Innovative Solution for Rapid Crossing the Danube, with Absolute Technical, Economic and Financial Accessibility

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Abstract: The EU Strategy for the Danube Region (SUERD) is among the priority objectives connecting the Danube region and increasing prosperity, and the development of infrastructure can help achieve these goals. Over time, there were practiced several solutions to cross rivers on under- or over water, mainly bridge or tunnel, both having advantages and disadvantages in the multiple facets of several possible analyses, but certainly costly and time consuming. The cheaper and feasible solutions of crossing the Danube, independently of political, financial, group interests, can be an important step in the real development of the region, in making a flowing connection between large and small cities, on both sides of the river, economic development of less favored areas, eliminating marginalization and isolation caused by lack of infrastructure and to contribute to the success of implementing strategies. In this paper, the authors present an original solution for crossing the Danube using floating pontoon-type floating sections anchored at one of the river banks and foldable floating bridge. In terms of construction, the involved technical and economic elements are easy to perform, so this is the best solution for rapid crossing of the Danube, very accessible including areas with poor financial situation. As it involves a correlation of vessel traffic and vehicles, the solution applies especially in areas with relatively low vessel traffic, such as in Romania over the Danube between Sulina and Cernavoda, where most vessels pass the Danube-Black Sea Canal. The advantages are very important for the poorer localities but with potential, the economic impact for crossing being generated almost immediately by the adequate infrastructure, paying off the construction costs in a short time, thus favoring the overall development of the area.

Keywords: floating deck; floating pontoon; pivot

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1. Introduction

The benefits and need for infrastructure development at the level of Eastern Europe gain official recognition in the 90s, with the opening of the Conference series of Pan-European Transport. There were initially established the approach centered on transport corridors, the so-called Helsinki corridors or Pan-European corridors, ten in total, each with a road and a railway component. Except the Corridor VII which is represented by the Danube segment that crosses also the Romanian territory, along with Corridor IV and Corridor IX.

The EU Strategy for the Danube Region complements these efforts with activities focused on the target area and its realities, identified on each segment separately. The interconnection of the region and increase of prosperity while protecting the environment and strengthening the region are essential objectives for a favorable evolution, and the infrastructure investments represent a determined pre-condition, mainly by highways, fast roads, bridges and tunnels.

In order to develop the region realistically, we believe that attention should be paid to each administrative component at the level of the Danube, not just major cities, so as to achieve a continuous connection between regions, on both sides of the river, an equitable competitiveness, eliminating bottlenecks, the marginalization and isolation caused by the lack of infrastructure. In this context, the inexpensive and feasible solutions to cross the Danube, beyond the political or financial interests, can be an important step for economic development of the areas less favored, that would generate benefits to the entire territorial network and to contribute to the success of the implementation of strategies.

2. The EU Strategy for the Danube Region - Objectives and Priorities

Part of the pan-European transport Corridor VII, the Danube represents a significant waterway, which connects the Western Europe and Constanta port, thus providing a direct access to the Black Sea and connecting EU with the wider region of the Caucasus and Central Asia.

The river importance is recognized but at the same time, it is visible that it has a potential for economic growth insufficiently developed.[1] This is obvious especially at the level of localities that are lined up on the both sides of the bank of the Danube, in less favored areas of the EU and we refer in particular to Romania and

[1] http://www.cdep.ro/afaceri_europene/afeur/2011/fi_783.pdf.

cities with untapped potential due to the lack of adequate infrastructure to bind them at the level of the river and connect them in at national, European level and the wider region of Asia.

The EU Strategy for the Danube Region (SUERD) is “a community mechanism for cooperation of the Danube basin states, for economic and social development of the Danube macro-region, by strengthening the implementation of EU policies and legislation in the region”.

SUERD is the second EU macro-regional strategy, promoted as a policy initiative of Romania and Austria, taking the cooperation model developed by the EU Strategy for Baltic Sea (adopted in 2009) with adaptation to the specific of the Danube region.

The strategy is structured around four main **objectives**:

- connecting the Danube Region;
- protect the environment in the Danube region;
- prosperity in the Danube region;
- strengthening the Danube region.

