

DESIGN DEVELOPMENT AND INNOVATION AT RG TANNA COAL TERMINAL

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Abstract: The purpose of this paper is to describe the advances and innovation in design developed for the skeletal steel marine structures at RG Tanna Coal Terminal over the last 25 years. This is achieved through a comparison of the original facilities for Berth 1, with the most recent expansion for Berth 3 recently completed. RG Tanna Coal Terminal Wharf is a semi-exposed facility consisting of an approach jetty, a wharf, and independent berthing and mooring dolphins. All primary framing (piles, headstocks and bracing) is steel. Decking is provided where required, and is typically steel grating or precast concrete.

Connell Wagner was responsible for the design of the original facilities and all marine upgrades at RG Tanna Coal Terminal (commissioned 1980,1986,1988, and recently completed construction). The following key design issues are considered:

- Steel frame design
- Wharf design developments
- Berthing and Mooring Dolphin design evolution
- Alterations to existing structures

While the overall design approach and primary framing has remained essentially unchanged, there have been advances in construction technology and numerical analysis techniques, which in turn produce significant efficiencies in design, resulting in better value for the capital dollar.

Keywords: Wharf, Coal Terminal, Gladstone, RG Tanna, Dolphin, Offshore, Design Development

INTRODUCTION

RG Tanna Coal Terminal export wharf is in a semi-exposed location within Gladstone Harbour on the east coast of Queensland, Australia. The export wharf structures consist of an approach jetty, a wharf, and independent berthing and mooring dolphins. All primary framing (ie. piles, headstocks and bracing) of these structures is steel, with decking provided by either grating or precast concrete.

Connell Wagner was responsible for the design of the original facility at RG Tanna Coal Terminal, and has continued its association by completing all subsequent wharf extensions. The historical developments for the wharf facilities have been:

- Berth 1, commissioned in 1980
- Berth 2, commissioned in 1988
- Berth 3, commissioned in 2003

