normal creep (mm), as shown in the graph above, compared to the Rectangular box girder bridge and RCC Bridge, which both have 1.60E-03.

VI. CONCLUSION

The present study carried out a finite element-based comparative analysis of different deck slab configurations in an MNB bridge using ANSYS software. Three bridge models, namely RCC T-beam bridge, rectangular box girder bridge, and trapezoidal box girder bridge, were analysed under IRC Class A and IRC Class AA loading conditions. The comparison was performed using shrinkage, equivalent creep, normal creep, shear creep, equivalent stress, normal stress, and shear stress as the main response parameters. The results show that the geometry of the deck slab/girder system has a significant influence on bridge behaviour. Under both loading conditions, the trapezoidal box girder bridge shows higher shrinkage and creep values, which indicates greater time-dependent deformation tendency.

Under IRC Class A loading, the trapezoidal box girder bridge also shows the highest equivalent stress and shear stress, whereas the rectangular box girder bridge shows comparatively lower equivalent stress. Under IRC Class AA loading, the rectangular box girder bridge shows the highest equivalent stress and shear stress, while the trapezoidal box girder shows the highest normal stress. The RCC T-beam bridge shows comparatively lower shrinkage and creep values but may be less efficient than box girder systems where torsional stiffness and improved load distribution are required. Overall, the study concludes that ANSYS finite element analysis is an effective tool for comparing bridge deck slab configurations and supporting the selection of a suitable bridge superstructure system.

VII. FUTURE SCOPE

1. The present study can be extended by performing nonlinear material analysis to include cracking, crushing, and post-elastic behaviour of concrete.
2. Moving load analysis can be carried out instead of static live load application to understand realistic vehicle-induced bridge response.
3. Experimental validation using scaled bridge deck models can be performed to verify the ANSYS results.
4. Prestressing effects, tendon profiles, and loss of prestress can be included for more realistic box girder bridge modelling.
5. Cost analysis and optimization can be added to identify the most economical and structurally efficient deck slab configuration.

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