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Design of a shipyard extension and reconversion in the Danube waterway - Tulcea, Romania

Etude d'une extension et d'une reconversion de quai dans la voie navigable du Danube - chantier naval de Tulcea, Roumanie

C. RADU, C. NĂSTASE
Concept Structure, Bucharest, Romania

A. C. OLTEANU
Technical University of Civil Engineering of Bucharest, Bucharest, Romania

R. CIORTAN
Ovidius University, Constanta, Romania

ABSTRACT: Quays and shipyards, among other maritime works, are defined at the interface of geotechnical and structural engineering. The worldwide growth in naval trade leads to enormous challenges for harbour constructions due to the development in shipping technologies over the past decades, resulting in the necessity of adopting complex structural solutions for maritime works. The accuracy in assessing such special works is considered highly dependant of the applied geotechnical engineering techniques, soil-structure interaction being a key element that has to be considered in the design and study of a valuable infrastructure project.

RÉSUMÉ: Les quais, parmi d'autres ouvrages maritimes, sont définis à l'interface de l'ingénierie géotechnique et structurale. La croissance du commerce maritime dans le monde entraîne des défis énormes pour les constructions portuaires en raison du développement des technologies de navigation au cours des dernières décennies, d'où la nécessité d'adopter des solutions structurelles combinées pour les travaux maritimes. La précision de l'évaluation de ces travaux spéciaux est considérée dépendante des techniques de génie géotechnique appliquées et l'interaction sol-structure est un élément clé à prendre en compte dans la conception et l'étude d'un projet d'infrastructure important.

Keywords: quay, analysis, foundation, shipyard, soft soil

1 INTRODUCTION

In the case of Romania's developing Danubian maritime infrastructure, the extension of the Tulcea shipyard results as a necessity of updating its technological capabilities in order to comply with the high-end technological level set by the shipbuilding industry. In the context of maritime works, the successful design of a performant high capacity shipyard is vital, thus imposing the need for a strong correlation between geotechnical and structural engineering in the construction process of a modern transportation hub with a high economical role in the Danube River Basin, the world's most international river basin.

Initially developed in 1975, the Tulcea shipyard has been part of several expansion processes and under its current owner is being subjected to several reconversion works in the period set between 2014 and 2020, divided in several stages of investment.

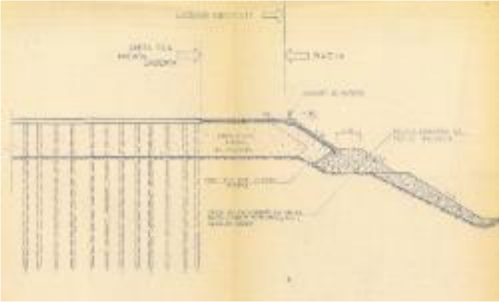

Figure 1. Archive plan of the initial 1975 solution

The shipyard's target is the expansion of its production capacity, aiming to deliver larger ships of up to 24000 tons. Part of the proposed investment is presented in the current paper while the final stage is due in 2020.

One of the most important parts of the development process is represented by the fitting in the current production scheme of a Goliath crane, having a 700 ton capacity.

The location of the quay next to the Danube river is characterized by thick layers of alluvions and soft soils, thus providing low bearing capacity in comparison to the generated loads. Deep foundations (piles) with diameters varying between 400mm and 1400mm and lengths of up to 40m are part of the adopted solutions for supporting the previously constructed structures.

2 DEVELOPMENT HISTORY

The shipyard has been subjected to several stages of modernization during its operational period, past investors carrying out various development plans.

The Syncrolift platform is the newest addition to the shipyard's production line and is an ensamble used for delivering newly constructed ships in the yard's basin, formed by two piled dikes supporting winches with a total capacity of 75000 kN. Ships are transported on tracks onto the Syncrolift metallic deck, lowered and launched in the interior basin through the winches.

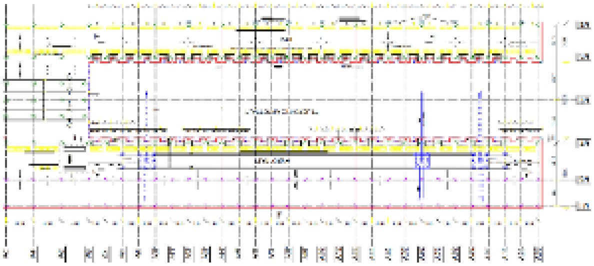

Figure 2. Syncrolift platform

The Syncrolift's infrastructure is comprised of two dikes based on several rows of piles with 1180mm-1400mm diameters and lengths of up to 38.0m, positioned at a distance of 6.0m.

