Conceptual Design of a New Shipyard on River Sava

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ABSTRACT

This paper presents first the observed situation in Croatia with respect to inspection, repair, maintenance and building of inland waterway vessels. It implies current economical circumstance, environmental conditions, potential locations, design requirements, as well as basic operational and technological procedures. Next, the technical problems with respect to the required yard infrastructure, necessary equipment and workmanship are considered. The background of common political and economical reasoning is given, as well the principal arrangement of the planned yard facilities, at the first moment for primarily for inspection and repair, and hopefully, in the future for new buildings. Some technical calculations examples with more interesting details are provided in order to illustrate the proposed vessel lifting procedure. Finally, the paper presents evidences of the building activities on a new shipyard at the river Sava in progress or completed so far.

Keywords: Inland shipbuilding, repair, maintenance, new building, shipyard, towing wagon, railways.

1. INTRODUCTION

During the war in the former Yugoslavia many inland waterway vessels were trapped in rivers Sava, Kupa and Drava in Croatia and have been cut of main European waterways. Several vessels have been sunken. Many of the ships were put out of commission and most of them are nowadays ready for scrap. The inspection of a number of unrigged vessels indicates serious deterioration of superstructures, accommodations, deckhouses and outfit, but relatively good condition of the steel hulls. However, due to the essential lack of normal docking facilities on Croatian inland waterways, a number of vessels require urgent inspections and maintenance followed by great investments in renewals to be back into service. In spite of the feasibility analysis of a provisional docking procedure using hulls of laid-up ships [1] for lifting of floating objects in inland waterways, Fig. 1, the investors decide to continue the investigations of a traditional lifting procedure [2], by using the idea of marine railways [3], mostly due to technical advantages in safety and durability, as well as following the common sense reasoning about economy in a long term. Therefore, the paper presents the preliminarily investigations, conceptual design and technical feasibility study, having in mind potential benefits of building ways for lifting inland vessels in Croatia. The encountered situation and the observed data are summarized in order to define the design requirements. The specific loads are particularly considered for the towing wagons, railways and for the groundways. Results of a 2D and 3D FEM structural analysis applied to towing and transportation wagons are briefly presented for a number of relevant load cases. The building activities in progress are illustrated in concluding remarks.

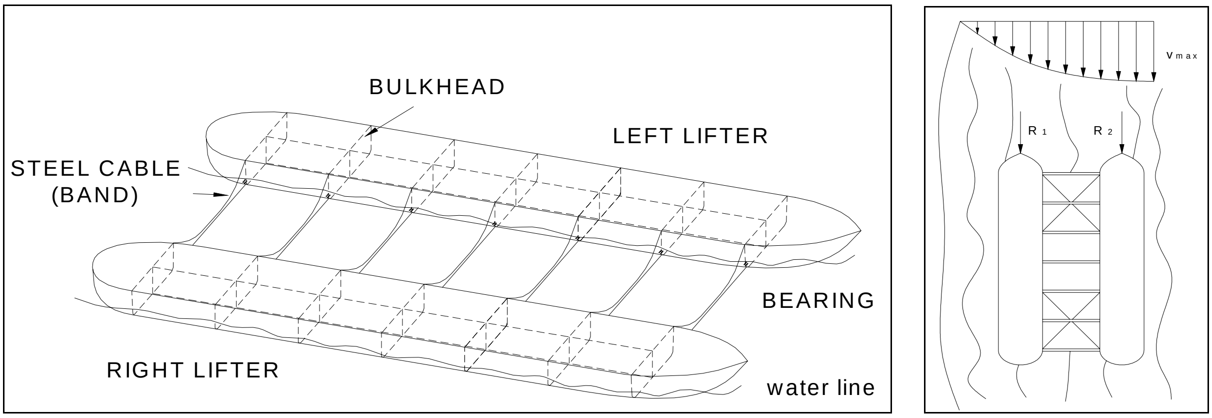

Fig. 1. Docking arrangement with two laid-up tankers floating in river current

2. THE OBSERVED SITUATION

The Croatian inland navigation facilities provide over 300 vessels classified under Croatian Register of Shipping (CRS). The average age of all the vessels is over 25 years [4]. Normal maintenance procedure according the CRS Rules and regulations, require inspection every five years, also including the compulsory survey of underwater hull. Moreover, repairs of hull damages in ship service have to be checked and certified for continuation of the vessel's service permit.

Croatian inland waterways at present do not provide any facilities for inspection and repair ashore. Relatively small number of vessels has been inspected ashore under CRS survey, most of them outside Croatia, and only few of them in Croatia using provisional slipways or fluctuating river water level.

Hence, two or three slipways are anyhow needed in Croatia with realistic chance to be beneficial. The two potential locations are at river Sava in Sisak and Slavonski Brod region, and the another location could be at rivers, either Drava or Danube, near the, either Osijek or Vukovar. A number of 50 vessels available per year are a sound guarantee for full usage of repair yard facilities in Sisak employing about 70 employees. Moreover, the existing infrastructure of the formerly repair workshops on this location can be renewed and easily brought to usefulness as the facilities of the planed shipyard on this place. Vessels of about 400 tones in mass and up to 80 meters in length are planned to be pulled ashore sideways at appropriate wagons towed on railways. In a preliminary analysis, the vessels in Croatian inland waterways and their main characteristics are observed, e.g. number of ships with respect to length, Fig. 2.

