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Structural Analysis of Box Girder Bridge using ANSYS

[1] Swayam Sahu, [2]Mr. Shrikant Mishra

[1]Research scholar, [2] Assistant Professor
[1] Department of Civil Engineering,
[1]SSTC, Bhilai, India

Abstract: The bridge deck is one of the vital components of bridge structure. The bridge deck bears actual vehicular load. The vehicular load tends to induce high deformation and high stresses. The objective of current research is to evaluate the structural stability of bridge deck subjected to vehicle loading conditions. The analysis is conducted using FEA simulation tool. The FEA simulation provided a comprehensive understanding of the deformation, stresses, and elastic strain distribution within the bridge structure. These findings can inform design considerations and structural integrity assessments, helping engineers ensure the bridge's safety and performance under various loading conditions.

***IndexTerms* - Bridge deck, FEA**

I. Introduction

The fundamental purpose of a bridge deck is to provide structural support for vertical traffic loads and effectively transfer them to the steel superstructure. The walkway of a bridge is commonly designed to extend uninterrupted across both its width and length. In a significant number of instances, the bridge deck is affirmatively connected to the girders, particularly when concrete deck slabs are fastened to steel girders through the utilization of shear connectors. In such cases, the deck can be employed to enhance the rigidity and stiffness of the upper flange of the composite section. The superstructure is experiencing localised transverse flexural bowing due to the slab spanning over the girders. This can be attributed to the tyre pressures of the vehicle. Longitudinal pressures resulting from span-wide flexure also impact the composite deck. Once the deck is firmly fastened to the girders, it provides continuous support to the upper flange of the finished structure and enhances the overall stability of the bridge system. The deck can serve as a horizontal diaphragm, facilitating the transmission of lateral stresses, such as wind or seismic pressures, to the supports.

II. LITERATURE REVIEW

Fam and Nelson [1] examined the utilisation of curved glass fiber-reinforced polymer (GFRP) plates as a viable option for concrete flooring, which featured interlocking links. The structural configuration involved the substitution of the lower reinforcement layer with a Structural Insulated Panel (SIP) form, while the upper reinforcement layer was composed of Glass Fibre Reinforced Polymer (GFRP) mesh. The majority of the assessments focused on the structural performance of cantilevered platforms and the efficacy of composite decking systems in conjunction with concrete girders. As demonstrated, this method of decking proved to be highly effective.

Dieter et al. [2] developed and evaluated a hybrid fiber-reinforced polymer (FRP) concrete deck system, which was subjected to field testing. The testing methodology employed by Dieter et al. (2018) was comparable to that of Ldpez's system. The tension rebars situated at the base of the deck were substituted with stay-in-place (SIP) structural formwork composed of FRP pultruded profiles featuring square tubes. The enhancement of the upper section of the deck system involved the reinforcement of FRP grids, which were affixed to the concrete through the utilisation of coarse grit.
Cheng et al. [3, 4] The Fibre Reinforced Polymer (FRP) panel, which was reinforced, functioned as both a bending support and a Structural Insulated Panel (SIP). In accordance with the guidelines set forth by the American Association of State Highway and Transportation Officials (AASHTO) HS20, a series of experiments were conducted to investigate the static behaviour of the hybrid deck system. The study revealed that the static performance was in compliance with the design specifications, and

demonstrated favourable resistance to wear with minimal degradation. The system complied with the prescribed standards for its strength and functionality.

Keller et al. [5] conducted research to evaluate the performance of a novel bridge platform system that combines fiber-reinforced polymer (FRP) and concrete materials. The framework of this bridge involved the placement of ultrahigh performance concrete (UHPC) over lightweight concrete (LC), which was interposed between the fiber-reinforced polymer (FRP) with T-upstands. Two distinct types of LC and LC/FRP connectors were utilised in comparative evaluations. The decks exhibit a delicate mode of failure, whereby they can sustain a weight loss of up to 40%, while concurrently experiencing an increase in strength of 81%.

He et al. [6] proposed a cost-effective solution for a hybrid deck system utilising glass fibre reinforced polymer (GFRP) and concrete materials. The utilisation of T-shaped glass fibre reinforced polymer (GFRP) ribs on the rebars that were inserted through the apertures functioned as connectors, thereby enhancing the rigidity of the structural insulated panel (SIP). The system underwent bending static tests and sand loading analyses.

III. OBJECTIVE

The objective of current research is to evaluate the structural stability of bridge deck subjected to vehicle loading conditions. The analysis is conducted using FEA simulation tool.

