LNG Berths for open seas: Part 1 Dahej LNG terminal, a case study

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Introduction

PLL had commissioned its 5 MMTPA LNG receiving and re-gasification terminal (the first in the country) at Dahej – Gujarat (built at the cost of approximately US$550 million) in February 2004, and expansion of the same to handle 10 MMTPA LNG was also completed in March 2009, currently at an advanced stage in doubling its capacity. PLL has also commenced the construction work for its second LNG receiving and re-gasification terminal (2.5 MMTPA expandable to 5 MMTPA) at Kochi, Kerala in Feb 2008.

Petronet LNG Limited (PLL) is India's premier company in the natural gas sector and currently brings over 25 per cent of India's natural gas requirements through imports. The company is promoted by leading Public Sector Undertakings from India's Oil Sector and has successfully undertaken the challenging task to build LNG terminals and bring imported gas to India. Bringing LNG to India has been a major milestone and goes a long way into meeting the energy demands of buoyant Indian economy in an environmentally friendly manner.

The company set up India's first LNG terminal at Dahej in the state of Gujarat on the western coast. Numerous challenges have been faced in the course of execution of the Dahej Project but the challenges have been met by the concerted efforts of a dedicated team. The LNG terminal is now operating with an open berth without a breakwater, even though the conceptual design and the scope of EPC contract provided for a breakwater.

The development of Dahej LNG berth is a landmark and the transformation from a sheltered berth to an open berth, with improvements in design and operational procedures, has been successfully carried out with detailed studies by experts, the flexibility to adapt fresh met-oceanic data for the most optimum layout at the construction stage and the innovation to retrofit additional facilities which would enhance the berth availability for safe and reliable operations.

The location of LNG berth at Dahej site is in the open sea and close to the mouth of river Narmada in the Gulf of Khambat. It was a challenging job to execute the construction of marine facilities due to high tidal currents, unique bathymetry, complex wave patterns, moving sea bed and highly turbid seawater. These met-oceanic conditions called for specialized studies for determining the layout of the marine facilities as well as layout for the approach & berthing of the LNG tankers.

The construction of breakwater, which was originally conceived, was abandoned after initial constructional difficulties led to detailed review of the downtime assessment, with and without breakwater and potential morphological impact assessment based on the updated specific met-oceanic data.

