IOP Conference Series: Materials Science and Engineering

PAPER • **OPEN ACCESS**

Numerical Modeling of New Connection Pontoon under Static and Dynamic Loads

To cite this article: Ahmed S Elareshy *et al* 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **974** 012006

View the article online for updates and enhancements.

Military Technical College
Kobry El-Kobbah, Cairo,
Egypt

13th International Conference
on Civil and Architecture
Engineering
ICCAE-13-2020

Numerical Modeling of New Connection Pontoon under Static and Dynamic Loads

Ahmed S Elareshy[1], Mostafa M Abdel Wahab[2], Shreif A Mazek[3], and Ashraf M Osman[4]

[1] M.Sc. Student, Department of Civil Engineering, Military Technical College, Egypt.
[2] Professor at Department of Civil Engineering, Military Technical College, Egypt.
[3] Professor at Department of Civil Engineering, Military Technical College, Egypt.
[4] Asst. Professor at Department of Civil Engineering, Military Technical College, Egypt.

Corresponding author: samy_mtc@yahoo.com

Abstract. The development of floating bridges is a major engineering challenge to make the existing bridges durable and easy to construct. The connection pontoon unit between the heavy communication bridge (HCB) and the assault bridge (AB-PMM71) is discussed as developed by Mazek et al. [1]. The new connection pontoon (NCP) should offer fast assembly time to operate the combat floating bridge.
The floating bridge system including the HCB, the AB-PMM71, and the NCP is modeled. The 3-D numerical model of the floating bridge system is proposed by the nonlinear finite element analysis under static and dynamic Military load Class MLC70. The field test for the new floating bridge system was conducted by [1].
The proposed finite element model of the floating bridge system is verified based on the practical field test developed by [1]. The numerical results have good agreement with those obtained by the reviewed field test.

Keywords: Floating Bridges, Dynamic Analysis, Military Load Class 70 ton (MLC70).

IOP Conf. Series: Materials Science and Engineering **974** (2020) 012006 doi:10.1088/1757-899X/974/1/012006

1. Introduction

The floating bridge is considered a very important structure in military operations. There is a great engineering interest to develop the floating bridges. One of the most important properties of the floating bridges is the assembly time to operate the heavy floating bridge which is a difficult process. The new connection pontoon (NCP) has been designed and validated experimentally by [1]. In this paper, a numerical study has been conducted using 3-D finite element analysis on the NCP. The numerical results have been compared with those obtained by the field tests conducted by[1].

The floating bridges offer an economic and efficient solution for crossing obstacles and barriers where the situation is unstable for traditional bridges [2]. The construction cost of conventional bridges is about four times more than the cost of floating bridges [3]. The structural system of floating bridges differs from one location to another. There are no defined rules to analyze and design floating bridges [4]. There is no code to find out the dynamic behavior due to the large variation in many factors such as water current, wave forces, depth of water, and the width of the water channel [4]. There is no engineering database for these floating structures. A direct design approach needs to be used for each bridge [5].

In recent years, engineering efforts have been conducted to increase the efficiency of floating bridges to be more lightweight, high-capacity, higher maneuverable and more competence [6]. Khalifa et al. [7] used the 3-D finite element method to study the best method to improve the assault floating bridge (AFB) performance from MLC60 to MLC70 for different five proposals. Khalifa et al. [8] presented the analysis of the old assault floating bridge under MLC60 and MLC70 and upgraded this bridge to carry MLC70. Viecili et al. [2] studied analytically and experimentally the dynamic behavior of ribbon pontoon floating bridges under two-axle vehicle loading. The maximum displacements of pontoon floating bridges at different vehicle speeds and weights were predicted and compared with experimental results.

Sun et al. [9] studied the hydrodynamic response of a newly designed pontoon floating bridge under regular waves by an experimental test. A numerical analysis was conducted to compare the results with the model test results. The bending moment along the entire floating bridge was obtained and analyzed to get the nonlinear hydroelastic effects. The results showed that the bending moment along the floating bridge model wasn't firmly linearly proportional to the wave heights, which might result from nonlinear connectors or nonlinear hydrostatic forces. It was concluded that nonlinear connections have an important influence on bending moment and should be considered in the design of floating bridges.

Zhang et al. [10] studied the dynamic responses with hydrodynamic influence coefficients for different water depths on two types of floating bridges; the continuous pontoon floating bridge and the separate pontoon floating bridge. Analytical models based on beam theory have been presented to study the dynamic responses of two types of floating bridges subjected to moving loads. The results showed that the displacement response curves happened due to a high-speed moving load is smoother than a low-speed one, and the water depth can be neglect during the floating bridge design.

Fu and Cui [11] studied the hydroelastic responses of a ribbon floating bridge consisting of several nonlinearly connected modules under moving loads from both experimental and numerical tests. The results showed that the downward dynamic response slightly increased with the moving load speed while the upwards dynamic response increased with the increase of the load moving speed and was more sensitive to the moving speed compared with the downwards response. The nonlinearity of the connectors had a great influence on the dynamic response of the floating bridge especially for the upward dynamic responses. Raftoyiannis et al. [12] studied the dynamic response of a continuous floating bridge under the action of a moving load with various constant velocities. This study was formed by an analytical method based on the Runge-Kutta method and numerical analysis to verify the analytical method. The analytical results showed that the velocity of the dynamic load had a great effect on the maximum oscillation amplitude of the bridge. The wave forces cause oscillations with significant amplitude in the cases of light-weighted pontoons, while for heavy-weighted pontoons this effect is significantly lower. The results showed that the difference between the analytical and numerical results was about 5%.

