Structure planning of 13470 DWT capacity jetty on Liquid Berth II Caspian Sea, Turkmenistan

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Abstract. Liquified Natural Gas is one of the products produced from refineries in the Caspian Sea. LNG production increases due to demand, causing the addition of new offshore platforms. To provide loading and unloading services for LNG, a special dock is needed, for this reason a special liquid bulk jetty with a capacity of 13470 DWT is planned. Structural planning using STAADPRO V8i Select Series 6 software, using British standards in planning. The jetty structure is expected to be strong against the loads that work due to environmental conditions and ship impacts. Structural analysis is carried out by comparing the structure's Unity Check Ratio value with the Unity Check Ratio permitted based on applicable standards. The result is that the structure is able to withstand the working load with details of 4 Breasting Dolphin structures, 2 Mooring Dolphin structures, 1 Jetty Head Platform structure, and 1 Trestle structure.

1 Introduction

A port is one of the facilities located at the end of lands, rivers, lakes, and coastal areas, serving the function of providing a place to anchor or dock for arriving and departing ships [1]. Ports, as a part of sea transportation infrastructure, serve various functions based on their specific purposes, including fish ports, oil ports, cargo ports, storage ports, and transit ports. Each port requires a crucial structure known as a pier. The pier is one of the structures within a port used for docking and mooring ships that are engaged in loading and unloading goods and disembarking passengers.

The Caspian Sea is one of the oldest seas in the world and is the largest inland body of water located in the central part of the land. One of the main characteristics of the Caspian Sea is its wealth of natural resources, particularly oil and natural gas. The region surrounding the Caspian Sea is known for its abundant reserves of oil and natural gas. One of the results of processing natural resources in the Caspian Sea is liquefied natural gas. The escalating demand for LNG has prompted the establishment of new offshore platforms to bolster production. To facilitate the efficient loading and unloading of LNG, a dedicated liquid bulk jetty with a substantial capacity of 13470 Deadweight Tonnage (DWT) is being planned. This specialized dock will cater specifically to the needs of LNG transportation, ensuring smooth operations and meeting the growing requirements of the industry.

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1.1 Formulation of the problem

Based on the background description provided above, several issues can be formulated as follows:

- How to plan the appropriate dimensions of a jetty-type liquid bulk terminal to be built at Liquid Berth II, Caspian Sea, Turkmenistan?
- How to design a safe structure for the jetty-type liquid bulk terminal that can withstand the forces acting on Liquid Berth II in the Magtymguly Gas Recycling Development Project area?
- How to determine the optimal concrete and steel profiles to ensure a robust construction against seismic loads, ship impacts, mooring forces, waves, and wind?

1.2 Research purpose

In this research, considering the aforementioned issues, the purpose and objectives of planning the structure of the liquid berth II in the Caspian Sea, Turkmenistan are as follows:

- To establish dimensional planning for the liquid berth, taking into account the specific requirements of the project.
- To determine a structurally sound design that can withstand the forces acting upon both the upper and lower sections of the berth.
- To select the appropriate concrete and steel profiles to be used in the structural planning, ensuring durability and efficiency.

1.3 Scope

Based on the background of the problem, formulation of the problem, and research objectives outlined above, the scope of structural planning is as follows:

- The calculation of the dimensional plan of the dock structure, including the length, width, and elevation of the jetty head platform, breasting dolphin, mooring dolphin, and trestle.
- The calculation of structural element dimensions encompasses the dimensions of steel pipe piles, beams, pile caps, and floor plates. The structural modeling and analysis are conducted using the StaadPro Select Series 6 V8i software. Additionally, the reinforcement planning for the dock's structural elements is meticulously carried out.

2 Literature review

2.1 Overview of LNG jetty structures

Liquefied Natural Gas (LNG) jetty structure is an important component of the LNG facility, It serves as an important link between onshore and offshore operations. The structure is designed to accommodate a safe and efficient transfer of LNG from the melting plant to the LNG conveyor for transport. A LNG jetty usually consists of several essential elements, including loading platform, mooring dolphins, breasting dolphin, and trestle. Loading Platform provides a safe and stable area for LNG carriers to land, ensuring a secure and controlled transfer process. Mooring dolphins play an important role in securing LNG carrier ships during unloading operations, while breasting dolphin provides additional support and stability to LNG carriers [2]. Approach trestles, on the other hand, connect the jetty to the shore, providing access forTrestle, on the other hand, is a vital structure to connect the jetty

with the land, providing access to the personnel, workers and equipment needed for maintenance and operation. The structure is designed to withstand harsh marine environments, including strong currents, waves, and wind loads, thus ensuring durability and long life of the structures.