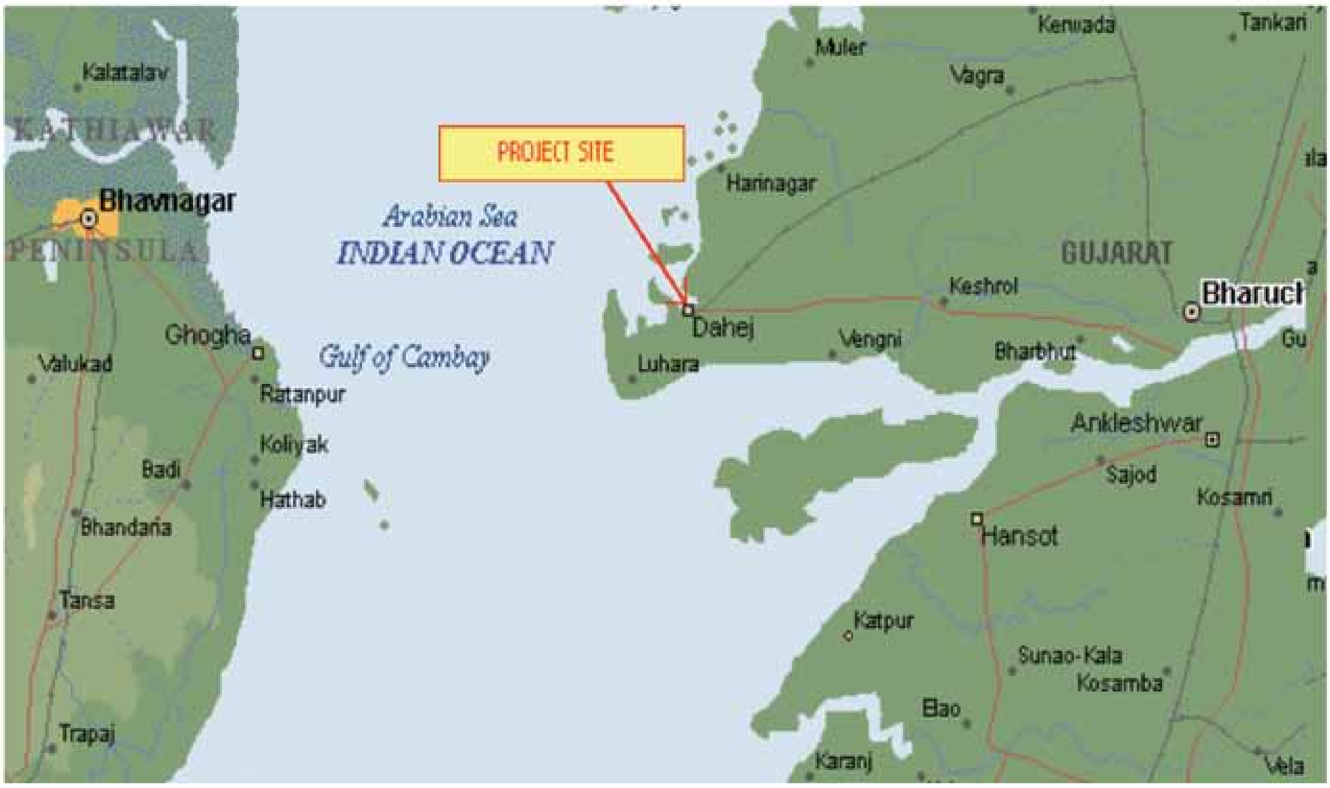

Figure 1. Location of Dahej Terminal.

Figure 2. Physical view of the site.

This session will provide insight into:

- The unique site specific met-oceanic conditions
- Specialized studies carried out to mitigate their effects
- Assessment of downtime and potential morphological impacts
- Specialized facilities provided for safe and reliable shipping operation
- Specialized construction approach adopted
- Shipping logistics and arrangements for bunker, etc.

Specific conditions of LNG terminal site at Dahej and their impact on design

The location at Dahej in the state of Gujarat on the west coast of India (Figure 1) was selected due to the available network of pipelines, and an already developed consumer base.

Geographically, the Dahej LNG Project site is located on the eastern shore of the Gulf of Khambhat, in the Bharuch district of Gujarat State. This Gulf connects several major Indian rivers to the north – east part of the Arabian Sea. The site is on a flat band