Shixiao et al. [13] studied the dynamic response of a nonlinear connected floating bridge taking into account the nonlinear properties of connectors and the vehicle's inertia effects. The equations of motions were proposed and solved with the Newton-Raphson iteration method. As a result, nonlinearities and the initial gap of the connectors must be considered for the nonlinear connected floating bridge since they have a noticeable effect on the static deflection, dynamic displacement responses and dynamic connection forces of the bridge. Qiu 2009 [14] analyzed numerically the dynamic response a free–free flexible beam floating in a boundless water field under the effect of moving loads. A finite element method was developed directly in a time domain and was applied to solve the 2-D problem. The results showed great effects of the traveling speed, the water depth and the beam length on the behavior of the floating elastic beam.

Xujun Chen et al. [15] investigated the hydrodynamic performances of a moored pontoon in finite depth water by numerical and experimental analyses. The dynamic behavior of the floating pontoon, as well as the chain forces in different wave heights and wave angles, were calculated with a wide range of wave periods by the numerical method. From the results, it can be concluded that both wave heights and wave angles have clear influences on the motions and the chain forces of the pontoon. The numerical results showed greet agreement with the model tests in majority of cases.

2. Problem statement

Many types of research on floating bridges focused on increasing the capacity of the bridge with decreasing own weight [1]. The decrease in the erection time is an important factor to operate the floating bridge during the war. For this reason, the bridge reoperation time has a great effect to operate the bridge after damage. A new steel floating structure called new connection pontoon (NCP) was used, designed and tested experimentally by [1]. The heavy communication bridge (HCB) takes a relatively long time in structure operations with respect to the assault floating bridge (AFB) [1]. Therefore, the NCP was designed to connect the HCB to the AFB PMM71 due to partial damage to operate again the bridge. The ANSYS 18 software is used.

In this paper, the static and dynamic responses of the NCP are investigated using the 3-D FEM under military load class of 70-ton (MLC70). The study introduces the techniques and procedures used in the ANSYS program to create a geometry model, to generate finite element meshes, to establish boundary conditions, and to select the type of analysis. The maximum bridge displacement is computed at different load speeds and cases of loads. The numerical results are compared to those obtained by the field test conducted by [1].

3. Model description

The bridge system model consists of three parts. The three parts are the HCB, the AFB, and the NCP, as shown in Figs. 1 and 2. The HCB consists of individual pontoons assembled together to form a rigid continuous beam rested on water modeled as elastic supports. The connection between the pontoons is modeled as a rigid connection type from both the top and bottom of the pontoon. The individual pontoon has dimensions of 2.4 m width, 5.25 m length, and 1.5 m height, as shown in Fig. 3. The HCB width is 9.9 m, as shown in Fig. 4. The HCB consists of four individual pontoons with 10 cm spacing between them. The bridge system model used the four individual pontoons for both the HCB and the AFB in the longitudinal direction.