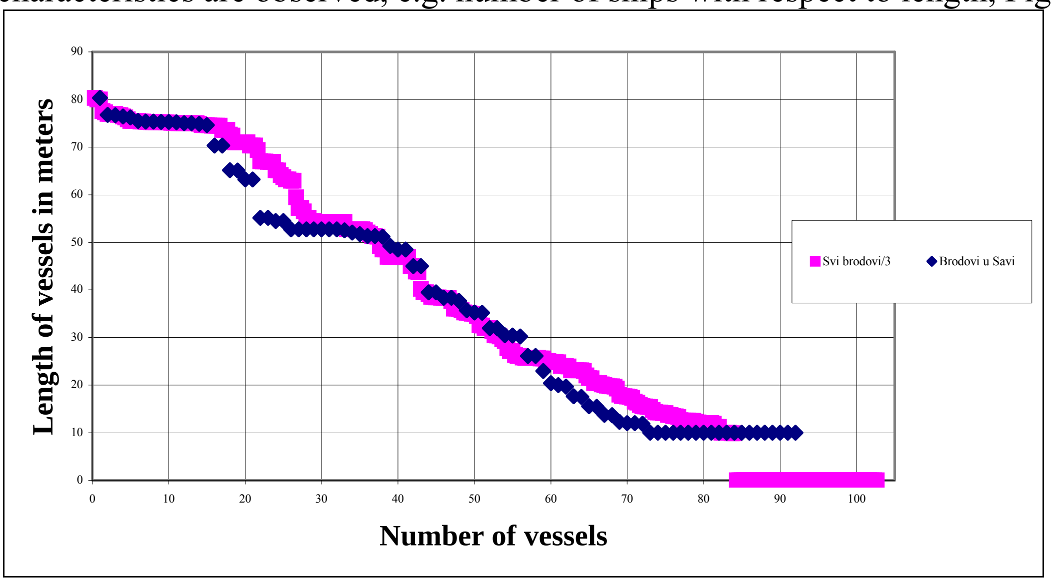

Fig. 2. Number of vessels in Croatia and in river Sava only (bright line) by length

3. THE LOCATION DESCRIPTION

By inspection on the specified location at the left bank of river Sava near Sisak, the natural and technical conditions were observed [5], as follows:

The appropriate available area is of almost rectangular shape, with the diagonal approximately following the flow of river Sava. The overall available length of the riverbank at the selected shipyard location is 320 meters.

A huge inclined working platform of at least 80 meters in length and of about 50 meters in widths is encountered, Fig. 3.

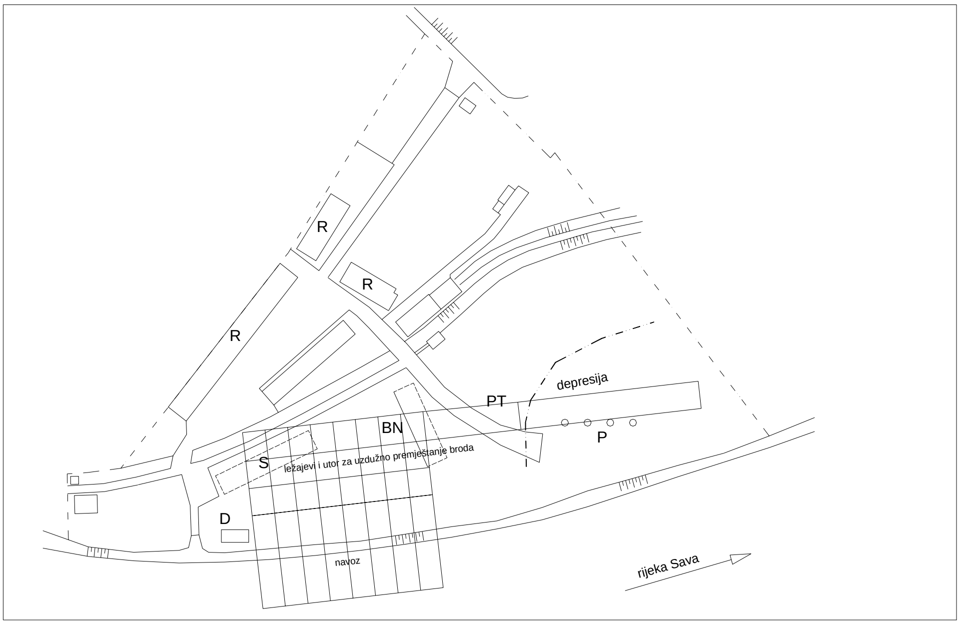

Fig 3. The current location and disposition of the groundways

Long-term observations indicate oscillations in water level elevation of about 8 meters. The map in scale 1:1000 from the year 1997 was found useful but required corrections. By examining the cross profile of the river, the bottom is on the attitude of 87 meters and the position at the top of the yard is at 99.3 meters, Fig. 4. Hence groundway on this location can be conceived as an inclined platform with maximal slope of 15 degrees, providing the requested operational capacity.

