Steel Jetties

By A.Q.C. van der Horst
WOB/DMC

1 Introduction

1.1 Jetties; definition and main components

Jetties are, within the context of this paper, defined as the structures at the interface between on-shore activities and sea/river transports, excepted quaywalls. This paper mainly deals with the civil engineering aspects of jetties.
As such jetties will allow ships to safely approach, berth and stay in berth, allow transportation of goods and personnel and will allow vessels to safely depart.

Main components of jetties are

- *Dolphins*
  Dolphins will absorb the berthing energy of ships upon arrival and will provide support once the vessel is in berth by direct contact to the ship's hull and mooring points to fix the mooring ropes.

- *Loading Platform*
  The loading platform allows for the loading and unloading operations and provides the access to the ships in berth.
  For this reason a loading platform is normally provided with cranes, loading arms and a gangway tower and supports the top works, which may consist of product lines, conveyor belts etc.
  Also supporting systems as fire fighting, pollution control devices and operational systems are often found on the loading platform.

- *Trestle*
  The trestle provides access between shore and the loading platform.
  Depending upon the functional requirements, the trestle may consist of pipeways, a roadway/walkway or rail track, conveyor belts, utility lines, etc..
  It is quite common that along the trestle electrical substations and firewater pump platforms are located.Long trestles are often provided with passing bays.

1.2 The operational meaning of jetties

As mentioned before, jetties serve the interface between on-shore activities and sea/river transports.

In many cases jetties are dedicated to a single product and as such form a unique link at the interface. This makes the jetty a vulnerable element in the operational process. Therefore special attention is normally paid [and should be paid] to the design basis of jetties in terms of conceptual design, loadings and loading combinations, anticipated lifetime and maintenance aspects.

Especially the interface between ship and jetty [lay out and concept of dolphins] and the environmental condition / analysis [operational and extreme loads] have proven to play a vital role in the reliability and redundancy of jetty structures.

1.3 The meaning of jetties for HBG in general

The industry permanently calls for repair and upgrading of jetties as well as development of new infrastructural schemes.
Also the exploration of new markets [cryogenic LNG for example] requires new infra- structure. Jetties are at the interface between different transport modalities [sea, road, rail] as well as the interface between sea transport and land based storage.

Given the market strategy of HBG jetties form one of the concepts within HBG's general scope of work, but more and more it is realized that by combining land based schemes and jetties, a total package can be offered to a client, thus avoiding problem-generating interfaces. As success of jetty schemes heavily depend on knowledge and experience and as this experience both in design and construction is to quite an extend available in HBG, jetties form an interesting aspect of HBG's capability towards the industry.

2 Type of jetties

2.1 Product orientation

If the products to be loaded/unloaded are used as a key, following distinction can be made.

- Jetties for bulk materials : iron ore, grain, etc.
- Petrochemical jetties : oil, gas, petrochemicals
- Container jetties
- Passenger jetties

Each and any of the above itemized jetties has it's own characteristics in terms of access, loading/unloading devices and space requirements.

2.2 Environmental exposure

The extent of environmental exposure is of paramount importance. A distinction is made in sheltered and exposed sites.

- *Sheltered sites*
  A jetty at a sheltered site can, in general, be designed, constructed and operated without relevant constraints.

- *Exposed sites*

  In case of exposed sites all steps of the scheme development process should be carefully examined.

  * Design:

    Apart from the significant consequence of high design values on concept and material demand a variety of aspects should be addressed.

    - Dolphins, energy absorption and mooring loads:

      The present state of the art in marine engineering hardly allows for a reliable assessment of the dynamic effects of a ship in berth which is subjected to exposed conditions. For tentative concept development, mooring gear based design is normal practice whilst for final design even model tests in basins at specialist research centres might be required.

    - Deck levels:

      Waves, trapped underneath a platform deck, exert loads which are of excessive magnitude. As such wave slamming against decks should be avoided. Thus, deck levels will be governed by the extreme levels of the wave crest under high tide in combination with set-up effects from storm and sea level rise. Deck levels do have a substantial impact on the working envelope of loading/unloading equipment as well as on access provisions to the ship in berth.

    - Availability:

      Under severe conditions ships have to leave the jetty to ride the storm at open sea. Therefore, environmental conditions have an important ingluence on the availability of the facility and as such on throughput figures as well as on the specification of land based storage facilities.

      Special analysis techniques are normally applied to simulate these effects.

  * Construction:

    In case of exposed sites the construction methodology is governing for both the concept and the required equipment.

    If actual construction has to be performed under exposed conditions, activities at site will be kept to a minimum thus leading to a high degree of prefabrication and reduction of the number of elements to be placed by increasing the span between supports.

    Also activities which create risk exposure over a certain period of time [concrete hardening of vital components/connections] will normally be replaced by techniques which provide direct availability of strength and/or stiffness.

  * Operational:

    Given their vital importance, exposed jetties have to be safeguarded throughout their lifetime. This is normally done by development of operational environmental windows for the facility and by installing monitoring devices to read waves, winds and currents in combination with support of a reliable MET Office to precast adverse conditions.

3 Concrete versus steel

The question whether concrete or steel should be selected as construction material for jetties is too general to be answered. Both steel and concrete have proven their specific right of existence in the past.