In addition, security features such as fire protection systems, emergency extinguishing systems, and monitoring equipment are integrated into the LNG port structure to mitigate risks and ensure safe LNG handling. Overall, the LNG jetty structure is carefully designed to facilitate LNG transfer efficiently and safely, thus playing an important role in the global LNG supply chain.

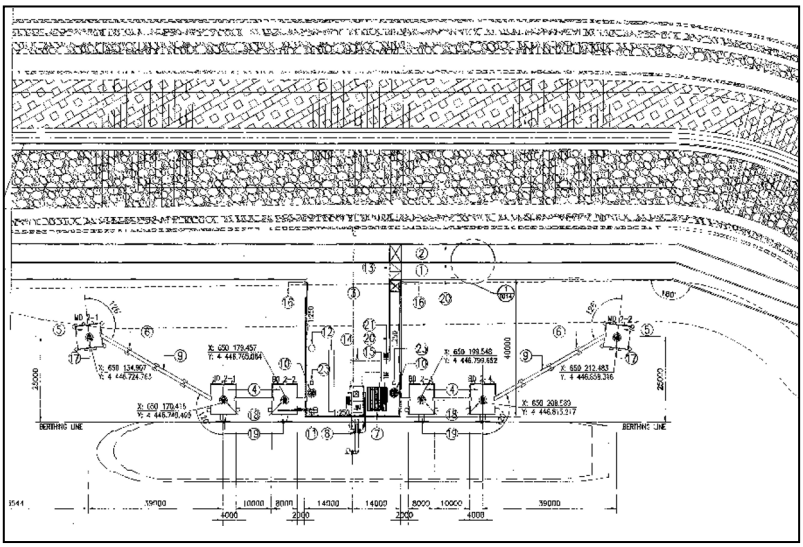

Fig. 1. Jetty plan layout.

2.2 Applicable standards

The research mentioned the following codes and standards as the basis for the planning 13470 DWT Capacity Jetty On Liquid Berth II Caspian Sea, Turkmenistan :

- ACI 318-14: Building Code Requirements for Structural Concrete
- BS 5400-1990: Steel, Concrete and Composite Bridge
- BS 5950-2000: Structural Use of Steelwork in Building
- BS 6349-2014: British Standard for Marine Structures
- UBC-1997: Uniform Build Code for Earthquake design
- AISC 360-16: Specification for Structural Steel Buildings
- OCDI 2020: Technical Standards and Commentaries for Port and Harbour Facilities in Japan

Guidelines and specifications for the planning, building, and security of port constructions are provided by these codes and standards. The design and construction of structural concrete is governed by ACI 318-14, while the usage of steel and concrete in the construction of buildings and bridges in this case, trestles is governed by BS 5400-1990 and BS 5950-2000. Guidelines for the planning and building of marine constructions, including ports, are provided by BS 6349-2014. Guidelines for earthquake-resistant design are provided by UBC-1997, while AISC 360-16 specifies requirements for the design and construction of structural steel structures. Ensuring that the port structure meets the necessary performance

and safety criteria may be achieved by basing the planning, design, and building process on these standards and rules.

2.3 Jetty dimensions

The dimensions of an LNG jetty can vary depending on local conditions and the size of the LNG carriers that will be using it. In planning, pier dimensions include water depth, jetty elevation, the distance between breasting dolphins, and the distance between breasting dolphins and mooring dolphins.

The determination of pier elevation is based on the following factors [3]:

- Highest water level or HHWL (Highest High Water Level)
- Design wave height
- Pier freeboard

The jetty elevation is measured from the lowest water level or LWS (Lowest Water Spring), which can be calculated using the equation:

$$HB = HHWL + 0.5\ HS + FB \quad (1)$$

Where
HB : Jetty Elevation
HHWL : Highest High Water Level
HS : Design wave height (m)
FB : Jetty Freeboard (m)

The distance between breasting dolphins ranges from 0.25 to 0.4 of the LOA (Overall Length) of the smallest ship for inner breasting dolphins and from 0.25 up to 0.4 of the LOA of the largest vessel for the outermost breasting dolphin [4]. Then the distance between the mooring dolphin and breasting dolphin is determined by the following equation :

$$Distance = 0.5(LOA - Distance\ Between\ Breasting\ Dolphin) \quad (2)$$

2.4 Unity check ratio

Unity check ratio is a term used in engineering to evaluate the safety of a structure or component. It is the ratio of the actual value of a force, moment, or stress to the allowable value or capacity of the structure or component [5]. A unity check ratio of less than or equal to 1 is considered good, while a ratio greater than 1 is considered bad [6]. The unity check ratio is used to ensure that the structure or component can withstand the loads and forces that it will be subjected to during its lifetime. The unity check ratio is calculated by dividing the actual value of the force, moment, or stress by the allowable value or capacity. In this study, the UCR value was limited to between 0.7 and 0.9 ($0.7 < UCR < 0.9$).

