

LNG Berths for open seas: Part 2

Dahej LNG terminal, a case study

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Part 1 of this article was featured in Port Technology International 45.

Initial engineering and construction of Dahej LNG terminal

After the contract was first awarded in December 2000, physical model studies were carried out by M/s HR Wallingford, UK, and the physical model tests were carried out in August and September 2001.

The tranquil conditions sheltered by the breakwater were verified in the physical model and were found to be acceptable. With minor modifications, the stability of the breakwater was also established in the physical model. Construction commenced, and around ten per cent of the total volume of stone required for the breakwater was dumped at the breakwater site.

The construction of the jetty commenced, with a 2.4 km long approach trestle and unloading platform fitted with unloading arms. Marine facilities include four breasting and five mooring dolphins, for berthing tankers, and other equipment required for safe and reliable berthing.

The jetty is built on 536 steel piles with an average depth 50m. The total weight of steel used was about 14,500 tons, and approximately 30,000 tons of concrete. Four passing bays were also provided on the approach trestle, which allow for the passing of vehicles coming from opposite sides.

Six-meter deep fenders for the berths were designed – large enough to cope with the high tidal variation (10m), and ensure flat body contact for various positions of the ship, whether it is fully loaded at low water or ballasted at high water.

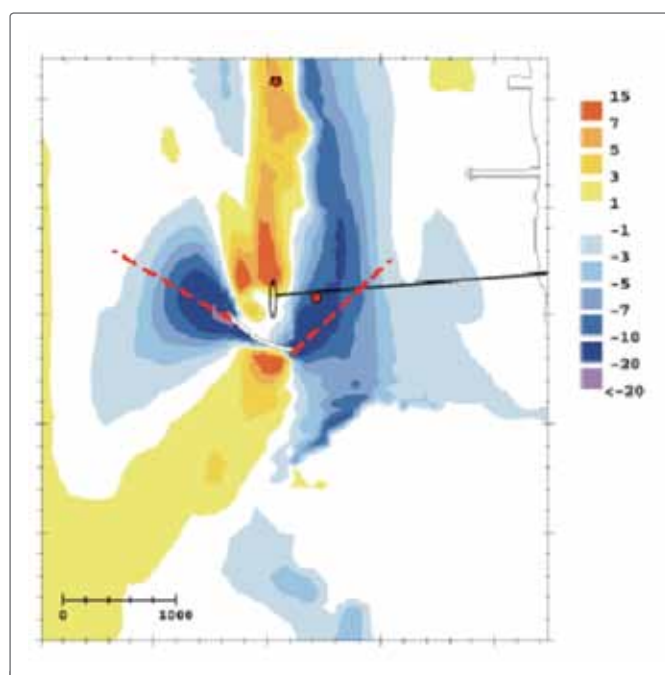


Figure 6. Morphological impact of breakwater.

An elevator-type gangway was also designed to cater to similar positions of ship deck. A large envelope for unloading arms (16" x 75' in size) was provided; and mooring dolphins were offset 45m from the berthing line, to minimize need for frequent tending of lines by the ship. In hindsight, this large offset brought the additional benefit of reducing loads on the mooring lines, coupled with the use of longer tail lines, discussed later in this paper.

Measuring current and waves at the site was extremely difficult, due to the frequent loss of the conventional instruments initially deployed. Specialized equipment and techniques had to be evolved to collect the current and wave data for the site.

High tidal currents and high tidal variations posed several challenges in terms of construction. Specialized construction equipment such as jack-up barges were deployed, along with floating barges with strong anchoring and launching girders for the construction of the trestle. Piling had to be started during slack tides, and piles were temporarily braced during construction to ensure stability, and maximum use of prefabrication techniques. The structures were designed to cater for vortex-induced vibrations, and the multiplying effect of wave forces from high currents.