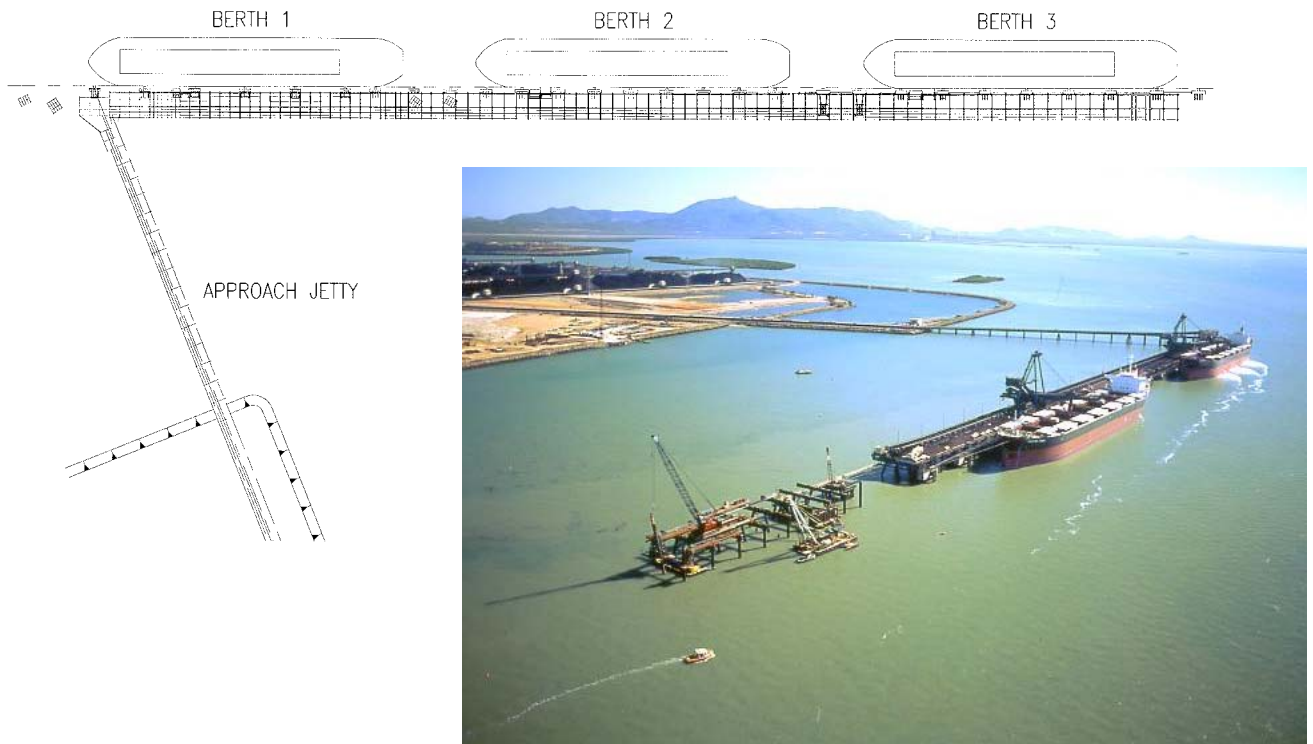


Figure 1. General Arrangement of RG Tanna Coal Terminal Wharves, and Berth 3 Under Construction

From 1980 to 2003, there have been many design developments and some innovative approaches adopted by Connell Wagner for this facility. While the basic structural concept (of steel framing and precast concrete decking) has not greatly changed, the detailing and structural elements have undergone significant developments to identify and produce more efficient design output, resulting in better value for the capital dollar.

STEEL FRAME DESIGN

The most fundamental design decision common to each of the berths is the use of steel rather than concrete for the primary structural members of the wharf and dolphins. Reasons include:

- Higher strength to weight ratio of steel results in significantly lower erection costs.
- Difficulties and consequent costs of forming and pouring cast insitu concrete in offshore and/or over water locations.
- Availability and ability of local and regional fabrication shops to produce large structural steel members at a competitive price.

The original design philosophy (which remains unchanged) was based on the use of large tubular sections for all primary members, including piles, headstocks, rail girders and bracing. Pre-fabrication was maximised, with simple site connections and realistic erection tolerances.

The direct connection of tubular piles and headstocks was a significant advancement by Connell Wagner in the mid 1970's. This enabled the use of closed form headstocks, and avoided the need for various cap plates, gussets and stiffeners in the pile to headstock connection. Over the years Connell Wagner has made various improvements to this connection – the main improvement being the use of a semi-circular base to the headstock. This has improved fit up in construction and reduced stress concentrations, as well as providing a “clean” and accessible connection for protective treatment and maintenance.



Figure 2. Typical Pile to Headstock Connection Prior to Touch-up Painting

The Berth 1 and 2 designs were based on the use of Grade 250 steel, while the most recent Berth 3 design is based on the use of Grade 350 steel. The improvements in material properties and weldability of higher strength steels, along with the low cost premium of using Grade 350 steel has permitted significant overall cost savings in the basic wharf structure.

WHARF DESIGN DEVELOPMENT

Wharf Structure

Whilst the overall framing arrangement of the primary wharf structure has not changed from Berth 1 to Berth 3, the following changes are evident in the most recent designs:

- Bent spacing increases from 10 metres in Berth 1, to 12 metres in Berth 2, to 14 metres in Berth 3. This is mainly due to the larger crane sizes (from 90 t cranes for Berth 1, to cranes in the range 200 t to 400 t today) now more readily available in the construction industry, combined with the ability of Grade 350 steel to withstand higher loads.
- Depth of the headstocks has increased from 1,150 mm in Berth 1 to 1,800 mm in Berths 2 and 3. The deeper headstock is necessary as the span increases, but Grade 350 steel makes it possible to maintain the same depth for Berth 3.