3 Methodology

A few key milestones in the study process that led to the capacity structure planning of the 13470 DWT port in Liquid Berth II in Turkmenistan's Caspian Sea are shown in the accompanying image.

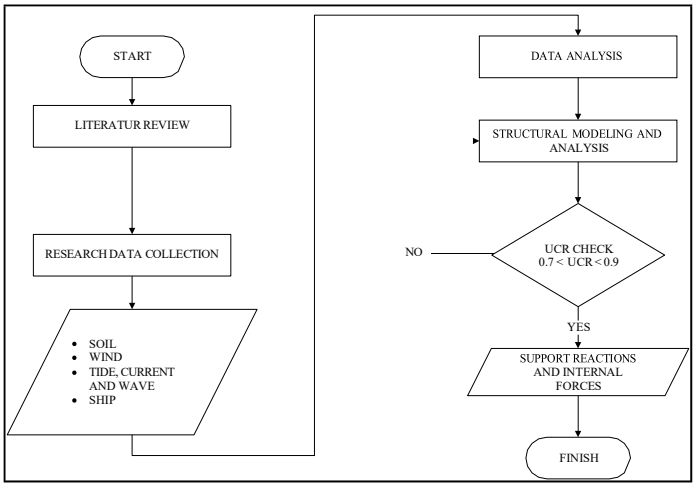

Fig. 2. Methodology flowchart.

3.1 Data collection

In this research, the author undertook a comprehensive analysis by examining project documents acquired from relevant agencies. The purpose of this study was to gather data and gain insights into the subject matter. The obtained data is presented as follows:

- The sea level height
- Climatic conditions
- Geotechnical
- Ship specifications

3.2 Load analysis

The port structure underwent various loads during its operation. These loads could be categorized as static and dynamic [7]. Static loads include the weight of the structure itself, as well as the weights of equipment or materials placed on it. Besides, the static load also covers the weight of any vehicle or engine that may be on the jetty. However, the force that the water, wind, or wave exerts on the jet is known as the dynamic load [8]. These dynamic loads can vary in intensity and direction, posing significant challenges in the design and construction of port structures.

Therefore, it is essential to assess and consider these burdens carefully to ensure the structural integrity and security of the port. The loads that work on the port structure are the reserve load, the load of the deck, the environmental load (earthquake, wave, and wind load), the structural and non-structural own load. Here's the formula used to calculate the load that works on the structure.

$$E_N = 0.5 \times C_M \times M_D \times V_{berth}^2 \times C_E \times C_S \times C_C \quad (3)$$

E_N : Normal berthing load
C_M : Virtual mass coefficient
M_D : Ship displacement
V_{berth} : Berthing velocity
C_E : Eccentricity coefficient
C_S : Softness coefficient

C_C : Berth configuration coefficient

$$E_A = S_F x E_N \quad (4)$$

E_A : Abnormal berthing load
S_F : Virtual mass coefficient

$$F_{TW} = C_{TW} x \rho \ x \ A_L x \ V^{w\,2} x \ 10^{-4} \quad (5)$$

$$F_{LW} = C_{LW} x \rho \ x \ A_L x \ V_w{}^2 x \ 10^{-4} \quad (6)$$

F_{TW} : Mooring load due to wind (transversal)
F_{TW} : Mooring load due to wind (longitudinal)
C_{TW} : Transversal wind coefficient
C_{LW} : Longitudinal wind coefficient
ρ : Wind density
A_L : Longitudinal projection area
V_w : Wind velocity

$$F_{TC} = C_{TC} x \ C_{CT} x \rho \ x \ L_{BP} \ x \ d_m \ x \ V^{c\,2} x \ 10^{-4} \quad (7)$$

$$F_{LC} = C_{LC} x \ C_{CL} x \rho \ x \ L_{BP} \ x \ d_m \ x \ V_c{}^2 x \ 10^{-4} \quad (8)$$

F_{TC} : Mooring load due to current (transversal)
F_{LC} : Mooring load due to current (longitudinal)
C_{TC} : Transversal current coefficient
C_{LC} : Longitudinal current coefficient
ρ : Sea water density
d_m : vessel draft
L_{BP} : Length between perpendicular
V_c : Current velocity

3.3 Structure modelling and analysis

The planning of a jetty structure with a capacity of 13,470 DWT refers to the planning data that has been previously collected and analyzed. The planning and structural analysis are conducted using the StaadPro V8i Select Series 6 application, following the BS 5950-1-2000 standard for steel structural elements, and the ACI-318-14 standard for concrete structural elements [9,10].

