Effect of Floating Bridges on Bottom Topography

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ABSTRACT

Aims: To ensure the safety topography of the bottom under the floating bridge, this study aims to determine the maximum load of the floating bridge, define the dimensions of the floating bridge (height, width) and identify the integrity and validity of the soil under the bridge in order to be maintained, treated, replaced or covered with a gravel layer.

Study design: A practical model used for a water channel with standard dimensions and is cut by the floating bridge connecting the two ends of the channel. When water flows, it is observed that the erosion processes under the bridge and the optimal use of floating bridge load should be studied without affecting the bottom shape (bridge width, bridge height from the bottom, maximum load of the bridge without erosion or after treatment, bridge location for the waterway, water depth at the bridge site and the maximum discharge in the waterway).

Place and Duration of Study: Department of Faculty of Engineering of Shubra, Banha University, Egypt between 2017 and July 2018.

Methodology: This study investigated the effect of floating bridges on bottom topography and erosion under bridges through installing a floating bridge in the laboratory. Next, one hundred and sixty-eight experiments were conducted to examine five variables, including: drainage; water depth in the channel; floating bridge width; loads mounted on the floating bridge and bottom soil type. In addition, the study explored variations occurred in these five variables during experiments. The erosion readings with and without a floating bridge were recorded to report the changes between the two cases. Also, readings for erosion with the variables of drainage, depth, loads, width and soil type were reported to obtain results on the emergence of direct and inverse relations among the study variables and to ensure the representation of the model in reality in the environment of river or lake.

Results: The results of this study revealed that the relationships among those five variables were either positive or negative. Finally, the result of study experiments demonstrated safety of origin, good safety factor, acceptable design and a geometrical view appropriate to the nature of the area on which the bridge will be built.

Conclusion: Experimental model of a floating bridge has been created. Due to the distinctive climate and geographical features, the bridge has encountered many problems such as erosion, overloading, aging and deterioration. Accordingly, the structural strength of the floating bridge may be decreasing gradually..

Keywords: Floating Bridges, erosion, Bridge Response, Interceptor Dikes, clay and sand soils

1. INTRODUCTION

Water is an essential element for life. The relationship between rivers and human life is a close relationship managed through human intervention. Certain issues, such as urbanization, population growth, increasing life requirements, human basic needs for life and the connection to rivers lead man to find solutions for the emerged problems and failure of enterprises. Changes in the nature and the requirements of life make human thinking about addressing the problems of different origins that emerge in any city under certain circumstances. The study of erosion at the bottom of the rivers and the bottom of the installations is necessary, especially when the facilities are close to the banks of rivers and areas of water collision. Erosion occurs at the bottom of the river or downstream due to the collision of water waves with the structures and riverbeds. Because of the energy carried by water waves, the soil and rocks disintegrate from earth surface in a certain area and move to another area. This study investigates the processes of erosion in the rivers under the floating bridges to find out the causes and solve problems of such type of installations. The importance of this type of bridge has become evident in Europe during the Second World War (1939-1945) when the withdrawing troops blew up bridges built on rivers. The Egyptian military engineering has built floating bridges, which facilitated the fighters and mechanical equipment crossing the Suez Canal and smashing the Barlev line in the battle of October 1973. In addition, Iraqi military engineering has used such bridges in the battles of liberating the district of Faw from the Iranian forces in a record time in 1988.

This type of bridge has also been used by the Iraqi military engineering in the liberation battles of Mosul, Sharqat, Hawija, Heet and others in 2017. Additionally, the floating bridges have been used in the United States of America as permanent bridges in places where the depth of water is too large, which prevents the construction of bridges because of their high costs. This study investigates the erosion processes under the floating bridges. Then, these processes will be compared to the same waterway and under the same conditions, but without a floating bridge to report the change occurred due to the use of floating bridge and to develop solutions and treatments to preserve the origin and form of watercourse and safety factor suitable for changes and accidental accidents. The erosion process changes the features of the watercourse. Thus, the current thesis focuses on examining this situation under the floating bridge. In order to ensure the stability of bridges and installations according to the most difficult conditions, it is necessary to determine that the river or watercourse is not affected by the floating bridge. When dealing with the impacts of the floating bridge, one should take into account the season of flooding, extreme discharges and human intervention in natural rivers for designing, planning and implementing such types of bridges.

A thorough understanding of the basic characteristics of the river under natural disasters, harmful effects and the benefit of human interests without affecting the course of river is essential through training. The extensive facts of the river should be studied during the previous period and previous incidents. Adding to that, the characteristics and specifications of the facility link to the floating bridge should be studied to record changes and maintain the shape and strength of the campaign according to the most difficult circumstances.

Without bridges, the construction of highways and railway across valleys and water bodies would not be possible [1]. The history of floating bridges is dated back to 2000 BC. There are several types of floating bridges, depending on the type of barriers to be crossed and the conditions of the ground. Compared to ground bridges, limited information is available for floating bridges in many areas, for example, previous meteorological records and durability. Recently, it has been possible to design floating bridges more scientifically because of the evolution of mathematical analysis and due to theoretical developments in hydrodynamic interactions between liquid and floating objects.

