INTEGRAL ABUTMENT BRIDGE MODEL EXPLORATION: DIFFERENT BOUNDARY CONDITIONS FROM SIMPLY SUPPORTED TO FULLY-FIXED.

Muhammad Khairil Ibrahim, Azlan Ab Rahman, Baderul Hisham Ahmad, and Fairul Zahri Mohamad Abas

Department of Structure, Faculty of Civil Engineering, Universiti Teknologi Malaysia, Malaysia

Jabatan Kerja Raya, Kuala Lumpur, Malaysia

imkhairil@gmail.com, azlan@utm.my, baderul@utm.my, fairul@jkr.gov.my

ABSTRACT Integral Bridge is the type of bridge which is constructed without any movement joints between span or between span and abutment. It is an innovation in a bridge design by fusing the articulation between span and abutment from traditionally as a simply supported condition to the fully fixed in all degree of freedoms. Before the emergence of an integral bridge, most of bridges in Malaysia are commonly being designed as simply supported. The evolution of integral bridge from simply-supported not only alters the static behaviour of the bridge but also its dynamic characteristics, i.e. natural frequency, mode shape and damping ratio. Essentially, the dynamic characteristics is used as an indicator for damage evaluation in structural health monitoring and forensic engineering. This paper presents the differences of dynamic characteristic of a beam and slab type of bridge by changing the boundary conditions from simply-supported to fully-fixed. The investigation has been carried out by 3-D modelling in finite element package. In a fully fixed state, gradual changes of substructure stiffness component have been introduced by firstly taking account only the abutment. Secondly by including the pile foundation into the model to act as a fully integral type of bridge together with the soil interaction. The objective of this paper is to explore the changes in dynamic characteristics from traditional bridge design to integral bridge with different types of supports. The outcomes of this paper may be used for as references and behavioural prediction in relevant applications as mentioned above. From the investigation, the result shows an increase of natural frequencies from simply supported to the fully fixed type of articulation between span and abutment. Also, the results shows higher value of natural frequencies as the stiffness of substructure increased. Moreover, integral bridge model demonstrates a significant different in mode shape behaviour, as compared to simply supported type. However, further study is suggested to be conducted on a real specimen to verify the theoretical results.

1. INTRODUCTION

1.1 Bridge

Bridge is a man-made structure/mechanism to cross obstacles such as river, valley, road, etc. The history of bridge same as old as human history. Besides the evolution of bridge construction materials from readily available material such as wood, steel, concrete to the most advance material like fibre reinforced polymer (FRP), bridge design concept also evolves radically (Smith, J. W.1994).

1.2 Simply Supported Bridge

This type of bridge is a common type bridge that been used in centuries. The simplest concept of design and construction, made this type of bridge very popular in the bridge engineers community. The lateral movements of the bridge are being accommodated by bearing and expansion joint. Although this type of bridge is considered popular, the shortfall of this bridge is due to maintenance of bearing and expansion joint.

1.3 Integral Bridge

Current trends in bridge design have evolved from traditional simply supported type to integral bridge or semi integral. Using this type of bridges the two components which have short lifespan period, i.e. bearings and expansion joint is being abandoned (J. Connal, 2004). The lateral movement and the rotational moment in this design is being tackled by full response of the bridge (M Dicleli&S.M. Alhabishi, 2004). Behaved as a frame in design concept, the movements will be transferred entirely to the bridge from the superstructure and substructure including the supporting piles.

1.4 Eigen Frequencies

Extraction of Eigen frequencies has been carried out by numerous researchers (Morales et al, 2003). The different boundary conditions resulted in different modal characteristic, e.g. natural frequency and mode shapes (H. Bachman & W. Ammann, 1987). For simple beam with different boundary condition, the natural frequency and mode varies significantly, the three dimensional bridge structure is more complex to predict their characteristic.

2. METHODOLOGY

2.1 Modelling

ABAQUS software being used to model this bridge. An initial model is a simply supported type. The extraction of dynamic characteristic of simply supported bridge is then being compared with open researches to validate the result. Simply supported model being chose as a comparison subject is due to unavailability of open literature on dynamic characteristic for semi integral and integral bridge. After the validation of simply supported model being made, the model is further extended to semi integral to obtain the dynamic characteristic of the semi integral bridge.

2.2 Eigen Frequency Extraction

The dynamic characteristic of the bridge i.e. natural frequencies and mode shapes were obtained through the frequency step module and natural frequency extraction capability offered in ABAQUS software. The Lanczos Eigen solver method was chosen with the minimum number of Eigenvalues of 4. The application of the Lanczos Eigen solver as a tool for extraction of the extreme eigenvalues and the corresponding eigenvectors of a sparse symmetric generalized Eigen problem has been well accepted by many researchers (Abaqus, 2013).

