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Bulk Materials Handling Berths

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Abstract
The increasing level of coal and mineral exports from Australia has created a strain on existing export facilities and has resulted in the need for expansions to existing facilities and for the creation of new export facilities. Larger bulk materials carrier of sizes up to 360,000DWT are now in service, however many existing ports can only handle vessels up to a maximum of 220,000DWT. Thus, there will be a need for new berths to be designed for these vessels, and there are continuing pressures on existing terminals to accept larger ships.

As well as the need for new facilities, many installations are at the end of their original nominal design life. In normal circumstances, the owners would carry out a mid-life refurbishment to allow the life of their facilities to be extended. However, due to the strong demand for commodity exports and high prices, downtime is critical.

This paper examines the issues associated with shiploader and berth configuration for new and existing marine terminals, including:

- *Types of shiploaders*
- *Berth layout*
- *Design and specification*
- *Independent proof auditing of structural compliance*
- *Berthing and mooring equipment*

1. Introduction

Design of berths for the loading of bulk materials is a challenging exercise due to factors such as the following:

- Configuration of wharf structure to accommodate vessel type, width, length and draft, tidal range, movement of vessel in waves, and vessel keel clearance;
- Configuration of the shiploading equipment;
- Effects of waves, wind and earthquake;
- Difficult and uncertain foundation conditions;
- Difficulty of construction over water; and
- Need to tie in with existing facilities.

In addition, many existing facilities are being stretched beyond their original design envelopes due to larger ship sizes and capacity upgrades. Therefore, there is a need to retrofit the facilities to safely cater for the changed parameters.

2. Ship Characteristics

Dead weight tonnage, or "DWT", is the commonly used designation for the size of ships for transport of bulk materials. DWT is the total carrying capacity and includes the cargo and consumables such as fuel and water. Bulk carriers fit into broad classes based on DWT and other dimensions.

Handysize
Handysize usually refers to a dry bulk vessel between 15,000-35,000DWT. Handysize ships are very flexible because their size allows them to enter smaller ports, and in most cases they are 'geared', i.e. fitted with cranes, which means that they can load and discharge cargoes at ports which lack cranes or other cargo handling systems. The most common industry-standard specification for Handysize is now around 32,000DWT on a summer draft of about 10 metres, and features five cargo holds, with four 30 metric tonne cranes for cargo handling.

Handymax
Handymax is a term for a bulk carrier, typically between 35,000 and 60,000DWT, and larger than Handysize vessels. Modern Handymax designs are typically 52,000-58,000DWT in size, have five cargo holds, and four cranes of 30 tonnes lifting capacity.

Panamax
Panamax ships are the largest ships that can pass through the Panama Canal and are typically 65,000-80,000DWT. The size is limited by the dimensions of the lock chambers and the depth of the water in the canal. Their dimensions are as follows: length: 294.13m; beam (width): 32.31m; and draft: 12.04m. The majority of Panamax vessels are not equipped with ships' cranes i.e. they are "ungeared".

Post Panamax
After the current expansion project (scheduled to be completed by 2014), the Panama Canal will be able to handle vessels of larger capacity up to 426.72m long, 54.86m wide, with a draft of 18.29m.
Capesize
Capesize cargo ships were originally too large to transit the Suez Canal. To travel between oceans, such vessels once had to pass either the Cape of Good Hope or Cape Horn. Capesize vessels are typically above 150,000DWT. A standard Capesize bulker is around 175,000DWT, although larger ships up to 220,000DWT are commonly in use for coal and iron ore. Almost without exception, Capesize vessels are “ungeared”.

Chinamax
Chinamax are the world’s largest ore carriers, built to export iron ore to China and Europe with a capacity in the order of 350,000 to 400,000DWT.

Generally speaking, there is a trend that larger vessels result in a more economic freight rate. Larger vessels, although more expensive to build, have significant efficiencies of scale in terms of operating and labour cost per tonne of cargo. This trend is more pronounced on longer voyages. Smaller vessels remain economic for either smaller volumes of cargo or shorter sailing distances.

Other factors to be considered in determining the size of vessel to be selected include:

- The draft available at loading and inloading ports and along planned sailing routes;
- The volume of cargo that is to be handled annually;
- The stockpile capacities at the loading and discharge ports;
- The capacity of loading/unloading equipments at the loading/unloading ports;
- The sailing distance between loading and unloading port;
- Availability of other customers requiring compatible cargos that can be aggregated to allow a larger vessel to be used; and
- Availability of other cargoes near the discharge port that can be carried as backloading on the return voyage.

