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pontoon bridge, mobility, initial stability, displacement

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CASSETTE PONTOON BRIDGE OF HIGH MOBILITY

Summary. Looking through the known and used buoyant systems, it can be remarked that the single buoyant segments are the stiff objects made of steel or plastic with variable dimensions and a complex construction. The ready to use buoyant segments, that assure the proper displacement, must have the factory leak-tightness. They take up a big transportation volume and need the assurance of the suitably abundant means of transport. Usually the heavy wheeled vehicles are needed because of high own mass of buoyant segment and large gauges. The exploitation of such constructions is very expensive. A cassette pontoon bridge, presented in this paper, is the proposition of the increase of the mobility of construction. The decrease of the single buoyant segment dimensions with the assurance of the capacity leads that more segments fit into in the same dimensions of the loading compartment of the vehicle and storage accommodation. The application of standardized joints assures the assembly efficiency with not numerous crew.

PONTONOWY MODUŁ PRZEPRAWOWY O WYSOKIEJ MOBILNOŚCI

Summary. W znanych i stosowanych mostach pływających służących jako przeprawy zastępcze, pojedyncze segmenty konstrukcji pływających stanowią metalowe obiekty o różnych wymiarach w postaci zamkniętej. Ich cechami niepożądanymi jest duża objętość transportowa i wymóg zapewnienia bardzo licznych środków transportowych, sprzętu towarzyszącego i zespołów obsługujących. Mobilność takich konstrukcji jest bardzo ograniczona z powodu ich cech połączeń. Pontonowy moduł przeprawowy, przedstawiony w pracy, jest propozycją zwiększenia mobilności tego typu konstrukcji. Zmniejszenie gabarytów modułu, przy zachowaniu nośności powoduje, że w tej samej objętości ładunkowej i magazynowej mieści się większa liczba segmentów co pozwala na przewiezienie sprzętu przy pomocy ograniczonej liczby pojazdów o standardowych wymiarach oraz redukcję miejsca na jego składowanie. Zastosowanie zunifikowanych połączeń zapewnia sprawność montażu, przy niewielkim zespole obsługującym. W pracy przedstawiono wstępny etap badań polegający na określeniu wyporności konstrukcji. Przytoczono przykład jej zastosowania do przeprawy typowego samochodu dostawczego.

1. INTRODUCTION

Since the pontoon bridge allows moving or supporting heavy equipment loads over the canals, streams, rivers, lakes, inlets and bays, its nonmilitary applications are limited in modern times.

A permanent pontoon bridge is supported by boat-like pontoons in order to support the bridge deck and its dynamic loads. In military application the pontoon bridge is a modular system consisting of interior and ramp pontoons which are transported, launched, and retrieved by a heavy-duty vehicle. Individual steel type pontoons, which assures the proper displacement, must have the factory leak-tightness, and they take up a big transportation volume and need the assurance of the suitably abundant means of transport, accompanying equipment (e.g. cranes) and service personnel. The loading and unloading of such pontoons as well as the service and assembly on the water need numerous, highly qualified crew and the specialized equipment. All of these limit the scope of applications of such heavy constructions. The lack of proper mobility is the reason of their uselessness especially in the hard cross-country conditions, what limits the operational capabilities. The exploitation of such constructions is very expensive. The usage of the steel pontoons needs the assurance of the proper storage and service conditions. Those serious limitations and disadvantages in usage and exploitation of the up to date buoyant systems can be remarkably reduced or eliminated in the scope of the usage of the proposed cassette pontoon bridge.

The most important component of a floating bridge is a pontoon which should be lightweight, easy to build and transported. In 1851 the Goodyear Rubber showed, on display in London, the first pontoon made of India-rubber [9]. During Civil War the U.S. Army tried to used this type of construction. An inflatable, collapsible military pontoon bridge is described in detail in US242383 patent from 1947. In this construction the air compartments are placed in rigid, semi-cylindrical part with constant volume [7]. The air compartment is used as a supporting element in a construction described in CA886879 patent [1]. At present a major element of the Joint Enabled Theater Access Sea Port of Debarkation (JETA SPOD) Advanced Concept Technology Demonstration is the Lightweight Modular Causeway System (LMCS). The assumption of the LMCS was to be lighter, faster and easier to assemble, and require less manpower than existing Army causeway systems [3]. A great disadvantage of the solutions presented in CA886879 patent and in the LMCS construction is lack of any protection against damages caused by projectiles or explosives.