3.0 ANALYSIS & RESULT

3.1 Governing Equation

The natural frequency for undamped finite element model using Eigenvalue can be written as:

$$(\mu^2 M + \mu C + K)\,\phi = 0 \qquad (1)$$

Considering K is symmetrical and neglecting C in Eigen value extraction will lead to real squared Eigen value and vectors.

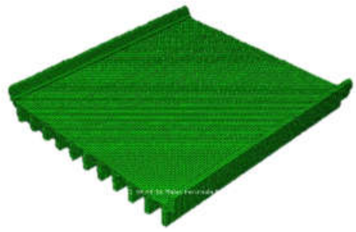
Assuming K is positive semi definite, the equation (1) can be written as:

$$(-\omega M + K)\phi = 0 \qquad (2)$$

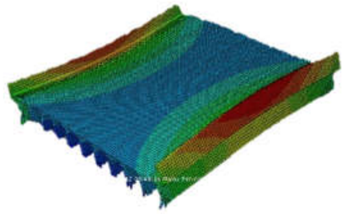
Where:
ω is a circular frequency
M is a mass matrix
K is a stiffness matrix
C is a damping coefficient
Φ is an Eigenvector

When is positive definite, all eigenvalues are positive. Rigid body modes and instabilities cause to be indefinite. Rigid body modes produce zero eigenvalues. Instabilities produce negative eigenvalues and occur when you include initial stress effects.

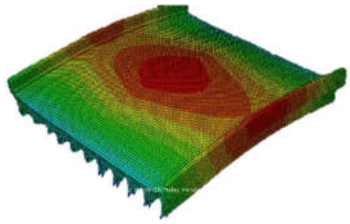
3.2 Dynamic Characteristic



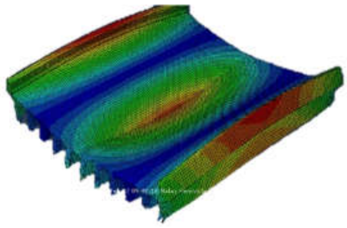
a. Initial Condition



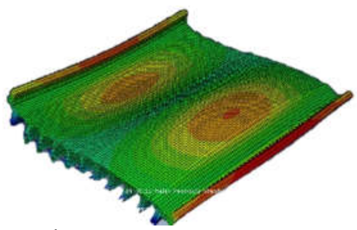
b. 1st Mode : 9.025 Hz



c. 2nd Mode : 9.343 Hz



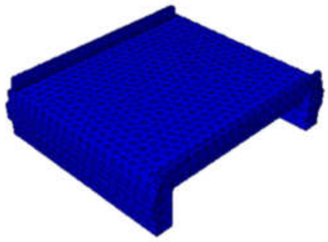
d. 3rd Mode : 10.197 Hz



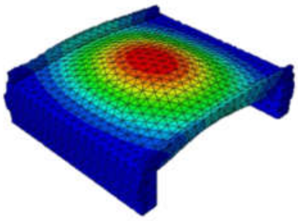
e. 4th Mode : 10.955 Hz

Fig. 1 (a-e) Natural Frequencies and Mode Shape for Simply Supported Bridge

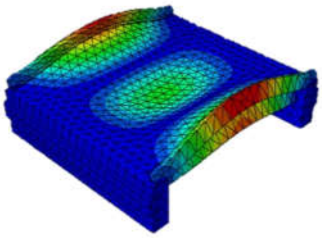
For simply supported bridge, we can see that the natural frequency occurs at 9.02 Hz to 11.00 Hz gradually increase from the first mode to fifth mode. The bending mode happens at the first and second mode, while for third and fourth mode, the mode shapes tend to exhibit the torsional type.



