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REVIEWING STUDY OF THE FLOATING BRIDGES

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ملخص البحث

الجسر العائم هو عبارة عن مجموعة من المراكب أو العوامات الخاصة والمربوطة مع بعضها البعض والتي تستخدم في عبور نهر أو قناة عن طرية ممر أو مسار أعلي هذه العوامات. معظم الجسور العائمة التي بنيت قديما كانت بهدف الحرب. هذا البحث هو عبارة عن مراجعة للدراسات السابقة المتعلقة بالجسور العائمة, وقد خلص البحث إلي أن معضم الدراسات المتعلقة بالجسور العائمة تناولتها من وجهة النظر الميكانيكية ولم يكن من الممكن إيجاد دراسات هيدروليكية متعلقة بالجسور العائمة. ولذلك كان من الضروري دراسة تأثير الجسور العائمة علي الجريان في القنوات المكشوفة.

Abstract

Floating bridge is a collection of specialized, shallow draft boats or floats, connected together to cross a river or canal, with a track or deck attached on top. Most early floating bridges were built for the purposes of war. This study was made to review the previous studies concerned about the floating bridges. Almost all the studies concerned with floating bridges covered them from the mechanical point of view and it wasn't possible to get any studies concerned with floating bridges from the hydraulic point of view, so it is necessary to study the effect of the floating bridges on the open channels flow.

Keywords: Floating bridges, Pontoons, Historic, Review.

Introduction

A floating bridge, also known as a pontoon bridge, uses floats or shallow-draft boats to support a continuous deck for pedestrian and vehicle travel. The buoyancy of the supports limits the maximum load they can carry.

Most pontoon bridges are temporary, used in wartime and civil emergencies. Permanent floating bridges are useful for sheltered water-crossings where it is not considered economically feasible to suspend a bridge from anchored piers. Such bridges can require a section that is elevated, or can be raised or removed, to allow waterborne traffic to pass.

Pontoon bridges have been in use since ancient times and have been used to great advantage in many battles throughout history, among them the Battle of Garigliano, the Battle of Oudenarde, the crossing of the Rhine during World War II, and during the Iran–Iraq War Operation Dawn 8.

A pontoon bridge is a collection of specialized, shallow draft boats or floats, connected together to cross a river or canal, with a track or deck attached on top. The water buoyancy supports the boats, limiting the maximum load to the total and point buoyancy of the pontoons or boats, [8]. The supporting boats or floats can be open or closed, temporary or permanent in installation, and made of rubber, metal, wood, or concrete. The decking may be temporary or permanent, and constructed out of wood, modular metal, or asphalt or concrete over a metal frame.

Historic uses

In ancient China, the Zhou Dynasty Chinese text of the Shi Jing (Book of Odes) records that King Wen of Zhou was the first to create a pontoon bridge in the 11th century BC. However, the historian Joseph Needham has pointed out that in all likely scenarios, the temporary pontoon bridge was invented during the 9th or 8th century BC in China, as this part was perhaps a later addition to the book (considering how the book had been edited up until the Han Dynasty, 202 BC – 220 AD). Although earlier temporary pontoon bridges had been made in China, the first secure and permanent ones (and linked with iron chains) in China came first during the Qin Dynasty (221–207 BC). The later Song Dynasty (960–1279 AD) Chinese statesman Cao Cheng once wrote of early pontoon bridges in China

The Greek writer Herodotus in his Histories, records several pontoon bridges. The Persian Emperor Darius used a 2 kilometers (1.2 mi) pontoon bridge to cross the Bosphorus and Emperor Caligula built a 2 miles (3.2 km) bridge at Baiae in 37 AD. For Emperor Darius I The Great of Persia (522–485 BC), the Greek Mandrocles of Samos once engineered a pontoon bridge that stretched across the Bosporus, linking Asia to Europe, so that Darius could pursue the fleeing Scythians as well as move his army into position in the Balkans to overwhelm Macedon, Fig (1).

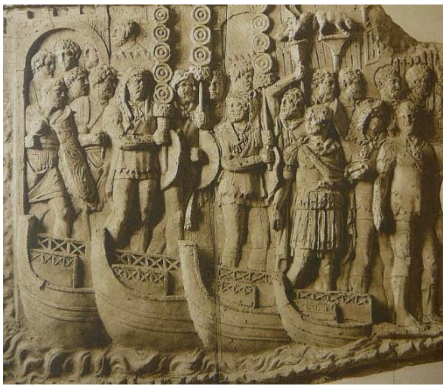

Fig (1) A relief of a Roman bridge of boats by Cichorius

Although pontoons declined in use during the European Middle Ages, they were still used alongside regular boats to span rivers during campaigns, or to link communities which lacked resources to build permanent bridges, [5]. According to the chronicles, the earliest floating bridge across the Dnieper River in the area was built in the 1115. It was located near Vyshhorod, Kiev.