4 Results and discussion

4.1 Load analysis results

After obtaining the necessary data, an extensive analysis of the loads exerted on the structure is carried out. These loads encompass a range of factors, including berthing loads, wind-induced mooring loads, current-induced mooring loads, environmental loads, as well as structural live and dead loads. Besides, any additional facilities that may be installed at the port are also considered. Comprehensive details of these loads can be found in the following table, which gives detailed information on each category.

Table 1. Load exerted on the structure.

Load category	Load value
Berthing load	395.54 kNm
Mooring load due to wind (tranversal)	279.775 kN
Mooring load due to wind (longitudinal)	82.28 kN
Mooring load due to current (tranversal)	329.23 kN
Mooring load due to current (longitudinal)	1.175 kN
Wave load	8.19 kN
Seismic load	*Generated in StaadPro*
Fender system	25.75 kN
Bollard	3.70 kN
Dead load	*Generated in StaadPro*
Live load	20 kN/m^2

4.2 Modelling and analysis results

Preliminary planning data and dimensions of the structure to be modeled have been obtained based on the calculations that have been made. This important step allows us to build a strong foundation for project development. The modeling results are presented in the illustration and the accompanying table, which provides a comprehensive overview of the results. This visual representation provides a clear and concise overview of the data, thus enabling a better understanding of this research.

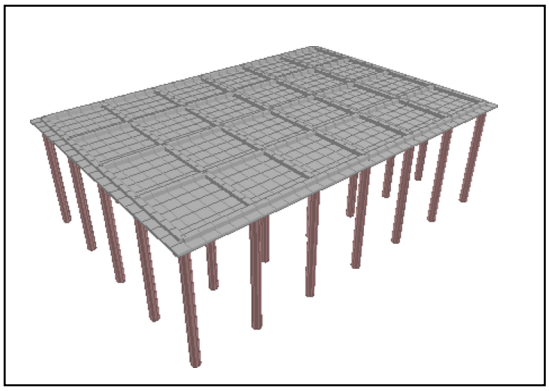

Fig. 3. Model of loading platform structure.

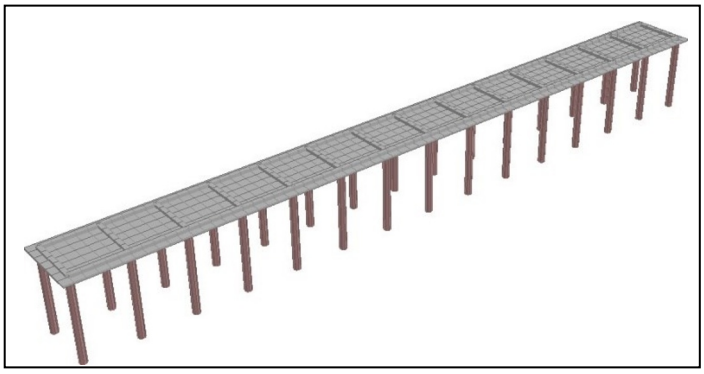

Fig. 4. Model of trestle structure.

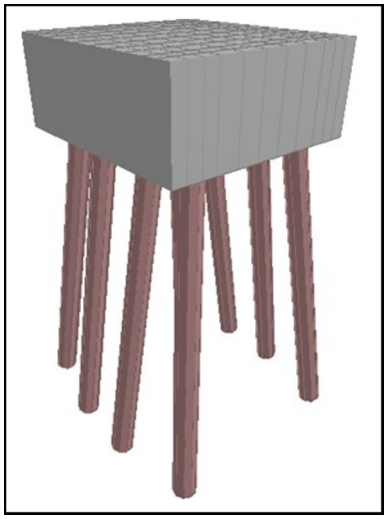

Fig. 5. Model of mooring dolphin.

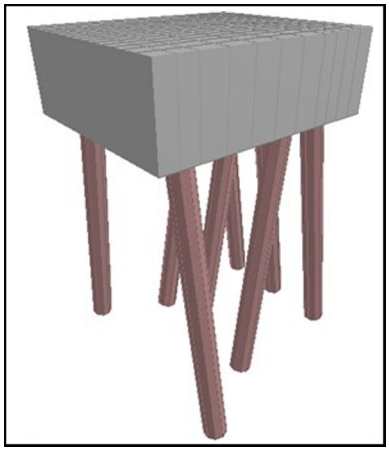

Fig. 6. Model of breasting dolphin.

