Vibration Analysis of Steel Deck Bridge Using FRP

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Abstract- *Most human activities involve vibration in one form or other. For example, we hear because our eardrums vibrate and see because light waves undergo vibration. Breathing is associated with the vibration of lungs and walking involves (periodic) oscillatory motion of legs and hands. Human speech requires the oscillatory motion of larynges (and tongues) . Early scholars in the field of vibration concentrated their efforts on understanding the natural phenomena and developing mathematical theories to describe the vibration of physical systems. In recent times, many engineering applications of vibration, such as the design of machines, foundations, structures, engines, turbines, and control systems. Most prime movers have irrational problems due to the inherent unbalance in the engines. The unbalance may be due to faulty design or poor manufacture. Imbalance in diesel engines, for example, can cause ground waves sufficiently powerful to create a nuisance in urban areas.*

I. INTRODUCTION

Most human activities involve vibration in one form or other. For example, we hear because our eardrums vibrate and see because light waves undergo vibration. Breathing is associated with the vibration of lungs and walking involves (periodic) oscillatory motion of legs and hands. Human speech requires the oscillatory motion of larynges (and tongues). Early scholars in the field of vibration concentrated their efforts on understanding the natural phenomena and developing mathematical theories to describe the vibration of physical systems. In recent times, many investigations have been motivated by the engineering applications of vibration, such as the design of machines, foundations, structures, engines, turbines, and control systems.

Most prime movers have vibrational problems due to the inherent unbalance in the engines. The unbalance may be due to faulty design or poor manufacture. Imbalance in diesel engines, for example, can cause ground waves sufficiently powerful to create a nuisance in urban areas. The wheels of some locomotives can rise more than a centimeter off the track at high speeds due to imbalance. In turbines, vibrations cause spectacular mechanical failures. Engineers have not yet been able to prevent the failures that result from blade and disk vibrations in turbines. Naturally, the structures designed to support heavy centrifugal machines, like motors and turbines, or reciprocating machines, like steam and gas engines and reciprocating pumps, are also subjected to vibration. In all these situations, the structure or machine component subjected to vibration can fail because of material fatigue resulting from the cyclic variation of the induced stress. Furthermore, the vibration causes more rapid wear of machine parts such as bearings and gears and also creates excessive noise. In machines, vibration can loosen fasteners such as nuts. In metal cutting processes, vibration can cause chatter, which leads to a poor surface finish. Whenever the natural frequency of vibration of a machine or structure coincides with the frequency of the external excitation, there occurs a phenomenon known as resonance, which leads to excessive deflections and failure. The literature is full of accounts of system failures brought about by resonance and excessive vibration of components and systems Vibratory systems comprise means for storing potential energy (spring), means for storing kinetic energy (mass or inertia) and means by which the energy is gradually lost (damper). The vibration of a system involves the alternating transfer of energy between its potential and kinetic forms. In a damped system, some energy is dissipated at each cycle of vibration and must be replaced from an external source if a steady vibration is to be maintained. Although a single physical structure may store both kinetic and potential energy, and may dissipate energy, this chapter considers only lumped parameter systems composed of ideal springs, masses, and dampers wherein each element has only a single function. In translational motion, displacements are defined as linear distances; in rotational motion, displacements are defined as angular motions.