Ballast water for ships at Dahej Port is not readily available, due to the high turbidity of seawater in the port. Currently, ballast water can only be taken in the wing tanks at Dahej. The ship comes in at the port with some ballast in its bottom tanks. After the vessel reaches the open seas, it pumps out the muddy ballast water and fills them up again with clean water. The vessel is provided with spray system to clean the topside tanks.

Studies based on site-specific data

As construction progressed, site-specific met-oceanic data was also collected. The initial results revealed that the actual data was divergent from the data considered at the FEED stage, which was based on wave transformation modeling and visual observations of ships at the mouth of the Gulf of Cambay.

By 2003, studies modeling tidal and wave disturbance at berths; hydrodynamic studies of breakwaters, navigation simulations and preliminary downtime studies with updated data were available. These indicated that there would not be a significant difference in the downtime of the LNG berth with a breakwater or without a breakwater. On the contrary, higher downtime was estimated during the construction stage of the breakwater, caused by the formation of eddy currents at the LNG berth while constructing the breakwater. The modeling study also showed that:

- The LNG tanker can be safe at the berth with or without a breakwater, as the predicted mooring loads were within acceptable limits.
- The morphological impact of the breakwater was more severe than considered during the FEED stage.
- The scour below the piles of the LNG jetty structures was anticipated to be much higher than allowed in the design of piles.
- The sedimentation in the berthing area was estimated to be high enough to call for frequent maintenance dredging at the jetty.

TABLE 1: INITIAL ESTIMATED DOWNTIME OF BERTHS

Parameter	Case 1: 16 lines	Case 2: 18 lines	Case 3: 20 lines
Potential downtime (Hours/monsoon)			
Navigation			
Arrival	72	72	72
Departure	27	27	27
Ship at berth			
Connection	12	6	6
Unloading (x wind)	36	36	36
Unloading (x waves)	81	57	56
Loads on lines	360	72	0
Total	590	264	197
Potential downtime (% within the monsoon period of 3.5 months)			
Total	23%	10%	8%
Real downtime (per monsoon) in two assumptions of berth occupancy			
2 days per week (30% berth occupancy)	177 hours (~ 7.5 days)	78 hours (~ 3.2 days)	62 hours (~ 2.5 days)
4 days per week (60% berth occupancy)	354 hours (~ 15 days)	156 hours (~ 6.5 days)	124 hours (~ 5 days)

The construction of the breakwater remained suspended in light of these studies.

Further site-specific met-oceanic data for the 2003 monsoon was collected, which included time period of the waves and wave direction. Such sophisticated data was necessary to refine the earlier studies and design an optimum berth. Upward correction factors have been applied to the monsoon data, considering long-term trends to obtain 'design monsoon' statistics. Time series data evaluation was done to estimate realistic downtime.

The studies established that the wind and the waves are considerably low, during morning hours (02:00 to 14:00 Hrs) in the monsoon period. The navigation of the ship was therefore considered during slack tides in morning hours. This resulted in a considerably lower estimate of downtime during navigation.

The downtime of a ship at the berth was estimated for various configurations of mooring lines. The increase in the number of mooring lines resulted in a considerable reduction in downtime for the ship at berth.

The studies also revealed that:

- Additional shore-based mooring lines would be essential during the construction of the breakwater, to reduce mooring loads within acceptable limits.
- Although mooring loads are within limits for "No breakwater" and "With breakwater" cases, additional mooring lines from the shore would be advisable as a safety measure.

The downtime estimated under various conditions is as per Table 1.

It can be noted from the above table that the concept of real downtime based on berth occupancy factors was introduced. Thirty per cent occupancy of a berth signifies the unloading capacity of 6.5 MMTPA against the requirement of 5 MMTPA, in the first phase. Sixty per cent occupancy of a berth signifies the unloading capacity of 13 MMTPA against the requirement of 10 MMTPA, in the second phase.