The main goal of the paper is to present a new idea of a single segment of the pontoon bridge consisting a metal cassette with the air cushion inside.

2. CASSETTE PONTOON BRIDGE

The cassette pontoon bridge [4] is considered as an object assembled as any composition of the single buoyant segments having the configurations and dimensions that are the multiplication of the basic dimensions of the single buoyant segments presented in Fig. 1a and 1b.

The single elements can be assembled into the cassette pontoon bridge with the usage of the joints between solid parts of every element [5].

The main element of the single segment construction is the cassette made of the lightweight metal. The cassette is sealed, which assures the initial load capacity of the construction, resulted from the difference between the uplift pressure and deadweight, and enables the easy assembly directly on the water.

The element that assures the displacement is the air cushion filled with pressured air, made of a flexible textile and reinforced with the usage of the composite layers (Fig. 1d). In the closed position, the air cushion textile is stored inside the cassette which upper part is also a roadway surface for moving vehicles. The door is opened with the mechanism that uses the pressure inside the air cushion, and is closed by the easy mechanism and the previous air cushion taking down into the cassette. The elastic net, which stabilized the cushion, is fixed to both cassette lids and helps to pack the air cushion. The opened door protects the air cushion from the side against damage and in the military applications it is the ballistic protection.

The joints between the air cushions in the adjoining elements are realized by the pressure quick-action fastenings. The hinge joints assures the connection with the limited movement ability of the elements to each other.

The single buoyant element is characterized by a modular construction, which enables the disassembly of the basic parts of the set for the transportation aims. In the transportation position, the air cushion located in the cassette chamber leading to the savings in the transportation area and increasing the mobility of the buoyant sets.

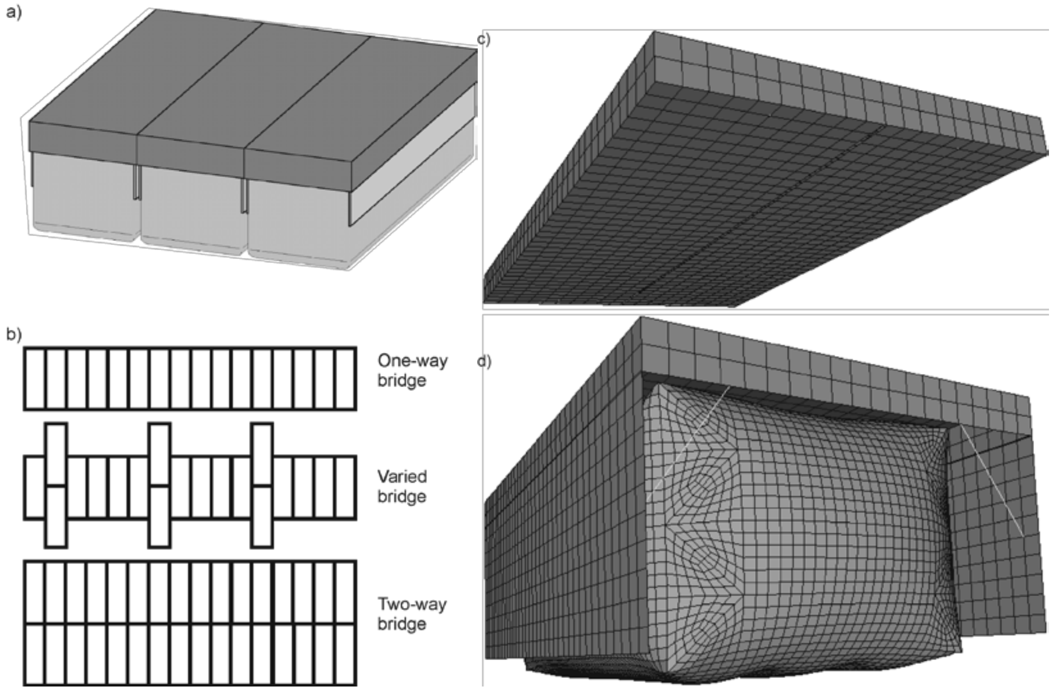

Fig. 1. a) Multiplication of the single buoyant segments; b) Any composition of the single buoyant segments; c) The transportation position; d) The exploitation position

Rys. 1. a) Połączenie pojedynczych modułów; b) Przykłady zestawienia pojedynczych modułów; c) Moduł pontonowego mostu kasetowego w pozycji transportowej; d) Moduł pontonowego mostu kasetowego w pozycji eksploatacyjnej

3. DISPLACEMENT

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 and the mass of the moving vehicle.