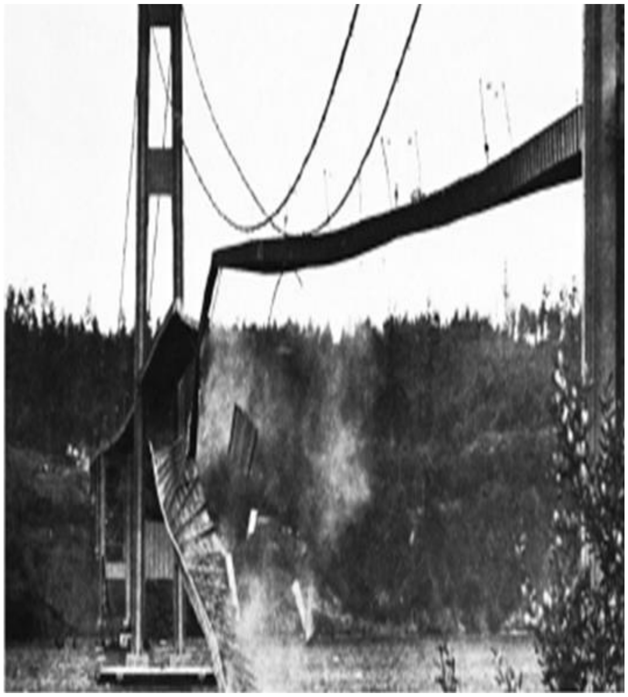

Fig.1 Tacoma narrows bridge

In 1940 Tacoma Narrows Bridge, the first bridge was a suspension bridge in U.S. state of Washington that spanned the Tacoma narrow strait of Puget sound between Tacomo and the Kitsap peninsula. It opened to traffic on 1 July,1940 and dramatically collapsed into Puget Sound on November 7 of the same year due to wind induced in vibration. The bridge was the third longest in the world in terms of main span length, behind the Golden Gate Bridge and the George Washington Bridge

1.1 Objectives

Within this over all aim the main objectives are defined as below,

1. Study of steel girder bridge under influence of moving Time in accordance with IRC.
2. To analyses design parameters such as type of truss, bridge behavior using finite element modeling tool in ANSYS and its verification.
3. To check Response of steel deck bridge under influence of moving Time using FRP.

II. LITERATURE REVIEW

It was found that large numbers of research works were conducted on Bridge vibration due to moving Time. Mostly among all available literature and experimental work was based on the bridge vibration due to moving TimeThe following literature surveys for "A Study of Steel Deck Bridge Due to Vibration of Moving Time" have been covered.

Lipeng Ana, Dejian Li , PengYua, Peng Yuan To systematically study the vehicle bridge coupled dynamic response and its change rule with different parameters, a vehicle model with seven degrees of freedom was built and the total potential energy of vehicle space vibration system was deduced. Considering the stimulation of road roughness, the dynamic response equation of vehicle–bridge coupled system was established in accordance with the elastic system principle of total potential energy with stationary value and the ''set-in-right-position'' rule. On the basis of the self-compiled Fortran program and bridge engineering, the dynamic response of long span continuous girder bridge under vehicle Time was studied. This study also included the calculation of vehicle impact coefficient, evaluation of vibration comfort, and analysis of dynamic response parameters. Results show the impact coefficient changes with lane number and is larger than the value calculated by the ''general code for design of highway bridges and culverts (China)''. The Dieckmann index of bridge vibration is also related to lane number, and the vibration comfort evaluation is good in normal conditions. The relevant conclusions from parametric analyses have practical significance to dynamic design and daily operation of long-span continuous girder bridges in expressways. Safety and comfort are expected to improve significantly with further control of the vibration of vehicle–bridge system.

Yufen Zhou, Suren Chen Vehicle ride comfort issues for the drivers are related to not only individual satisfaction of driving experience, but also driving safety and long-term health of the drivers .A new methodology of ride comfort analysis is presented for typical vehicles driven on long-span bridges consider in realistic traffic and environmental Times such as wind excitations .Built on the simulation framework developed previously by the writers, complex interactions among the long-span bridge, all the vehicles in the traffic flow and wind excitations are appropriately modeled. Vehicle ride comfort condition is evaluated by extending the advanced procedures as currently recommended in the ISO 2631-1 standard to the scenarios of multiple vehicles in the stochastic traffic flow, including obtaining the whole-body vibration response, frequency weighting the original response and determining the Overall Vibration Total Value (OVTV). The proposed methodology is then applied to a prototype long span cable-stayed bridge and traffic system to demonstrate the proposed ride comfort valuation methodology. The study starts with the baseline scenario when the vehicles are driven on the rigid road without considering the interactions with the supporting structure and wind excitations, followed by the scenarios of vehicles driven on the bridge. The influences of dynamic interactions, presence of other vehicles and wind excitations on the ride comfort are also numerically evaluate