To produce an efficient bulk transport operation, the selection of the ship size must be considered as part of the total system, which includes the materials handling and marine facilities at both the loading and discharge ports, and the availability of other cargoes that may be handled as part loads or backloads.

3. Loading of Ships

As ships need to be loaded in a specific sequence so as to not overstress the hull, the shiploader movement tends to concentrate near the centre of the holds. A typical loading sequence for first pass filling of holds is shown in Figure 1. Usually two passes per hold will be required to fill a bulk carrier of the type used for iron ore. On this basis, around a figure of 100 shiploader movements per million tonnes is considered a suitable value to use for shiploader movements over the centre part of the wharf. As demonstrated in Figure 1, the shiploader movements drop off away from the centre of the ship.

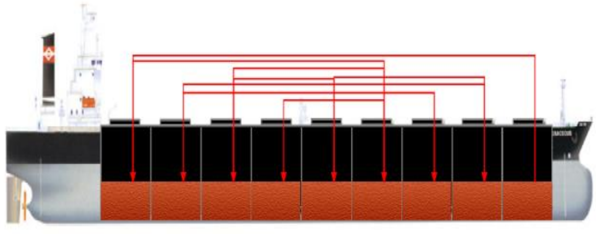

Figure 1 Typical shiploader movements for first pass

4. Shiploader Selection

Determination of a suitable configuration of machine and performance parameters such as outreach, throughput rate, utilisation, design life, etc, is intimately linked to the business objectives and process/quality requirements for the materials being handled. Futures trends in business and shipping are also important. Allowance for flexibility and responsiveness to the market may also need to be considered in the equipment selection and specification.

The length of the berth is determined by the largest ship expected and to a lesser extent by the type of shiploader selected. Some of the most frequently used types of shiploaders are shown below in Figures 2, 3, 4, and 5. In the case of a long travelling shiploader, the travel length (and berth length) should be at least equal to the distance between extreme hatches on the largest ship using the berth to avoid the need to move the ship along the berth (termed warping).

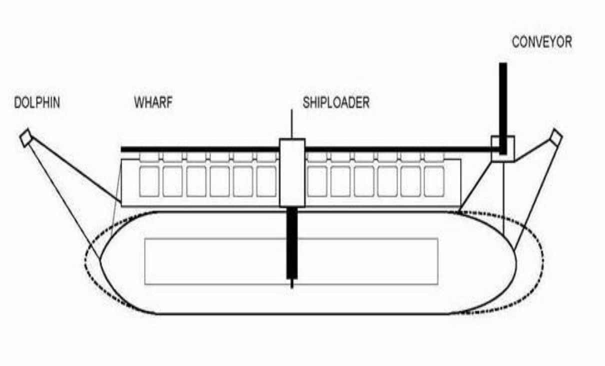

Figure 2 Long travelling shiploader

The use of radial loaders or linear loaders can lead to a reduction in berth length. Both linear and radial type shiploaders pivot about a central point, the former having a longitudinal runway beam adjacent to the berth and the latter having a quadrant beam on a radius. Single shiploaders of this type are limited to ships of maximum size 100,000DWT and 65,000DWT respectively. For larger ships a long travelling type shiploader or dual quadrant (radial) shiploader system is required.

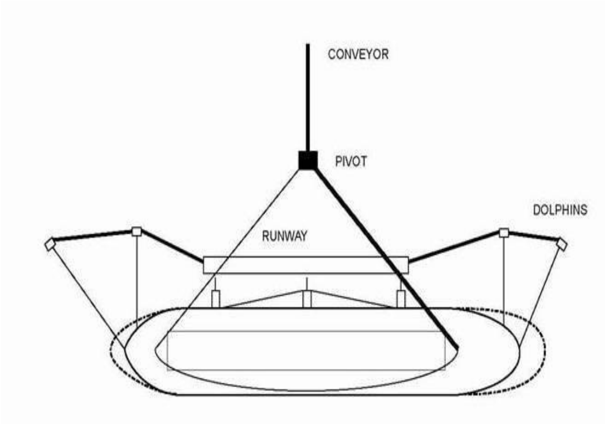

Figure 3 Linear shiploader

A major advantage of linear and radial type shiploaders is the ability to minimise dust and spillage as the transfer from the approach conveyor system to the shiploaders is at a single point, whereas a long travelling shiploader requires wharf conveyor and tripper which increases the potential for dust and spillage.