Floating bridges have been used since ancient times about 4000 years ago. The first floating bridges were boat bridges [2], which were used in many battles. Even today, military floating bridges, which are of temporary type, have been used to transport soldiers, vehicles and ammunition. In 1874, a mobile wooden pontoon railroad bridge was built across the Mississippi River in Wisconsin, which was rebuilt regularly but finally abandoned. Bridges are usually effective ways of connecting islands and peninsulas with each other and/or the mainland. The societal benefits can be quite substantial, as they improve the infrastructure between cities and surrounding areas, which saves commuting time and may therefore benefit job markets, productivity and competition [3]. However, in some instances, a traditional suspension or pillar bridge might not be feasible due to wide or deep water, or because the bottom is too soft to support a pillar bridge foundation. One example is the crossing of Lake Washington in Washington, USA, where the lake bottom consists of deep layers of soft clay. Here, floating bridges were found to be the most cost-efficient. Wu and

Sheu [4] studied the coupled heave and pitch motions of a simplified non-uniform ship hull floating on a steady water surface and subjected to a moving load. The effect of water depth on floating bridges carrying moving loads was studied by Zhang et al. [5].
Humar and Kashif [6] studied the dynamic response of a simply supported clear span bridge traversed by moving vehicles. Most of the analytical and experimental work related to bridge dynamics stated that there are three alternatives to obtain the bridge dynamic response, namely: applying codes of practice, dynamic analysis and full scale dynamic tests, as reviewed in [7]. There are two types of floating bridges, separate floating bridges and fixed floating bridges. A floating bridge can be simplified as a beam supported by floating elements, which are defined either as pontoon-structures or as semi-submersible structures [8]. A pontoon-structure is a floating component with a small depth compared to its width, and is suitable in areas with calm water, such as inside a cove or near the coastline. Semi-submersible structures consist of columns with watertight ballast compartments attached to pontoons, and due to the ballast compartment, they are appropriate for large wavelengths and wave heights. The author in [9] presented analytical models of floating bridges under moving loads and studied dynamic responses with hydrodynamic effect coefficients for different depths of water. According to [10] two basic approaches must be considered for floating structure, namely, frequency and time domains. The floating bridge that is subjected to various environmental loads, such as wind and wave; as well as current loads has been carried out in [11]. Seif and Inoue [12] studied the analysis of discrete pontoon floating bridges subjected primarily to wave loading with varying parameters. The finite element (FE) models of a ship deckhouse and a floating bridge girder are established. The girder response to ship deckhouse collision is investigated through integrated numerical simulations. Parametric studies are conducted to compare the girder response for various girder designs and collision scenarios [13].The damping effects on weak axis bending moment prediction are studied in [14].

Many authors classify loads for floating bridges into four categories as presented in Table1 and Table 2 showing the main subcategories under principle, secondary loads and particular equivalent to the above-mentioned loads, respectively.

Table 1. The main subcategories under principle and secondary loads

Principal Loads	Secondary Loads
Dead load	Wind load
Live load	Water and swell effects
Impact load	Effect of earthquake
Earth pressure	Temperature effect
Hydrostatic pressure	Current load

Table 2. The particular equivalent of the loads

Particularly Primary Loads	Particularly Secondary Load
Tidal variation effect	Effect of tsunami and storm
Effect of seabed deformation	Collision loads from ships and drifting materials
Effect of support movement	Effect of marine growth
Snow/ice load	
Centrifugal load	

A straight floating bridge will most likely require mooring lines or tethers to ensure sufficient horizontal stiffness to withstand the horizontal loading from wind, waves and current. Installing mooring systems into deep water is very costly considering both design and operation. The curved bridge concept that is suggested withdraws the need for additional stiffness from mooring due to the arch action. In contrast to a straight bridge that will resist the load by beam action, transverse loads are enabled to be carried by arch action in the curved bridge design.

2. MATERIAL AND METHODS

Erosion control is desirable not only for environmental reasons, but also for highway safety purposes. Uncontrolled erosion during highway construction and subsequent sedimentation could potentially cause adverse impacts on streams, damage to drainage structures and public or private lands, and cause public criticism. When installed correctly, BMPs minimize soil erosion, which prevents sedimentation into nearby state waters. It should be noted that storm water is not treated before being discharged into state waters.

Effective implementation of erosion control BMPs will reduce maintenance and prevent potential sediment discharges through the following suggested activities to minimize the total amount of soil exposed [15]:

1. Use redundant management project in series to minimize overloading and prevent potential failures.
2. Limiting erosion reduces stress on sediment control management project.
3. Use both erosion and sediment control measures on project to prevent sediment discharges.
4.Stabilize disturbed areas as soon as practical consideration of this work through 25 cm high of a clay soil to control the erosion and investigate, as can be seen in Fig .1.

Fig. 1. Erosion control through stabilizing the area of the waterway

In the beginning, the maximum discharge on sandy soil and the depth of water constant in the channel (12) cm will be controlled and the measurement will be recorded without the floating bridge. Then, the same experiment will be repeated under the same circumstances, but the discharge will be changed through using three pumps and discharge rate (0.07) m^3/s. After that, the same experiment will be restored through using two pumps and discharge rate (0.05) m^3/s, as illustrated in the plan view in Fig. 2.