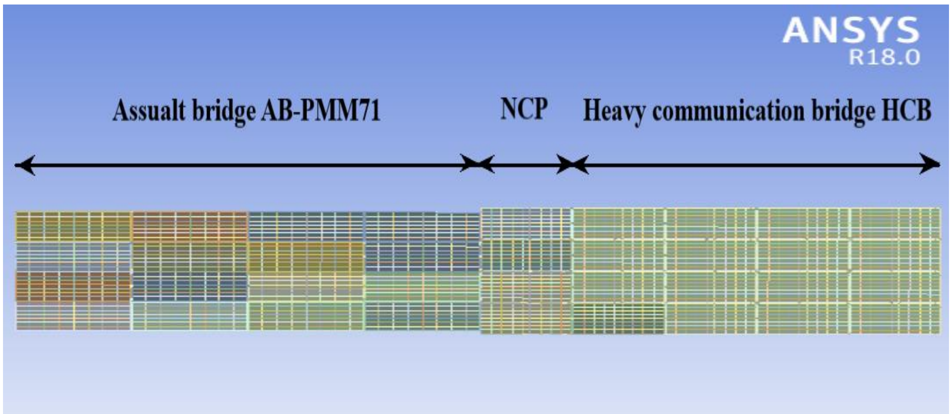

Figure 1: Plan of the bridge system model

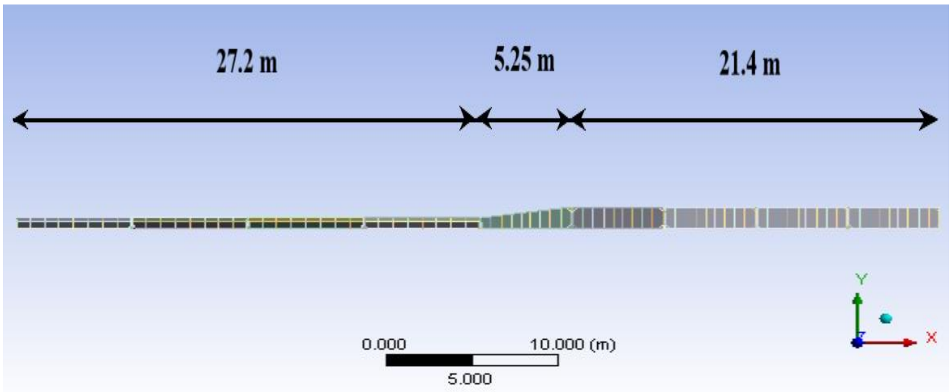

Figure 2: Side view of the bridge system model

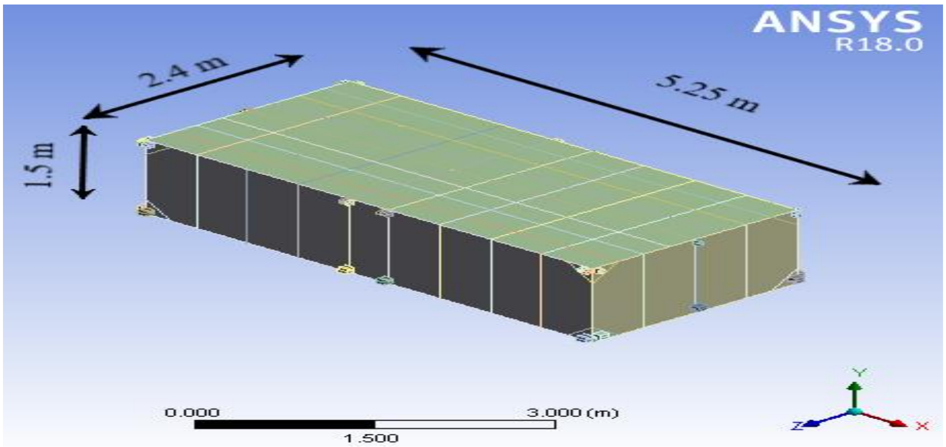

Figure 3: Single heavy communication pontoon

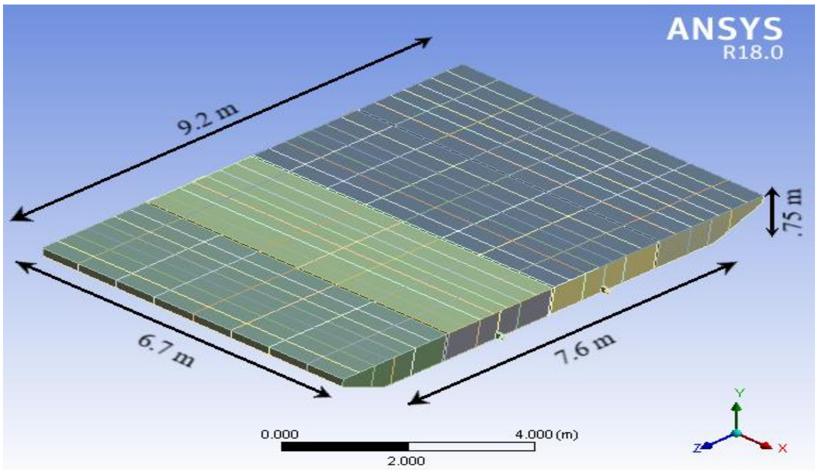

Figure 4: Single unit of the assault bridge AB-PMM7

The AFB consists of four pontoons already assembled together in W-shape. These pontoons were opened automatically as they were launched in water to take the straight shape, as shown in Fig. 4. The connections between the pontoons of the AFB are hinged joints to link the internal pontoons. The connections between the pontoons are set at the bottom without joints at the top to allow rotation about the lateral direction of the bridge. Two steel wires used at the top of the two external pontoons to limit this rotation. These connections resist bending moment beside the shear force. The dimensions of the AFB are 9.2 m width, 6.7 m length, and 0.75 m height. The bridge system model used the four individual pontoons for both the HCB and the AFB in the longitudinal direction [16].

The NCP is the floating structure connecting the two previous bridges together. The longitudinal section of the NCP is trapezoidal shape, as shown in Fig. 5. The height of the one end for the NCP is 1.5 m while the height of the other end is 0.75 m, as shown in Fig. 5. The boundary conditions of the NCP are a rigid connection at the deep side and a hinged connection at the other small side. The width of the NCP is 2.4 m and its internal structure is like the heavy pontoon bridge. The HCB, the AFB, and the NCP have rigid connections in the lateral direction.