Consider the single buoyant segment of arbitrary shape and volume V surrounded by a water [8]. The force the water exerts on the single buoyant segment within the water is equal to the weight of the water with a volume equal to that of the single buoyant segment. This force, named buoyant force, is applied in a direction opposite to gravitational force that is, of magnitude ρVg where ρ is the density of the water, V is the volume of the displaced body of water, and g is the gravitational acceleration at the center of gravity. The mass density of fresh water is 1 t/m^3.

The single buoyant segment is floating in equilibrium and the sum of the forces on the object is zero,

$$mg - \rho Vg = 0 \tag{1}$$

therefore

$$m = \rho V \tag{2}$$

shows that the depth to which a floating object will sink (its "buoyancy") is independent of gravitational acceleration regardless of geographic location.

The weight of the volume of the water that is displaced by the underwater portion of the air cushion and cassette is equal to the weight of the single buoyant segment and the weight of carrying loads.

Since the mass of the single buoyant pontoon segment is considered as the mass sum of the flexible air cushion and the cassette, the mass of the assembly strongly depends on the cassette mass. The air cushion textile mass can be negligible due to textile material.

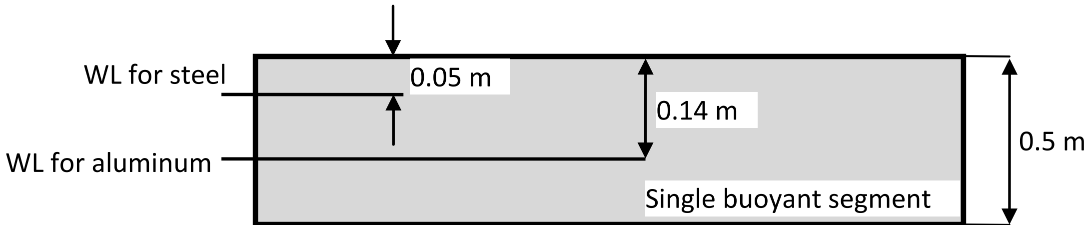

Fig. 2. The waterline for cassette with unfolding air cushion
Rys. 2. Schemat linii wody dla kasetowego mostu pontonowego

Two kinds of cassette material are taken into account: steel and aluminum alloy. The crucial element is a deck of the single buoyant segment which should be stiff enough to carry a moving vehicle. Therefore this part of assembly is made of steel in both cases. Waterline (WL) for cassette with unfolding air cushion for each case is shown in Fig. 2. Waterline indicates the limit to which the single buoyant segment may be loaded for specific water types and temperatures.

When air cushion is filled to the depth of 1.1 m, the buoyancy of a single buoyant pontoon segment made of light alloy increases from 0.47 t to 7.95 t for waterline location 0.1 m below the upper cassette surface.

If a single buoyant segment is inclined by external force as wind or waves, the centre of gravity should not change position, but the centre of buoyancy will shift to the geometric centre of the new underwater volume. Since the forces of buoyancy F_B and gravity F_G are equal and occur along parallel lines, but in opposite directions, a rotation is developed and a righting moment is created. The righting moment tends to bring the single buoyant segment back to the upright position where the forces of buoyancy and gravity balance out. The righting moment (Fig. 4a) is the best measure of the single buoyant segment overall stability [6].

