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Analysis of Bridge Deck Panel Using Polyurethane Material

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Abstract
Deck is a super structural element of a bridge and is considered as the most susceptible element of a bridge. The main problem in the highway system is its Bridge deck deterioration. The Use of advanced material for bridge deck system is a long-term solution for the deterioration problem for decks made up of concrete. Here a bridge deck with polyurethane core is considered.
Keywords: *Bridge deck, Polyurethane, Finite Element Analysis.*

1. Introduction

The primary function of a bridge deck is to support the vehicular vertical loads and distribute these loads to the steel superstructure. The deck is typically continuous along the span of the bridge and continuous across the width of the span. In most applications, the bridge deck is made composite with the steel.

A steel polyurethane sandwich plate is a sandwich plate in which a polyurethane core layer is filled between two steel plates. Polyurethane is a low density material, whose density is 1/7 of steel, has greater elasticity compares to steel. The steel polyurethane sandwich plate has several advantages such as high stiffness, anti - aging characteristics and high impact resistance. In this paper we studies the behaviour of trapezoidal steel polyurethane bridge decks.

2. Structural model and material property

It is a single span bridge deck of 1.56 m width. Two models are considered. Trapezoidal bridge deck with steel alone and trapezoidal bridge deck with steel and polyurethane as shown in fig.1 and fig.2. In this longitudinal stiffeners are provided at a spacing of 300 mm. The thickness of the polyurethane layer provided is 15 mm.

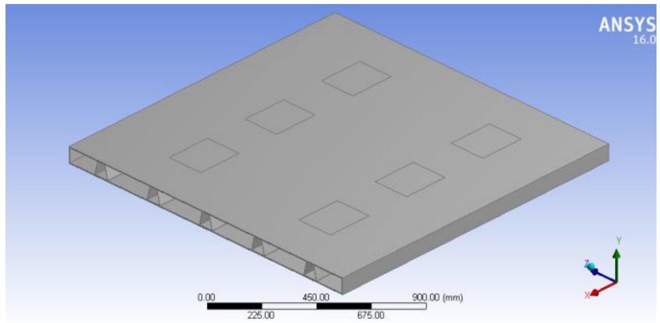

Fig.1 Trapezoidal bridge deck with steel

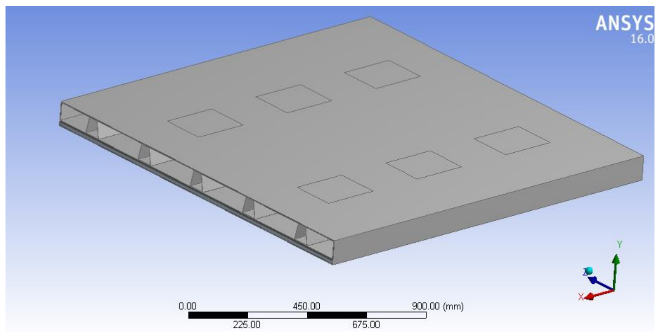

Fig.2 Trapezoidal bridge deck with steel and polyurethane

2.1 Software used

ANSYS stands for Analysis systems. It offers a suite of engineering simulation software for engineers and designers. The software creates simulated computer models of structures, electronics, or machine components to simulate strength, toughness, elasticity, temperature distribution, electromagnetism, fluid flow, and other attributes. Here ANSYS WORKBENCH 16.0 was used to model the steel bridge deck. Workbench provides a single interface to all of ANSYS tools. The goal is to provide a single platform that allows users to take advantage of a simpler, schematic style approach to build simulation tasks.

2.2 Material properties

The engineering data manager provides a powerful tool for defining, organizing, and storing material properties. Material properties of structural steel were already available in ANSYS engineering data. Material properties of steel and polyurethane are given in table 1.

Table 1: Material properties

Material	Density (kg/m3)	Elastic modulus (MPa)	Poisson's ratio
Steel	7850	2.1x105	0.3
Polyurethane	1172	800	0.46

2.3 Meshing

ANSYS meshing is a general purpose, intelligent, automated, high performance product it produces the most appropriate mesh for accurate, efficient multiphysics solutions. A mesh well suited for a specific analysis can be generated with a single mouse click for all parts in a model. Here automatic meshing was done in bridge deck.

2.4 Loading and boundary conditions

After meshing loading is applied as per IRC Class AA. Loads were taken as per IRC 6-2010 standards. Simply supported boundary conditions were applied.

3. Finite Element Analysis

3.1 Static Analysis of the Bridge Deck

Static analysis was carried out to determine the static deformation and stresses of the structure. A static analysis can, however, include steady inertia loads (such as gravity and rotational velocity), and time-varying loads that can be approximated as static equivalent loads (such as the static equivalent wind and seismic loads commonly defined in many building codes). In static analysis steady loading and response conditions were assumed, that is, the loads and the structure's response are assumed to vary slowly with respect to time.

From static analysis deformation and equivalent stresses are less in trapezoidal steel polyurethane bridge deck compared to trapezoidal steel bridge deck as shown in table.2. From this, it is clear that trapezoidal steel polyurethane bridge deck shows better performance compared to other bridge decks. Fig.3 fig.4 shows the deformations in trapezoidal steel bridge deck and trapezoidal steel polyurethane bridge deck respectively.