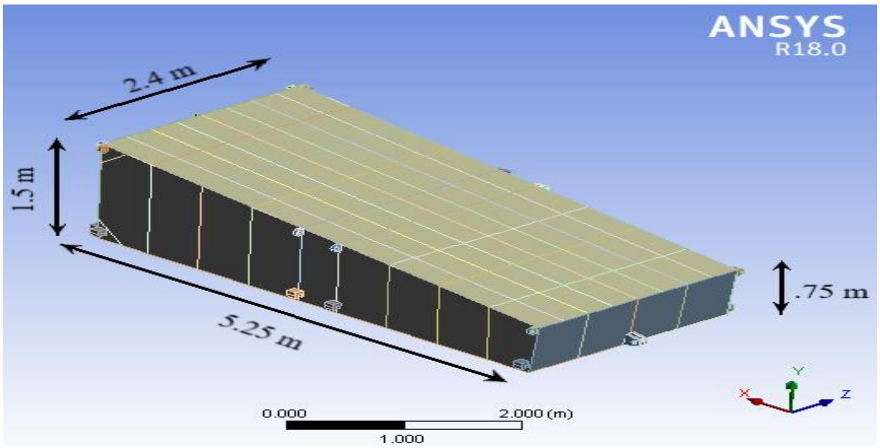

Figure 5: The new connection pontoon

The statical system of the NCP consists of internal structural members that include equal angle, UPN, and I beam sections, as shown in Fig. 6. The NCP is also covered by steel plates. Steel 44 is used in the HCB, the AFB, and the NCP. The water structure interaction is modeled as a beam resting on elastic supports. The stiffness of the elastic support is equal to the buoyancy force which acts upward and equal to the weight of water displaced by the submerged hull of the floating bridge system.

This numerical study was conducted by the 3-D FEA. 3-D beam elements and shell elements are used to model the internal structural members and the steel plates, respectively. The FEM of the floating bridge system consists of 124,093 nodes and 88,366 elements, as shown in Fig. 6.

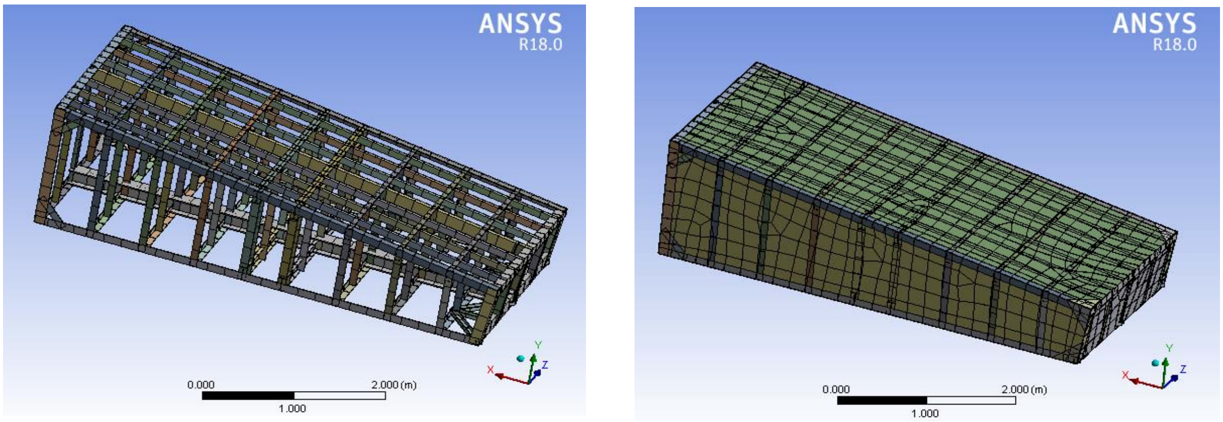

Figure 6: 3-D finite element model of the NCP

4. Floating stability of NCP

The trapezoidal shape of the NCP is considered an engineering challenge to study the stability of the pontoons in water. However, the center of gravity position was changed to be approximately above the center of buoyancy by increasing the weight of the NCP at the lighter side [1]. The draft depth of the HCB is 32 cm after the HCB is placed in water. Therefore, the draft depth of the NCP from the HCB side was the same as the draft depth of the HCB to facilitate the assembly process between the NCP and the HCB. Fig. 7 shows the floating stability and the draft depth of the NCP under its own weight only.

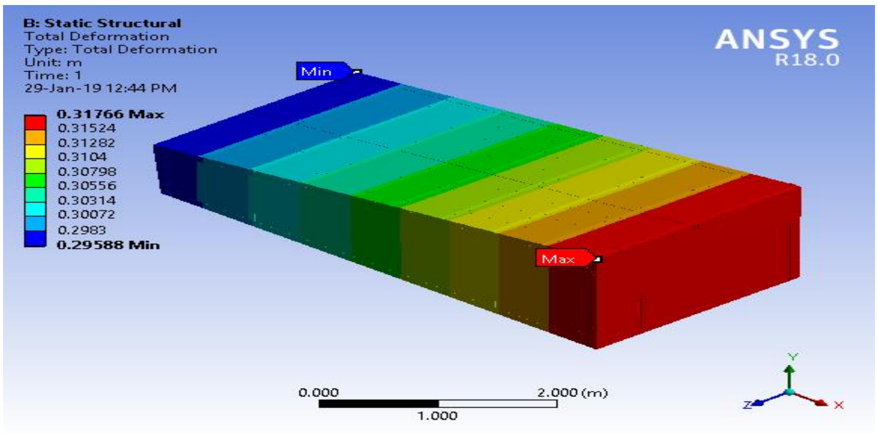

Figure 7: Draft depth of the NCP under its own weight only

5.Static analysis

A static load of 82 tons is used to compute the static deformation and stresses on the bridge using the 3-D finite element analysis (FEA). The static load has been applied in two positions on the bridge system as adopted in the field study [1]. The first case of the static load is placed only on the NCP, as shown in Fig. 8. The second case of the static load is placed on both the NCP and the AFB, as shown in Fig. 9. The static load acts on an area of 4.5 m length and 3.5 m width as this static load simulates the dimension of the tank.