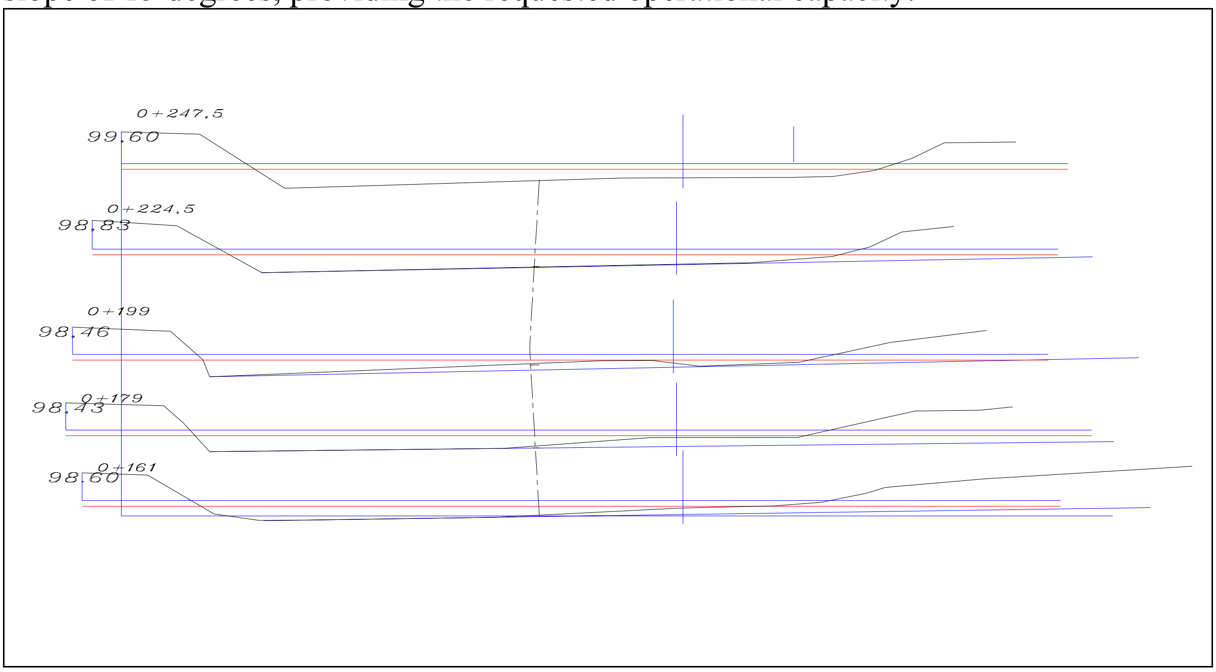

Fig. 4. The river Sava cross profile at the considered location

Technical objects, such as roofs, protecting walls, rails for cranes, ways and gangs, were observed on the location, as well as same old towing wagons in relatively good shape, which might be either usefully applied, modified or removed. Orientation of the groundways on the selected location can be either orthogonal to the shoreline or orthogonal to the river inundation. Considering carefully all the observed conditions and limitations, a compromising orientation is selected, Fig. 3.

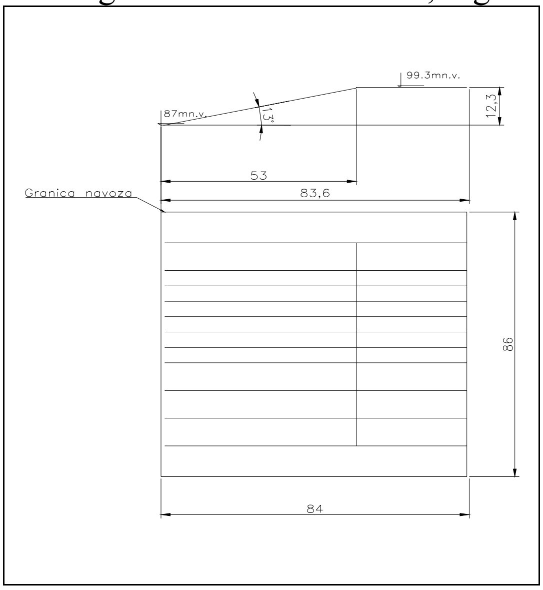

Fig. 5. The main particulars and slope of the ground way at the selected location

The orientation mostly orthogonal to the inundation, but slightly rotated towards the shoreline provides the required length of 80 meters with potentials for lengthening in the river downstream direction. Moreover, the breadth of such a platform is appropriate for three vessels, Fig. 5. The slope angle is now preferably smaller amounting to α = 13 degrees. The selected orientation needs additional costs due to required changes in the river flow, Fig. 4, but simultaneously, implies cost reduction due to easier founding.

4. DESIGN REQUIREMENTS

The design requirements applied to the selected location on the left bank of river Sava in Galdovo near the town of Sisak, on a place where earlier operated a repair shipyard, can be summarized according to starting conditions, as:

- The maximal length over all of the longest ship $L_{oa} = 80\ m$
- The maximal mass of a heaviest ship: $G = 400\ t$
- The upper: $v_g = 99\ m$
- The lower attitude of the operational platform: $v_d = 88\ m$
- The maximal slope: $\alpha = 15$ degrees (preferably smaller).