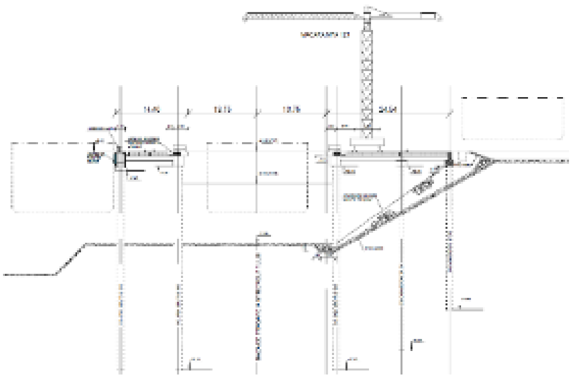

Figure 3 – Transverse section – Syncrolift

The superstructure is comprised of transverse precast concrete beams and a connecting monolithic plate linking the elements. The winches, with a capacity of 2500 kN per piece are connected to 1400mm diameter piles.

The inland transportation is ensured to the Syncrolift through the transfer runway and a 125 ton crane.

The depth of the water basin inside of the Syncrolift platform is 11.86m with respect to the capping level of the platform, +6.46m, corresponding to natural ground level.

In 2012, the Syncrolift‘s piles were coated with a concrete lining as part of a consolidation process.

Given the fact that the newly designed extension will be constructed adjacent to the Syncrolift‘s deck, while the ensamble is in use, the geotechnical and structural complexity of the proposed project is high. The scale of the investment requires consideration of several factors that are essential, such as production methods, costs and timing.

Figure 4. Tulcea shipyard layout prior to the expansion

An extra technical criteria is represented by ensuring the functionality of the shipyard during the implementation of the designed reconversion and extension works.

3 GEOTECHNICAL CONDITIONS

Geologically, the Tulcea county is the widest lacustrine surface in Romania, with over 20% of its area covered by lakes and inland wetlands, with a specific lithology consisting in soft soils, and sands.

The available geotechnical report indicates a lithology consisting in thick highly compressible packages of non-cohesive soils or alluvial deposits.

The Romanian NP 074-2014 “Norm regarding geotechnical documentations for constructions” describes the project’s geotechnical risk as major, imposing the necessity of carrying out geotehnical investigations consisting in 40.0m deep boreholes. The aforementioned risk is generated due to the site layout and the adopted technologies, considering the fact that the reconversion process of the shipyard is being developed while equipment and ships are still in production.

The identified lithology in the boreholes consists in silty clays and sandy silts, followed by fine sands down to 35.0m from natural ground level, confirming the area‘s local lithology and the expected low bearing capacity of the soil by comparisson to the anticipated significant loads.

4 RECONVERSION SOLUTION

The proposed works require an expansion of the transportation runway from 6 to 16 tracks.

The key reconversion component of the shipyard is the embeddment of the new Goliath 700 ton crane in the present layout of the site, by creating two new runways, one of which will be placed in the current Syncrolift‘s structural system.

The Syncrolift and the new Goliath crane‘s runway will generate the necessity of extending the quay‘s length to 116m allowing mooring and barge transportation for launching newly constructed vessels.

Design loads have been made available by the general designer of the crane and result of simulations of the ship‘s transfer on the runways using metallic trolleys (bogies) at ground level.

Figure 5 – Metallic trolley of the Goliath Crane (photo taken during assembly)

Other studied hypotheses reffer to the convoy of forces corresponding to ship manipulation in different positions on the runways and in maneuvering positions, as for quay transfer and barge loading, thus dimensioning other elements along such as beams, caps and other connecting elements.

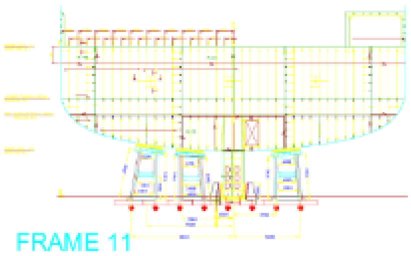

Figure 6 – Transverse section – example of ship transfer loading scheme

4.1 Extension of the runways

During the extension process, the runways for the future vessels have been extended from 6 to 16 pieces, enabling transportation for large ships, up to 24000 tons, and a capacity of constructing in parallel two ships with dimensions of up to 40x180m.

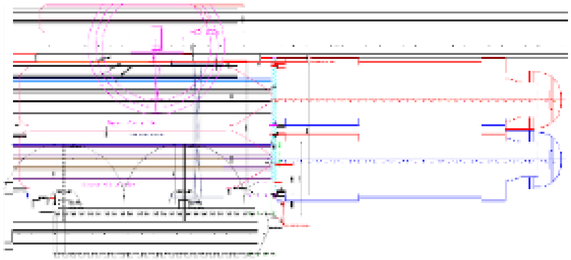

Figure 7 – Transportation lanes

The existing transportation runways have been demolished and have been replaced by a newly constructed 1.00m thick raft laid on deep foundations consisting in 600mm diameter piles positioned directly under the runways and 400mm piles positioned in the adjacent areas.