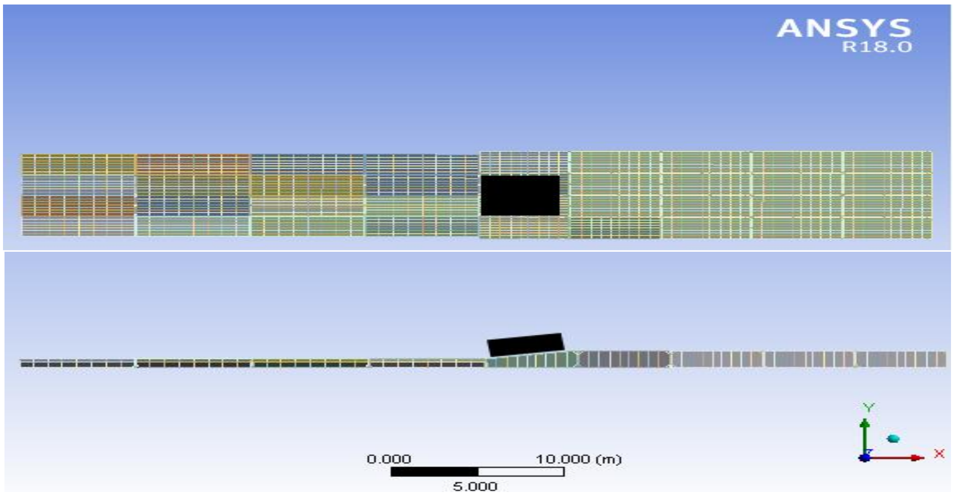

Figure 8: First case of static load

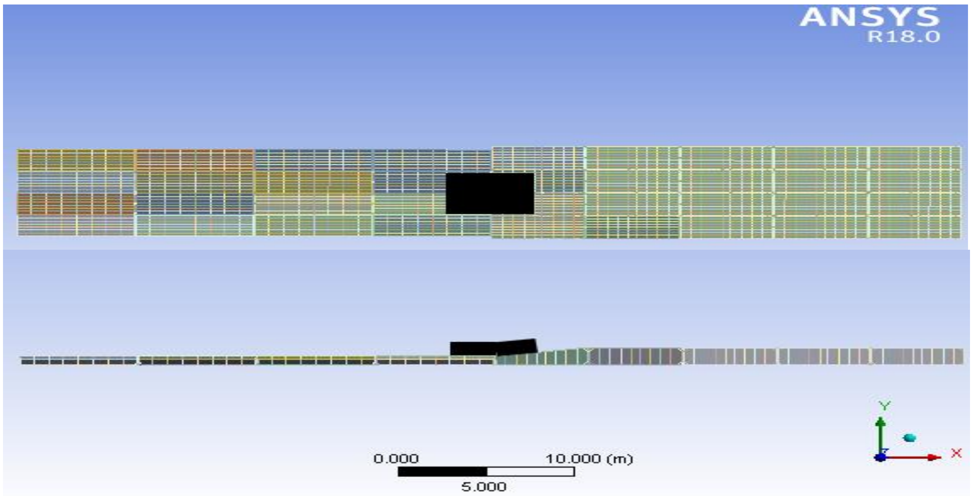

Figure 9: Second case of static load

The results of the first case of static load show that the maximum draft of the bridge is 0.733 m at the NCP edge. The maximum stress developed at the NCP is equal to 860 kg/cm^2. These results show good agreement with the results obtained by the field test [1]. The maximum measured draft depth is equal to .74 m. The discrepancy between the measured and the computed results is 2%.

The second case of static load shows that the maximum calculated draft depth of the NCP is 0.778 m. The maximum calculated stress of the bridge system is equal to 950 kg/cm^2. The second case of static load gives the maximum field draft depth of the NCP to be 0.79 m [1]. There is a good agreement between the calculated readings and the field readings for the draft depth of the NCP as shown in Figs. 10 to 15.

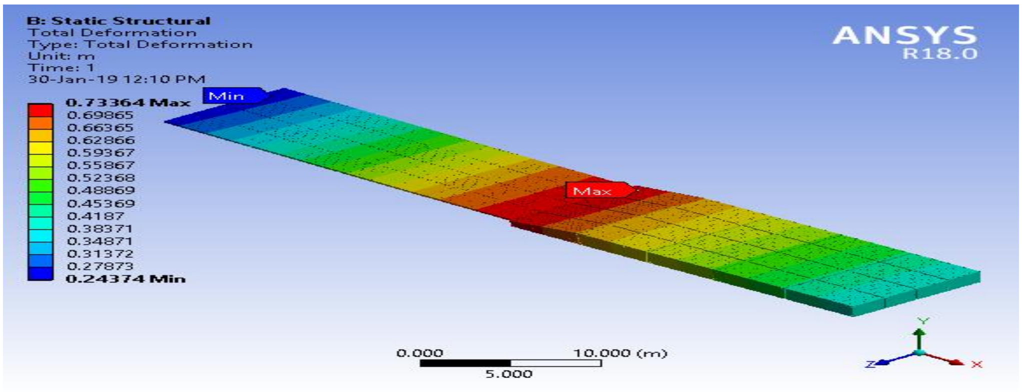

Figure 10: Calculated draft depth of the bridge system under the first static load case