Each objective of the strategy corresponds to specific areas of action, grouped into 11 priority areas, each priority area is coordinated by 2 states / provinces in the region, namely:

Within the Interconnecting of the Danube Region it is stated:

• Improve mobility and multimodality

a. inland waterways (Danube) (Austria and Romania)

b. road, rail and air networks; (Slovenia and Serbia)

• Encouraging sustainable energy; (Hungary and Czech Republic)

• Promoting culture and tourism, people to people contacts; (Romania and Bulgaria)

The major benefits that the strategy brings to Romania are:

• Developing the quality of life by increasing competitiveness and attractiveness of the Danube localities;

• Attracting investments in strategic areas such as transport infrastructures, environment and energy.

• Contribution to the increase of the capacity to absorb structural funds and investment that incumbent to Romania.

3. The Existing Solutions for Rapid River Crossing

Rapid river crossing can be done with ferries, bridges, tunnels drilled tunnel under the riverbed or caisson type of items placed on the bottom of the water after a preliminary deepening of it.

Some of these types of crossings are presented below.

3.1 Bridge across the River

Calafat-Vidin Bridge is a rail and road bridge on the Danube, connecting the cities Calafat (Romania) and Vidin (Bulgaria). The bridge is part of Pan-European Transport Corridor linking (endpoints) the German city Dresden to Istanbul in Turkey and Thessaloniki in Greece.

The investment would cost 300 million euros, of which the Romanian government should provide 150 million euro. It is estimated that in the next 15 years it will amortize the construction costs.

Figure 1. Calafat-Vidin bridge on the Danube[1]

[1] Guide Bulgaria: "New Danube bridges Oryahovo-Beket and Silistra-Calarash negotiated with Romania", Article published on 5 December, 2008.

3.2. Drilled tunnel

The example is shown in Figure 2 one of 3 tunnels under the Danube in Vienna. It is a tunnel with a length of 1.5 km, the tunnel has four sections, each with two lanes in each direction and a reservation service for special situations.

Figure 2. Entering in the tunnel under Danube in Vienna[1]

3.3 The Immersed Tunnel

The immersed tunnel is used for road and rail crossings of rivers. A**n immersed tunnel** is an underwater tunnel composed of segments, constructed in a dry dock and floated to the tunnel site to be immersed into a chosen place and then linked together.

The tunnel is made up of separate elements each built in a dry dock, blocked at its heads with blind that permits to float. At the same time, the corresponding parts of the path of the tunnel are prepared, with a trench on the bottom of the channel being dredged and graded to fine tolerances to support the elements. The next stage is to place the elements into place, each towed to the final location, in most cases requiring some assistance to remain buoyant. Once in position, additional weight is used to sink the element into the final location, this being a critical stage i.e. to ensure each piece is aligned correctly. After being put into a place it is made the joint between the two elements. This process is continuing sequentially along the tunnel.

[1] https://ro.wikipedia.org/wiki/Metroul_din_Viena#/U2_Donaustadtbr.

The main advantage of an immersed tunnel is that they can be considerably more cost effective than alternative options like a bored tunnel under water bottom crossed. Other advantages:

• Their speed of construction;

• Minimal environment influence;

• Minimal disruption to the river;

• Resistance to seismic activity;

• Safety of construction, because is built in a dry dock;

• Flexibility of profile (although this is often partly dictated by what is possible for the connecting tunnel types);

The disadvantages include:

• Direct contact with water necessities careful waterproofing design around the joints;

• The segment requires careful design of the connections, where longitudinal effects and forces must be transferred across;

• The starting point of an immersed tunnel design is required to have cross-sectional area;

• Dimensional requirements vary from country to country.

Inside of tunnel existing adequate space on the roof for ventilation booster fans, luminaries and signal.

In figure no. 3 it is shown an immersed tunnel ready to float to the immersed area.

Figure 3. Segments of immersed tunnel ready[1]

The costs of achieving such crossings are approx. 120 billion Euro the amortization of the expenses being in 5 years and a half.

4. Original Solution for Rapid River Crossing

The solution is based on the construction of floating sections of the floating pontoon type anchored at one of the banks of the river, preferably on the opposite bank of the navigable channel of the Danube, and foldable floating bridge across the waterway.