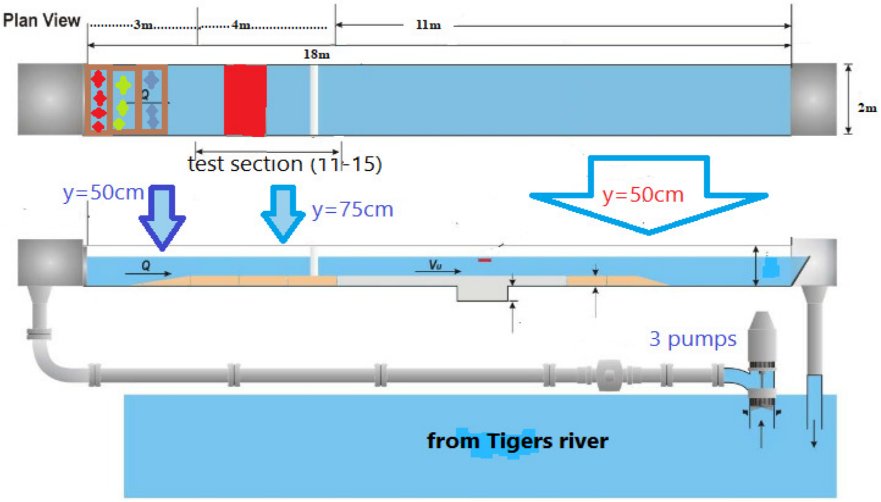

Fig. 2. The plan view of the proposed experiment

Note the change in readings in sandy soils. In the same circumstances and for the same three experiments, the bottom soil is changed to mud. It is noted that the clay soil is less affected by the conditions. It is more stable than the sandy soil. Based on the readings, it is observed that the relationship between drainage and erosion is a direct one. (6) Without a bridge, two types of soil, variable discharges and constant depth, the water depth of the channel must be changed, the floating bridge should be connected to the channel and the change should be observed at each time.

A bridge of 50 cm width, 12 cm water depth, and 0.11 m^3/s drainage with a sandy soil bottom was designed. The readings were observed. When the water depth is changed to 14 cm or 16 cm, the change in the readings was noticed as well.

This research will employ three exclusions (0.05, 0.07, and 0.11) m^3/s, three depths (12, 14, and 16) cm and variable widths of the bridge (50, 60, and 70) cm.
Two types of soil (sandy soil, clay soil) are used. This project will validate all transactions and change one in each experiment so that the total number of experiments in this research is (168). The bridge widths of (50, 60, 70) cm are considered in order to achieve symmetry with the nature of the weights placed on the bridge (20, 25, 30) kg and in order not to sink or coup floating bridge. The water depths in the channel (12, 14, and 16) cm are used for a flow corresponding to reality. A relationship will be established between drainage, erosion, water depth, soil type and bridge width to benefit from a relationship between the results obtained in the laboratory and commensurate with nature or reality.

This research studied the effect of floating bridges of different geometry/dimension on the topography of the bottom; as well as their impact on erosion operations below, at the top and at the back of the bridges. A concrete channel length 18 m, width 70 cm and the variable depth 75-50s was utilized. The same depth continues (11) m from the beginning of the channel and at a depth of (75) cm from the distance (11) m to a distance of (15) m. From the beginning of the channel and at a distance of (15) m from the beginning of the channel is the depth (50) cm to the end of the channel and (75 cm) with variable soil (clay and sand) at a depth of 25 cm. The center of the floating bridge shall be at the center of the basin, i.e., 13 m from the beginning of the channel. The channel shall contain a channel at a distance of 1 m from the beginning. The regulator of flow and speed should be at 2 m from the beginning of the channel. This regulator is a metal cage along the width of the watercourse with (40) cm width and (50) cm depth placed inside the flatten to regulate the flow of water to the channel.
In this research, five pumps were used to give maximum discharge (0.11) m^3/s, three pumps to give the average discharge and two pumps to give less discharge. So, this study would have three discharges (0.05, 0.07, 0.11) m^3/s and three depths of water in the channel (12, 14, 16) with variable widths of the bridge (50, 60, 70) and variable balances on the bridge (20, 25, 30). Two types of soil quality (sand soil, clay soil) were utilized. This study will confirm the collection of the coefficients and change one in each experiment so that the total number of experiments in this research was (3 * 3 * 3 * 3 * 2) experiments without the bridge. Thus, the total number of experiments was (168) attempts.
The under-water volume of the pontoon (Vw) determines this buoyant force (Fw). The draft has to be investigated for two cases, namely, (1) when it is loaded with a full traffic load and (2) without traffic load as shown in Fig.3.

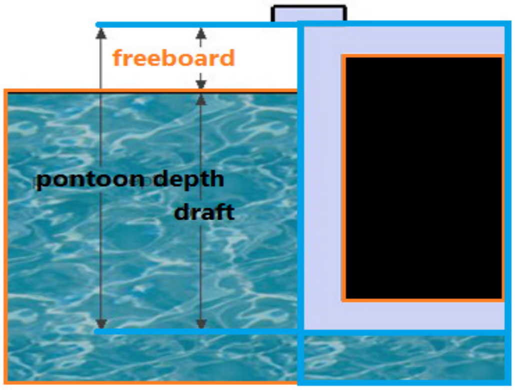

Fig.3. Pontoon depth

The pontoon depth = freeboard + draft

The draft (d) = the total load per unit length (Fw) / the pontoon width (W)

$$d = \frac{F_w}{w \cdot \gamma_w} \tag{1}$$

The total load per unit length = Traffic load + bridge weight + vertical mooring load

3. RESULTS AND DISCUSSION

The freeboard of a single floating pontoon is noticed according to the significant wave height and it is calculated from the road level to the water surface for an unloaded bridge. The maximum settlement of the bridge due to the traffic load, the wave amplitude and the maximum expected vertical response due to the wind/wave load should not exceed the freeboard in all load combinations.