Y. Zhang, D. ZhuThis paper investigates the random responses of a coupled vehicle-bridge system due to track irregularities. The train model consists of 9 vehicles, and each vehicle is constructed by a rigid body, two bogies and four wheels, while the bridge is modeled by three-dimensional Euler beam elements. The equations of motion of the train and bridge are built respectively. Based on the displacement compatibility condition of the interface with track irregularities, the equation of motion of the coupled system can be achieved by eliminating the dependent DOFs. When the track irregularities are regarded as stationary random processes, the stochastic analysis of the coupled system is carried out by using pseudo-excitation method (PEM), and a mean extreme value estimation of the non-stationary responses is proposed.

J. Zwolski Wroclaw P. Rawa Wroclaw J. Bie Wroclaw Forced vibration test is a method enabling us to analyze the changes of dynamic characteristics of steel bridge structures. In some cases, it helps monitor their technical condition. In this paper a of a monitoring system applied by team from the Wroclaw University of Technology is described. A comprehensive computer-based system for programming and control of vibration tests as well as for data acquisition and processing is presented. As an example of practical use of the monitoring system, results of steel footbridge tests are shown. The tested suspended structure after renovation was equipped with mass dampers thus special attention was paid to the identification of dynamic characteristics changes caused by the dampers

Patel S G Vesmawala G R Vibration testing of bridges can give very helpful information based on the behavior and performance during its service life. Ongoing researches are carried out based on the vibration-based assessment of the bridge structure to evaluate the structural condition and overall integrity. A structural distress, locally or globally leads to de-creasing in stiffness and free energy stored in the system or structure. Under the influence of the ambient and force excitation, vibration response is influenced by system parameters (stiffness, mass and damping), changes in these parameters may lead to changes in the vibration response such as natural frequencies, mode shapes and modal damping. The dynamic response of the bridge structure ismeasured. With thismeasured response modal parameters as well as system parameters can be obtained. These identified parameters can be used to monitor the performance of the bridge structures. Analytical models can also be used to validate using these parameters. In this paper, detailed review of the ambient vibration testing of bridge is given.

ThiriPhyoeDr. Kyaw Lin Htat This paper presents vibration analysis of steel truss bridge under various moving Times by using STAAD-Pro Software. The proposed bridge is warren truss, through type. The bridge length is 240ft. The considered Timings on bridge are dead Times, live Times, wind Time, impact effect, seismic effect and temperature effect. For vehicle live Time, two types of Timing (train and truck Timings) are considered. Truck is HS25-44 truck of AASHTO Specification and train is Meter Gauge train of IRS Specification. For the bridge model, AASHTO (2010) Timing combination is used. Design calculation of structural steel members are considered according to the design criteria of AISC-ASD Specifications. Deflection checking is carried out in order to e nsure that the structure is safe under the various Times. In the vibration analysis, moving Times are considered as harmonic Timing and then, vibration effect is analyzed. Finally discussions and conclusions are made for this vibration analysis.