The main particulars of a typical tanker for inland transportation, Fig. 6, are:

$L=72\ m,\ B=10\ m,\ H=2.45\ m,\ T_{max}=2.04\ m,\ T_{LS}=0.44\ m,\ DWT=1000\ t,\ LS=250\ t.$

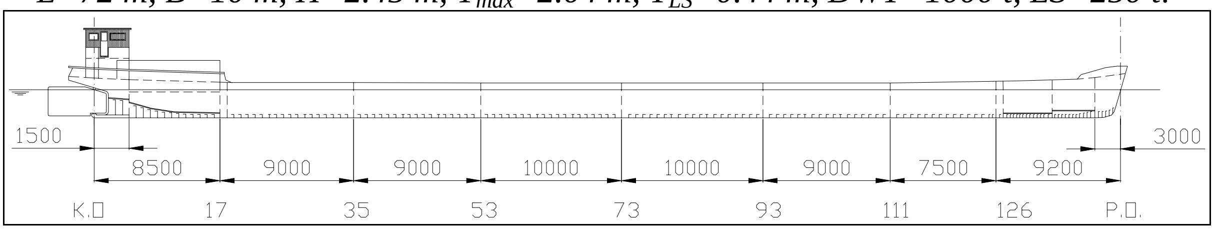

Fig. 6. General arrangement of a typical inland tanker considered for repair

The towing or launching speed is not specified, may be considered as irrelevant or of less significance, actually, very low.
Additional requirements effecting the decision are listed below:
Minimization of building and renewal costs,
The time up to the finishing and start of operations has to be realistic,
To retain as many as it is possible of the existing infrastructure,
To provide sufficient capacity according the expected work and number of ships,
Future capacity growth is to be feasible,
The disposition, the main particulars and slopes are presented on Fig. 5.

5. BASIC TECHNOLOGICAL AND OPERATIONAL PRINCIPLES

Vessels depending on type and size, are towed or launched sideways supported in horizontal position by a suitable number out of all available independently arranged basic towing wagons [6, 7] of two types, Fig. 7. The ten wagons are placed on rails, five and nine meters apart, Fig. 8. Each of the wagons is joined to a single winch by steel cable at the slope appropriate to the shore configuration, Fig. 9. At each of the towing wagons, the movable upper transportation wagon is used for disposition of vessels ashore on their final positions for inspection and repair on the horizontal part of the operational platform, Fig. 9. The inclined and the horizontal part of the operational area provide together a placement for three to five vessels simultaneously, Fig. 10, with rails appropriately fixed to the ground, Fig. 11.
During the towing operation the movable upper transportation wagons are fixed on the rails at the top of the basic lower wagons, Fig. 7. At the end of the lifting operation upper rails located on the lower wagon and horizontal rails at yard's horizontal operational platform have to be at the same level, Fig. 12. The upper wagon has 4 pairs of wheels at 1300 mm distance, Fig. 7. The basic lower wagon and the upper transportation wagon have to be designed jointly in order to achieve optimal load distributions and efficiency, Fig. 12. The number and arrangement of wagons are to be defined in accordance to the common vessel construction, providing adequate supports at the most appropriate structural parts of the vessel, such as transverse bulkheads (normally 9 meters apart in tankers, Fig. 6) or web frames. Vessels up to 80 meters will be supported by 10 wagons with allowable fore and aft overhanging of 4 m. Smaller ships up to 35 meters with specific scantlings will be handled with a combined wagon assembled of 3 smaller wagons. Number and arrangement of the wagons insure slipping of the most expected ships according to investigation of types and sizes of vessels in Croatia. The independent action of a single or of a group of a number of wagons, even all of them, is intended to provide more operational flexibility, increases efficiency and competitiveness of the shipyard.

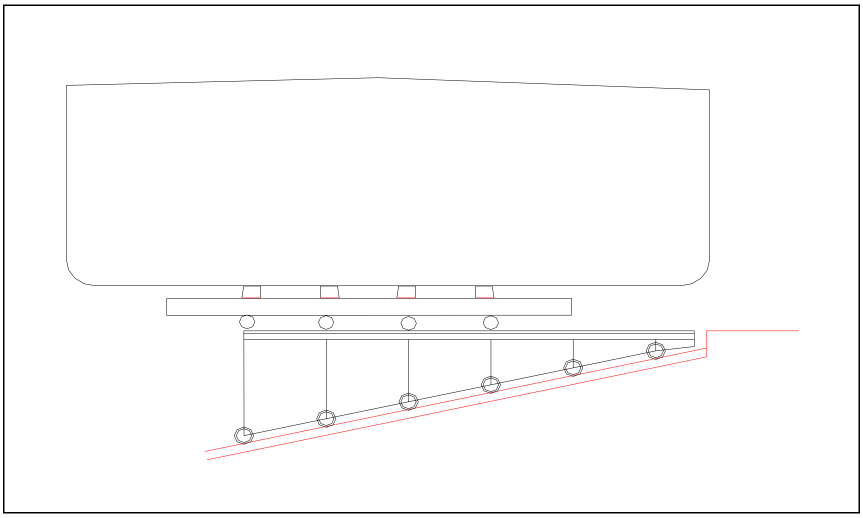

Fig. 7. The towing system of the lower towing wagon and upper transportation wagon