- Pile sizes have remained unchanged, typically 1200 mm diameter by 16 mm wall thickness, but with the adoption of Grade 350 steel for the Berth 3 piles permitting fewer piles to be used than would otherwise have been the case. The Berth 3 cross-section consists of only three piles per wharf bent, whereas the Berth 1 cross-section required four piles per wharf bent.
- Greater use of the portal action along the wharf – Original designs were based on relatively stiff anchor points to resist longitudinal loads. The Berth 3 design has utilised full 3D structural models of the wharf (all three Berths) to more accurately assessed the longitudinal stiffness of the wharf structure as a whole. Longitudinal loads can be shown to be shared between the anchor points and typical wharf bents in portal action, such that additional longitudinal raking piles are not necessary (either in a new strongpoint, or for strengthening the existing strongpoints).

Some other wharf designs are making use of secondary steelwork at deck level to effect a lateral and/or longitudinal distribution of transverse load. Whilst this can provide some economies in steel supply, it introduces additional steelwork and connections, increasing the time and complexity during construction, and which ultimately requires more maintenance. Such maintenance is especially difficult under a wharf that is fully decked between shiploader rail girders. The preferred design approach is therefore to minimise the number of structural members and connections, and to have a clean and open structure.

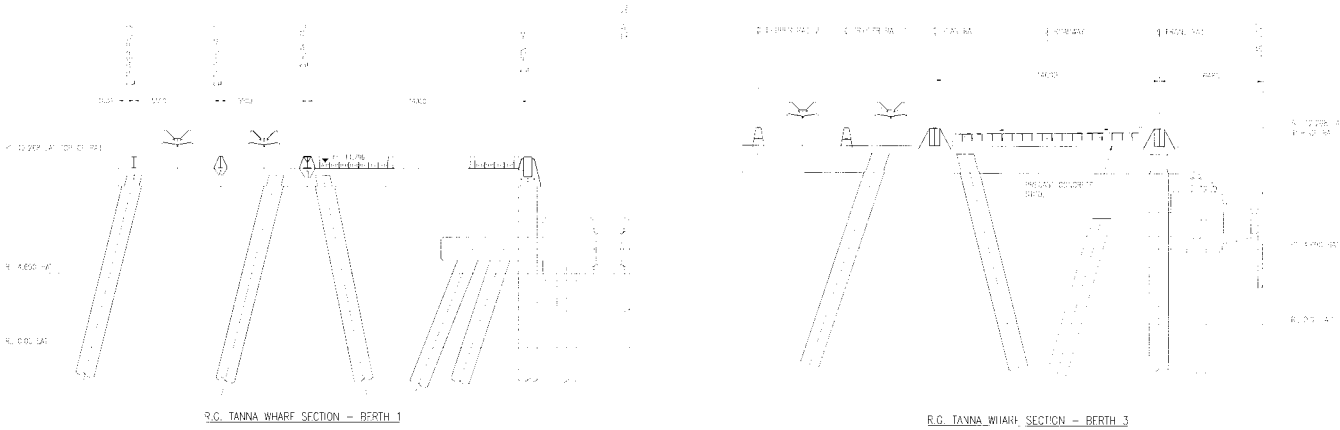


Figure 3. Comparison of Berth 1 and Berth 3 Wharf Typical Cross-Section

Decking

The typical approach to decking of these wharf structures was to minimise the extent of decking – saving capital investment. This occurred for Berth 1 at RG Tanna. It was recognised that this placed some operational constraint on the facility, but this was considered an acceptable compromise. As the infrastructure became heavily utilised and expansion required, an appreciation of the full operational cost of issues such as extent of access was considered. For Berths 2 and 3 the decision was taken to provide full width decking – providing greater accessibility for operations.