Luca Della Longa Antonino ,Morassi Anna Rotaris This paper deals with a class of free vibrations for a two-span, two-lane steel-concrete bridge. The deck structure is modeled as a thin, homogeneous, orthotropic plate stiffened by beams running along the longitudinal direction of the bridge. The method of separation of variables is Used to find exact solutions for a class of free vibrations of the structure. A comparison between analytical and experimental natural frequencies and vibration modes of the bridge is presented and discussed

Geert Lombaert1, Joel P. ConteVehicle-bridge interaction has been studied for a long time to investigate the structural behavior of bridges and vehicle ride comfort. An original frequency domain method is presented where the vehicle-bridge interaction problem is solved in a frame of referencethat moves with the vehicle. The Fourier transform of the interaction force is compute directly from the vehicle compliance and bridge compliance, without requiring any iterations. The method is particularly useful when a closed-form solution of the bridge compliance isavailable, as in the case of a simply supported Euler-Bernoulli beam model for the bridge. The solution is, therefore, well-suited for parametric studies on the bridge and vehicle response characteristics and offers a reference for more detailed models of the bridge and the vehicle or more complicated bridge configurations (e.g., continuous beam on multiple supports). The frequency domain approach also leads to enhanced physical understanding, because it shows how the interaction force decomposes into a term resulting from the dynamic response of the bridge to the constant moving Time component and a term because of road surface unevenness.

III. METHODOLOGY

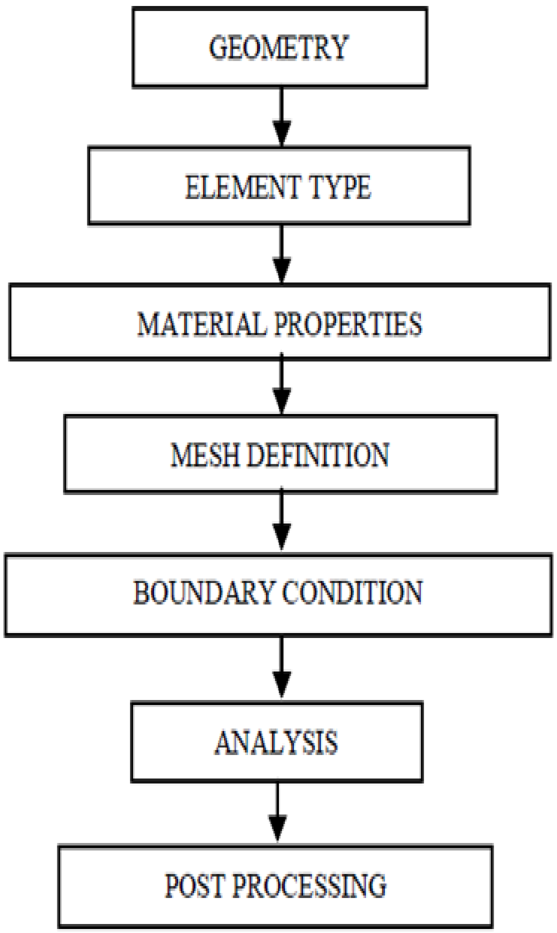

Fig.2Solutions Technique and Steps

The finite element method (FEM) is the most popular simulation method to predict the physical behavior of systems and structures. Since analytical solutions are in general not available for most daily problems in engineering sciences numerical methods like FEM have been evolved to find a solution for the governing equations of the individual problem. Much research work has been done in the field of numerical modelling during the last thirty years which enables engineers today to perform simulations close to reality. Nonlinear phenomena in structural mechanics such as nonlinear material behavior, large deformations or contact problems have become standard modelling tasks. Because of a rapid development in the hardware sector resulting in more and more powerful processors together with decreasing costs of memory it is nowadays possible to perform simulations even for models with millions of degrees of freedom. In a mathematical sense the finite element solution always just gives one an approximate numerical solution of the considered problem. Sometimes it is not always an easy task for an engineer to decide whether the obtained solution is a good or a bad one. If experimental or analytical results are available it is easily possible to verify any finite element result. However, to predict any structural behavior in a reliable way without experiments every user of a finite element package should have a certain background about the finite element method in general. In addition, he should have fundamental knowledge about the applied software to be able to judge the appropriateness of the chosen elements and algorithms. This paper is intended to show a summary of ANSYS capabilities to obtain results of finite element analyses as accurate as possible. Many features of ANSYS are shown and where it is possible we show what is already implemented in ANSYS.14 Workbench.