The relationship between the floating bridge width and load is defined in order to test the ability of the floating bridge to carry the objects and investigate the height of the pontoon dipped inside the water, as in Fig. 4, and Fig.5 for different values of weights.

Fig. 4. The Floating Brige construction

Fig. 5. Weight on the Floating Bridge test

The draft or pedding pontoon when (5-45) kg weight subjected on the floating bridge of 40 cm pontoon is shown in Fig. 6.

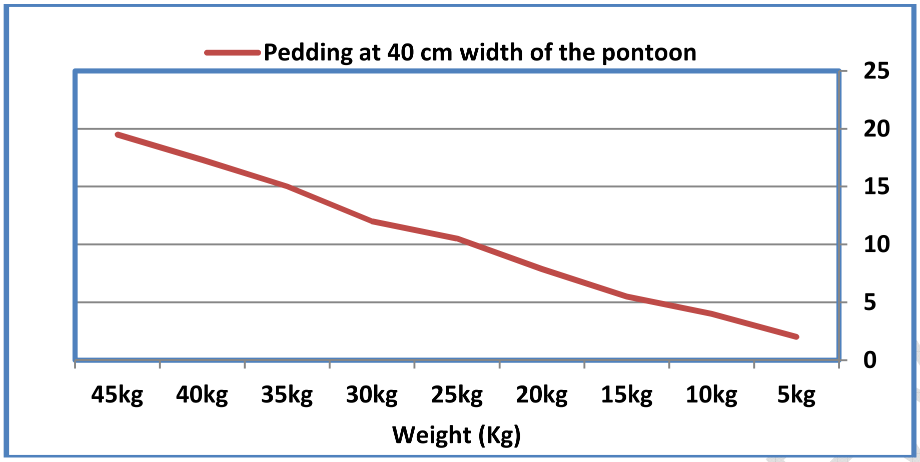

Fig. 6 Draft height on the 40 cm potoon width

The draft or pedding pontoon when (5-45) kg weight subjected on the floating bridge of 50 cm pontoon is shown in Fig.7.

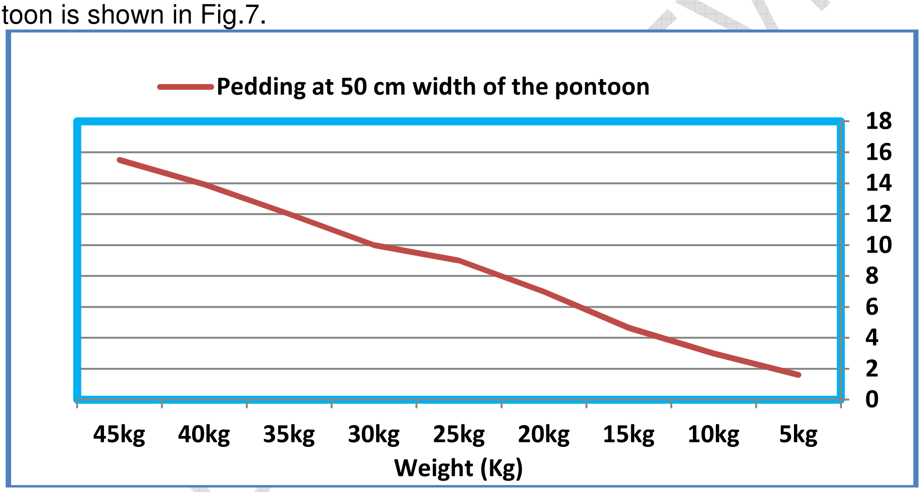

Fig.7. Draft height on the 50 cm potoon width

The draft or pedding pontoon when (5-45) kg weight subjected on the floating bridge of 60 cm pontoon is shown in Fig. 8.

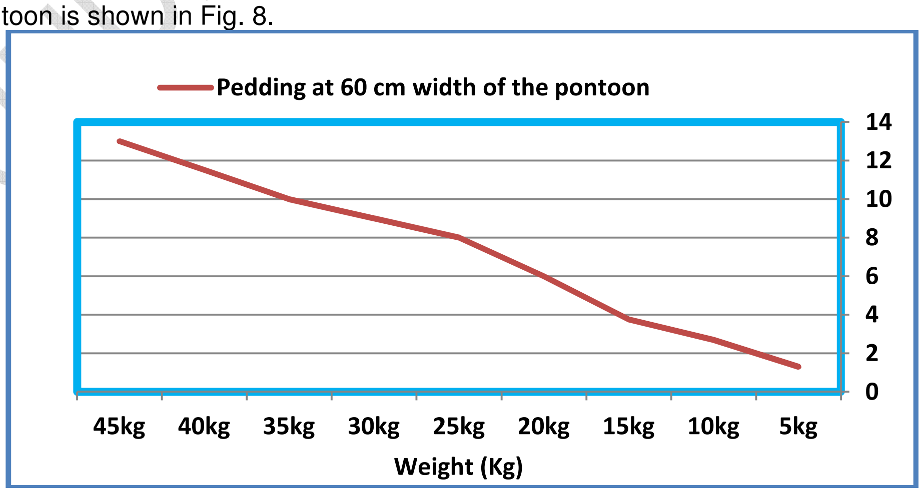

Fig. 8. Draft height on the 60 cm potoon width

The draft or pedding pontoon when (5-45) kg weight subjected on the floating bridge of 70 cm pontoon is shown in Fig.9.