IV. METHODOLOGY

The structural analysis of bridge deck is conducted using FEA simulation technique. The FEA simulation process involves designing of bridge structure, meshing and boundary conditions.

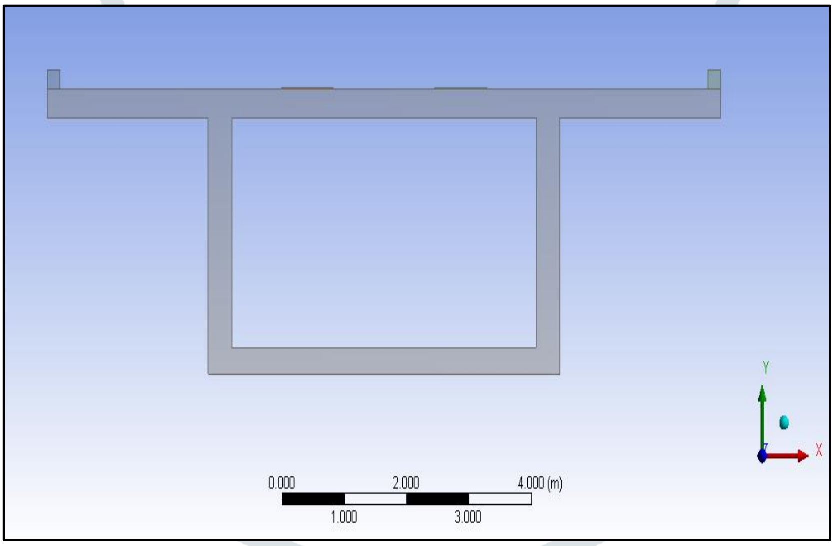

Figure 1: CAD model of bridge deck (front view)

In the initial step, the bridge structure is modeled in design modeler of ANSYS software. The front view of bridge deck is shown in figure 1. The model comprises of 4 different features.

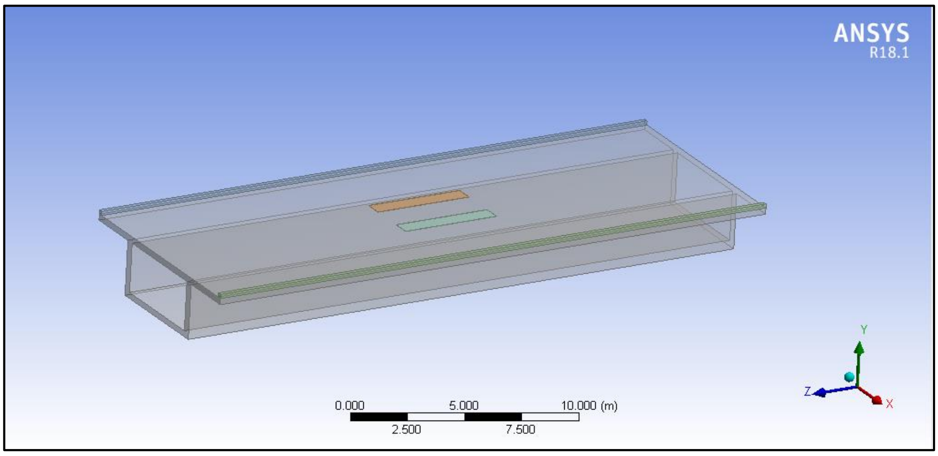

Figure 2: CAD model of bridge deck (isometric view)

After modeling, the bridge deck model is discretized using hexahedral elements. The discretization process involves setting up element size, inflation. The meshed model of bridge deck is shown in figure 3 and figure 4.