3.1 Material modeling

The definition of the proposed numerical model was made by using finite elements available in the ANSYS code default library. SOLID186 is a higher order 3-D 20-node solid element that exhibits quadratic displacement behavior. The element is defined by 20 nodes having three degrees of freedom per node: translations in the nodal x, y, and z directions. The element supports plasticity, hyper elasticity, creep, stress stiffening, large deflection, and large strain capabilities. It also has mixed formulation capability for simulating deformations of nearly incompressible elastoplastic materials, and fully incompressible hyper elastic materials. The geometrical representation of is show in SOLID186

3.2 Failure criterion

Two limits are established to define the ultimate Time for each finite element investigation: a lower and an upper bound, corresponding to concrete compressive strains of 0.2%, and 0.35%, respectively. These two limits define an interval in which the composite beam collapse Time is located. A third limit condition, hereinafter referred to as the stud failure point, can also be reached when the composite beam’s most heavily Timed stud reaches its ultimate Time, as defined from the appropriate push-out tests. If the stud failure point is located before the lower bound of concrete (i.e., the corresponding Time of the stud failure point is smaller than the lower bound Time) then the mode of failure of the composite beam is considered as being stud failure. Conversely, if the stud failure point is located after the upper bound of concrete, the mode of failure is assumedas being concrete crushing. For the intermediate case, where the stud failure point lies between the lower and upper bounds of concrete, than the mode of failure could be either of them. Therefore, the proposed finite element model is able to predict the failure modes associated with either slab crushing or stud failure.

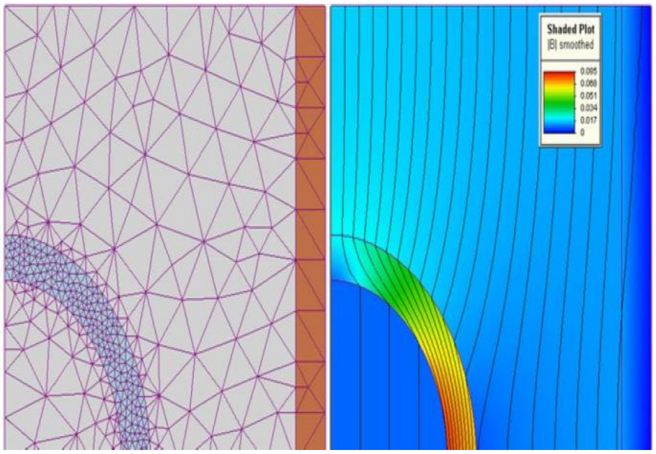

Fig.3 Finite Element Method

FEA is a tool used for the evaluation of structures and systems. It is useful for problems with complicated geometries, Timings, and material properties where analytical solutions can not be obtained. The finite element method has been an obvious choice for the modeling and analysis of reinforced concrete systems for many years. Finite elements have the unique capability to conform to virtually any geometry that could be physically implemented. Thus, the finite element method has gained acceptance as an appropriate tool for the analysis of flat plates, especially those with highly irregular or unusual geometries where the direct design and equivalent frame techniques are not valid. The finite element method can be shown to accurately solve for the distribution of stress. Few of these achievements have been implemented in practical applications for structural engineers in the design office. While much analytical work has been focused on the application of nonlinear constitutive modeling of reinforced concrete, most software packages currently implemented offer only linear elastic finite element capabilities

3.3 Problem Statement

In this chapter the steel deck bridge analyses with effective span 35m, slab thickness 100 mm and section area 85. 91cm^2.The deck having depth of section(h) 350mm, width of flange (b) 250mm, thickness of web (tw) 8.3 mm Ixx=19159.7 cm^4, Iyy=2451.4cm^4rxx=14.93cm ryy=5.34, w=67.4kg

Material Property

STEEL

Yield strength, fy= 248 MPa (33 ksi)
Modulus of elasticity, Es= 200 GPa (29,000 ksi)