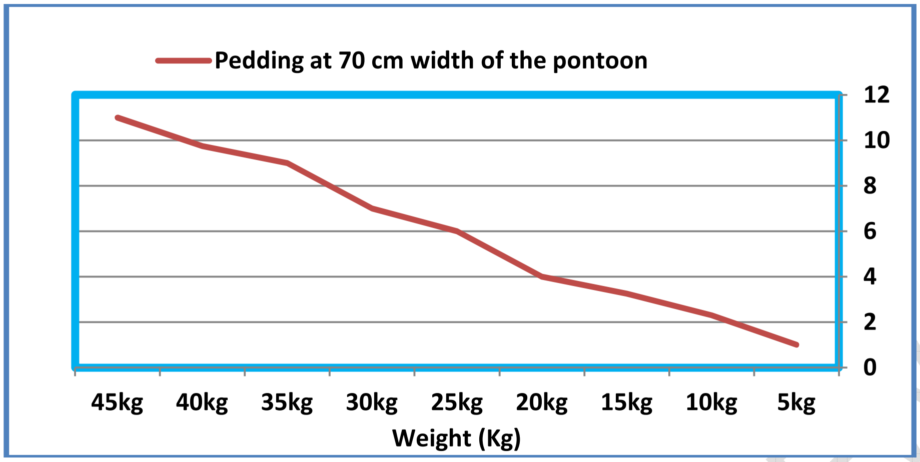

Fig.9. Draft height on the 70 cm potoon width

The draft or pedding pontoon when (5-45) kg weight subjected on the floating bridge of 80 cm pontoon is shown in Fig.10.

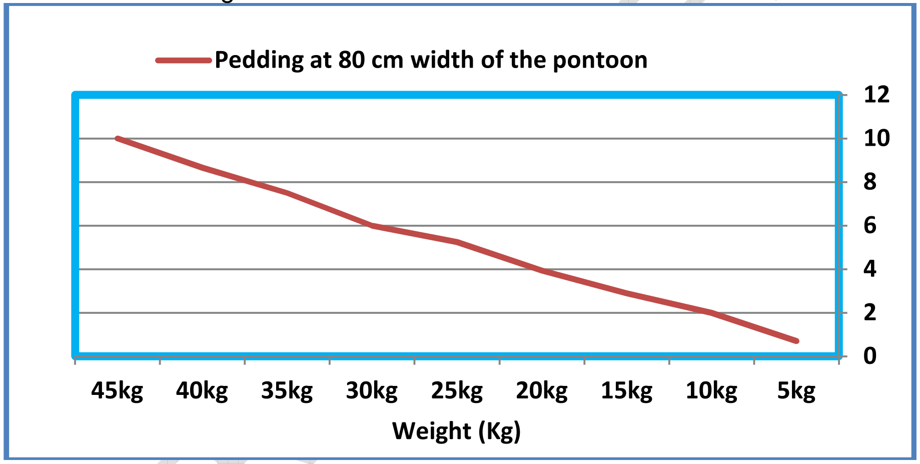

Fig.10. Draft height on the 80 cm potoon width

The draft or pedding pontoon when (5-45) kg weight subjected on the floating bridge of 90 cm pontoon is shown in Fig.11.

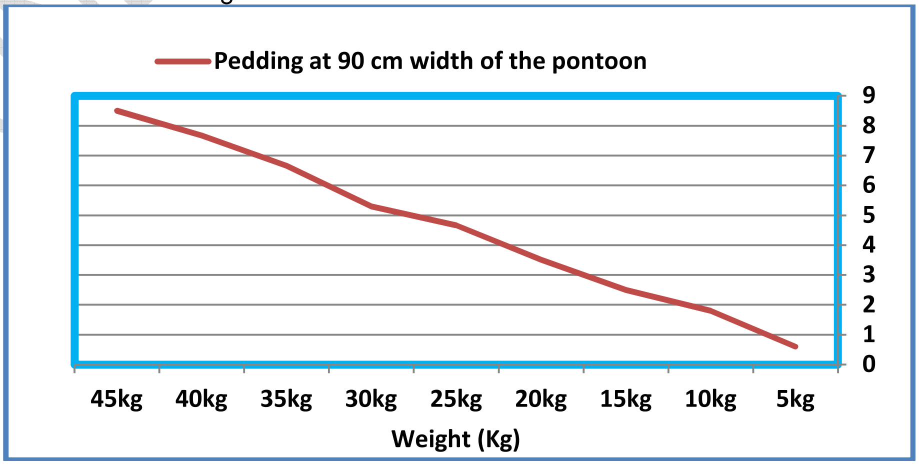

Fig.11. Draft height on the 90 cm pontoon width

The maximum pedding object in (cm) which occur at 40 cm (red) pontoon width and the minimum pedding at (90cm) pontoon width show the effectiveness of the constructed floating bridge as it has an inversely proportion with load subjected, as shown in Fig.12.