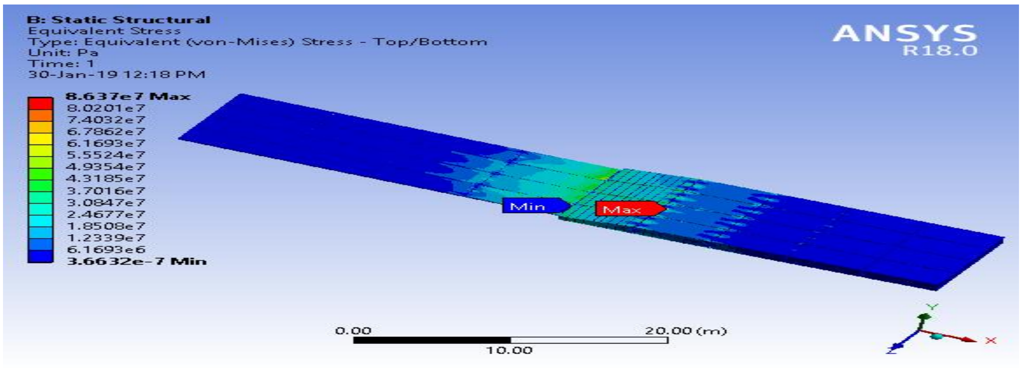

Figure 11: Equivalent stress of the bridge system under the first case of static load

Fig. 12: Field draft depth of the NCP under the first case of static load [1]

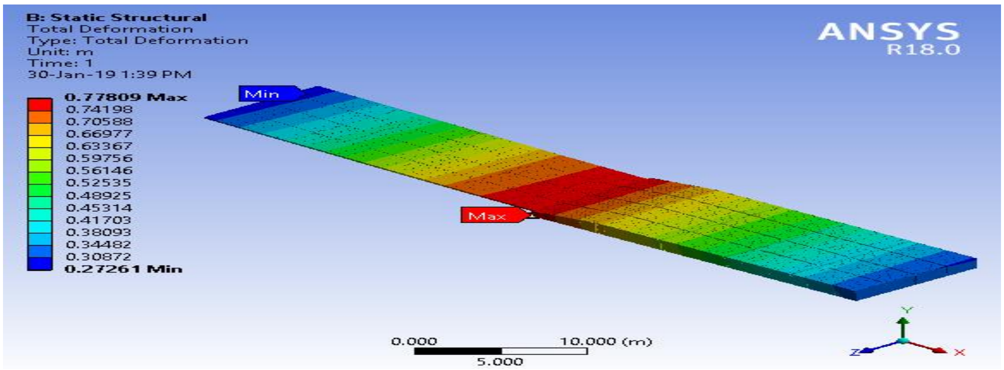

Figure 13: Calculated draft depth of the bridge under the second case of static load

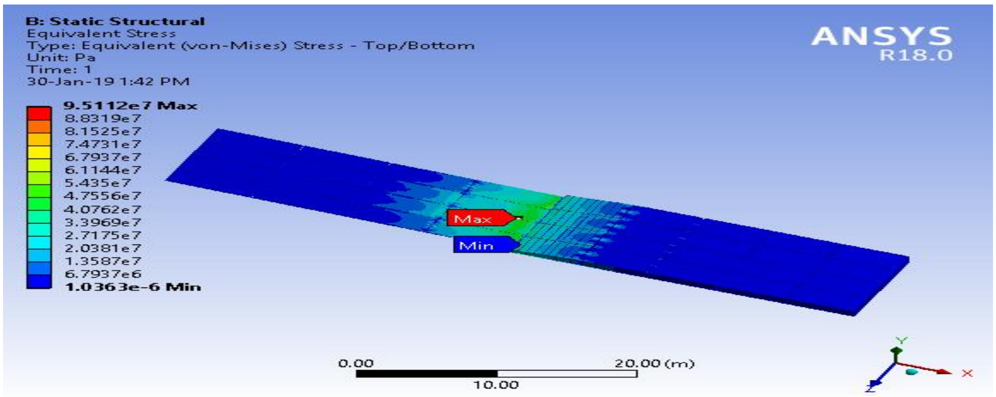

Figure 14: Equivalent stress of the bridge system under the second case of static load

Figure 15: Field draft depth of the bridge system under the second case of static load [1]

6. Dynamic analysis

The Trilateral Design and Test Code (TDTC, 2005) [17] was published to regulate an accepted design limits for different types of military bridges. A 70-ton tank was used in this study in which the 70-ton tank was called MLC70 according to TDTC. The 70-ton tank has two tracks. The footprint of the tank track has 4.57 m long and 0.6 m width. Two cases of operation speeds were used to study the performance of the floating bridge system. The operation speeds of the moving tanks are 8 km/hr. and 16 km/hr.

The results showed the draft depths of the bridge system as presented in Figs. 16 and 17 under the dynamic load MLC70 with speeds 8 km/hr. and 16 km/hr. respectively. The maximum draft depths of the bridge system were 0.756 m and 0.789 m, respectively. The maximum stresses of the bridge system are 1.58 t/cm^2 and 1.63 t/cm^2, respectively, as shown in Figs. 18 and 19.