Further studies carried out based on site-specific data

The aforementioned studies were commissioned by the EPC Contractor and performed by Sogreah, France. In light of the critical findings of these studies, PLL subsequently arranged for an independent agency, M/s HR Wallingford, UK, to independently assess downtime of the LNG berth "with breakwater" and "without breakwater". The updated met-oceanic data was used for these studies. The results of these studies are summarized below:

No breakwater:

Advantages

- Lesser morphological impact on the jetty and other terminals in the vicinity
- No further breakwater construction challenges
- No interruption to navigation during construction period
- No navigation obstruction
- Potential improvement to navigation safety due to ability to berth either side.
- Lower capital investment

Disadvantages

- Marginally higher downtime than with the breakwater

Original 660m breakwater:

Advantages

- Lower waves and currents at the berth
- Lower downtime than without a breakwater

Disadvantages

- High morphological impact on the jetty and other terminals in the vicinity
- Additional navigational constraints
- Additional construction challenges
- Likely higher downtime during construction
- Navigation obstruction
- Higher capital investment.

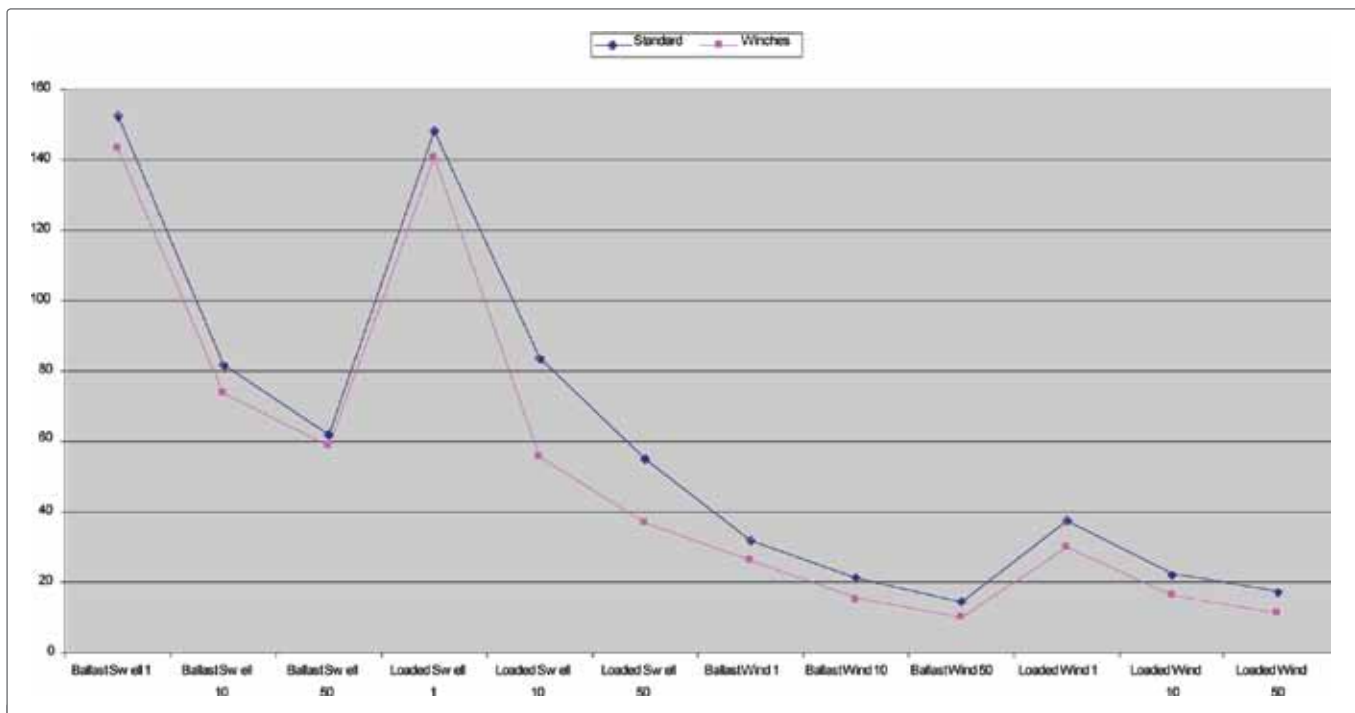


Figure 7. Impact of winches on mooring loads.