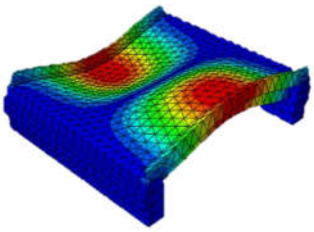
a. Initial Condition



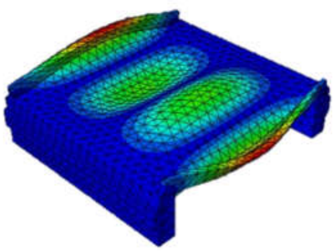
b. 1st Mode :23.930 Hz



c. 2nd Mode : 25.084 Hz



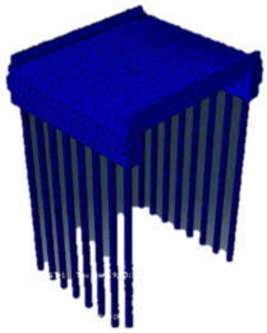
d. 3rd Mode : 26.401 Hz



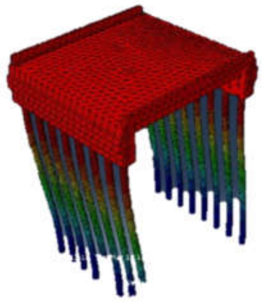
e. 4th Mode : 28.011 Hz

Fig. 2 (a-e) Natural Frequencies and Mode Shape for Semi Integral Bridge

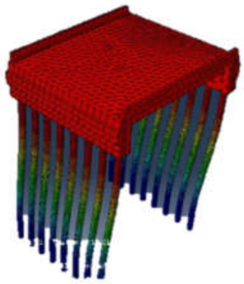
As for semi integral bridge, the natural frequency is 23.9 Hz for first mode, gradually increase to 28.01 Hz for fourth mode. The mode shapes of this type of bridge still exhibit the same as simply supported which is bending and torsion type of mode shape can be recorded.



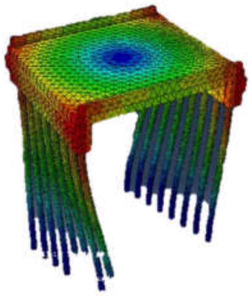
a. Initial Condition



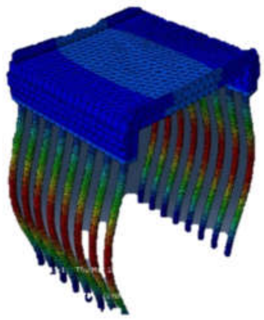
b. 1st Mode : 0.451 Hz



c. 2nd Mode : 0.455 Hz



d. 3rd Mode : 0.595 Hz



e. 4th Mode : 4.857 Hz

Fig. 3 (a-e) Natural Frequencies and Mode Shape for Integral Bridge

For Integral bridges' first three modes, natural frequency shows the value of 0.45 Hz to 0.595 Hz respectively. The fourth mode, show the natural frequency of 4.857 Hz. The deflected element in integral bridge happens mostly on supporting element which are piles.

CONCLUSION

As a conclusion, we can see that different types of boundary lead to significant change in natural frequency. As for mode shapes both simply supported and semi integral does have similarity in their deflected mode compared to integral bridge.

REFERENCES

Smith, J. W. Theory and design of bridges: by Petros P. Xanthakos, Wiley Interscience, New York, 1994.

Moreles, M. A., Botello, S., & Salinas, R. Computation of eigenfrecuencies for elastic beams, a comparative approach. Internal Report No I-03-09/25-04, 2003.

Connal, J. Integral Abutment Bridges–Australian and US Practice. 5th Austroads Bridge Conference. 2004

M.Dicleli & S.M. Alhabishi, 2004

Bachmann, H., & Ammann, W. Vibrations in structures: induced by man and machines (Vol. 3). IABSE.1987.

Dessault System. 2013. Abaqus 6.13. Abaqus/CAE Analysis Theory Manual.

Muhammad Khairil Ibrahim received the B.E. (2005) from Universiti Teknologi Malaysia, and M.E. (2010) from Universiti Putra Malaysia. He obtained his Professional Engineer from Board of Engineer, Malaysia in 2009.

Currently he is a PhD candidate under supervision of Prof. Dr. Azlan Ab Rahman, Assoc. Prof. Baderul Hisham Ahmad and Dr. Ir. Fairul Zahri Mohamed Abas.

Azlan Ab Rahman received the B.Sc. (1983) from University Manchester, U.K , M.Sc. (1986), and PhD. (1993) degrees from University of Surrey, U.K.

He is currently a full Professor in Structural Engineering, majoring in Bridge Engineering and Non-Destructive Testing of Concrete Structures. His other fields of interest are in Structural Health Monitoring of Bridges and Forensic Engineering Investigation of Structures.

Baderul Hisham Ahmad received the B.E. (1984) from Universiti Teknologi Malaysia, M.Eng. (1980) degrees in structural engineering from University of Bradford, U.K.

He is an Assoc. Professor, Department of Civil Engineering, Universiti Teknologi Malaysia. His Current interests include are in Advances Design and Structural Health Monitoring of Bridges

Fairul Zahri Mohamad Abas received the B.Eng. from University of Bradford, U.K, M.E. from University Putra Malaysia, and PhD from University of New South Wales.

He is a Senior Assistant Director, Bridge Unit, Public Work Department Malaysia.