The maximum draft depths of the bridge system were 0.71 m and 0.73 m at speeds of 8 km/hr. and 16 km/hr., respectively. These results showed good agreement between the numerical results obtained by the FEA and the results obtained by the field test [1].

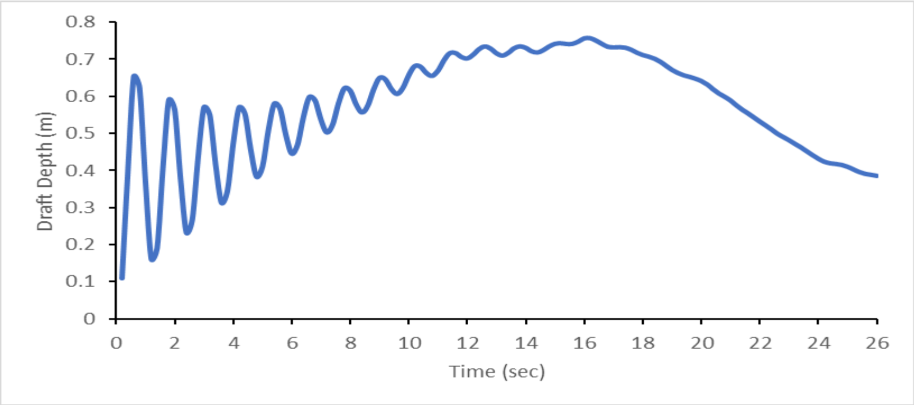

Figure 16: Draft depth of the bridge system under moving load with a speed of 8 km/hr

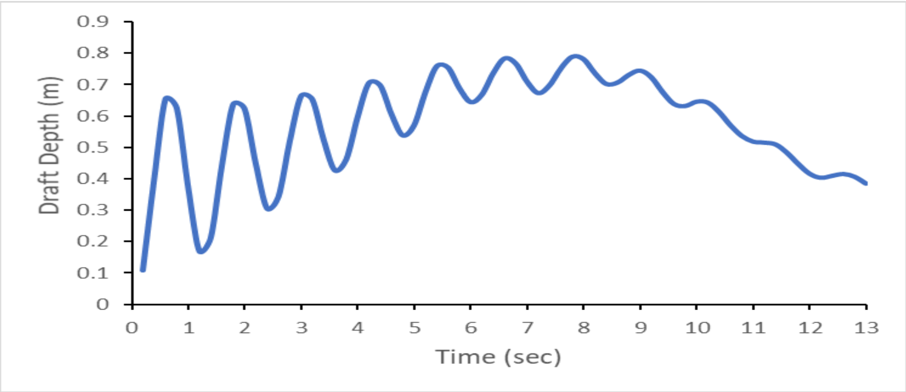

Figure 17: Draft depth of the bridge system under moving load with a speed of 16 km/hr

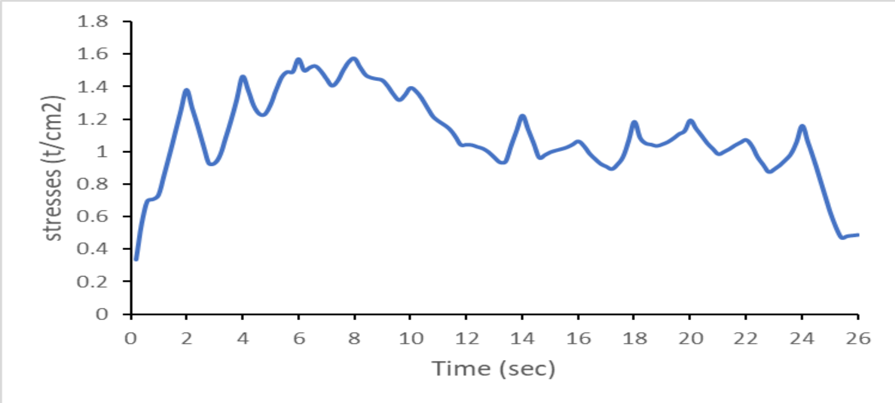

Figure 18: Equivalent stresses of bridge system under the dynamic load of speed 8 km/hr

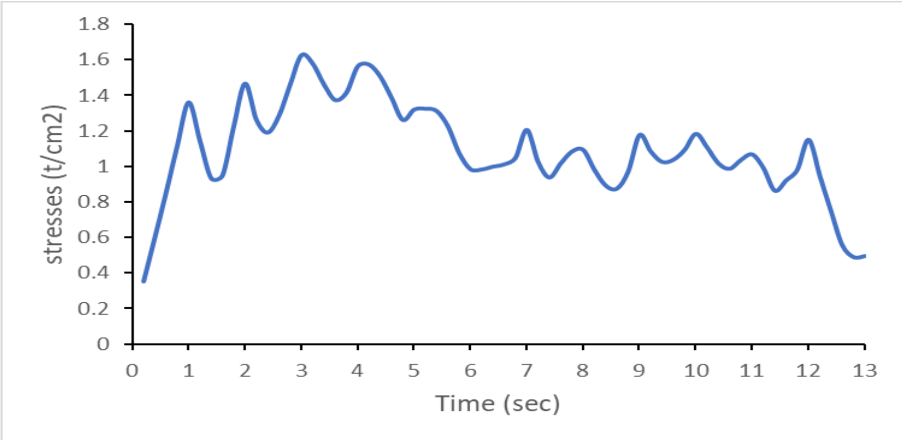

Figure 19: Equivalent stresses of bridge system under the dynamic load of speed 16 km/hr