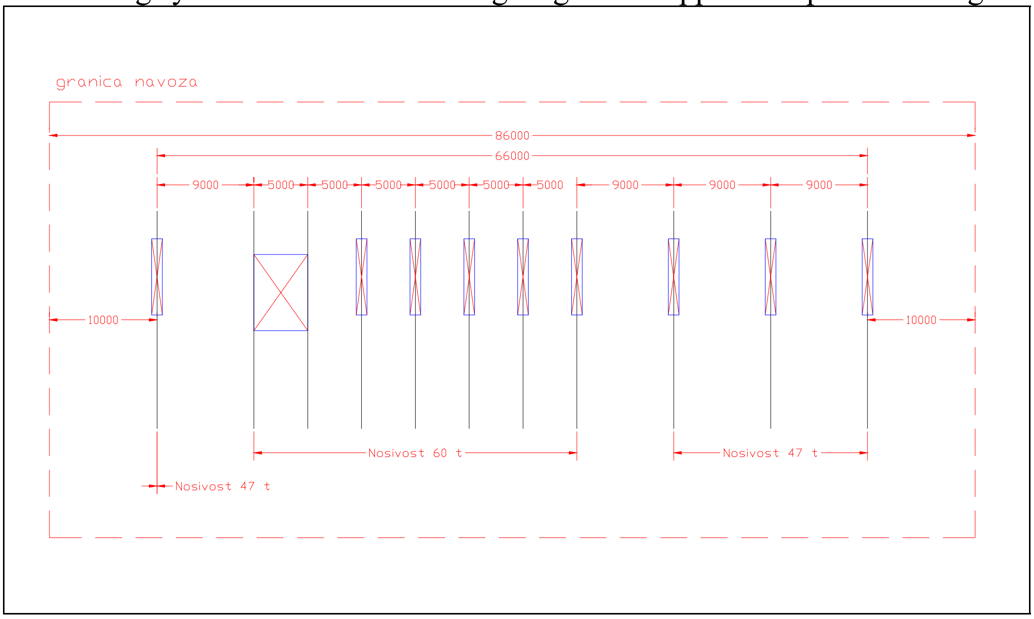

Fig. 8. Disposition of the graundways and towing wagons

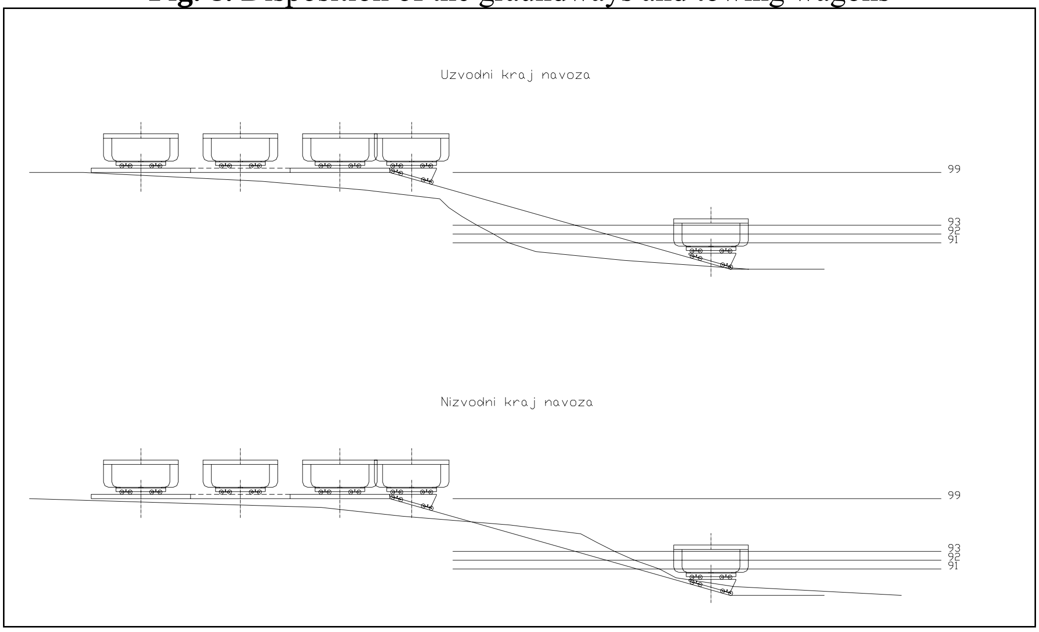

Fig. 9. Cross sectional view through the operational platform

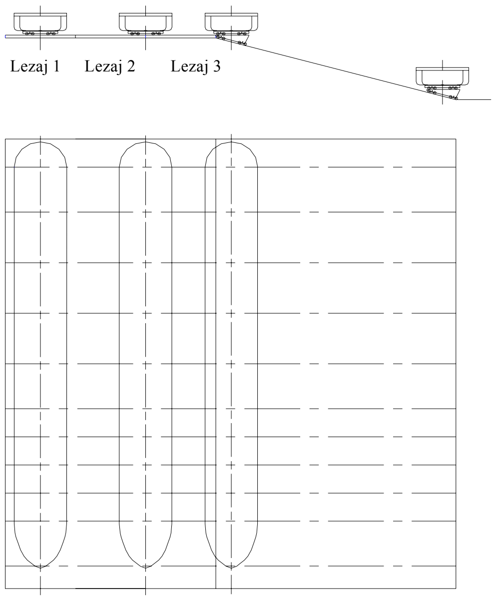

Fig. 10. Placement on the operational platform

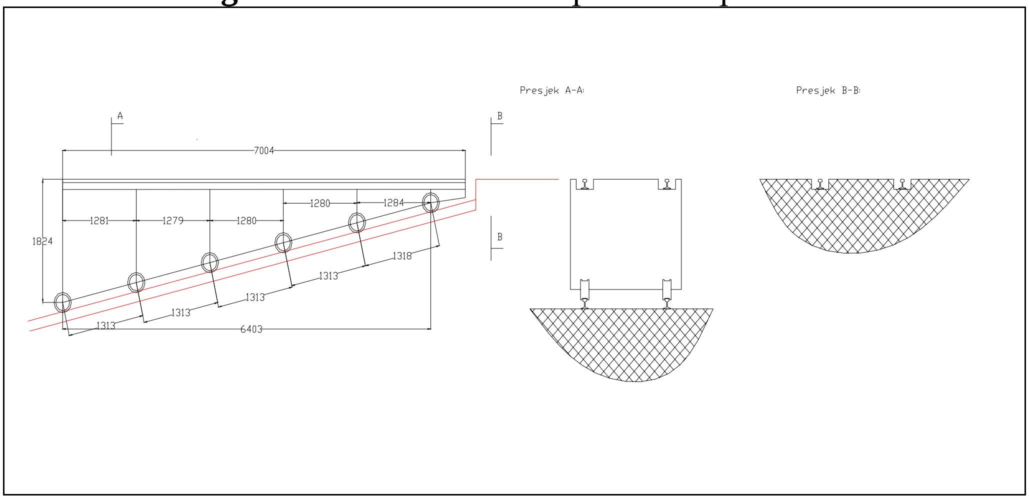

Fig. 11. Foundations under groundways

5.1. Existing towing wagons

There is a number of towing wagons encountered from earlier times with following principal characteristics, Fig. 12.

Length overall	9000 *mm*
Breadth total	1370 *mm*
Height total	560 *mm*
Number of wheels	8
Diameter of wheels	240 *mm*
Wheel pair distance	4000 *mm*
Wheel distance	1000 *mm*
Spread of the wheels	800 *mm*
Diameter of wheel shaft	80 *mm*
Towing speed	not known
The mass of wagons	4.0/4.2 tones
Material properties	not known

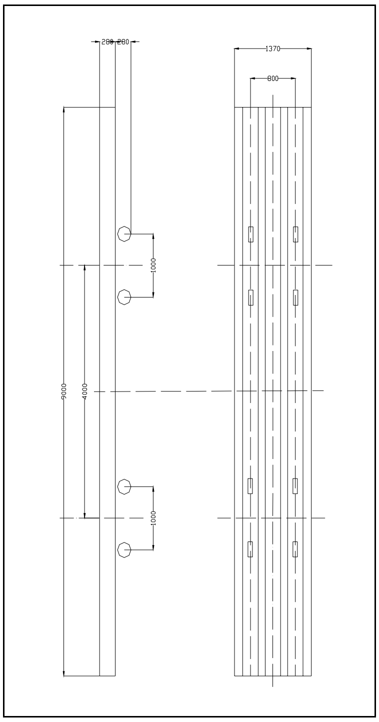

Fig. 12. The existing towing wagons

6. LOADINGS ON TOWING WAGONS AND ON GROUND

The supposed mass of the basic towing wagon with the appropriate horizontally supporting arrangement is $G_i = 8 tons$. The supposed mass of the transportation upper wagon is $G_r = 3 tons$. The required mass of the vessel of maximal assumed weight distributed to a single wagon amounts to $G_o = 80 tons$. The overall mass of a single towing arrangement is then easily summarized as $G = G_i + G_r + G_o = 8 + 3 + 80 = 91 tons$.