The only advantage of constructing the breakwater was the marginal improvement in downtime of the berth, which was estimated as per Table 2 (right).

The studies also concluded that it might be possible to achieve a reduction in downtime without the breakwater to required levels, by providing:

- Additional mooring facilities (i.e. constant tension shore-based winches) as long as these are correctly designed, organized and managed.
- Flexibility of ships to approach and depart the berth in either direction (by not constructing the breakwater).

This study also brought out that using 22m tails instead of 11m tails further reduces loads on mooring ropes.

Revised port configuration

Based on these studies, Petronet decided to provide the following facilities (as demonstrated in Figure 9).

TABLE 2: NEW ESTIMATES OF DOWNTIME OF THE BERTH, ACCORDING TO STUDIES BY M/S HR WALLINGFORD

Downtime estimate	Hours per year	Number of 6 hour occasions
With breakwater	30 (1.25 days)	< 5
Without breakwater	60 (2.5 days)	< 10

- Four shore-based winches and mooring lines, to overcome any eventual excessive downtime situation in bad met-oceanic conditions.
- Dropping the breakwater from the port concept.
- An additional LNG storage tank, to increase the flexibility of the LNG Terminal.

The construction of an additional storage tank was recommended, considering that the downtime studies had been

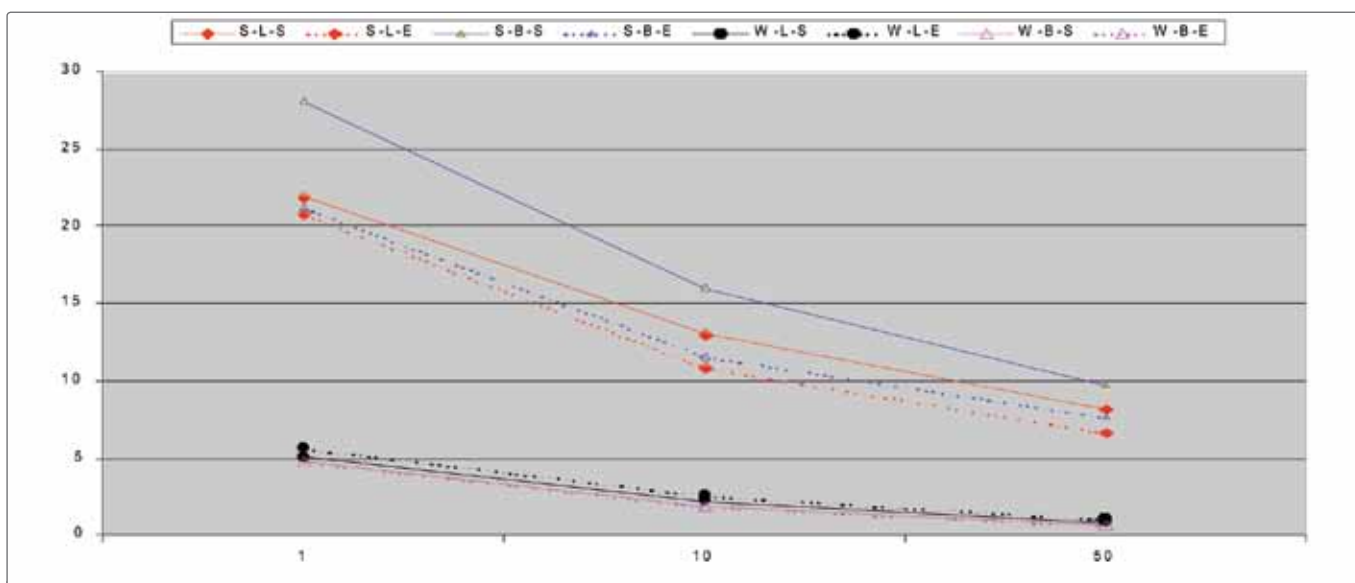


Figure 8. Reduction in mooring loads by using 22 m tails on mooring ropes instead of 11 m.