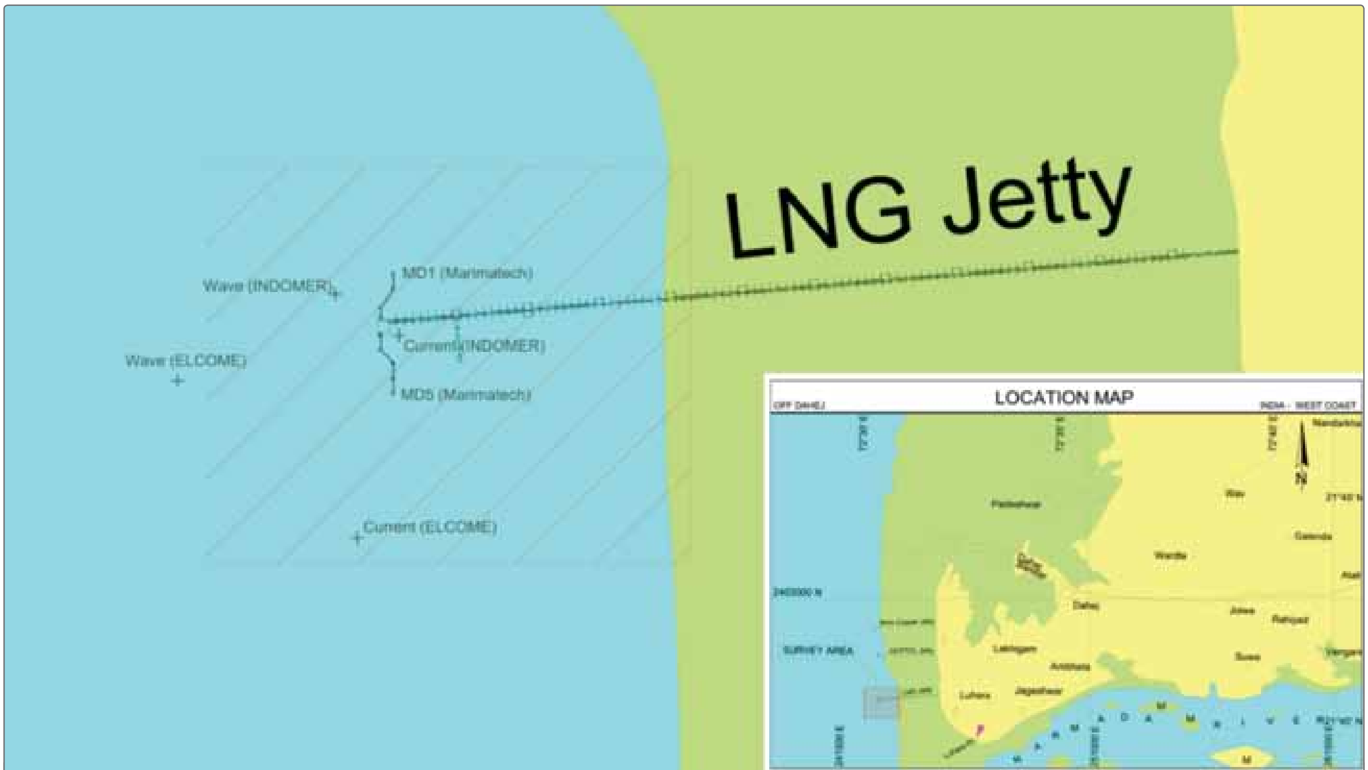

Figure 3. Layout of the jetty.

of sandy soils lying between the river Narmada (to the south) and the river Mahi (to the North).

The terminal is oriented parallel to the shore line, which runs N-S at the terminal location. The bathymetry near Dahej is rather specific. A very flat beach is first encountered, with the slope being less than 1/160 in the inter-tidal area, than at approximately 1,700 meters from the coastline; the sea bed profile suddenly assumes a significant slope (1/20). Further offshore, a rather flat bottom is encountered (Figure 2). The minimum draft of 14 meters, required for the selected size of LNG carriers, is available at a distance of approximately 2.5 Km from the shoreline (Figure 3). As mentioned above, the site is located between the two river mouths. These rivers bring large quantities of sediment to the Gulf waters.

The port has huge tidal variation of approximately 10 meters, and the tidal currents at the site are significantly strong. These currents could go as high as 3 m/s at flood and 2 m/s at ebb tide. The quality of seawater in Dahej area is also not good. The water is muddy and turbidity is very high. The sea bed in Dahej area experiences movement caused by sand waves, fine sea bed and high current.

The wave patterns in this area are complex. Both local waves and swells have been significant. The mechanism of wave transmission and transformation is impacted by complex interaction of current speed/direction, presence of features such as Malacca banks (dry and submerged features vary with tide), impact of wind etc. The impact of Malacca banks on the wave propagation could not be predicted during the FEED stage studies. Subsequently, this factor (when it became known during the detailed studies) played a crucial part in development of this berth.

The met-oceanic conditions at the site are complex also due to the occurrence of southwest monsoon, from June to August, which generates waves that pass through the Malacca banks before reaching the terminal. The channels and bars that comprise the banks disrupt incoming swells and trigger confused sea-states in their wake. During the monsoon season the waves and wind intensity follow a fairly consistent pattern, generally winds and waves are less intense in the mornings, increase in intensity during the afternoon, peak in intensity during the late afternoon/early evening and reduce again overnight. This pattern indicates that the temperature gradient have an impact on the conditions throughout the day. It is also noted that the highest wind and wave conditions also often coincide with the high tides.