The authors proposed solution uses two floating configurations, one fixed and one mobile:

- Floating pontoon, anchored with hawsers of keys and metal stoppers that fix it in the desired position;
- Floating deck which can pivot around an edge that belongs to the floating pontoon.

Pivoting is achieved by means of hydraulic cylinders that rotate on the floating deck at 90 degrees to the side facing the river's floating pontoon.

Pivoting is achieved only when a convoy of ships must pass, at which time, using the hydraulic cylinders it flips the floating deck, thus creating the necessary space

[1] https://ro.wikipedia.org/wiki/immersed tunnel.

for the passage of ships. The operating process of the floating bridge, which is performed with hydraulic cylinders, lasts 10 minutes, making it fast and secure.

Currently, the management system of vessels that circulate on the Danube upstream or downstream is tracked by specific systems by naval authorities, with whom it can collaborate to establish the opening or the closing system of the floating bridge.

After passing the ships, it returns into the position on the opposite pier of the floating deck. The floating deck is held in position by means of rabatable tampons (2) (seen in Figure 4).

From the construction point of view, as any pontoon, it does not involve complex technical problems and it can be achieved in a shipyard.

The calculation of the difficulties incurred by the floating pontoon in the continuous flow of cars and cars that transport loads from the drafts measured simultaneously with temperature and water density and using the documentation for loading or using the appropriate mathematical formulas. In calculating the amount of loads in continuous flow, some corrections intervene in order to eliminate the errors that occur due to the differences between the actual conditions of calculation and those for which the documentation has been prepared. The used method involves in the end the determination of an average values, called medium draft of the average. It then calculates the hardships known on board and the determination of the pontoon's constant. The same estimates are achieved also for the floating deck.

Within the prototype experiments there were performed a number of measurements of the weight of the transported loads estimated to the maximum flow during the crossing.

At the end of the experiments it was performed one last measurement taking into account the specific gravities of the floating deck.

In the first conducted experiments of the floating pontoon is given under the condition of partial shingle ballast. Ballast tanks were full which were verified by outpouring method.

For the empty tanks there were conducted surveys to determine the amount of ballast water. There were indicated in the bow and stern drafts on the draft scale located on the floating pontoon body. For the draft from the middle of the floating pontoon it was carried out its determination by measuring the distance between the water line and the deck.

From the height of the floating pontoon body (the distance between the keel and deck line) it was low previously determined distance and it was obtained the draft from the center.