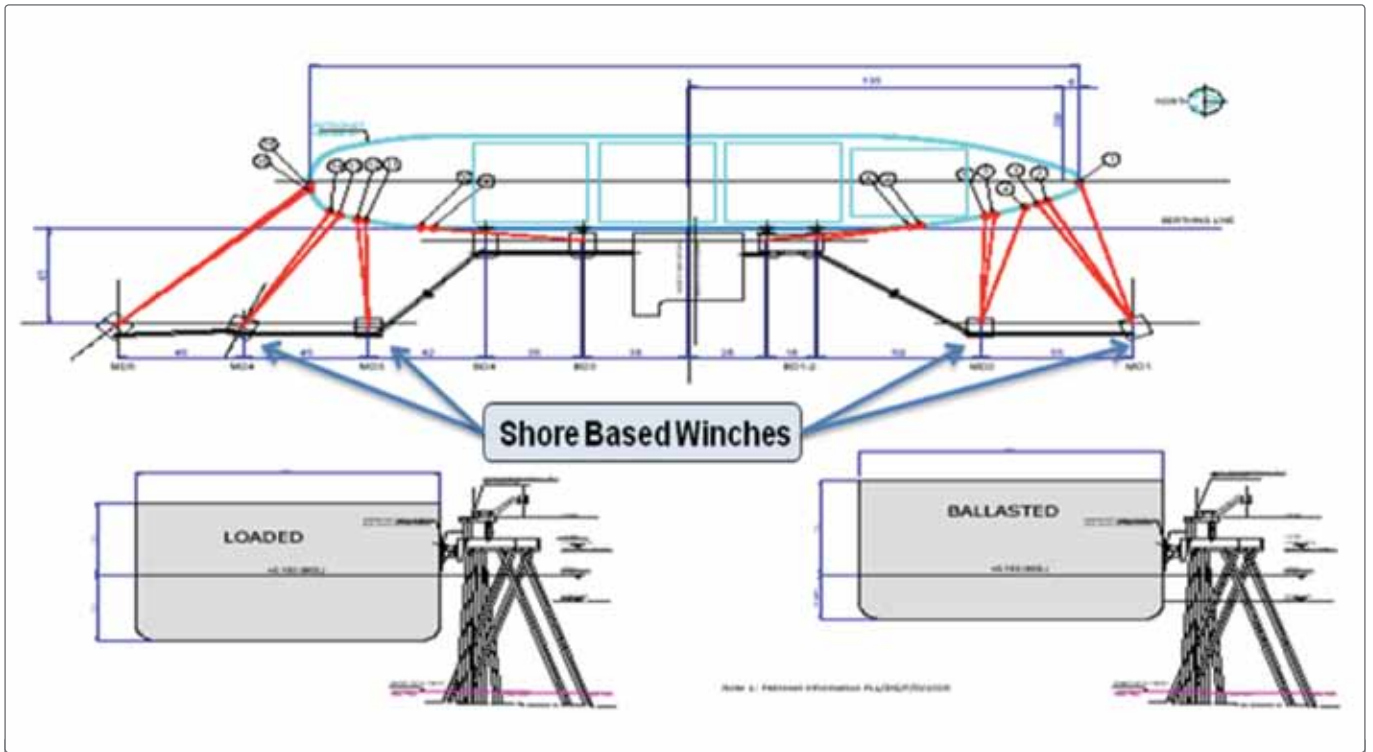


Figure 9. Diagram showing the revised port configuration.

based on average met-oceanic conditions and it would provide a safety factor, in case of exceptional probability conjunction for consecutive bad weather conditions leading to three consecutive days of downtime. The LNG tankers were already calling at the berth by this time.