Assuming uniform load distribution along the towing wagon, the total load is considered as point force at contact of each of the eight wheels and the ground, Fig. 12, as follows: $F = \frac{G}{8} 9.81 = 111 kN \ (12 \ tons)$.

Since the material properties of the existing wagons are not known, the permissible working stress is assumed in amount of $R_{dop} = 100 \ N/mm^2$.

Under this assumption, the wagon load carrying capacity is assessed for concentrated force at the mid of the span, employing wagon girder geometric characteristics, in amount of about $M_{\max} = 430 \ kNm \ (44 \ tonametara)$ $\quad P_{\max} = 430 \ kN \ (44 \ tons)$

The worst case towing situation on a slope of angle α for towing force Q is assessed for sliding friction as $Q = G \cos\alpha (tg\alpha + \mu)$. For steel-to-steel sliding without lubrication, the frictional coefficient amounts to about $\mu = 0.45 \div 0.80$, and with lubrication is applied, amounts to $\mu = 0.1 \div 0.16$. Assuming $\mu = 0.5$ for slope $\alpha = 15^o = 0.232 \ rad$ without lubricant, the towing force is calculated as $Q = 91 \cdot 0.966 \cdot (0.268 + 0.500) \cdot 9.81 = 662 kN \ (68 \ tons)$. Assuming $\mu = 0.12$ for lubrication, the towing force would be $Q = 91 \cdot 0.966 \cdot (0.268 + 0.120) \cdot 9.81 = 334 kN \ (34 \ tons)$.