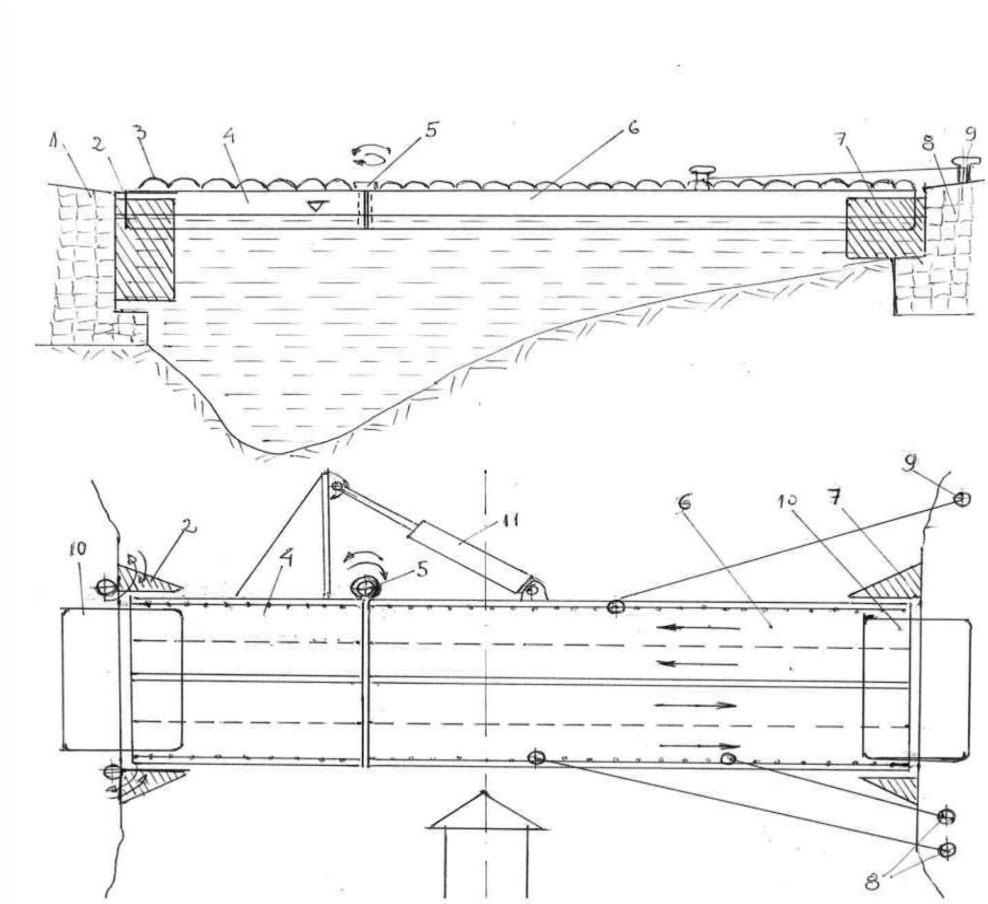

Figure 4. Proposed solution (lateral view-up and aerial view-down)

1 - water border; 2 - rabatable tampon for stabilized floating deck; 3 - floating deck border protection; 4 - deck; 5 - pivot mounted on the floating pontoon; 6 - floating pontoon; 7 - tampon for stabilized floating pontoon; 8, 9 - points of attachment to the loading bay of the water; 10 - the collision pontoon connection; 11 - hydraulic cylinder.

In Figure 5 there can be noticed the structural elements of the floating pontoon, and an overview in the moment of preparing for launch can be seen in Figure 6.

We should mention that the pontoon both fixed and rabatable of the deck is equipped with sound and light warnings in order to prevent any incident.

On the route of the river, downstream and upstream of these floating crossings there are installed river warning signals on approaching the crossing.

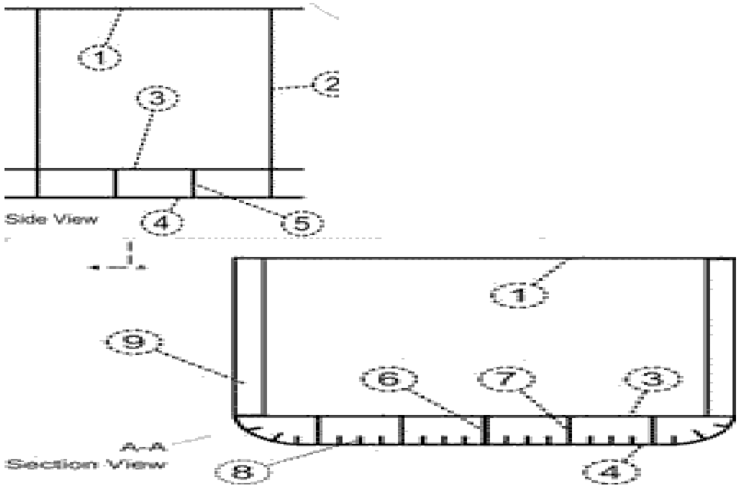

Figure 5. The structural elements of floating pontoon:

1 - bridge surface (main deck); 2 - Dividing wall; 3 - interior metallic plating; 4 - exterior metallic plating; 5 - transverse frame; 6 - The keel framework; 7 - Cockpit; 8- Longitudinal consolidation; 9 - crossbeam.

