PROPOSAL THE SUITABLE STRUCTURE ON SMALL VESSEL AND BARGE IN THICK SOFT SOIL AREA IN THE GEOLOGICAL AREA OF Tra Vinh Province, Vietnam

Nguyen Thanh Cong1*, Huynh Huu Tri2, Tu Hong Nhungh3

Abstract – Tra Vinh Province, with its interlaced river system, offers convenient navigation, especially for barges and small vessels under 1000 DWT. Geology in Tra Vinh Province mostly has a thick soft soil surface layer, averaging from 20 m - 40 m, even over 50 m in some places, structural solutions for docks in most places choose piers. Thus, a high platform on the pile foundation. However, in practice, it is evident that most of the proposed pier structure solutions for barges and small vessels are not reasonable, the piles in the pier structure have not brought into full play their bearing capacity, leading to investment costs for large projects, and uneconomical projects. Within the scope of the paper, a more rational pier structure solution is proposed based on the integrated analysis of the geological features of the structure, the load due to the ship, and the operating loads on the pier.

Keywords: barges, pier structure, small vessels, thick soft soil surface layer.

I. INTRODUCTION

Tra Vinh is a province in the Mekong Delta of Vietnam, located between the Hau and Co Chien rivers with 65 km of coastline adjacent to the East Sea; with an interlaced river system, convenient for navigation, especially for barges and small vessels under 1000 DWT. Over the years, there have been many studies [1–3] showing that many areas in Tra Vinh Province have a soft soil layer thickness of 10 m - 50 m, and the structural solution applied to the pier often chooses the type of soil that high tower pier was built on reinforced concrete pile foundation. The pier structural solutions are often used to withstand the impact of horizontal and vertical loads, such as impact force, anchor force, support force, and loading and unloading load, due to the high strength and rigidity of the structure.

In recent years, many piers have applied the above design solution. The design of the pier structure for barges and small vessels has become an inappropriate problem because the design has a lot of bearing capacity, so the construction cost is high. Several factors affecting economic and technical aspects need to be considered and adjusted to optimize structural solutions for piers, such as fully promoting the bearing capacity of the reinforced concrete pile foundation, engineering geological characteristics, ship tonnage, and live load acting on the pier. There have been many studies on pier structural solutions for small vessels and barges [3–5]. However, there has been no research on the optimal solution for the structure of small vessels and barges.

This study analyzes and evaluates pier structural solutions for small vessels and barges that are suitable for geology with the very thick soft soil layer of Tra Vinh Province.

II. LITERATURE REVIEW

Tra Vinh Province has low and flat terrain, with a dense and interlaced network of rivers. In some areas, the thickness of the soft soil layer on the surface is from 10 m to 30 m, and some places have a thickness of 50 m. For that reason, most of the pier structural solutions for barges and small vessels that we have encountered in practice are of a similar form with the following key elements: the pier structure can
be either onshore or off-shore (with a bridge), belongs to the type of soft-cast high-rise pier (the upper structure is a reinforced concrete slab beam system poured in-situ, the bottom is a steel pile foundation or concrete prefabricated reinforcement piles), horizontal and vertical pile steps are in the range of 3 m – 5 m, few piles are used because the horizontal force is not large, the pile head is firmly attached to the beam, the cross-sectional edge of the pile is from 300 mm – 450 mm. Figure 1 and Figure 2 are the cross-sections of some pier structures that have been designed in practice: Pier at Dinh An General Port [6], Pier at Co Chien Ferry Pier [7], Pier at Long Duc Inland Port [8], Pier at Vam Lau Port - Cau Ngang District [9].

Accordingly, this structural solution has been used for most of the barges and small vessels
in Tra Vinh Province. In general, these solutions are similar for the entire geology of Tra Vinh Province. This is not suitable because there may be different geological factors and some types of loads. In addition, the study of Shanthala [10] on pier structural behavior under the effect of loads has been synthesized and surveyed with many types of loads acting on the pier, and another study by Chen et al. [11] on analyzes the process and construction principle of the prefabricated pier structure and the pier and the top platform of the prefabricated bearing pier, which describes the principle of the prefabricated bearer structure, and the structural operation of the prefabricated bearer structure, and proposes a new type of prefabricated pier structure. The above research results have not yet explained the suitability of the applied pier structure solutions.