Table 2. Dimensions of the modeled structure.

Description	LP	BD	MD	Trestle
Length (m)	39.5	7.5	9	84
Width (m)	28	7	7.6	6
Floor Elevation	+ 4.2 m (from lowest mean sea level)			

Table 3. Maximum Unity Check Ratio of structures.

Beam No.	Structure	UCR	Allowable ratio
75	Loading platform	0.759	1
3	Breasting dolphin	0.807	
5	Mooring dolphin	0.809	
15	Trestle	0.879	

Based on table 2 and 3 the analysis that has been done, it is known that the trestle structure has the highest maximum UCR value of 0.879, whereas the platform loading structure shows the lowest maximal UCR of 0.759. The study focuses on the evaluation of UCR values, which are found to be in the range of 0.7-0,9 for both structures. It shows that the structure has been optimized and meets the desired criteria.

4.3 Structural design of the jetty components

In this study, the planned port structure includes Loading Platform (LP), trestle, Breasting Dolphin (BD), and Mooring Dolphins. (MD). Each of these planned structures consists of two structural components. The upper structure consists of a beam and floor plates, as well as the lower structure is composed of pillars and pillars. Planning results are presented in the following table 4-7:

Table 4. Steel pipe pile total length.

Description	LP	BD	MD	Trestle
Diameter, D (m)	0.813	0.914	0.813	0.813
Thickness, t (m)	0.016	0.011	0.016	0.016
Steel grade (MPa)	355	275	275	275
Inertia (m^4)	0.003182	0.003181	0.003182	0.003182
Pile length over virtual ground (m)	10	10	10	6.75
Virtual fixed point (m)	2.57	2.50	2.57	2.57
Total pile length (m)	12.57	12.50	12.57	9.32

Table 5. Pile cap design.

Description	LP	BD	MD	Trestle
Dimension (m)	2 *x* 2	7.6 *x* 9	7 *x* 7.5	2 *x* 2
Thickness, t (m)	1.5	3	3	1.5
Concrete grade (MPa)	40	40	40	40
Reinforcement	D22	D25	D25	D22

Table 6. Beam design.

Description	LP	Trestle
Breadth, b(m)	0.5	0.5
Height, h (m)	1.0	0.9
Concrete grade (MPa)	50	50
Reinforcement	D25	D25

Table 7. Slab design.

Description	LP	Trestle
Thickness, t (m)	0.24	0.23
Concrete grade (MPa)	40	40
Reinforcement	D25	D25

5 Conclusion

The planning and analysis produced some important conclusions about the structure of the port designed to accommodate Liquified Natural Gas (LNG) discharge operations with a capacity of 13470 DWT. This conclusion covers various structural aspects, including dimensions, strength, and materials used.

- The jetty structure is made up of particular parts that work together to enable the intended functions. It is made up of one trestle, two mooring dolphins, four breasting dolphins, and one loading platform. In conjunction, these components guarantee the safe and effective handling of LNG.
- The loading platform, which is a component of the dock construction, is 28 meters by 39.5 meters in size. This size allows for sufficient room for the operations of loading and unloading, in addition to accommodation the required staff and equipment.
- The breasting dolphins are 7 meters by 7.5 meters, and they are essential in securing vessels during berthing. These dolphins are placed in a strategic manner to hold the ships in place throughout the loading and unloading processes, limiting excessive movement and guaranteeing stability.
- Measuring 7.6 by 9 meters, the mooring dolphins provide the boats with extra points of support. These dolphins improve the dock structure's overall safety and stability by anchoring the ships at several points. preventing undue movement and maintaining stability when loading and unloading.
- The Trestle, measuring 84 meters by 6 meters, is a significant part of the jetty structure. The sturdy platform this expanded structure offers for loading and unloading cargo allows personnel and equipment to move about with ease during LNG operations.
- The pier structure satisfies the necessary strength requirements, according to an examination of the structure. The highest UCR (Ultimate Compression Ratio) readings, which show the pier's structural integrity, are between 0.7 and 0.9, which is considered adequate. The loading platform structure has the lowest maximum UCR value of 0.759, while the trestle structure has the greatest maximum UCR value of 0.879. These findings confirm the jetty's structural integrity and guarantee that it can sustain the anticipated loads and stresses.
- The planning calls for the use of FC 40 and FC 50 concrete classes in terms of materials. These particular concrete grades are strong and durable enough to handle the rigors of LNG loading and unloading activities. Furthermore, S275 and S355 steel classes of steel piling were used in the building of the dock structure. These steel types provide the necessary strength and resistance to corrosion, guaranteeing the pier structure's durability and dependability.

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