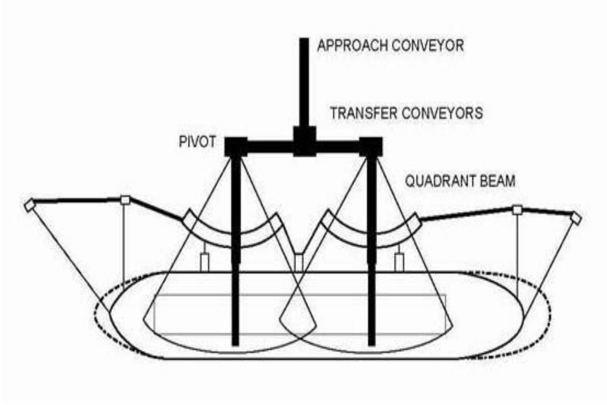

Figure 4 Dual radial shiploaders

A variation of the long travelling shiploader is the long travelling slewing shiploader. This has the advantage that it requires a shorter wharf rail length as the shiploaders can slew to cover the end bow and stern hatches. This type of shiploader can also allow ships to be loaded on each side of the berth, allowing for layout efficiencies. However this is usually only suitable where larger clear deck ships are used and the product range being loaded is limited.

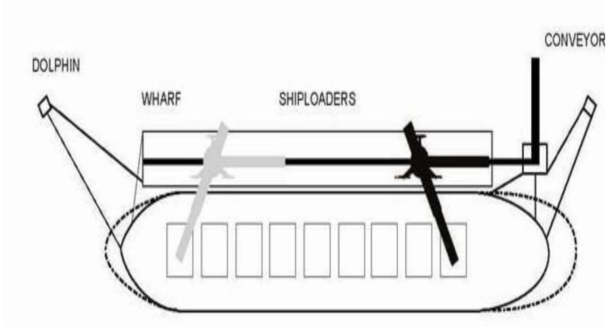

Figure 5 Long travelling slewing shiploader

Long travelling shiploaders with narrow wheelbase up to approximately 20 metres often have a portal gantry structure spanning the rails and a fixed boom gantry set at 90 degrees to the rail track as shown in Figure 6. The boom conveyor shiploading chute shuttles in and out to load the hatches and due to geometry, there are limitations on the length of inboard travel of the shuttle. The shuttle mechanism may vary the length of the boom or the boom may be of fixed length with the shuttle within the boom.

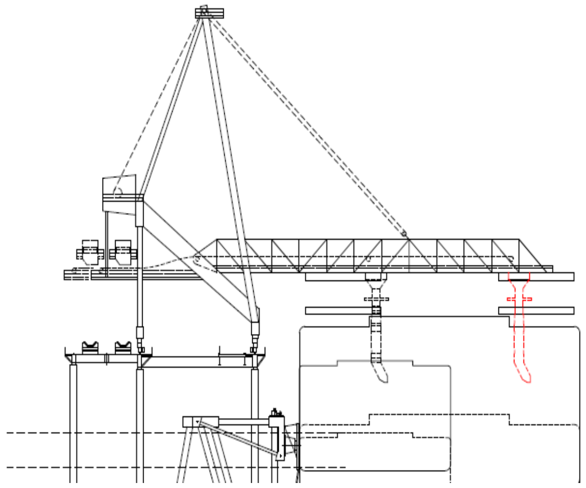

Figure 6 Long travelling portal gantry shiploader

Bridge shiploaders may be long travelling, radial or linear types. These shiploaders tend to be large and relatively heavy compared to portal gantry and portal slewing types. Metal fatigue in the bridge girder and at the boom head due to chute rotations is a common issue with this type of shiploader. For the long travelling bridge type, skew control is very important to avoid derailment or other major damage.

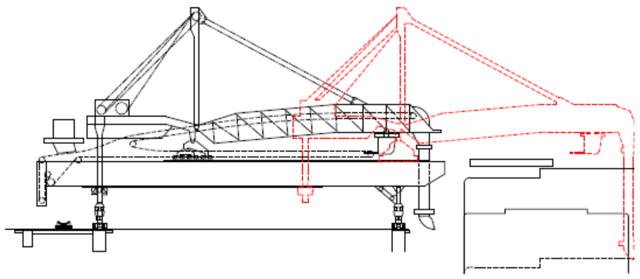

Figure 7 Long travelling bridge shiploader

5. Shiploader Specifications

The standard method for procuring bulk materials handling machines is a design and construct contract. The specification covers design, material and quality requirements for manufacture and installation, commissioning and handover to operations, provision of spare parts and requirements for ongoing maintenance. The specification needs to ensure that the configuration and performance parameters upon which the requirements for the machine were determined can be realistically met in practice.