Detailing

An ongoing issue for facilities such as RG Tanna is maintenance in the marine environment. As facilities survive for longer than may have been originally anticipated, greater emphasis on current designs is placed on detailing to minimise the cost of maintenance activities. Key areas that require attention are:

- Grating support and general walkway detailing
- Access for ships stores and personnel transfers
- Accessibility for conveyor maintenance
- Spillage collection and return

It is the small details that can be the most difficult to solve in limited design programmes, but these same details can be the source of ongoing issues for the owner. Improvements in these areas can still be made, but the challenge is finding the right balance between capital and maintenance costs.

BERTHING AND MOORING DOLPHIN DESIGN EVOLUTION

Berthing Dolphins

Berthing dolphin spacing for Berth 1 was set at 50 metres – determined to a small extent by the 10 metre wharf bent span, the suitability for the 220,000 dwt design vessel, and the desire to minimise capital investment. Operationally it was found that this spacing had its limitations for the smaller vessels (Handy class). Dolphin spacing for Berth 2 was reduced to 36 metres – suiting the 12 metre wharf bent span and operational preferences for the smaller vessels. Berth 3 has adopted a slight increase to 42 metres, to effect some economies with the increased 14 metre wharf bent span, while still catering for the range of vessels that use the facility.

The original design philosophy of having the berthing dolphins independent of the wharf has been retained for each of the RG Tanna Berths. Some of the more recent Connell Wagner designs at other facilities have connected the individual berthing dolphins to effect a sharing of longitudinal loads due to poor foundation conditions and the desire to avoid the costs and disruptions of tension anchoring of piles. Evaluation of such an approach for the foundation conditions (and also due to some operational preferences) at RG Tanna showed that it was not warranted.

A combination of improved foundation conditions, as well as greater individual member capacity due to the use of Grade 350 steel, enabled the deletion of three piles per berthing dolphin for the Berth 3 dolphin structures. As well as savings in the number of piles per dolphin, the mass concrete dolphin head (adopted in Berths 1 and 2 to minimise the tension carried by the piles), could be reduced in size due to an increased assessment of the geotechnical tension capacity available.

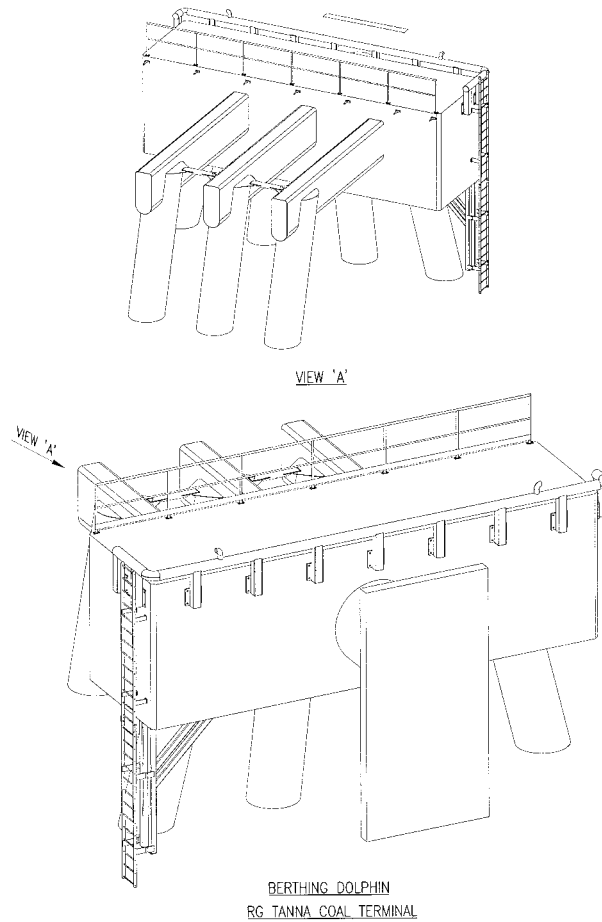


Figure 4. Berth 3 Berthing Dolphin – the Berth 1 and 2 Dolphins contained an extra row of rear raking piles, and a slightly larger concrete head.