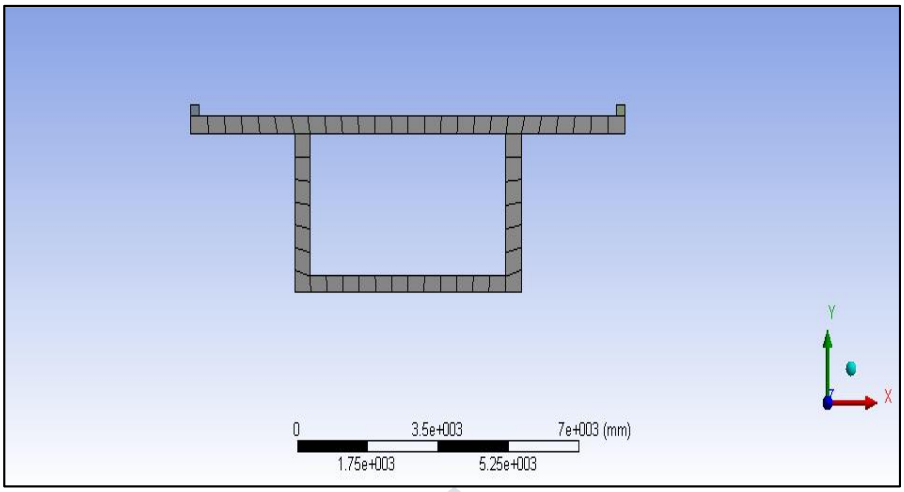

Figure 3: Meshed model of bridge deck (front view)

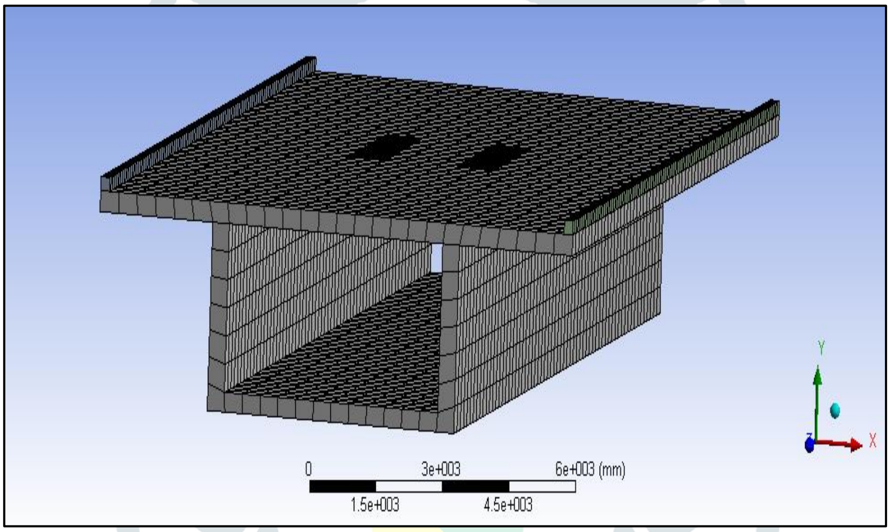

Figure 4: Meshed model of bridge deck (isometric view)

After meshing, the structural loads and boundary conditions are applied to the structure. The structural boundary conditions involve applying fixed support at the base as shown in dark blue color. The static vehicle load is applied on the bridge structure as per IRC conditions. The applied load is shown in figure 5.

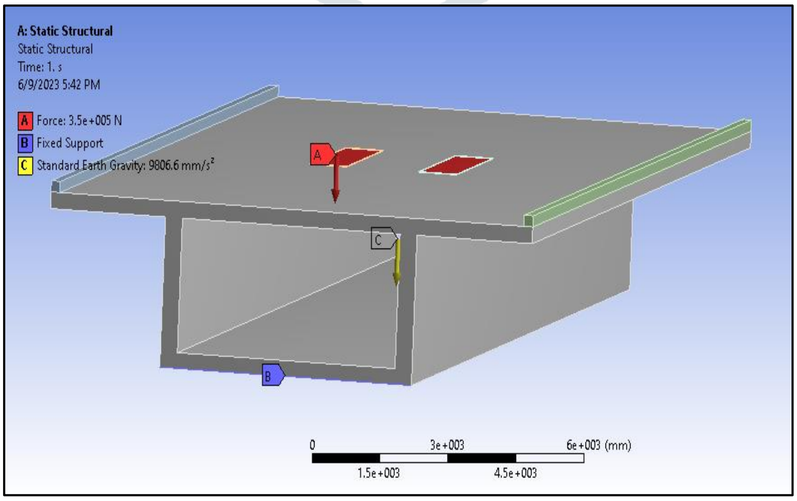

Figure 5: Structural load on bridge deck

After applying structural boundary conditions, the simulation is run. The simulation is run after application of structural boundary conditions. The FEA simulation is run as per standard solver settings.

V. RESULTS AND DISCUSSION

From the FEA simulation, the deformation, stresses and elastic strain plots are determined. The deformation is higher at the mid zone of bridge structure. The higher deformation at the center zone can be attributed to zone of load application.