The ideal towing situation up the slope under angle α is attainable only by rolling of wheels on rails, neglecting the bearing frictions, when the resisting force can be assessed as $Q_k = \frac{f}{r_k} G \cos\alpha$, and the total towing force as $Q = G \cos\alpha \left(tg\alpha + \frac{f}{r_k} \right)$.

For steel on steel rolling (wagon wheel on rail) the rolling moment arm is $f = 0.5 \ mm$.

For wheel radius of $r_k = 120\ mm$, the ratio amounts to $\frac{f}{r_k} = \frac{0.5}{120} = 0.0042$ and the assessment of the ideal towing force per wagon by rolling without friction in bearings for $\alpha = 15^o = 0.232\ rad$, is $Q = 91 \cdot 0.966 \cdot (0.268 + 0.0042) \cdot 9.81 = 235\, kN\,(24\ tons)$.

Since the bearing frictional properties are unknown, a simple towing force assessment under the assumption of dry friction in radial bearings with sufficiently high clearances, what is appropriate for very low towing speed, can be obtained as the upper limit of frictional force $Q_k = \mu_k G \cos\alpha$, giving for the total towing force the following expression $Q = G\cos\alpha\left(tg\alpha + \frac{f}{r_k} + \mu_k\right)$.

Taking $\mu_k = 0.125$ for $\alpha = 15^o = 0.232\ rad$, the towing force by rolling with friction in bearings amounts to $Q = 91 \cdot 0.966 \cdot (0.268 + 0.0042 + 0.125) \cdot 9.81 = 344\, kN\,(35\ tona)$

Finally, the towing force per one wagon can be assessed in the range 235 - 344 *kN*, that is 24 - 35 *tons*.

7. NEW TOWING WAGON PRELIMINARY STRUCTURAL DESIGN

Since the existing wagons have many shortcomings, and a lot of additional work should be done to bring them into service, the investor assessed that new towing wagons could be afforded. A preliminary design of new towing wagons had been agreed, primarily in order to improve the efficiency and safety of lifting operations. It is decided that the new towing wagons will be built of welded steel profiles in the existing workshops of the current Brodoremont facilities. The geometrical appearance is presented on Fig. 6. The load cases on Fig. 12. are considered for different relative positions of the lower towing and upper transportation wagons, with respect to the operational platform. A finite element method (FEM) analysis by using programs FEMGV and SHIPRIGHT-SDA was applied within a graduation thesis with permission for educational purposes from the Lloyd's Register in London.

First 2D modeling is performed, Fig. 13. Next, the 3D beam element model presented in wire view, Fig. 14. and finally, plate element 3D model, Fig. 15. are investigated. The calculations are provided in order to check deformations, stresses and critical buckling situations, with respect to different significant load cases.

