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A Review Study on Gravity Quay Walls

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ABSTRACT

Gravity quay walls are a common type of structures in construction of small ports. However, these types of quay wall are relatively cost effective and easy to perform, Gravity quay walls are used to receive huge ships carrying goods of various sizes, whether small or large. These walls are sturdy and strong to suit the surrounding environmental conditions such as seawater, temperature changes, and salinity associated with water.This Technical report focuses on the study an overviewof this type of quay walls as well as analysis of this type of retainingwall to illustrate the importance of each factor.

Introduction

Gravity quay walls are the most common types of docks. That is because of their durability;ease of construction and the possibility to reach a deep seabed level. The gravity quay wall has to be safe against the three design criteria, which are sliding, overturning and over stressing. The design steps of gravity quay wall seem to be reasonably clear. However, the deep gravity walls are subjected to a great deal of external forces. In this case, the stability of the wall may be quite sensitive to many factors; depth of the wall, pulling force, soil characteristics; and base stratum characteristics. The effect of different factors on the stability needs to be investigated. The study focuses on the analysis of gravity quay walls. Design steps are written in the form of computer program taking into account all factors affecting the analysis. This makes it possible to alternate factors in order to come to an ideal design [1]. Figure 1,2 and 3 show examples for quay walls and their functions.

Fig 1: Quay-wall-Caisson

Fig 2: Quay-wall—-East-Portsaid

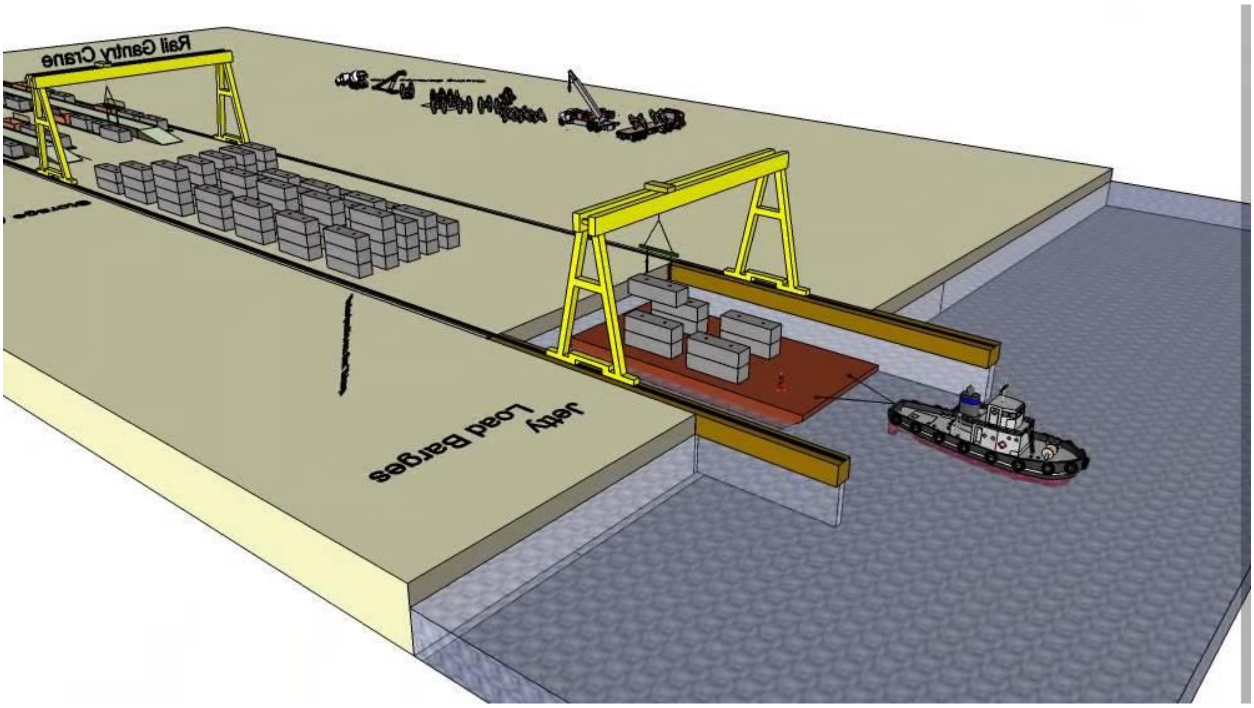

Fig 3: Quay-wall-function