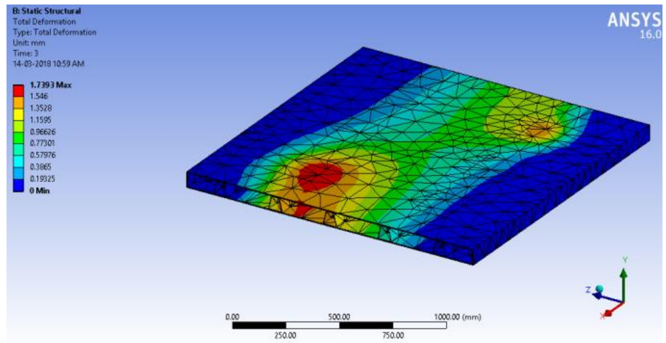

Fig.3 Total deformation in Trapezoidal steel bridge deck

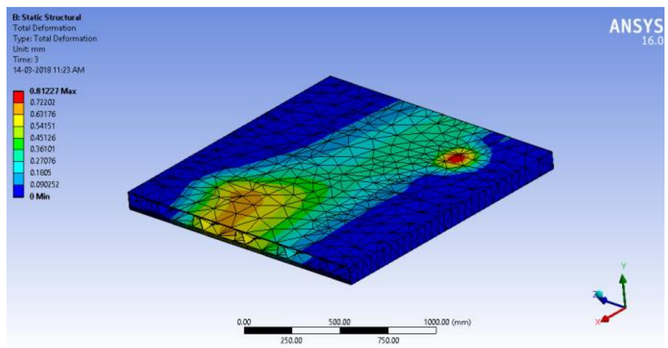

Fig.4 Total deformation in Trapezoidal steel polyurethane bridge deck

Table 2: Comparison of Results

	Total deformation (mm)	Equivalent stress (MPa)
Trapezoidal steel bridge deck	1.739	620.61
Trapezoidal steel polyurethane bridge deck	0.812	356.04

3.2 Modal Analysis of Bridge Deck

The goal of the modal analysis in structural mechanics is to determine the natural mode shapes and frequencies of an

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object or structure during free vibration. In structural engineering, modal analysis uses the overall mass and stiffness of a structure to find the various periods at which it will naturally resonate. If a structure's natural frequency matches an earthquake's frequency, the structure may continue to resonate and experience structural damage. Modal analysis is also important in structures such as bridges where the engineer should attempt to keep the natural frequencies away from the frequencies of people walking on the bridge. In this analysis first six modes of vibrations at different frequencies are considered for each cases of trapezoidal bridge deck.

In steel bridge decks deformation starts at a frequency of 285.68 Hz, as shown in table 3. Whereas in steel polyurethane bridge decks deformation starts at a frequency of 314.68 Hz. Fig.5 and fig.6 shows the sixth frequency mod of trapezoidal steel bridge deck and trapezoidal steel polyurethane bridge deck respectively. From this, it is clear that steel polyurethane bridge deck shows better performance compared to steel bridge decks.

Table 3: Comparison of Results

Trapezoidal steel bridge deck		Trapezoidal steel polyurethane bridge deck	
Natural frequency (Hz)	Total deformation (mm)	Natural frequency (Hz)	
285.68	4.696	314.68	5.261
310.39	6.353	359.38	5.137
427.76	3.039	408.05	2.228
448.15	6.349	487.89	5.240
653.48	6.759	741.19	5.257
681.59	7.199	788.55	6.525

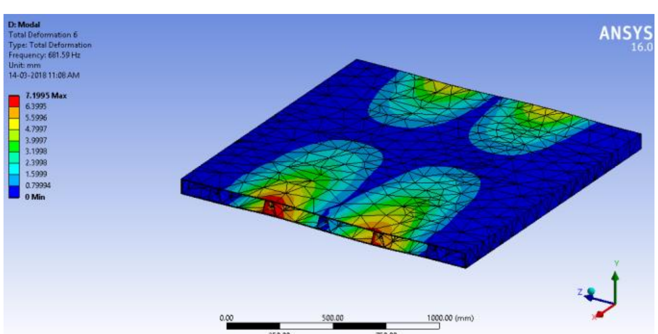

Fig.5 Sixth frequency mode of trapezoidal steel polyurethane bridge deck

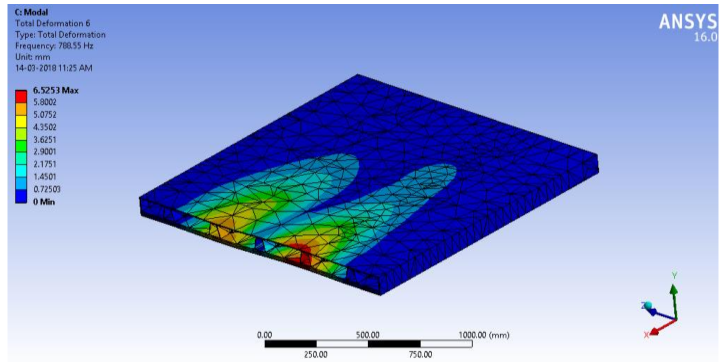

Fig.6 Sixth frequency mode of trapezoidal steel polyurethane bridge deck

4. Conclusions

In this project modeling and analysis of the steel and steel composite bridge deck was done. The deformation and equivalent stress obtained for trapezoidal steel polyurethane bridge deck in static and transient analysis is less than that of trapezoidal steel bridge deck. Also in trapezoidal steel polyurethane bridge deck deformation starts at a higher frequency compared to trapezoidal steel bridge decks. From this, it is clear that trapezoidal steel polyurethane bridge deck shows better performance compared to trapezoidal steel bridge decks.

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