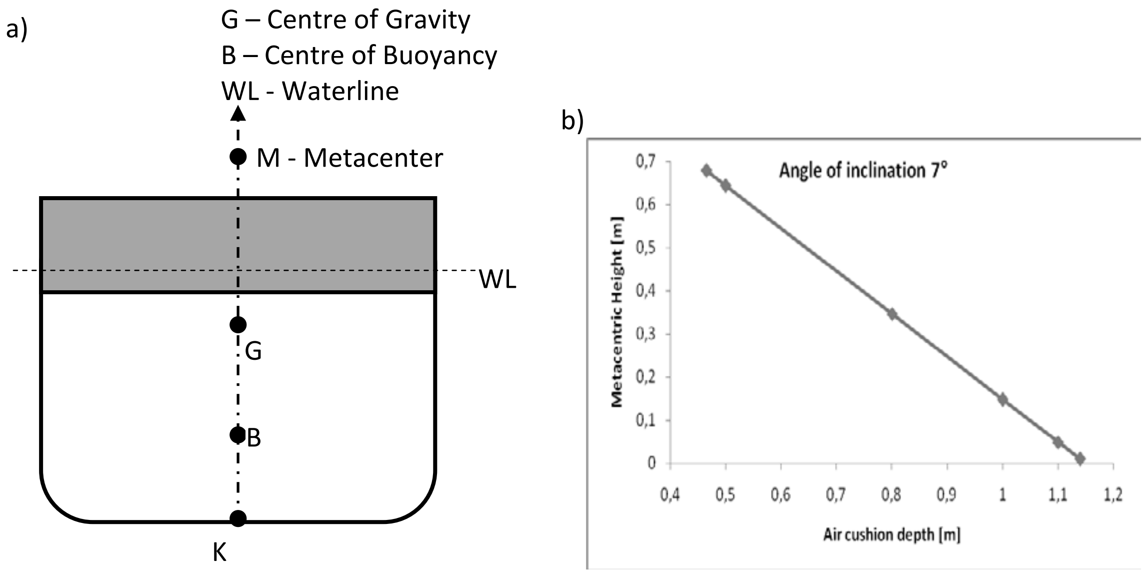

Fig. 3. a) Position of stability reference points; b) Metacentric Height for different depths of filled air cushion
Rys. 3. a) Położenie punktów odniesienia do określania stateczności; b) Wysokość meta centryczna dla różnych głębokości napełnionej powłoki

The moment of statical stability is the value of this righting moment. Initial stability of the single buoyant segment is indicated by the position of the Gravity and Metacenter (GM – Metacentric Height) (Fig. 3a). Metacenter is located at the intersection of the buoyant vector and the centerline for small angles of the single buoyant segment inclined. Under normal condition the metacenter is located above the single buoyant segment center of gravity (Positive Stability). The GM is said to be positive. For Neutral Stability the metacenter and the center of gravity are in the same location. For small angles of inclination (0° through 7° to 10°) the metacenter doesn't move. The Metacentric Height is calculated for different depths of filled air cushion and is shown in. Fig. 3b.

As the single buoyant segment is inclined, the center of buoyancy moves in an arc as it continues to seek the geometric center of an underwater hull body as shown in Fig. 4a.