FEED studies and determining scope of work for the LNG port facilities at Dahej

The FEED studies and feasibility report for the Dahej LNG terminal were carried out in 1998. Petronet had engaged Sofregaz of France for FEED and preparation of detailed feasibility report, Sofregaz in turn engaged the services of M/s Sogreah France, for the specialized work of design of LNG Port Facilities.

The LNG jetty facilitates berthing of ship and discharge of the cargo. It involves construction of approach trestle, loading platform, mooring and breasting dolphins etc. The availability of jetty for LNG ship operations depends upon prevailing conditions of wave, wind and current. Depending upon availability of berth as determined by modeling these met-oceanic conditions for ship berthing and mooring studies, design of jetty facilities such as number of mooring and breasting dolphins, specifications of the fenders, mooring hooks, setback distance and need of breakwater or otherwise is decided. However, in a tidal port (as Dahej), high currents (including current at the sea bottom) and soft sand characteristics throw additional challenge of scour and sedimentation due to shifting sands and it becomes crucial

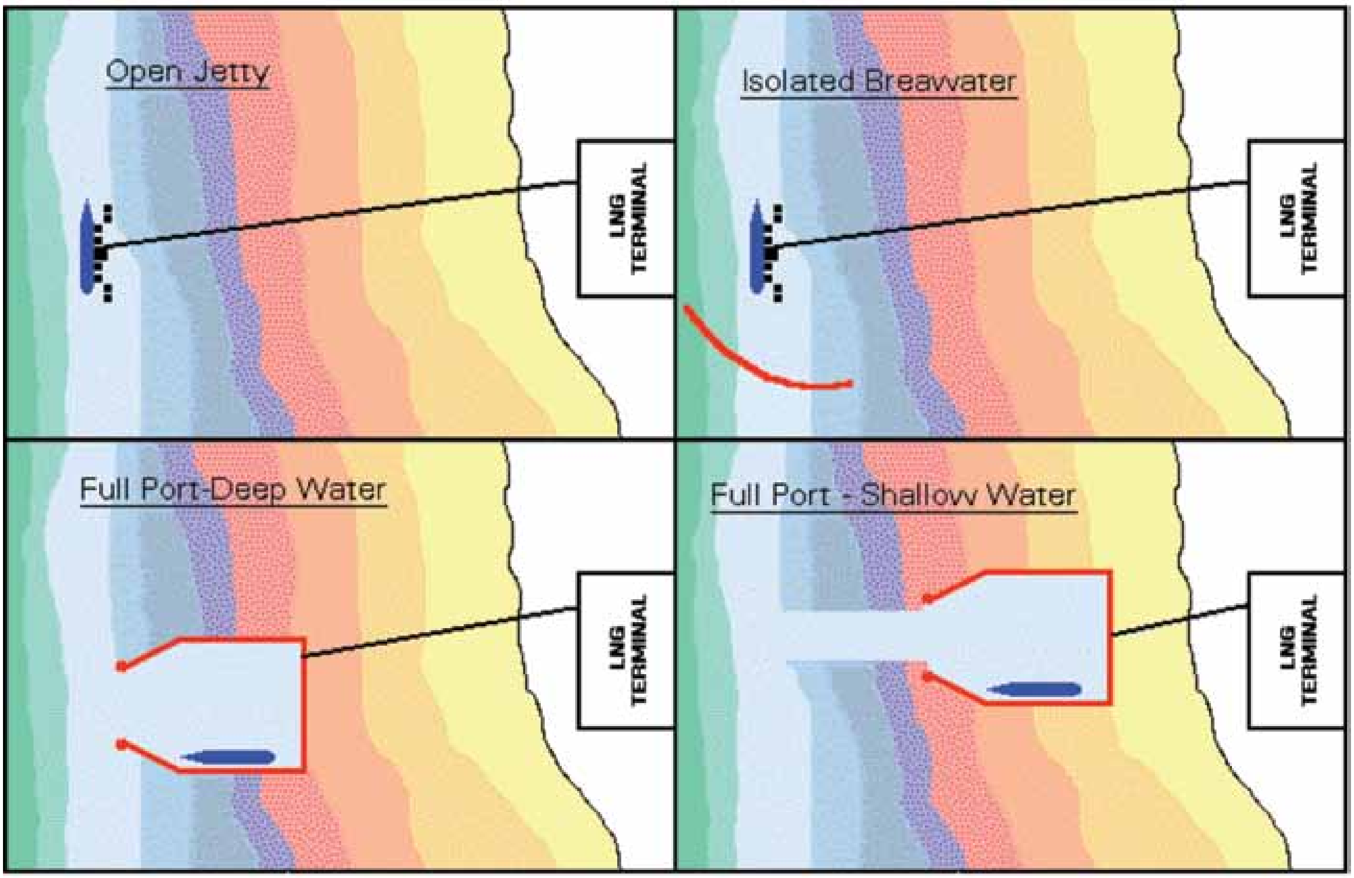

Figure 4. Mathematical modeling of alternative concepts of LNG port.

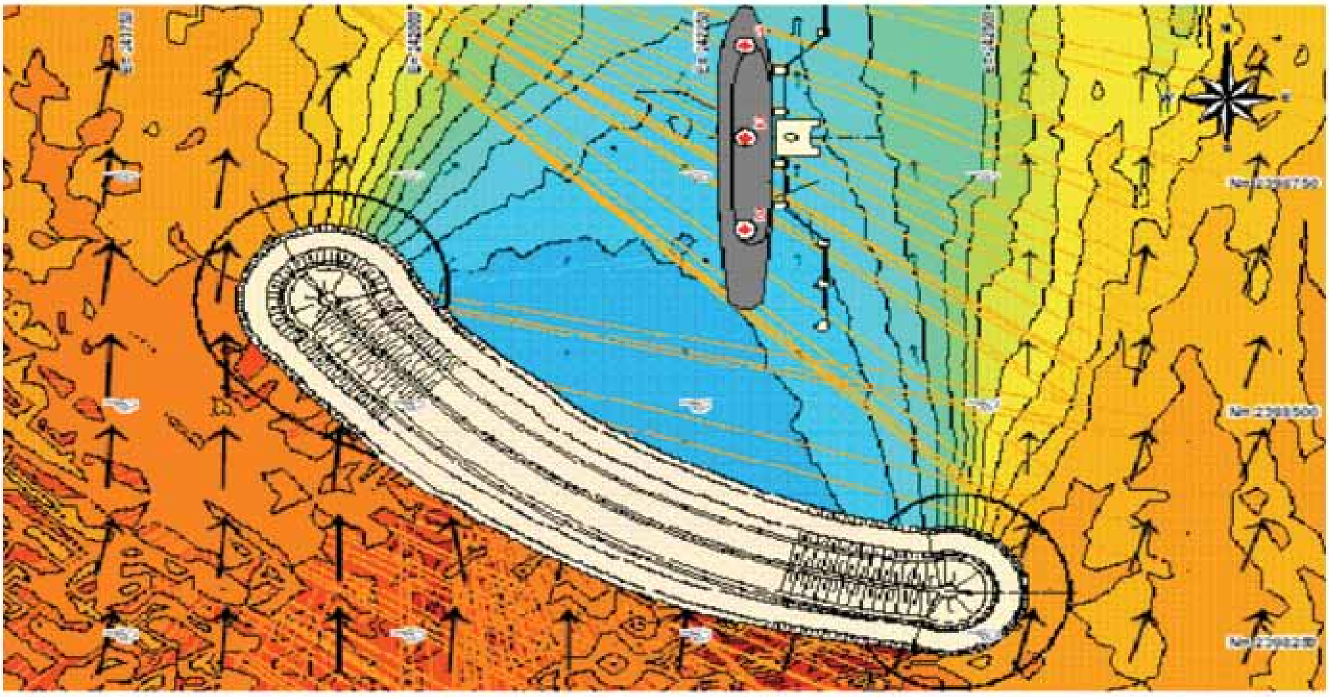

Figure 5. Port Concept at the award of the EPC Contract.

to include these in the list of parameters to be studied for finalization of the design. These are especially crucial for correctly ascertaining the morphological impact of any obstruction in sea (as the breakwater).