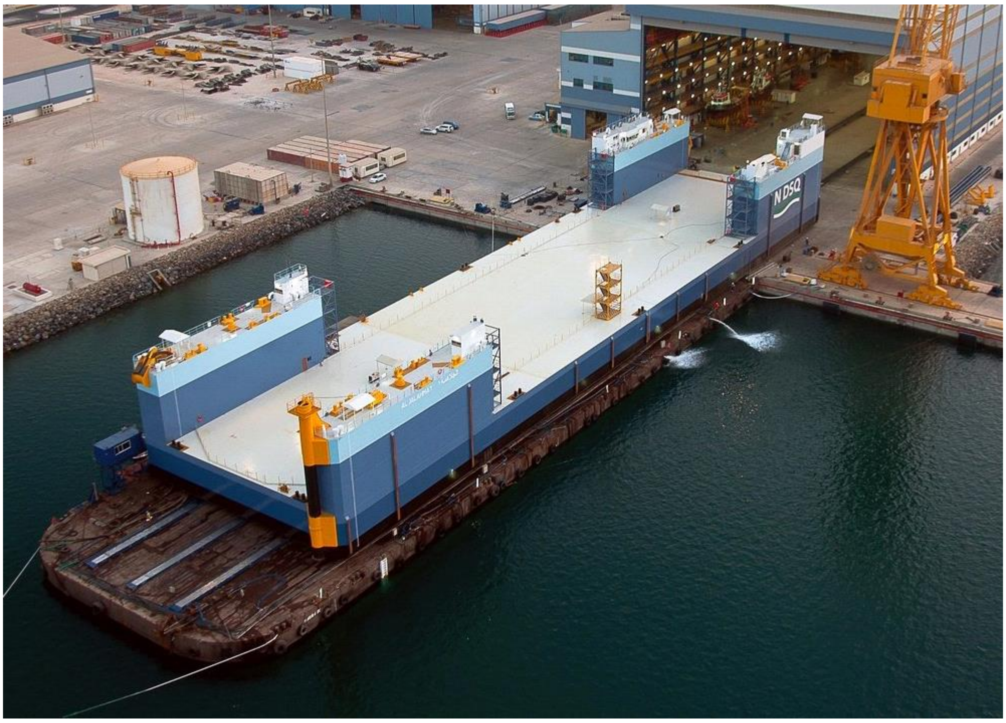

Figure 6. Floating deck ready to launch[1]

Regarding the costs of achieving the two floating structures in a shipyard, they are a maximum of 10 Billion Euro. We add to this the costs of feasibility studies and arranging the banks. Before beginning the construction of the floating sections, it is established the crossing area and there are build the docks where the floating pontoon and deck will dock, whose size will be crucial for the achieving of the floating sections.

The feasibility studies cost and quality can be improved by involving the local university researches.

[1] http://products.damen.com/en/ranges/floating-dry-docks

5. Conclusions

The originality of the solution is on the functionality of the assembly by using a fixed floating section making permanent connection to the land (one of the banks), while the second floating section engages the other side, by flipping around a pivot fixed to the end of the pontoon anchored to the waterfront.

The advantages of these crossings are:

- Simplicity, robustness and construction safety;
- Easy fixing related to the two piers river banks;
- The construction with local companies and materials;
- Creating jobs;
- It is not influenced by the increase or decrease of the level of the Danube, by the soil structure;
- The use is flexible and it can adapt to the existing conditions at any time and does not negatively affect the environment;
- It operates rapidly, saving time to the passage of river convoys;
- The costs of the production of the pontoon and deck floating flaps are at the level of under a quarter of the cost of a bridge or a tunnel, making it the best solution for rapid crossing of the Danube, very accessible including poor areas with poor financial resources;
- Connecting the two floating systems directly to the docks of the both sides of the river.

A drawback of this solution is caused by the interruption of the crossing when naval boats have to pass, but this disadvantage can be eliminated if in parallel it is built a crossing system identical to the first. When it opens one of the system, the other one can cross, then it closes the first system to be resumed the crossing on it and it opens the second for passing ships. In this way we achieve a rapid continuous crossing of the Danube.

Increasing the traffic in areas with a relatively weak economy, which enables the interconnection with regions of international and national interest, leads to the development of poorest localities, whose potential has not been exploited, being isolated by a river that should unite, but it cannot be accessed due to the lack of adequate infrastructure. The economic impact of crossing is generated almost immediately by the adequate infrastructure, amortizing the construction costs in a short time favoring the overall development of the area.

As it involves a correlation of vessel traffic and cars, the solution applies especially in areas with relatively low vessel traffic, such as in Romania over the Danube between Sulina and Cernavoda, where most vessels pass the Danube-Black Sea Canal. We mark this as a temporary disadvantage that can be overcome in time by increasing the resources, the interest of some investors, leading to the application of other more costly constructive solutions.

6. Bibliography

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