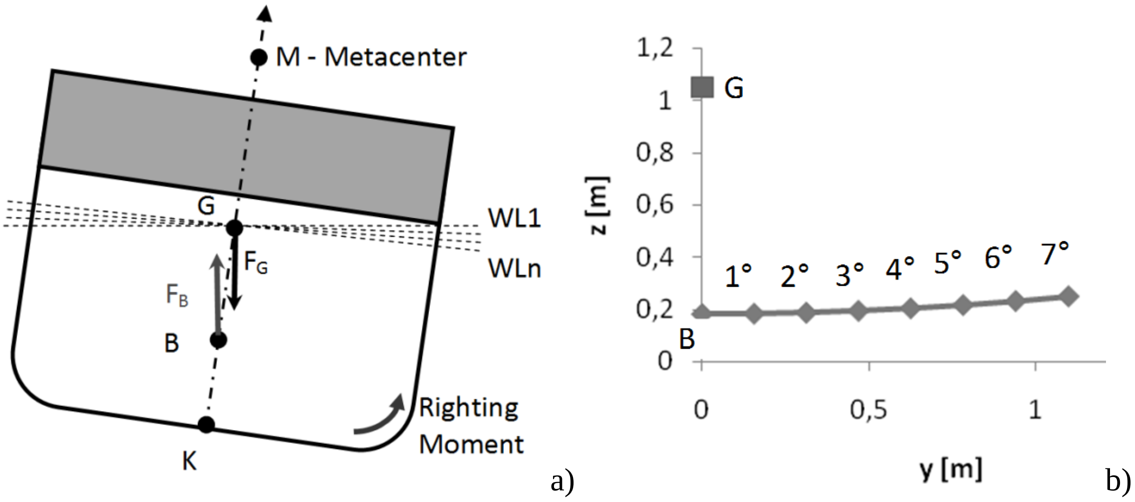

Fig. 4 a) Initial stability; b) The change of the centre of buoyancy for the cassette with filled air cushion
Rys. 4. a) Stateczności początkowa; b) Krzywa przemieszczania środka wyporu w trakcie przechyłu modułu

The change of the centre of buoyancy for the cassette with filled air cushion to the depth equal to 1.1 m for the seven values of angle of inclinations is presented in Fig. 4b. It shows the initial stability of the unloaded single buoyant segment and the ability assembly to upright.

4. APPLICATION

A Fiat commercial vehicle is used as exemplary application. The main dimensions and weight [2] are presented in Tab 1.

Table 1

The main dimensions and weight of the Fiat commercial vehicle [2]

GVM [kg]	Payload [kg]	Wheelbase [mm]	Exterior Dimensions	
			Total length [mm]	Total width [mm]
4005	2009	3450	5413	2050

The reserve of displacement after a single buoyant segment loading is shown in Fig. 5.

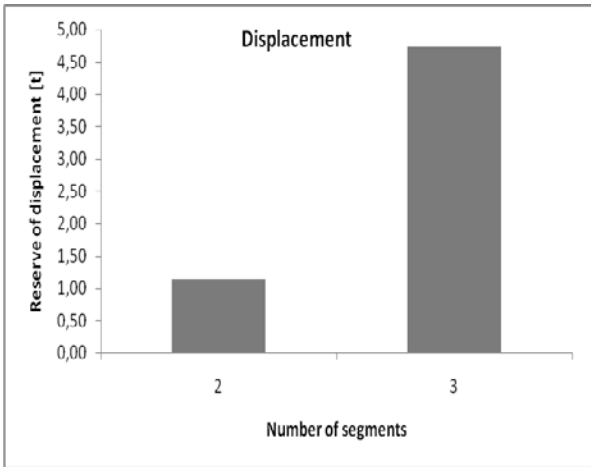

Fig. 5. Reserve of displacement
Rys. 5. Zapas wyporności

5. CONCLUSION

The single buoyant segment is designed and dimensioned for ease of handling, freedom of transport, simplicity of assembly, and practical economic application in civil and military applications at diverse locations.

The preliminary calculation indicates that the proposed single buoyant segment assures the initial stability in the unloading condition.

The objects built of single segments of the cassette pontoon bridge may be used as temporary crossings as a substitute for the damaged or broken crossing objects. The cassette pontoon bridge may also be used as a substitute crossing during the overhaul or conservation of the constant crossing objects and other elements of the water infrastructure. The original attribute of the single element of the floating cassette pontoon bridge that builds the total complicated floating system is its total repeatability and changeable displacement. It allows to reach the optional dimensions and building configurations of the cassette pontoon bridge.

The exploitation properties of the cassette pontoon bridge allows to develop the assumed floating systems building capabilities for any constructional configurations, the number of the used elements and the cushion filling level which allows to control the displacement of the cassette pontoon bridge. The multiplication of the assembly and disassembly processes, reaching the leak-tightness, as well as the great failure and damage resistance, realized by the usage of the strengthening textile with the higher strength, definitely widen the scope of the cassette pontoon bridge usage. It causes the rise of the bridge usefulness. The constructional properties of the described bridge single elements provide the easy transport of the larger number of the segments in the small cargo capacity and quick assembly of the long parts of the built floating systems as well as the compact construction thanks to the hidden cushion. It allows an easy storage and transport of the system elements. Because of the simple construction and small number of the parts, the assembly of the full functional floating objects is possible to be accomplished by the numerous crews with no special training.

Acknowledgements

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