The issue at hand pertains to the design of the pier structure and presents two potential approaches: adhering to the previously mentioned conventional solutions and enhancing and adapting the existing solution into a novel, more fitting one [6–9]. Therefore, this study proposes a more reasonable pier structure solution based on the integrated analysis of the geotechnical characteristics of the pier. The process encompasses evaluating the ship-induced load, considering the operating loads on the pier, and harnessing advanced construction technologies to ensure the structure’s ability to meet both its bearing capacity and economic efficiency.

III. RESEARCH METHODS

The study was conducted from March to May 2023, aiming to design documents for small vessels piers, and barges in Tra Vinh Province – in case, these piers have concluded of actual survey.

The study surveyed the docks in Tra Vinh Province used for small vessels under 1000 DWT and barges, mainly using the bearing structure system described in Figure 1 and 2. Because the load on the pier structure is small, engineers often design for safety. On the other hand, the design of the pier structure is almost the same, with very few changes to the plan, so the bearing capacity of the reinforced concrete piles in the pier structure has not been fully exploited.

This article has presented theory research and combined it with a practical survey of pier structural solutions. From there, the research analyzes and compares the advantages and disadvantages, then proposes a reasonable solution for the pier structure to apply the design for typical geology in Tra Vinh Province.

IV. RESULTS AND DISCUSSION

A. Common pier structure solution for areas with not too thick surface soft soil in the Tra Vinh geological area

Currently, some areas have a soft soil layer thickness of 10 m – 30 m, which engineers can consider as not too thick [12]. In this case, most of the pier structure solutions for barges and small vessels encountered in practice are almost the same. The pier structure can be onshore or offshore (with an access bridge), the soft high-rise pier is cast as a whole with the upper structure being a cast-in-place reinforced concrete beam system – underneath is a steel pile foundation or precast reinforced concrete piles, horizontal and vertical pile pitch ranges from 3 m – 5 m. In addition, bunch piles are rarely used because the applied horizontal force is not large, the pile head is firmly attached to the beam, and the cross-sectional edge of the pile is from 300 mm – 450 mm. Figures 1 and 2 show cross-sections of some pier works in Tra Vinh Province in practice.

B. Common pier structure solutions for areas with very thick surface soft soil in the Tra Vinh geological area

For areas with a surface soft soil layer thickness of more than 30 m, designers often still use the pier structure solution as mentioned above but with a slight change in piles: increase the length pile until the tip of the pile can be inserted into the good soil layer below; increase the pile cross-section so that the thinness of the pile does not exceed the allowable level.
The application of this solution helps the design to be carried out very quickly because the superstructure (beams, slabs) is almost unchanged (because the loads acting on the structure do not change), the bending capacity and the compression of the pile is increased (due to the increase in pile cross-section and the depth of the pile tip in the soil) so the calculation of the structure is only a formality, there is almost no need to worry about whether the structure has enough bearing capacity or not (because of course the bearing conditions are satisfied).

C. Analysis of unreasonable factors in the pier structure solutions

Barges and small vessels

For barges and small vessels, the transverse force caused by the ship (such as impact force, anchor force, or support force) acting on the pier is not substantial [13]. However, in the absence of pile foundations, the pile foundation should be sufficiently stiff when subjected to horizontal forces, the design engineer almost always has to choose a solution to harden the pile ends to the structure above. This is very unfavorable for the application of all-piece assemblies (joint joints) as well as non-uniform joints (joints or overlapping joints) to the superstructures (beam and slab system) of the pier. From the characteristics of barges and small vessels, the loading and unloading equipment is typically neither large nor excessively heavy, resulting in the longitudinal force transmitted to the piles much smaller than the load capacity according to the pile material [14, 15].

The thickness factor of the surface soft soil layer is very large

Because the surface soft soil layer is very thick, the conventional mounting point of the pile is also quite deep, the calculated span length of the pile structure (calculated from the conventional connection point of the pile with the superstructure to the conventional mounting point of the pile structure into the ground), called flexural length, is large, which indicates that individual piles have very poor lateral capacity (a small lateral force can also cause a large bending moment in the pile because the moment in the pile proportional to the square of the flexural length of the pile causing a lot of lateral displacement for the pile head), the pier must use many single piles rigidly connected to the superstructure to be able to accept the transverse forces exerted by the ship (in terms of strength and stiffness).