Gravity-type quay walls can be utilized at wharves that receive ships of any size and kind, ranging from tiny general cargo ships to the largest modern container ships, as well as very big bulk carriers and supertankers. These walls are very helpful and long-lasting in harsh marine environments, such as saltwater, extreme heat and cold, large waves, and huge ice loads. Gravity-type quay walls have been built in the past in a wide range of configurations. Specific site conditions, such as the availability of certain construction materials, dry dock facilities, the cost of local labor, and others, determined the type of walls employed for the marine application. When local foundation conditions prevent pile or sheet-pile driving, gravity-type constructions have been utilized in numerous circumstances in the past and present. Gravity-type constructions, in general, necessitate suitable foundation conditions due to their substantial weight and the nature of the load distribution at the base. Gravity-quay walls were traditionally erected in the dry using rubble masonry (Fig.4a) or cast-in-situ concrete (Fig.4b), assuming the site could be dewatered and a sufficiently strong foundation was available[2-5].

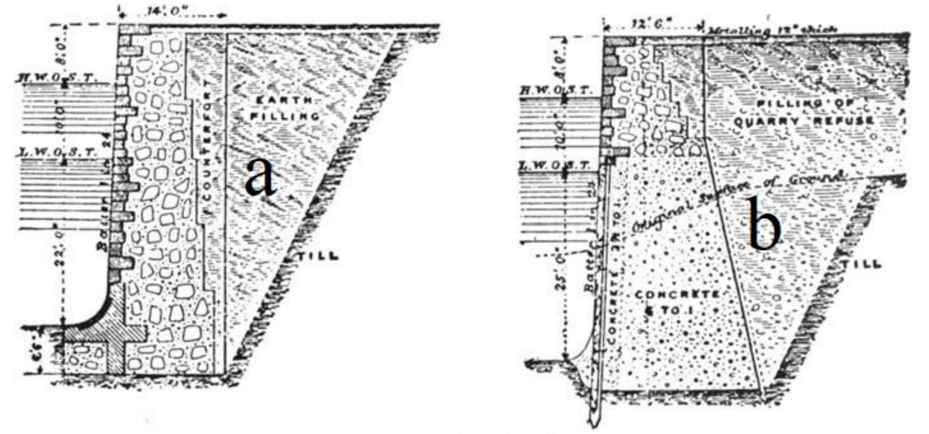

Figure 4: GreenockDock wall in UK.

Heavy gravity walls built in the dry were founded on piles in some cases when relatively weak foundation soils were encountered (Fig. 5). The pile foundation was often composed of wooden piles since wood does not rot when entirely submerged under water. The tops of these piles were normally concrete-encased and situated below the mud line, offering protection from marine critters. Following the invention of reinforced concrete and advancements in concrete technology, quay wall constructions became more refined. The counterfort walls and slender cast-in-place L shaped walls have been introduced(Fig.6) [6-9].