Australian Standard AS4324.1 was introduced in 1995 in response to a number of failures of bulk materials handling machines. It specifies requirements and design loads for rail mounted machine structures. AS4324.1 refers to AS1170.2 for wind loads, AS3990 for permissible stress steel design, and AS4100 for limit states steel design.

6. Design Audit

AS4324.1 Appendix K gives guidance for design auditing and certification by an independent third party engineering consultant. This may be by means of independent calculations or by checking and reviewing the original design calculations and computer analysis. Independent calculations are the preferred method. In conjunction with the design audit, it is desirable to hold one or more facilitated workshops with key staff from the designer, operator, maintainer and audit-engineering consultant present.

The audit engineer should be engaged before the specification for the machine is finalised to allow for a review prior to issue. Involvement of the audit engineer by the client in the tender review process is also desirable.

7. Berth Layout

Berthing and mooring forces are generally the critical loads for design of berthing and mooring dolphins. In offshore terminals, dolphins have different functional requirements to the deck and supporting elements for shiploaders and usually exist as separate structures in their own right.

Mooring dolphins are usually isolated structures supporting quick release mooring hooks with access provided by catwalks. Berthing dolphins are generally flexible structures designed to absorb the energy of ship berthing by deflection in addition to absorption by rubber fendering systems on their faces.

Ships of sizes considered generally require four mooring dolphins for each berth. Each dolphin must be designed for line pulls of up to 3000kN from several lines. Berthing dolphins attract loads of similar magnitude perpendicular to the berth for working load cases and shear along the berth due to sliding on the fender face. They should be designed to yield in extreme overload cases so as not to cause damage to the ship, particularly those with hazardous cargoes.

8. Marine Fenders and Mooring Systems

Marine fendering systems are necessary to absorb the energy of the moving ship as it berths at the wharf and thus protect the supporting wharf structure from damage. Mooring systems hold the vessel securely at the berth. If a ship undergoes excessive movements on its mooring lines, the fenders are required to prevent damage to both the ship and the wharf. Damage to the fendering system and the supporting wharf can occur when they are overloaded due to excessive ship impacts caused by berthing accidents or when ships larger than the system design capacity berth at the wharf. They can also suffer damage due to vessels which undergo excessive movement on their mooring lines or due to direct mechanical damage caused by protrusions from the vessel's hull. Modern fender units utilise sophisticated shapes and rubber compounds which enable the units to efficiently absorb relatively large amounts of energy. This is where modern fenders differ significantly from older fender designs.

When selecting a fendering and mooring system, several factors need to be considered. These include the size and tonnage range of the ships using the facility, the tidal range, and whether the facility is for unloading full ships or loading empty ships. For an exposed berth, the range of sea conditions must also be considered. At exposed berths, the effects of waves, currents and winds can cause a moored ship to undergo movements on its mooring lines, and the fendering system has to be designed to be compatible with the arrangement of lines, bollards, quick release hooks and support structures which form the mooring system. Fendering and mooring systems represent a significant capital expenditure and their continued performance can be critical in determining the safety, whole of life costs, and production capacity of a marine facility.

9. Fender Design

Fenders protect the berthing structure against ship impact. Theories have been developed to calculate the expected berthing energy, resulting from the mass and berthing velocity/angle of the ship. The berthing energy normally governs the fender design and depends mainly on:

•The mass of the ship;
•The berthing velocity of the ship, varying between 0.10m and 0.20m/second;
•The berthing angle, usually not more than 10 degrees; and
•The eccentricity of the ship towards the first point of contact with the berth which would ideally be at a quarter of the total ship's length, but can vary.

The installation level of the fender will be governed by the smallest ships so the freeboard at lowest water should still be able to have proper and adequate contact with the fender. The main function of frontal frames in front of the fenders is to distribute the fender reaction force over the hull of the ship to achieve a hull pressure of around 20 tonnes per square metre. They have a low friction surface to avoid rubbing forces in longitudinal as well as vertical directions, due to the movements of the ship.

Rubber fenders are available in different rubber qualities. By selecting a softer, but larger-sized fender, the fender reaction force can be reduced. Consequently, by selecting a more efficient fender, savings can be made in the costs of the dolphin structure resulting in a more economical structure.