Studies for selection of Port Concept

The preferred solution from techno-commercial considerations is to have the LNG berth very close to the shore (minimizing the capital and operating cost). This option (i.e. berth close to the shore, after carrying out the dredging to get requisite draft) was not considered as around four meters of sedimentation in the berth was expected every year, calling for extensive maintenance dredging. Therefore, the jetty head location of 2.5 km from the shore line was selected so as to have required draft (without dredging) for LNG tankers at all times, considering the maximum tidal variation.

Thereafter, various mathematical model simulations on the following alternative concepts of LNG port (Figure 4) were carried out.

i) Open jetty (unsheltered, without breakwater)

ii) Partially sheltered jetty (one isolated breakwater)

iii) Fully sheltered port (deep water with two breakwaters)

iv) Fully Sheltered Port (Shallow water with two breakwaters)

The jetty facilities were conceived to cater to a range of LNG ships (80,000 M^3 – 1,60,000 M^3). The layout of jetty was to be defined keeping in view the guidelines of Society of International Gas Tankers and Terminal Operators (SIGTTO) and Oil Companies International Marine Forum (OCIMF).

Safe operation of LNG ship (berthing, unloading and stay at berth) can be made only in conducive met-oceanic conditions, i.e. wave, wind and current parameters should be below threshold conditions required for LNG ship operations. The berth availability for LNG tanker operations therefore depends on availability of favorable met-oceanic conditions. If the unsheltered sea conditions do not provide adequate berth availability, construction of breakwater is the usual method to increase the berth availability. However, it may be noted that breakwater is of no help against the high speed wind. The breakwater reduces only the waves and currents to enhance tranquility of sea.

The occurrence of favourable met-oceanic conditions (within the threshold limits for safe operations) is probabilistic. The downtime of the berth accordingly depends on the probability of exceedance of met-oceanic conditions from the thresholds required for safe operations of LNG ship.

At the time of conceptual design, accurate site-specific met-oceanic data could not be obtained. Petronet therefore procured satellite measurements of wave data at the mouth of Gulf of Cambay. Sogreah carried out mathematical modeling and predicted the wave climate at Dahej LNG Jetty. Similar analysis was carried out to predict the wind climate at Dahej LNG Jetty. Detailed mathematical model studies were conducted to predict the current patterns.

Based on these predictions, the estimated downtime *without breakwater* was 31 days, which was mostly attributable to LNG ship navigation (maneuvering ship to berth). No downtime was envisaged for LNG ship to remain at berth as the probability of exceeding thresholds for leaving the berth was found to be negligible.

The downtime of the LNG berth *with breakwater* (C shaped, 660 meter long island breakwater) was estimated at 14 days.

Based on these studies, Petronet decided to include the breakwater as part of the scope of work for the EPC contract for Dahej LNG terminal.

Mathematical model studies such as mooring analysis, navigation simulations etc. were then carried out to validate the conceptual design.

Part 2 of this article, which describes the studies conducted at the site, and its subsequent construction, will be featured in Port Technology International 46, which is out in May.

ABOUT THE AUTHOR

Man Mohan Ahuja has been Senior Vice President (Technical) of Petronet LNG Limited since 1998. He is responsible for setting-up and operating LNG storage and re-gasification terminals in India, including selection of lump-sum EPC contractors, project management consultants, arrangement of shipping and monitoring of construction of terminals and LNG ships. He holds a degree in Chemical Engineering from Punjab University, Chandigarh, and is a life member of the Indian Institute of Chemical Engineers.