Mooring Dolphins

For Berth 1, uni-directional mooring dolphins were adopted – ie. the mooring dolphins were aligned with the primary direction of the mooring loads, and out of plane loads were minimised. The possibility of future wharf extensions was not considered in the setting of the mooring dolphin orientation. This produced significant design challenges due to the alignment and potential for clashes of piles. When Berth 2 was designed, the relevant mooring dolphins were set back from the quay line but designed to permit easy conversion to berthing dolphins with the wharf structure extended over the top. This still however resulted in the need for careful construction planning to keep Berth 2 operational while the Dolphins were converted for Berth 3.

The mooring dolphins at the end of Berth 3 have also been aligned orthogonally to the wharf, but specifically designed and located on the quay line as berthing dolphins, to suit a possible future wharf extension – even if considered unlikely at the time. This will make the design and construction for the interface with Berth 3 more cost effective.

ALTERATIONS TO EXISTING STRUCTURES

Two key elements of the Berth 3 project at RG Tanna Coal Terminal was the widening of the existing approach jetty, and the infilling of intentional voids in the Berth 1 wharf decking.

Jetty Widening

The existing approach jetty was originally designed with a clear width of approximately 4.4 metres. This width was found to be operationally suitable for the given the relatively short length of jetty, and the type of traffic for both Berths 1 and 2. With the extension to a third berth, and still a single point of entry for all three berths, the Gladstone Port Authority agreed that it would be preferable to have an approach jetty capable of allowing vehicle passing along the full length.



Figure 5. Jetty Widening Before and After Asphaltalting

A study of the existing jetty capacity identified that widening it to provide a clear space of approximately 5.7 metres was feasible without requiring an additional pile in each jetty bent. A study of the type of traffic using the jetty for operational and maintenance purposes indicated that this would permit suitable (low speed) two-way traffic flow and be of significant benefit to the operation of the facility.

Berth 1 Infills

Berth 1 was originally designed with a relatively narrow (3.3 metre wide) front roadway, coupled with a relatively wide (5.1 metre) rear roadway – leaving a gap of some 5.5 metres between the roadways. Berths 2 and 3 were designed with decking for effectively the full width between the shiploader rail girders. It was therefore desirable to “infill” the gap in the Berth 1 deck to provide a fully decked solution for all three berths.

This presented the challenge of structural capacity of the existing wharf bents – which were specifically designed for the two roadway arrangement. Options of lightweight decking with reduced live load capacity, additional structural plating to each headstock to permit full live load capacity, and offset or “dual” piling at each headstock were considered.