In the 1670s, the French devised the copper pontoon; after this point, rivers and canals ceased to present significant obstacles, [2]. The early modern period in pontoon use was dominated by the wars of the 18th and 19th centuries during which the art and science of pontoon bridging barely changed. This however did not stop all innovation, in 1708 a Swedish army used a leather pontoon bridge to cross a river before the Battle of Holowczyn

During the Peninsular War the British army transported "tin pontoons", [6]:353 that were lightweight and could be quickly turned into a floating bridge.

A comparison of pontoons used by each nations army shows that almost all were open boats coming in one, two or even three pieces, mainly wood, some with canvas and rubber protection, Belgium used an iron boat. America used cylinders split into three, [8].

The British Blood Pontoon MkII, which took the original and cut it into two halves, was still in use with the British Army in 1924, [8].

The First World War saw developments on "trestles" to form the link between a river bank and the pontoon bridge. Some infantry bridges in WW1 used any material available, including petrol cans as floatation devices, [8].

The Kapok Assault Bridge for infantry was developed for the British Army, using kapok filled canvas float and timber foot walks. America created its own version, [8].

Folding Boat Equipment was developed in 1928 and went through several versions until it was used in WW2 to compliment the Bailey Pontoon. It had a continuous canvas hinge and could fold flat for storage and transportation. When assembled it could carry 15 men and with two boats and some additional toppings it could transport a 3-ton truck. Further upgrades during WW2 resulted in it moving to a Class 9 bridge, [8].

Uses of The Floating Bridges

Floating bridges can be used in different fields as follow:

- Military purposes: to move soldiers and equipment, usually across rivers too deep to ford.
- Civil purposes: to provide passage over water barriers so as to pass railway, or road, for the purpose of traffic.
- Tourist purposes: as walk ways in the tourist resorts.
- Infantry purposes: to pass people through a water obstacle.

Types of The Floating Bridges

a) According to material of construction

Depending on the design requirements floating bridges can be classified as follow:

- Concrete floating bridges as SR-520 floating bridge, photo (1), and Kelowna floating bridge.
- Wooden floating bridges as Brookfield floating bridge which crosses Mississippi river,USA, Knapschaefer, and Congjiang floating bridge in china, 800years old, photo (2).
- Metal floating bridges (steel, copper …etc.) as Berbice River floating bridge in Guyana, and Bailey floating bridge in the United Kingdom.
- Aluminum alloy floating bridges.
- Pneumatic rubber floating bridges.
- Plastic floating bridges.

- Combination of materials floating bridges as Salhus floating bridge, and Bergsoysund floating bridge in Norway.

b) According to pontoons arrangement

- Separate pontoons.
- Continuous pontoons.

c) According to alignment

- Right angle floating bridge: as SR-520 floating bridge.
- Skew floating bridge: as Bergsoysund floating bridge in Norway.

Photo (1) SR-520 floating bridge placed.

Photo (2) Congjiang floating bridge placed.

Causes of Failure for Floating Bridges

Here are some samples of failure for floating bridges.

- The Saint Isaac's Bridge across Neva River in Saint Petersburg in Russia suffered two disasters, one natural, a gale in 1733, and then a fire in 1916.
- Floating bridges can be vulnerable to inclement weather, especially strong winds. The U.S. state of Washington is home to some of the longest permanent floating bridges in the world, and two of these failed in part due to strong winds.
- In 1979, the longest floating bridge crossing salt water, the Hood Canal Bridge, was subjected to winds of 80 miles per hour (130 km/h), gusting up to 120 MPH. Waves of 10–15 feet (3.0–4.6 m) battered the sides of the bridge, and within a few hours the western ¾ mile (1.2 km) of the structure had sunk. It has since been rebuilt.

Designing

When designing a pontoon bridge, the civil engineer must take into consideration the Archimedes' principle looking at the maximum amount of load that it is intended to support. Each pontoon can support a load equal to the mass of the water that it displaces, but this load also includes the mass of the bridge itself. If the maximum load of a bridge section is exceeded, one or more pontoons become submerged and will proceed to sink. The roadway across the pontoons must also be able to support the load, yet be light enough not to limit their carrying capacity.

Survey is important to determine the best location. The connection to shore often causes problems, requiring the design of approaches that are not too steep, keep the bank from crumbling and when tidal, can be used at all states of the tide.

Floating bridges were typically constructed using wood. Such a wooden floating bridge could be built in a series of sections, starting from an anchored point on the shore.

Pontoons were formed using boats; several barrels lashed together; rafts of timbers, or some combination of these. Each bridge section consisted of one or more pontoons, which were maneuvered into position and then anchored, using underwater, land based and/or overhead anchors. These pontoons were then linked together using wooden stringers called balks. The balks were then covered by a series of cross planks called chesses to form a road surface, [9], and the chesses were held in place with side guard rails. More modern pontoons use pre-fabricated floating structures, [4].