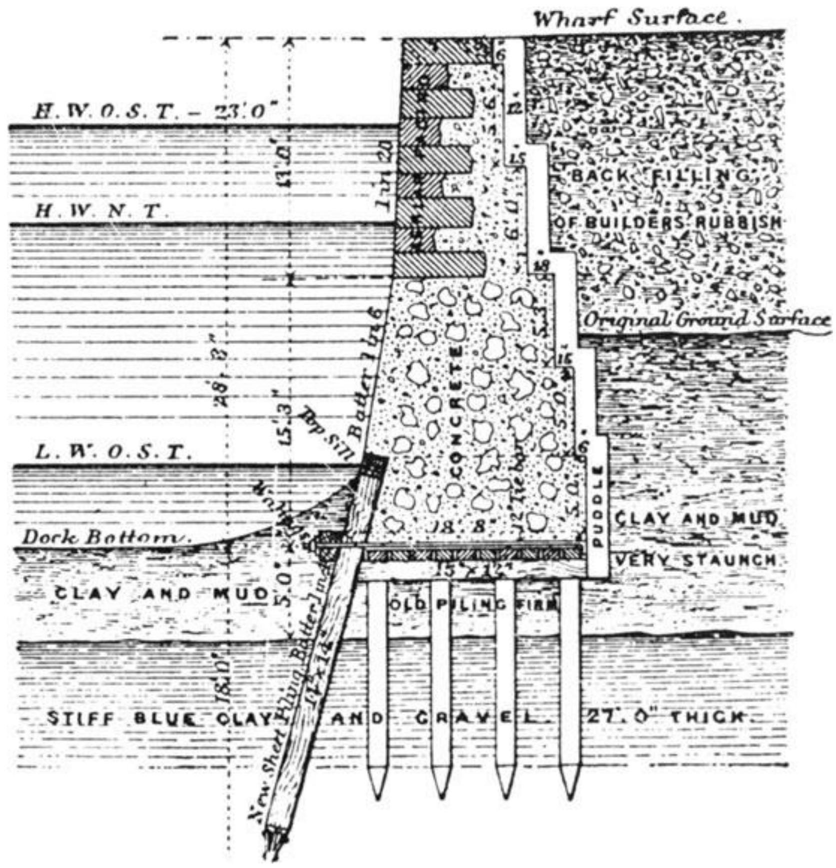

Figure 5: Mass Wall of concrete in UK.

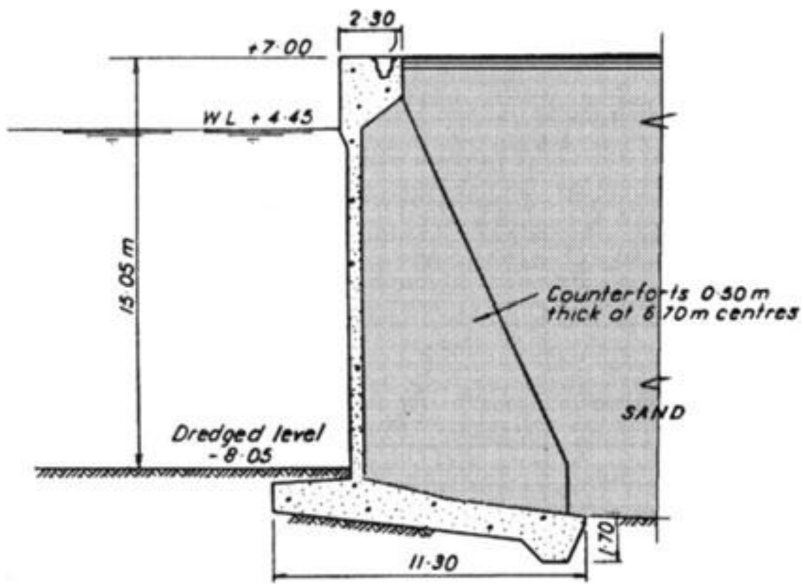

Figure 6: Quay wall at Belgium.

Quay Walls Structures Requirements

The entire quay structure must be able to satisfy numerous requirements imposed by:

- **location**
  - Conditions of soil,
  - sea water & groundwater levels,
  - Conditions of waves,
  - Earthquake conditions.
- **service conditions**
  - The durability,
  - Ships Size
  - Forces,
  - Specific requirements from the final user, port authority, etc.

Because of the inherent benefits of maritime transportation, which have been steadily increasing over the previous few decades and are expected to continue to rise, port authorities have no choice but to expand and upgrade their facilities. The design and building of new quay walls to accommodate ever-larger cargo ships has become an unending task[9].

Steel manufacturers were forced to develop novel solutions, such as the integrated wall system, as a result of the race to build larger vessels, increased depth of major ports, and the resulting requirement for more heavy-load berthing facilities. Traditional steel sheet pile walls have been replaced by combination walls, which are made up of two complementing elements: a primary stiff element (such as a sheet pile, steel tube, or box pile) and a second flexible element (intermediary sheet pile, predominantly sections). The result is a high-strength, high-bending-moment-capacity retaining structure that is both safe and cost-effective, as shown in Figure 7.

Gravity-type quay walls have been built in the past in a wide range of configurations. Specific site conditions, such as the availability of certain construction materials, dry dock facilities, the cost of local labor, and others, determined the type of walls employed for the marine application. When local foundation conditions prevent pile or sheet-pile driving, gravity-type constructions have been utilized in numerous circumstances in the past and present.