The most common type of fender achieves the maximum reaction early in the deflection range, then exhibits a buckling action with a fairly constant reaction until it reaches the end of its range at which stage the reaction increases rapidly. It is therefore important to size the fender to within the working range. Figure 8 below shows a typical deflection versus reaction and deflection versus energy absorption curve for a buckling action fender.

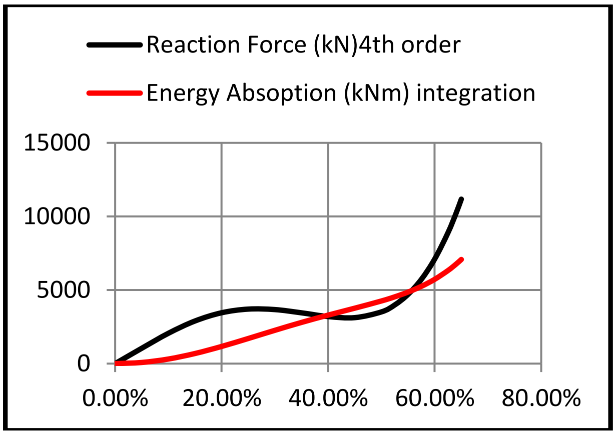

Figure 8 Fender curves

a. Cell Fenders

These consist of large rubber cylinders, placed perpendicular on the quay face, combined with a large front panel. Although smaller units are available, their normal range is from 1,000mm to 3,000mm, with energy absorption from 20 tonne-metre to maximum 400 tonne-metre each.

Figure 9 Cell fender

b. Cone Fenders

They are similar to cell fenders but the rubber cylinder is tapered. The cone shape gives a better performance during angled berthing. The largest size is 2,000mm in height, which can have energy absorption between 300 and 500 tonne-metre depending on the rubber grade.

Figure 10 Cone fender

10. Mooring Lines

The proper mooring of a ship not only requires the ship to stay at berth, but also to maintain position, within certain limits. For terminals that have separate mooring dolphins, the mooring quick release hooks will ideally be more than 35 metres away from the side of the ship. This will require access walkways (catwalks) or alternatively line boats to access the mooring points.

•Stern and head lines are the mooring lines at front and stern, to be placed as far away as possible, preferably at least 45 degree angles to the quay line.

•Aft and forward breast lines come from the same location on the ship but are approximately perpendicular to the quay.

•Spring lines come from the ship at approximately quarter length and run nearly parallel to the quay.

Figure 11 Ship with mooring lines

11. Rope Guards

Mooring lines are usually made out of synthetic materials such as nylon which has high elasticity. This elasticity has advantages and disadvantages. The main advantage is that in high winds, currents or wave action, excess stress can be spread among several lines. However, if a highly-stressed line does break or part, it causes a dangerous phenomenon called "snapback" which can cause fatal injuries. Rope guards are installed at many berths to provide protection against mooring line breakage.

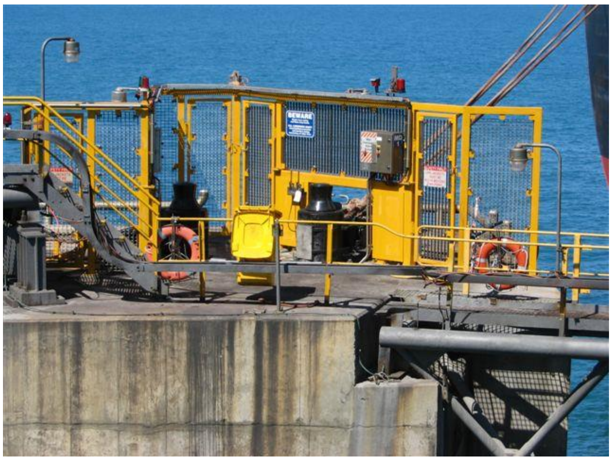

Figure 12 Rope guard on mooring dolphin

12. Proprietary Mooring Systems

Proprietary systems have been developed to overcome the problem of mooring line angles being quite inefficient in terms of load path. The MoorMaster™ system uses vacuum pads instead of ropes to provide the mooring attachment. Hydraulic cylinders connected to the vacuum pads generate forces in the horizontal plane to control the horizontal motion of the moored ship. The MoorMaster™ system has been used successfully on container ships and ferries for a number of years and has recently been applied to bulk materials berths.

Figure 13 MoorMaster™ Unit on container berth

13. References

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