CONCRETE

Modulus of elasticity, Ec =26.3 GPa (3.81 ksi)

FRP

Modulus of elasticity, E = 30 GPa
Ultimate tensile strength, Xt =1700 MPa
Ultimate compression strength, Xc = 639.54 MPa
Density = 2100 kg/m^3

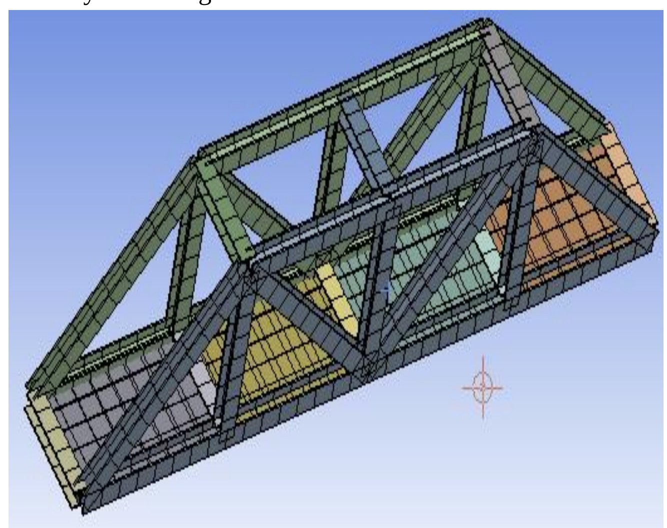

Fig.4 Mesh Formation

Cases Consideration

- Case 1 - FRP Thickness 50 mm
- Case 2 - FRP Thickness 100mm
- Case 3 - FRP Thickness 150mm

Timing Consideration

1. IRC Class AA
2. IRC Class A

In this study transient analysis is performed in ANSYS 16 which time dependant. A moving Time apply according to IRC Class AA Timing and IRC Class A Timing is passing through bridge deck for time period of 1min. Hence the time interval is taken as 0.2 second for each step.

IV. THEORETICAL CONTENTS

4.1 What is an FRP bridge deck?

A number of terms commonly used to describe a bridge's superstructure are illustrated in Figure shown below the components of the bridge above the bearings are referred to as superstructure, while the substructure includes all parts below. The main body of the bridge superstructure is known as the deck and girders/beams (Figure 1.1). An FRP bridge deck in this discussion is defined as a structural element made from FRP materials that transfers Times transversely to the bridge supports such as longitudinal running girders, cross beams, and/or stringers that bear on abutments.

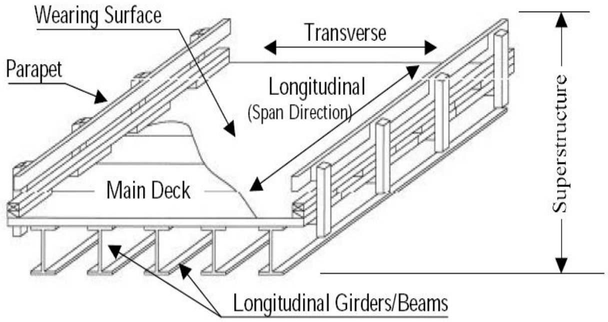

Fig.5 Superstructure of a bridge illustrating bridge engineering terms

Different from conventional construction materials, FRP is an engineered material. Engineers can design the material properties and structural shapes of FRPs based on their requirements. Therefore, it is essential to know the composition of FRP material. FRP material consists of two major components: a polymer matrix resin and fiber reinforcements. Fillers and additives, as a third component, can improve certain characteristics of the final product.