Figure 8 – Execution process of the runways

4.2 Extension of the launching quay

The quay extension is positioned at the end of the runways. The aim of the quay extension is to transfer the ships from the yard to the barges and allow mooring and shoring during the manipulation and transfer.

Drilled piles of 1200mm diameter bored to a depth of 40.0m, with permanent casing, were constructed inside the general bassin.

The connection between the quay's piles and the transfer runways will be ensured by reinforced concrete beams and caps. The existing quay elements and transfer runways will be demolished through hydrodemolition and connected by mechanical anchors to the new elements.

Figure 9 – Execution process of the quay

During the construction process of the caps and quay elements, special scaffoldings and technological elements have been adopted, allowing reinforcement installation and concreting, embedding metallic elements as part of the final ensemble of ship production.

The final configuration of the quay will ensure alignment with the Syncrolift platform.

4.3 Goliath 700 ton crane

The Goliath crane, with a 700 ton capacity, will assist the assembly in the shipyard, providing the necessary logistics for maneuvering 700 ton parts, improving productivity and execution precision of the vessels.

With a 98 meter opening, the crane‘s translation will be aided by two trolleys supported by reinforced concrete and metallic runways, transfering loads to the ground by bored piles.

Figure 10 – Goliath 700 ton crane transverse section

Surcharges resulting from the maximum weight of the load and the crane‘s self weight reach 20000 kN, traduced in 5000 kN design values per pile for the infrastructure‘s deep foundation system.

Limiting vertical displacements of the runway is a supplementary criteria taken into account when dimensioning the Goliath‘s infrastructure crane.

Given the total loads, the crane‘s infrastructure is designed as a deep foundation with 1200mm diameter bored piles, drilled with temporary casing inland and with permanent casing in wetland, towards the Syncrolift platform.

The distance between piles is approximately 3.0m. In order to allow construction of the new piles at the provided distance, the Syncrolift‘s platform has been partially demolished allowing the necessary space for the piles to be bored.

Figure 11 – Demolition and reconversion of the structural elements (existing and newly constructed)

Newly bored piles with permanent casing were drilled between the aforementioned piles of the Syncrolift‘s platform, following local demolition.

Goliath‘s infrastructure is embedded in the Syncrolift‘s platform by rebuilding several concrete elements, integrating new caps, transverse beams and connecting the newly constructed transfer runways with the existing piles.

Figure 12 – Execution process of Goliath’s piles (wetland, towards the Syncrolift platform)

The aim of the adopted design is to ensure that the influence of the new works is limited and the Syncrolift is kept in position and operational during the entire reconversion process.

Given the significant loading forces generated by the Goliath crane, a key hypotheses considered follows on limiting strains and displacements on the existing elements of the Syncrolift. The design scenario considers a fully functional Syncrolift with a maximum load applied to the integrated winches, as well as simultaneously transporting a maximum load in the Goliath crane.

The adopted solution of connecting the runways with the new ensemble turned out to be an economic and efficient structure with respect to the loads and geometric constrains, upon studying both execution and operation loads.

All design hypotheses, loading positions and load values have been modelled by means of finite element method, both 2D and 3D, by adopting numerical modelling both in dedicated geotechnical engineering software and structural engineering software.

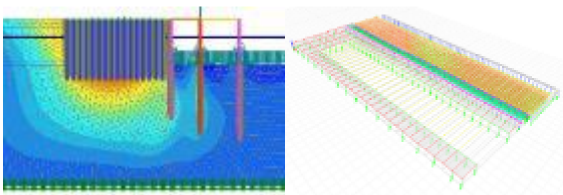

Figure 13 – Finite element modelling

In order to validate the soil‘s bearing capacity, compressive load tests of the piles were performed at a maximum value of 10000kN. Stabilized displacements of 30-50mm for the last incremental step were considered relevant and confirmed the designed bearing capacity of the piles.

The assembly of the Goliath crane will be ensured through metallic towers, provided by the crane‘s producer.

Figure 14 – Assembly of the Goliath crane

5 CONCLUSIONS

Tulcea‘s shipyard is one of the most important shipbuilding centers in the Danubian waterway. The accelerated growth of the shipyard‘s orders demanded the necessity of an expansion and allignment to current producing trends.

The shipyard‘s functionality and productivity are dependant on the the efficiency of the designed expansions. The atypical works required as well as the high geotechnical risk of the site imposed the need of a close coordonation between specialities and experts in the field of geotechnical engineering and maritime works, requiring a good comprehension of soil-structure interaction.

Figure 15 – Goliath 700 ton crane in operation

At the end of all stages of the current expansion stage, the shipyard‘s capacity will position Tulcea, Romania, as a top location for producing large vessels and ship parts, ensuring the possibility of developing a modern and performant maritime hub in the current industry of global naval shipbuilding.

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