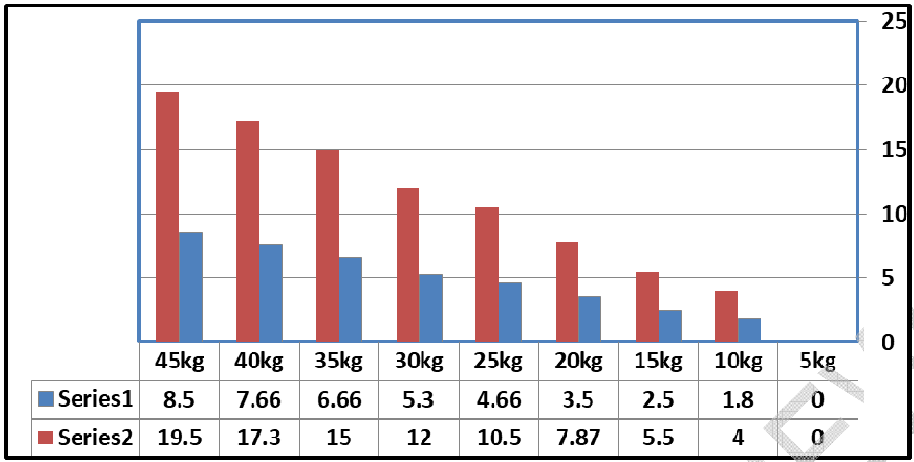

Fig.12. Max (red) and min (blue) pedding at 40cm and 90cm potoon width

Temporary interceptor dikes, which are temporary erosion control measures intended to reduce runoff velocity and divert water off the construction right of way, shall be installed following grading operations as shown in the beginning of the plan view in Fig.2 of the experimental figure within the first three meters of the floating bridge. Within three stages, the interceptor dikes are installed on all disturbed areas as necessary to avoid excessive erosion as can be seen in Fig.13.

Fig.13. Interceptor dike to control the erosion

In its effect on flow in a channel, a bridge abutment may be likened to a short contraction, such as indicated in Fig.14 for flow through a simple orifice. Two flow features are directly evident in the flow field through a contraction:

1. Flow contraction; and,
2. The generation and shedding of large-scale turbulence structures from the boundaries of the contraction.

Fig.14. Flow through a bridge opening

To reach 110 L/m, there are five pumps should be used to deliver the water from tigeresriver to the prototype floating bridge. For (Q=50L/s , 70 L/s), two pumps or three pumps are used to satisfy the needed amount of water in the bridge.

The erosion contours are illustrated in Fig.15.

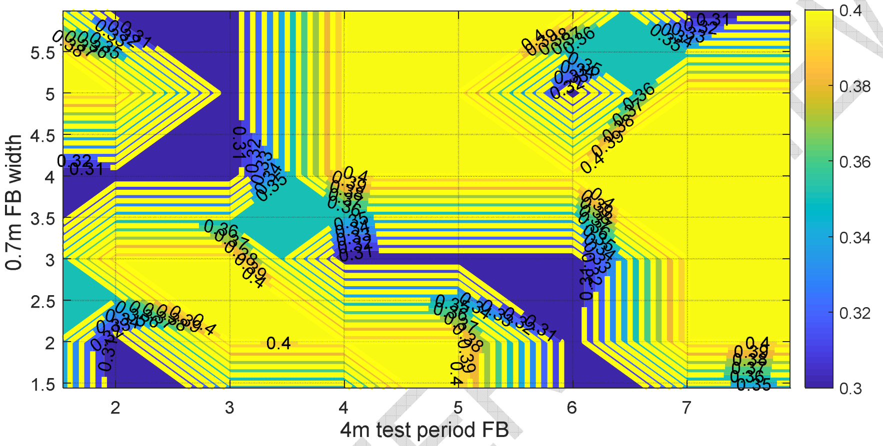

Fig. 15. Sandy soil erosion contours at 50L/s

The erosion contours with sandy soil and Q=70L/s are shown in Fig. 16.

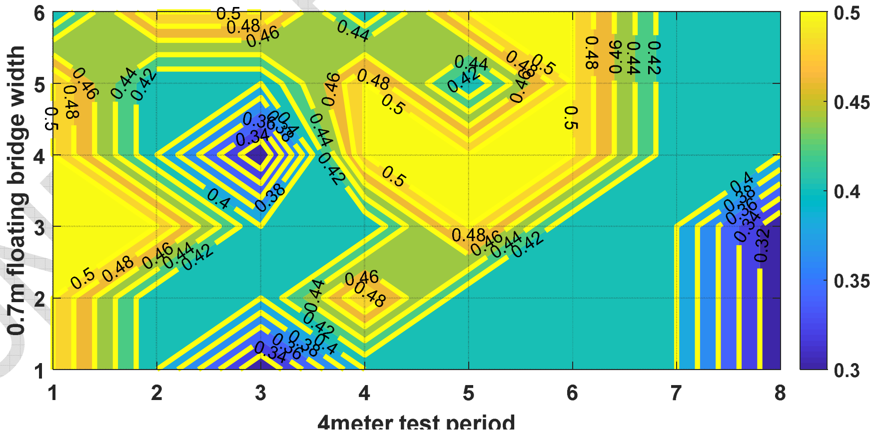

Fig. 16. Sandy soil erosion contours at 70L/s

The erosion contours with sandy soil and Q=110L/s are shown in Fig. 17.