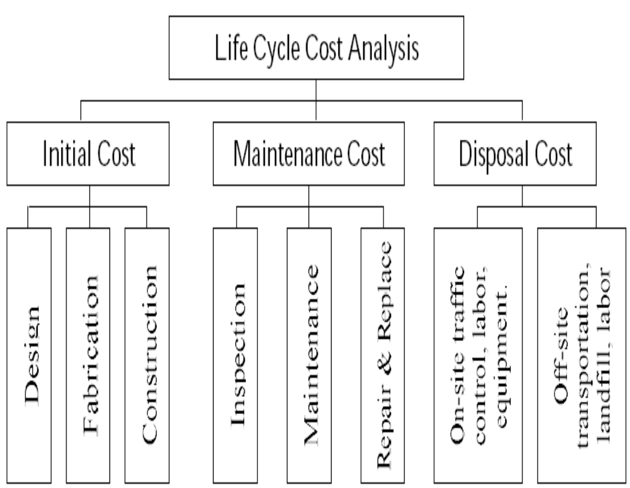

Fig.6Cost classification scheme for FRP bridge decks

4.2 Benefits and Challenges of FRP Bridge Decks

FRP bridge decks have successfully transitioned over the past decade from the experimental research stage to the field application stage. More than 100 bridges have been built or repaired with FRP bridge deck systems in the USA alone. This section summarizes the main benefits and challenges of FRP bridge decks based on their laboratory results and field performances.

The benefits of using FRP bridge deck systems are summarized as follows:

1) Non-corrosive properties of FRP can extend the service life of FRP bridge deck;
2) High quality results from well controlled factory environment;
3) Construction of FRP bridge decks is easier and faster than conventional bridge deck construction, which leads to less traffic control time, and less negative environmental impact;
4) Lightweight FRP bridge decks make it possible to increase the live Time carrying capacity of a bridge without retrofitting its substructure;
5) Compared with conventional materials, FRP material has high strength but relatively low stiffness. Since the design of FRP bridge deck systems is based on stiffness requirements, this innovative bridge deck has a very high safety factor;
6) FRP bridge decks are excellent replacements for 19th and 20th century steel truss bridges and moveable bridges because they can reduce deck dead Time, improve
7) According to the projected durability of FRP material, costs of bridge deck replacement and maintenance are significantly reduced, which results in lower life cycle costs.

Although many benefits have been proven by laboratory tests and field projects, there are still some challenges in the use of FRP bridge deck systems:

1) High initial cost is the major barrier to develop the FRP bridge deck market. Constrained construction budgets make it difficult to justify dedicating more funds in the beginning even though the life cycle cost of FRP bridge decks is relatively lower;
2) The design of FRP bridge deck is based on finite element analysis. No official guidelines nor specifications for the design and construction of FRP bridge decks are available on the market;
3) The lightweight attribute of FRP bridge decks may cause the bridge superstructure to be aerodynamically unstable, especially for large-scale bridges (Tang, 2003);

4) For field installation, the joint details need to be examined and further developed, which include joints between FRP panels.
5) Durability of the wearing surface needs to be well addressed;

Exchange of knowledge is still required between composite engineers and bridge engineers

V. CONCLUSIONS

The following conclusions have been drawn based on the results obtained from present study:

1. For moving Time FRP bridge deck gives better performance
2. Total Deformation is reduced using FRP by 25% which can affect the design approach of steel deck bridge
3. Strain energy observed more than without FRP
4. Normal stress is 20% less than without FRP
5. shear stress is observed 20% to 25%less without FRP it indicates better shear resistance against vibration induce due to moving Time
6. FRP layers can be used for rehabilitation of bridge deck
7. According to time step Timing total deformation normal stress, shear stress and strain energy are decrease continuously using FRP layer for IRC Class A
8. According to time step Timing total deformation normal stress, shear stress and strain energy are decrease continuously using FRP layer for IRC Class AA
9. In vibration analysis in ANSYS the application of FRP reduces the response peak displacement by 15%

VI. SCOPE FOR FUTURE WORK

- Another field of wide research could be the vibration analysis and design of precast girder with base isolation system
- The study of vibrational behavior of structural system could be extended using one another software

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