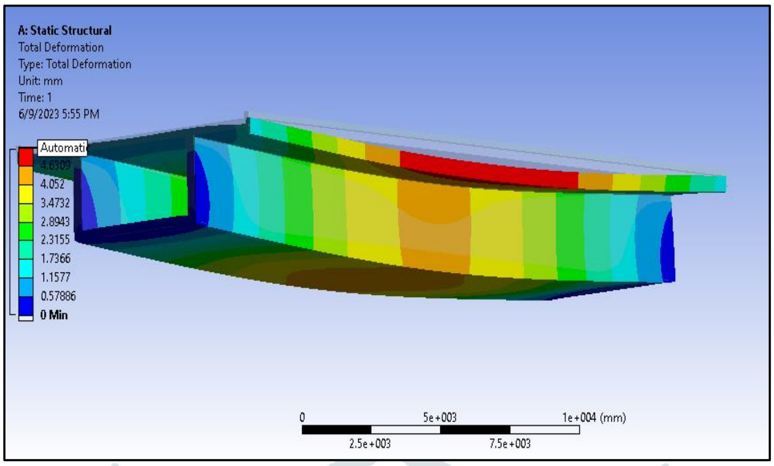

Figure 6: Deformation plot on bridge deck

The induced normal stress on bridge structure is shown in figure 7. The induced normal stress is constant for most of the regions. The normal stress 2.22MPa at most of the regions.

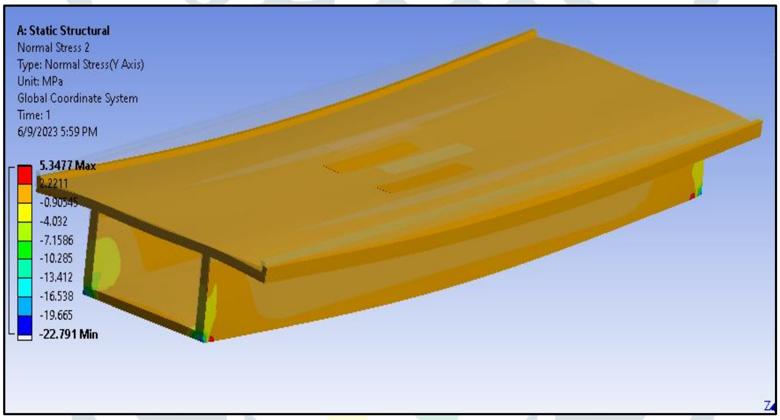

Figure 7: Normal stress on bridge deck

The normal stress is maximum near the support region. The normal stress at this zone is nearly 19.6MPa compressive. The normal stress is tensile at the support region as shown in red colored region. The stresses are compressive at other regions.

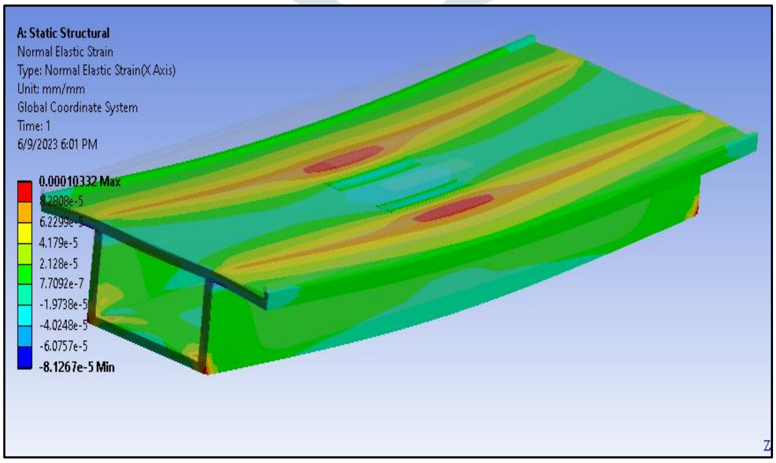

Figure 8: Normal elastic strain on bridge deck

The normal elastic strain distribution plot is obtained for bridge deck as shown in figure 8. The normal elastic strain is higher at the zone of load application with magnitude of .00010332mm/mm. The elastic strain is maximum at the zone of load application as shown in red colored region.

VI. CONCLUSION

From the FEA simulation, the structural behavior of bridge structure is evaluated under static loading conditions. The FEA simulation provided a comprehensive understanding of the deformation, stresses, and elastic strain distribution within the bridge structure. These findings can inform design considerations and structural integrity assessments, helping engineers ensure the bridge's safety and performance under various loading conditions.

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