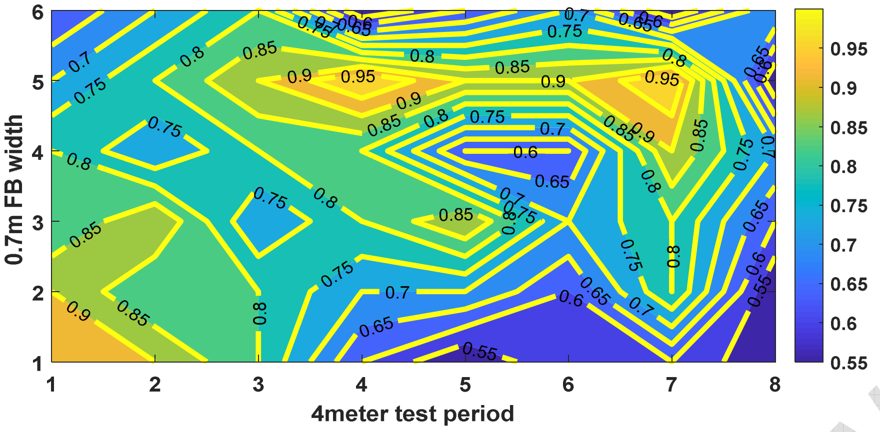

Fig. 17. Sandy soil erosion contours at 110L/s

The contour of Q=50L/s with clay is shown in Fig. 18.

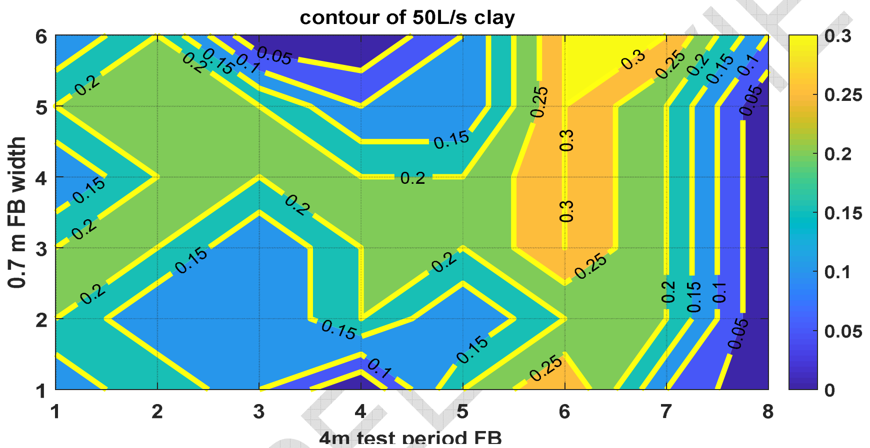

Fig. 18. Clay soil erosion contours at 50L/s

The contour of Q=70L/s with clay is shown in Fig. 19.

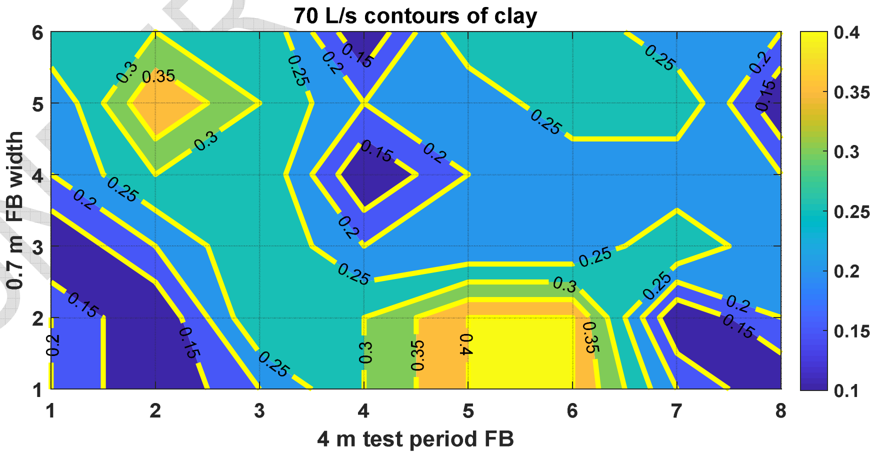

Fig. 19. Clay soil erosion contours at 70L/s

The contour of Q=110L/s with clay is shown in Fig.20.

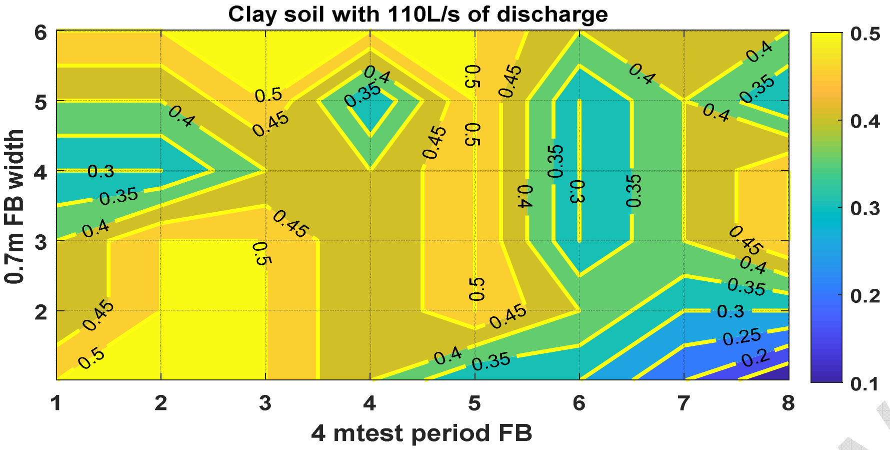

Fig. 20. Clay soil erosion contours at 110L/s

The effectiveness of the proposed work to control can be shown in checking the power/ frequency ratio with the normalized frequency or the power spectral density of the floating bridge as illustrated in Fig. 21, which is designed based on the environment obtained from (test 168)