3.1 Length of span

The governing trigger for material selection is the length of span along the trestle: the longer the span, the stronger the tendency to apply steel as construction material because of the required lifting capacity of the equipment and stiffness requirements. For spans up to approx. 21 metres the choice is mainly influenced by local cost levels for concrete/steel, local available materials, client's preference and local experience. Above 21 metres we enter into the domain of space frame steel structures.

It was generally believed that for sheltered sites an increase of span length upto 21 metres and even 24 metres would results in economical concepts. This is, in general, a true statement but not valid in specific regions in the Far East: 9 metre spans are the most cost effective span in those regions! The lesson is: check it out!!

There are circumstances which dictate the use of larger spans [> 21 metres] and as such automatically set the switch for steel as construction material.

- *Exposure*
  If a site is exposed to severe environmental conditions there is a trend to apply a high degree of prefabrication and to reduce the number and duration of site activities. This can be realized by long spans [Brunei: 36 metres] and by prefabrication of the full span inclusive of all top works.
  Large fully assembled, spans normally dictate the use of steel space frames to reduce lifting weights but also to provide adequate stiffness to the trestle structure.
  As a consequence of the choice for steel also insitu connections are normally made between steel members by welding/bolting, as such providing strength directly upon completion.

- *Subsoil*
  For each and any project the interaction between superstructure and foundation should be examined to find the optimum between cost for spans and cost for the foundation.
  Thick overburdens of loose/soft material overlying a strong and sound stratus are normally a signal to go for larger spans. 1]

3.2 Foundation Piles

If the foundation consists of piles it is common practice to apply open ended steel piles, although in the Far East concrete spun piles can be quite cost effective.
Steel piles have proven their effectiveness, not only in load bearing capacity but also in driveability, ease to install rock-anchors, easy lengthening of piles in case the toe level should be deeper as anticipated, easy connections between piles and superstructure and the high capacity in taking wave loads and imposed movements.

3.3 Dolphins

The dolphins which absorb the berthing energy [breasting dolphins] are the first [and also the last] line of defence of each and any jetty.
This means that due attention should be given to overloading scenarios.
Steel, flexible, breasting dolphins, properly designed, provide an enormous hidden capacity in energy absorption after development of a plastic hinge in the dolphin pile. As such steel flexible dolphins can provide the redundancy required.
Fixed concrete dolphins, pile founded, equipped with rubber tenders will take energy up to the design values but don't have redundancy once the capacity is reached.

1] Also spread foundations, where from a practicle point of view minimum dimensions are required, often provide a bearing capacity which tends to larger spans.

4 State-of-the-art - example: Brunei LNG loading facility

4.1 Site Brunei

Brunei is located along the north coast of Kalimantan [former Borneo]. Site Brunei consists of an existing LNG plant and an existing LNG loading jetty penetrating 4 km's into the sea. The present jetty can be considered as exposed and subjected to severe environmental conditions.

4.2 New Facility

The new facility consists of a new loading platform inclusive of dolphins and a trestle which ties in into the existing trestle. The new loading platform is also located some 4 km's offshore and subjected to the same conditions as the existing jetty.

4.3 HBG's Involvement

Delta Marine Consultants [DMC] were consultants to Shell International Petroleum Company to prepare the concept of the new facilities inclusive of top works. Tebodin was subconsultant of DMC to develop the top works.

The joint venture ITH [Interbeton, Tebodin, HCG] was awarded the D/C contract.
DMC was subconsultant towards Interbeton to carry out the detailed design of the civil components.

The project is completed and performs satisfactory.

4.4 Concept Strategy

Given the environmental exposure, remote site characteristic and short construction period, large, prefabricated, fully assembled spans were selected [span lengths 36 metres].
The cryogenic lines were provided with non-rotational bellows which put severe limits on the deformations. This resulted into a space frame trestle structure. As the soil information was limited a jacket type support was selected to provide an upper limit of stiffness as concept changes upon receipt of additional soil information was not considered as feasible/realistic.
Once the concept of trestle and trestle support was frozen, the concepts of loading platform and tie in platform were a logical consequence of the trestle concept: these platforms were designed as jacket structures. The platform decks were almost completely prefabricated and pre-assembled and consisted of steel girders topped with a concrete deck. The dolphins were designed as flexible steel dolphins provided with rubber fenders. Given the exposed characteristics, the dolphin concept was model tested in a basin. The lay out of the overall scheme was tested by real time simulations of the approach procedure.

4.5 Specific Structural Aspects

- *Maintenance*
  All structural members had to be designed as hollow sections provided with end plates. As such final design consisted of rectangular hollow sections.

- *Trestle*
  The trestle is a space frame type of structure, consisting of rectangular hollow sections and providing support to the cryogenic LNG lines and a rail track. Specifically the three dimensional connections between bottom chord, transversal beams and vertical members have cost a lot of discussions before agreement was reached:
  Originally planned as tubulars, final design wanted to incorporate partly tubulars, partly rectangulars. Such connection was not transparent with the ruling code although each component of the connection was supported by documented research. This aspect resulted finally in rectangulars for all members.

- *Dolphins*
  The flexible dolphins were initially designed by simple hand calculations, in final design by multi-linear spring characteristics of the subsoil and independently mirrored by a dynamic analysis by a specialist research institute.
  It is worthwhile to report that all 3 exercises resulted, within normal tolerances, in the same performance characteristics of the dolphins.

5 Additional information

For Additional Information please contact Delta Marine Consultants, A.Q.C. van der Horst or K.B. Davies.