According to regulations on the design of pier works using piles, the pile tip must be plugged into the bearing soil layer of at least 2 m [12, 16]. When the surface layer of soft soil is very thick, the length of the pile must also increase, making the thinness of the pile increase. If the thinness of the pile does not exceed the allowable value, the cross-section of the pile must be increased. The use of piles with a larger cross-sectional area increases not only the investment capital for the project but also the bearing capacity of the pile according to the material (bending and tensile/compression), which increases waste in taking advantage of the bearing capacity of the members in the pier structure.

Increasing the cross-section of the pile has increased the compressive capacity of the pile according to the ground, which can help reduce the number of piles by increasing the pile pitch in both directions (horizontal and vertical). However, due to the habit of the designer or choosing the pile step in small piers in the range of 3 m – 5 m, it is difficult to avoid waste (in fact, the selection of the initial pile step is only preliminary, after calculating, it must be checked and adjusted to be more reasonable, but most designers often skip this step).

D. Proposing a reasonable pier solution for areas with very thick surface soft soil in the Tra Vinh geological area

From the analysis in section IV.B, there is a need for a more reasonable structural solution for pier works for barges and small vessels in areas with very thick soft soil layers. Refer to Nguyen Quoc Toi’s monographs [17, 18] and Compilation agency, Ministry Transport, Vietnam [19] and the actual pier project at Thanh Phu Fishing
Port-Ben Tre Province [20] and the actual pier construction at An Thoi Fishing Port-Kien Giang Province [21]. From there, the author proposed a pier structure solution shown in Figures 3 and 4 of the high platform pier type with some new adjustments and improvements. This study proposes qualitative suggestions. The case of detailed calculations for a specific pier structure solution will be examined in further research.

- Given the relatively small horizontal force applied by the ship, it is sufficient to employ just 1-2 double pinch piles in each transverse frame to absorb this horizontal force. These piles also possess the capability to withstand significant vertical forces. In this approach, there is no need to involve single piles within the frame. The utilization of double pinch piles serves to greatly reduce the bending moment experienced by the piles. Instead, it leads to an increase in compressive and tensile forces acting on the piles in the cluster. The tensile force, however, does not pose a significant risk as it is mitigated by the pile’s weight and the compressive force induced by the vertical loads on the pier. This additional compressive force capitalizes on the ample load-bearing capacity of the pile, both in terms of its material and the underlying soil. This is made possible by employing piles with substantial cross-sections and considerable length.

- Increase the horizontal pile pitch to the maximum (the piles still have sufficient bearing capacity), which helps to reduce the number of unnecessary small load-bearing piles. This increases many spans of transverse beams, but this shortcoming is easily overcome by using box girders (or T-sections, I-shaped sections) of pre-stressed concrete at the factory. This is now commonly shaped and used in the bridge industry (except in special cases where it must be redesigned, otherwise it can be easily ordered at factories that manufacture prestressed reinforced concrete components). The bridge deck also uses prefabricated pre-stressed reinforced concrete panels assembled into the upper horizontal-vertical beam system. Using prefabricated structures is not only convenient for water construction, but also helps to speed up the construction progress.

V. CONCLUSION AND RECOMMENDATIONS

Proposing pier structure solutions requires engineers to be flexible according to reality. Otherwise, the designer needs to consider all factors that can affect the structural solution for piers, such as natural conditions, technology diagram of loading and unloading on the pier, type, and size of ships docked, ability to construct and apply advanced technologies, universality variation and service life of materials. It is necessary
to analyze, compare, and synthesize factors so that the proposed structure is reasonable, feasible, and technically guaranteed, and achieves high economic efficiency.

The selection of initial dimensions for the members as well as for the pier structure is not necessarily taken according to the dimensions recommended in the reference documents because it is not necessarily reasonable. The preliminary selection of the initial size is not important (because there is still a step to check and adjust), but if there is analysis and consideration before choosing, it will help reduce the need to calculate many times.

Designers need to follow the design process: (1) preliminary selection of section → (2) calculation of internal force → (3) calculation of cross-section → (4) test of strength, stiffness, stability determination → (5) repeat step (1) if not satisfied. This process repeats until the optimum pier structure is achieved.

REFERENCES