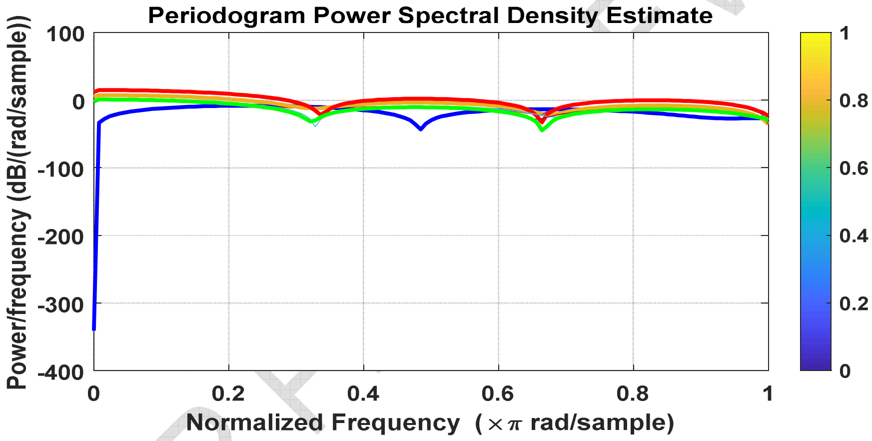

Fig. 21. Power Spectral density of the floating bridge

The simplest way to measure flow is by measuring directly the time needed to fill a known size container. The water is pumped from the pump to be measured by a tube to this container, and the filling time is measured by a stopwatch. A tank capacity (5000) liters was considered and the time of filling was calculated accurately. To obtain the real discharge of the pump, the size was divided on time. This process was repeated with each pump to see the discharge. Pump No. 1 has a diameter of (1.5) Ang. It took (555) seconds to fill the reservoir. For the discharge, the following equation was applied:

$Q = V / t = 5000/555 = 9 l / t$

and the same was done for each pump.

The volumetric method is used to measure the discharge of each one of the five pumps according to the (Q=volume/time). The operation of pumps discharge is illustrated in Fig.22.

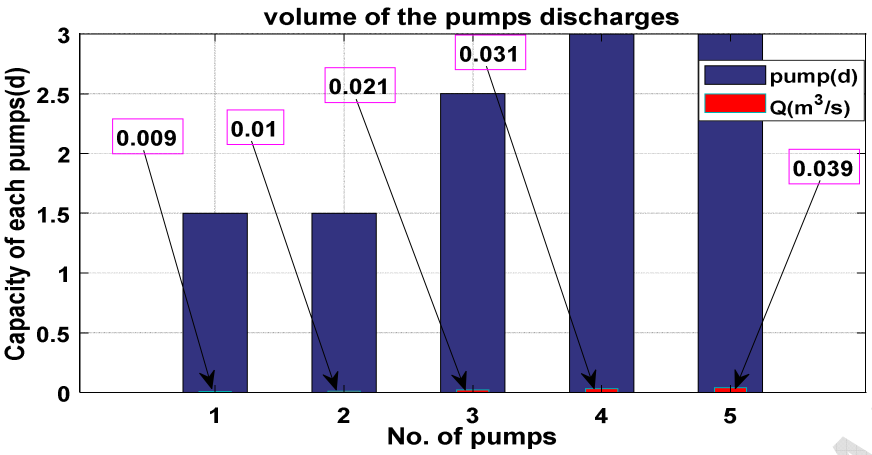

Fig. 22.Volumetric capacity of the pumps

4. CONCLUSION

In order to maintain the safety of bridges and prevent structural deterioration, such as the effect of river erosion, heavy vehicle overloading on the bridge has to be considered with the reliable measured information.

Based on the results, the study demonstrated that by introducing a very effective design of the floating bridge according to the standard specifications and environment in the region where the prototype is constructed, the vertical displacement was significantly reduced according to the better design of the potoon width corresponding to the height of water level and load. The results also revealed that the pedding of pontoons is inversely proportional to the pontoon width when the floating bridge has been tested with load (5-45) kg and the pontoon width varied from (50-60-70-80-90) cm.

Constructing a monitoring area (4 m test point) is important to increase the long life of the bridge as important safety factor. This is the main reason why developing a reliable monitoring and warning system for long term monitoring and structural analysis for bridges is very important.

When utilizing a simple model, some of the achieved results were realistic, but nearly all results indicated that the utilized models were too stiff. By introducing a more complex cross-section, i.e. including the stiffeners and girders, the stiffness is slightly reduced and the mass would be significantly reduced. The model will then be able to resist the vertical loads, and at the same time give more results that are realistic in longitudinal direction and for the dynamic results.

The interceptor dikes, which are temporary erosion control measures intended to reduce runoff velocity and divert water off the construction right of way, are installed following grading operations in the beginning of the floating bridge within the first three meters. The interceptor dikes are installed as a necessary tool to avoid excessive erosion. This was very effective way to control the erosion, and smaller pontoon dimensions are required to achieve stability in the large floating bridges.

The current experiments indicated that there is a correlation between erosion and the two variables, namely, the bridge width and direct discharge. This is because erosion level has been increased according to these two variables. In addition, there is a relationship between water depth in the channel and reverse erosion, i.e., the higher the water depth in the channel, the less erosion (clay soils are more stable and resistant to drift than soils). This is due to that the weight and loads over the floating bridge have increased erosion.

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