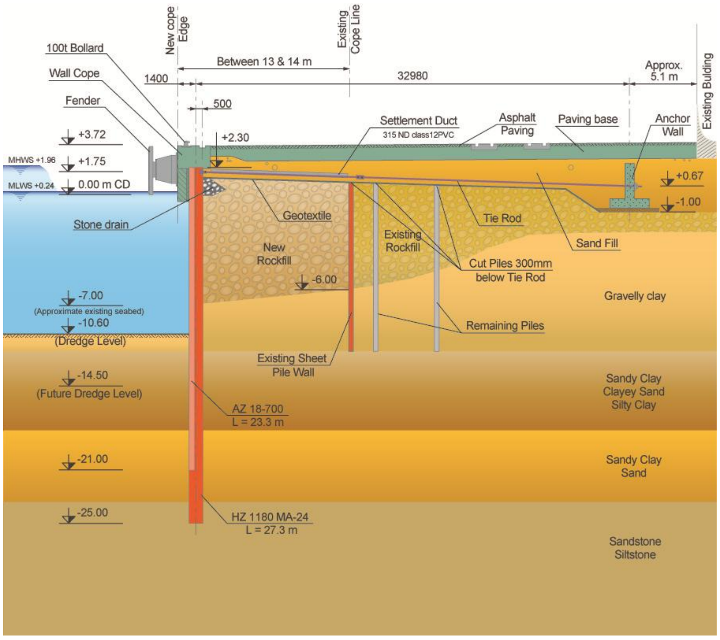

Figure 7: Berth 12 in South Africa.

1. Types of Quay Walls

1. Sheet piled quay walls.

Fig 8: Sheet piled quay walls.

2. Combi walls.

Fig 9: Combi walls.

3. Steel cellular / caisson quay walls.

Fig 10: Caisson quay walls

4. Reinforced concrete diaphragm walled quay walls.

Fig 11: Diaphragm walled quay walls.

5. Gravity block quay walls.

Fig 12: Gravity block quay walls.

6. Reinforced concrete counterfort quay walls.

Fig 13:counterfort quay walls.

2. **Loads Acting on Gravity Quay Walls**

Two types of forces act on the gravity retaining quay wall, namely: stability forces and failure forces.

4.1 Stability Forces

Two vertical stability forces are: weight of soil over the projection part of the blocks and own weight of blocks.

- **Weight of Soil (W_S) =**The weight of the soil resting on top of the projection part of the block (in tons), acting at its central of gravity (c.g.) of each part.
- **Weight of Blocks (W_B) =**Own weight of block (in tons), acting at itscenter of gravity (c.g.).
- Total stability forces acting on the wall per meter length (in tons) ($\mathbf{W_T}$) =

$$\mathbf{W_S + W_B} \ldots\ldots\ldots\ldots\ldots\ldots \mathbf{(1)}$$

4.2FailureForces

There are four horizontal forces acting as static failure forces: -

1. Lateral earth pressures
2. Pull bollard
3. live load
4. horizontal crane load

Conclusion

Design of plain concrete blocks gravity quay wall is usually a clear-cut one. However, for deep docks or those subjected to huge forces and resting on semi-strong soil, stability is difficult to achieve. Factors affecting equilibrium condition become essential and their influence on the final design of the gravity quay wall needs to be investigated. From the analysis and the parametric study, the following may be concluded.

1. The back-fill characteristics have a great influence on the stability of gravity quay wall.

2. A ship load and dimensions affect the berth in terms of pollard force, magnitude of live load, and depth of the quay wall.

3. The concrete crown should be carefully checked, since it is the most critical part of the quay wall particularly when the pulling force acting on mooring guns is quite large. Thus, a groove of (1m) length should be done to prevent sliding and create a shear resistance.

4. Dimensions of each block can be determined by checking sliding first then checking for overturning and stresses.

5. Configuration of the quay wall can be improved by reducing lateral forces, which can be achieved by extending the backfill to a distance equal to the

height of the wall.

6. Live load should be applied on the berth just behind the blocks. It means that, it produces lateral pressure and may not contribute to weights.

7. Increasing the unit weight of the concrete participates into the stability of the wall. Therefore, it is recommended to use blocks with unit weight not less than 2.4t/m3 particularly for deep quay walls.

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