7. Conclusions

- The 3-D finite element analysis is used to model the floating bridge system composed of the new connection pontoon (NCP), the heavy communication bridge (HCB), and the assault bridge AB-PMM71.
- The structure interaction between the floating bridge system and the water media is modeled based on the case study proposed by Mazek et al [1].
- The performance of the 3-D FEM for the floating bridge system is verified with the experimental results obtained from the field study presented by [1].
- The 3-D FEM of the bridge system is studied under static loads. However, the discrepancy between the numerical readings and the experimental readings is about 2 %.
- The 3-D FEM of the bridge system is studied under moving loads based on different tank speeds. However, the discrepancy between the numerical readings and the experimental readings reaches 6%.

8. References

[1] S. A. Mazek and his collegeas. “Design and Implementation of a New Connection Pontoon NCP between the Heavy Communication Bridge HCB and Assault Bridge AB-PMM71,” Military Technical College, Cairo, Egypt, 2018.

[2] G. Viecili, A. E. H. O. A. El Halim, A. Braimah, and O. El-Desouky, "Transportation Optimization of Ribbon Floating Bridges: Analytical and Experimental Investigation," *Open Civ. Eng. J.*, vol. 8, no. 1, pp. 42–56, 2014.

[3] E. Watanabe, C. M. Wang, T. Utsunomiya, and T. Moan, "VERY LARGE FLOATING STRUCTURES : APPLICATIONS, ANALYSIS AND DESIGN," National University of Singapore, Singapore, 2004.

[4] O. E.-D. M. Ibrahim, "Dynamic Behaviour of Short-Term Floating Bridges," Ph.D. dissertation, Dep. of Civil and Environmental Eng., Carleton Univ., Carleton, 2011.

[5] A. Rahman, "Dynamic analysis of floating bridges," *Procedia Eng.*, vol. 194, pp. 44–50, Dec. 1997.

[6] D. Van-johnson, "Numerical and Experimental Investigation of Ribbon Floating Bridges," M.S. thesis, Civil Eng. Dep., Carleton University Ottawa, Ontario, 2018.

[7] Y. A. Khalifa, M. M. Abdelwahab, and A. H. Salem, "Structural Systems Effect on Stability of Ferries Using 3D FEM," in *the 9th Int. Conf. on Civil and Arch. Eng., Cairo, Egypt, May 29-31*, 2012.

[8] Y. A. Khalifa, M. M. Abdelwahab, and A. H. Salem, "Structural Analysis for Upgrading Metallic Rigidly Connected Floating Bridge Using 3D FEM," in *the 9th Int. Conf. on Civil and Arch. Eng., Cairo, Egypt, May 29-31*, 2012.

[9] J. Sun, P. Jiang, Y. Sun, C. Song, and D. Wang, "An experimental investigation on the nonlinear hydroelastic response of a pontoon-type floating bridge under regular wave action," *Ships Offshore Struct.*, vol. 13, no. 3, pp. 233–243, 2018.

[10] J. Zhang, G. ping MIAO, J. xun LIU, and W. jun SUN, "Analytical Models of Floating Bridges Subjected by Moving Loads for Different Water Depths," *J. Hydrodyn.*, vol. 20, no. 5, pp. 537–546, 2008.

[11] S. Fu and W. Cui, "Dynamic responses of a ribbon floating bridge under moving loads," *Mar. Struct.*, vol. 29, no. 1, pp. 246–256, 2012.

[12] I. G. Raftoyiannis, T. P. Avraam, and G. T. Michaltsos, "Analytical models of floating bridges under moving loads," *Eng. Struct.*, vol. 68, pp. 144–154, 2014.

[13] F. Shixiao, C. Weicheng, C. Xujun, and W. Cong, "Hydroelastic analysis of a nonlinearly connected floating bridge subjected to moving loads," *Mar. Struct.*, vol. 18, no. 1, pp. 85–107, 2005.

[14] L. Chao Qiu, "Modeling and simulation of transient responses of a flexible beam floating in finite depth water under moving loads," *Appl. Math. Model.*, vol. 33, no. 3, pp. 1620–1632, 2009.

[15] X. Chen, Y. Miao, X. Tang, and J. Liu, "Numerical and experimental analysis of a moored pontoon under regular wave in water of finite depth," *Ships Offshore Struct.*, vol. 12, no. 3, pp. 412–423, 2017.

[16] B. R. Russell and A. P. Thrall, "Portable and Rapidly Deployable Bridges: Historical Perspective and Recent Technology Developments," *J. Bridge. Eng.*, vol. 18, no. 10, pp. 1074–1085, 2013.

[17] *Trilateral Design and Test Code for Military Bridging and Gap-Crossing Equipments*. Department of USA Army, USA, 2005.