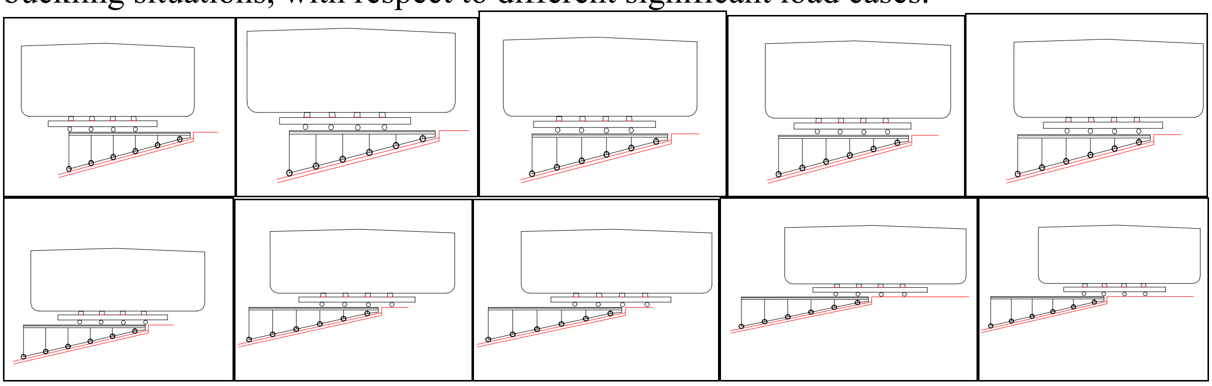

Fig. 13. Considered load cases

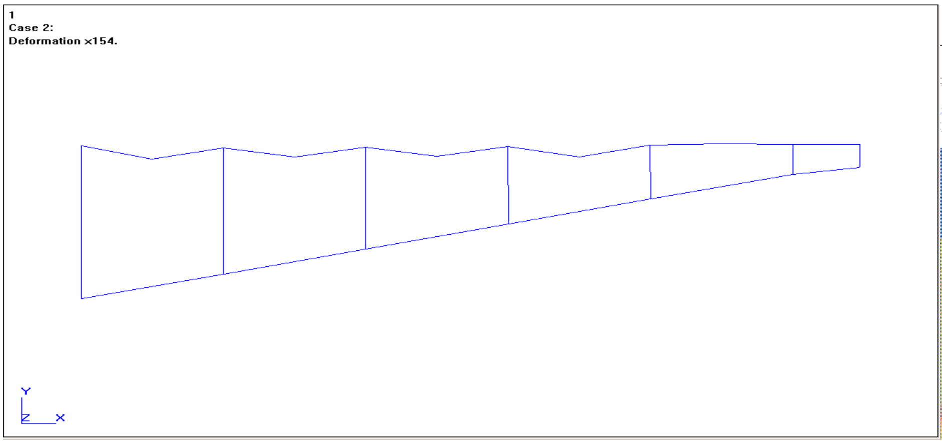

Fig 14. Towing wagon 2D beam element model deformations

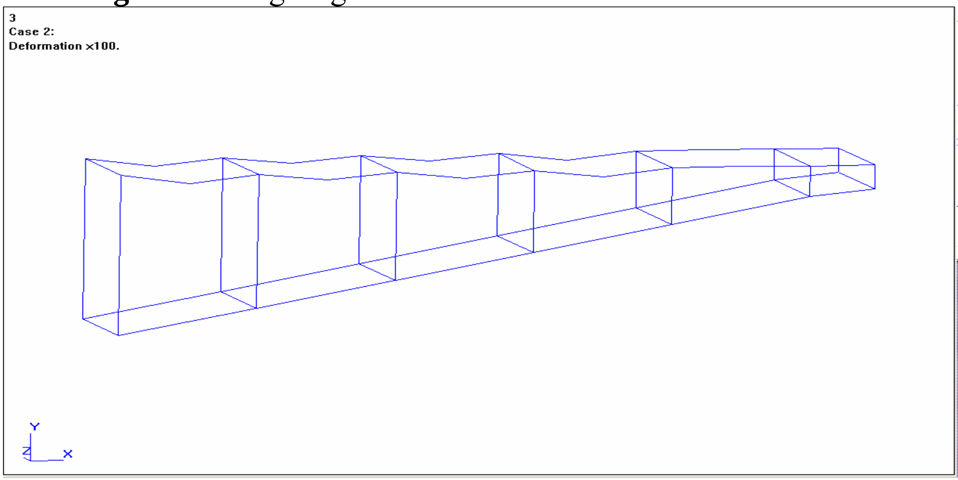

Fig 15. Towing wagon 3D beam element model deformations

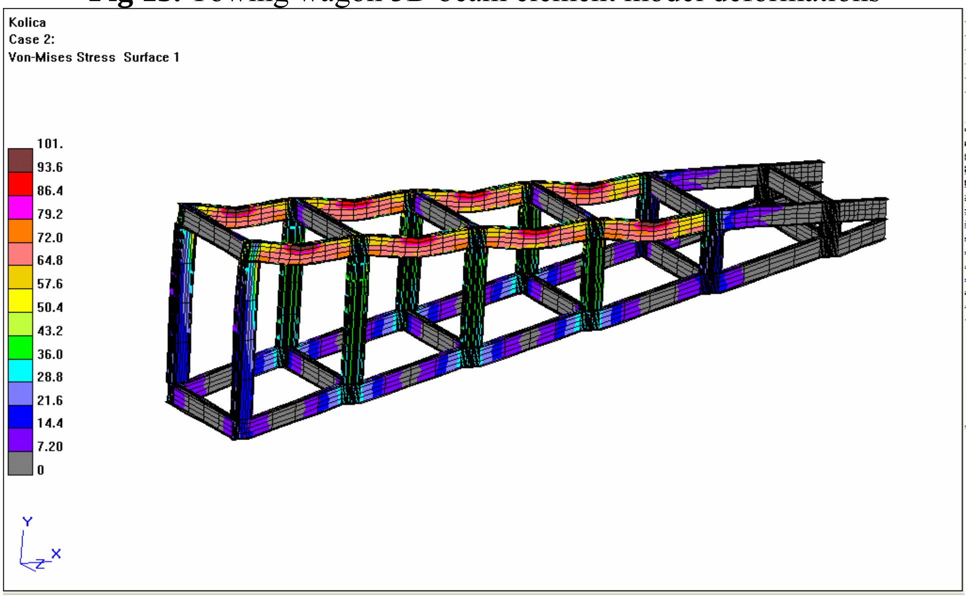

Fig 16. Towing wagon 3D plate element model deformations and von Mises stresses

8. CONCLUDING REMARKS

The feasibility study, partly presented in this article, indicates that the conceived shipyard infrastructure primarily planned for inland vessels inspection, maintenance and repair, can be realized on the selected location on river Sava near Sisak, mostly according to the natural conditions and investors requirements. The planned number and distribution of towing wagons on ground railways provide sufficient working capacities for the entire range of vessel types and sizes, encountered on Croatian inland waterways. For sideways lifting of vessels of maximal length 75 to 80 meters, all available towing wagons are provided. For ships up to 35 meters in length, for sideways lifting several towing wagons 4.5 meters apart are provided. For even smaller units, lengthwise lifting procedure using one appropriate wagon can be applied. Hence, the different towing wagon distances can afford flexible accommodations to vessels of different types, sizes and of different internal structures, contributing to overall working and operational flexibility and efficiency. The capacity, the operational platform, working facilities and workmanship are to be adjusted in the following years considering the realistic requirements on the market in order to contribute to the development of the Croatian inland waterway navigation.
The building of the groundway is planned to take 18 months. The work started with implanting of vertical pilots Fig. 17, preparing the ground, Fig. 18., and embeding of the armature for horizontal ground girders, Fig. 19.

Fig. 17. Implanting pilots

Fig. 18. Ground works

Fig. 19. Horizontal girders

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