Reviewing studies

Colin [1] studied the accuracy and precision in the analysis and design of floating bridges and he proposed the measurements of wind characteristics and kinematic performance of floating bridges, and he found that the relationship between these measurements is then used as a check of detailed analyses and a statement of accuracy. The use of these measurements and the detailed analytical results are applied to the initial design of these bridges.

Many large fixed bridges have been constructed across rivers as well as seas, however, floating bridges take advantage of the natural law that the buoyancy of water can support the dead and live loads on the bridge. Therefore, floating bridges have been constructed in many countries such as the USA, Norway, UK, Japan and Canada (Watanabe [13]; Watanabe and Utsunomiya [11]; Watanabe et al. [12]). Until now, two different structural forms for floating bridges have been used (Seif and Inoue [7]: Continuous concrete pontoon type floating bridges and the steel truss deck one which is supported by discrete pontoons. Regarding the structural dynamic responses of a floating bridge subjected to moving loads, Virchis [10] has once performed the numerical calculation to obtain the dynamic response of a military floating bridge subjected to tracked or wheeled loads by Runge-Kutta method, taking into account the initial condition of wheels, the variable speed and the separation status in vehicle-bridge system.

However, with the popularity of the computer and the development of the finite element method (FEM), it is possible for the researchers to simulate the main features of the vehicle and bridge models more clearly and accurately. Wu et al. [14], [15], presented a technique employing combined finite element and analytical methods to predict the dynamic response of an experimental mobile gantry crane structure due to the two-dimensional motion of the trolley. Wu and Sheu [16] investigated the dynamic performances of a rigid ship hull subjected to a moving load by simplifying the hydrostatic forces as the action of linear springs and dampers, obtained the motion behavior based on the solution of the heave-pitch coupled equation, and compared it with the corresponding experiment.

Wu and Shih [17] studied the elastic vibration of a partial-catenary-moored floating bridge (in still water) subjected to a moving load by taking the entire pontoon as a slender beam resting on an elastic foundation, and the influence of hydrodynamic forces as constant added mass, respectively. Furthermore, the stiffness and mass matrices of two-node beam element with different nodal DOF's have been derived to simulate the features of the rigid- or hinged-connection by using the FEM and the conservation of energy. Considering the nonlinear properties of the connection, Fu et al. [3] estimated the dynamic response of a military ribbon bridge subjected to a moving load by means of the super element method.

Fig (2) illustrates the vertical displacement of the vehicle-loaded substructures of the floating bridge with a constant static load of 588KN at the position amidst the longitudinal length of the five-connected bridge. It is found that the maximum displacement response is 65.5 cm and the influential length is nearly 51m. Furthermore, the deflection curve is oscillatory at the two ends of the influential length by taking the initial gap and the nonlinearities of the connectors into consideration, and this is not quite analogous to that of the nonlinearly connected ribbon bridge, Fu et al. [3].

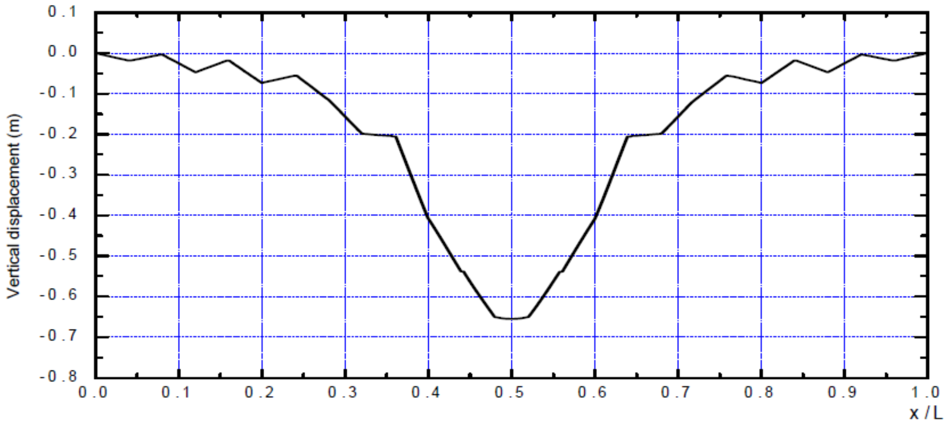

Fig (2) Static response of the floating bridge

Conclusion

- Floating bridges are important and historic hydraulic structures, which helped the humans from the old ages till now.
- Floating bridges can be studied from two points of view the mechanical point of view and the hydraulic point of view. The mechanical study is concerned with loads, weights and anchors, …etc, while The hydraulic study is concerned with the effect of floating bridges on flow in open channels.
- Almost all the studies concerned with floating bridges covered them from the mechanical point of view and it wasn't possible to get any studies concerned with floating bridges from the hydraulic point of view.
- So the effect of the floating bridges on the open channels flow have to be studied.

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