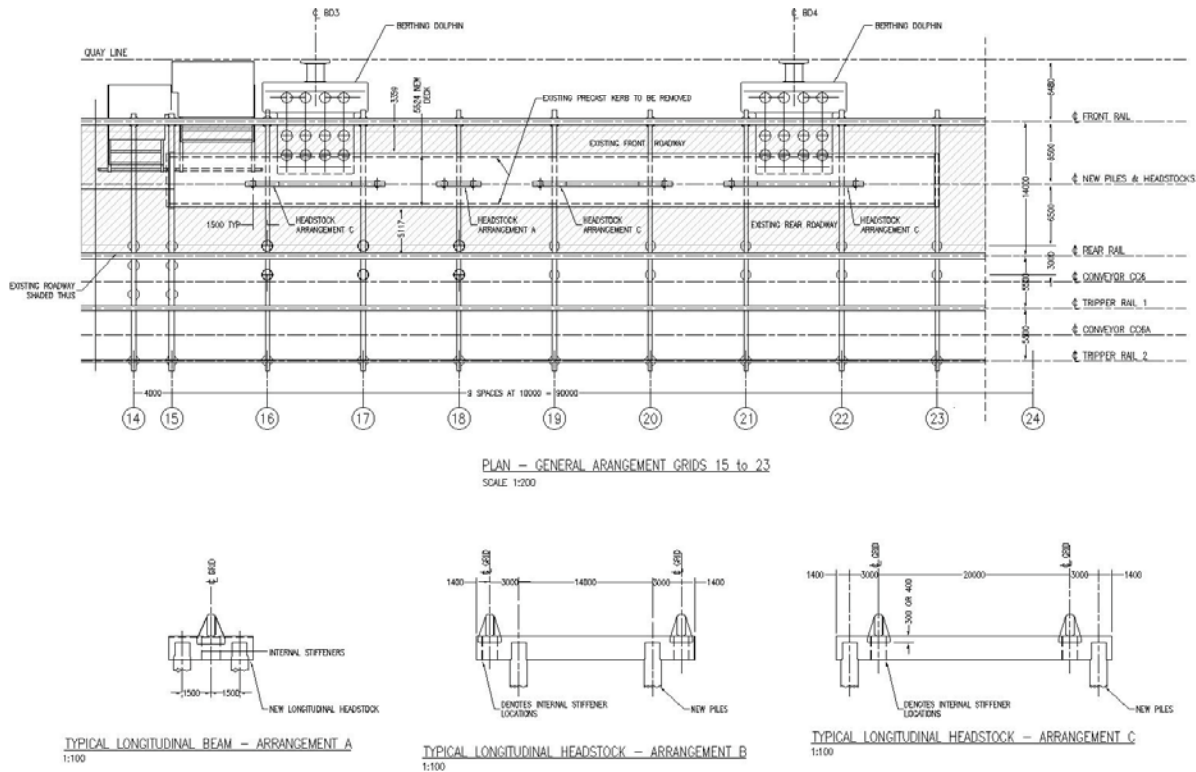


Figure 6. General Arrangement showing Berth 1 Infill Support Layout

The final solution made use of smaller diameter (900 mm) Grade 350 steel piles. Piles were driven immediately adjacent to existing headstocks, with sufficient clearance for a piling hammer to operate. Piles were connected by a small headstock, which was in turn connected to the underside of the existing headstock to provide central support and therefore a significant increase in capacity of the wharf structure.

Due to the presence of the independent berthing dolphins, it was not possible to create symmetrical support at each headstock individually. The design therefore produced an arrangement that consisted of a pile pair and 11.5 to 14.5 metre long new headstocks installed beneath and supporting two existing headstock bents. The slotted pile to headstock connections facilitated the ability to “slide” the new long headstocks into place beneath the existing headstocks, with a flared plate connection to the existing headstocks completing the works. Once the new supports were in place, the precast concrete deck units could be installed to provide the new full width deck for Berth 1.

In order to ensure operational access for Berth 2 and the construction front, a construction method was devised that consisted of firstly widening the narrow front roadway to an acceptable trafficable width. This was followed by widening of the rear roadway. As the deck construction is transversely post-tensioned precast concrete planks, it was necessary to develop a special central T-beam to complete the deck. This beam is therefore not integrally linked by post-tensioning to the remainder of the deck, but connected by means of support brackets and stainless steel bolted ferrules to the adjoining units.



Figure 7. The new infill supports in place, and closing the gap in the deck.

CONCLUSIONS

This paper has highlighted the design of skeletal steel marine structures, showing the developments and innovations that have occurred at the RG Tanna Coal Terminal in Gladstone. Design detailing has gradually developed, standardised and simplified over the period of some 20 years from the design and construction of Berth 1 to Berth 3. Higher strength steels (Grade 350) are now routinely used to the advantage of the project.

While the overall design approach and primary framing has generally remained conceptually the same for both wharf and independent dolphin structures, there have been significant advances in numerical techniques, in turn producing significant efficiencies in the structural design, and consequently in terms of capital cost. A greater emphasis has also been placed on operational and maintenance needs. While not all the detailing issues have been solved, advances have been made.

When designing at an existing facility, it remains important to consider the operational requirements and preferences. It is often when faced with alterations to the existing structure that the engineer is required to seek innovative design outcomes – to balance the requirements of improved operational efficiency, against minimising the capital cost of achieving it.

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