The constant tension shore-based winches were designed with great care, being a retrofit on existing mooring dolphins. Four such winches of 60-ton capacity were installed (as shown in Figure 10); one winch was provided on each dolphin. The winch was fitted to ensure maximum effectiveness of the mooring line from the winch to the ship. Two of these winches were enhanced by two roller sizes, after it became evident that a larger roller diameter to winch rope diameter ratio would enhance the life of these ropes. The ropes were subject to frequent cyclical loads, as the winches paid in and paid out with the waves to maintain constant tension. Specialized studies were carried out in this regard.

The mound of stones at the breakwater location was flattened

to a depth of 14.5m from chart datum, to ensure there is no possibility of impediment to navigation. This also opened additional approach and departure maneuvers, as earlier the presence of the breakwater prevented certain options.

Additional towage studies were conducted at a simulator in HR Wallingford, UK. The studies considered site-specific conditions and the effect of reduced efficiency of tugs caused by swell waves, as illustrated in Figure 11. Runs for berthing at high water with the approaching ebb tide, as well as low water with the approaching flood tide, were conducted and optimal approach and departures for various wind/wave directions arrived at.

The studies brought out that the towage configuration chosen by PLL (i.e. four anchor handling tugs of 55-bollard-ton capacity) was adequate for the threshold wave and wind limits set for navigation at the berth. Emergency departure was safe even considering the failure of one of the four tugs during simulation runs. The results of these studies were incorporated into operating procedures, including possible emergency departure scenarios.

Navigational simulations in the absence of a breakwater also showed that it is possible to berth the LNG tanker starboard side in non-monsoon period. Indeed, this is now the preferred



Figure 10. Constant tension mooring winch.

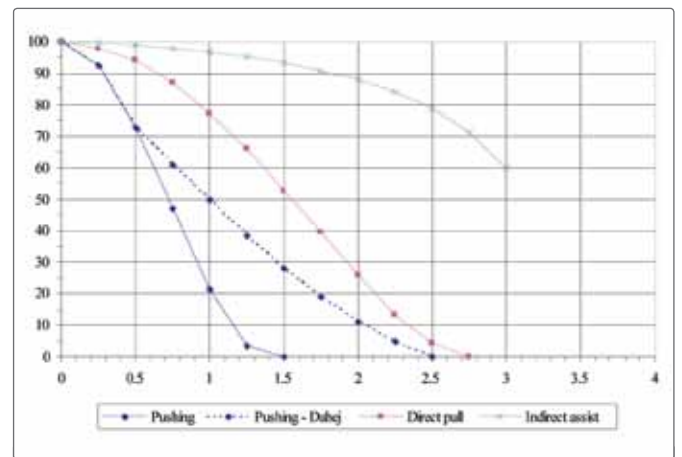


Figure 11. Tug Efficiency Reduction caused by swells.

option in non-monsoon period. In the monsoon period, portside berthing continues to be followed, with the LNG tanker facing the waves and southwesterly wind. It may be pertinent to mention here that the navigational simulations carried out during the FEED stage were based on the starboard side alongside in all cases, as the breakwater on the southwest of the berth largely precluded portside berthing because of difficulties in emergency departure scenarios.

Berthing Aid System

The major cost risk to the LNG terminal owner is the high demurrage or time charter charge incurred if there is a delay in loading or unloading. PLL has chosen to install most state of the art facilities to assist in ship berthing. These include:

- Electrical motor winches
- Mooring hook–stress measurement
- Ship docking assistance unit, including
 - Sensors (sea current, wave and tide measurement; wind measurement)
 - Display units
 - Portable display units
- Port Control Room fitted with:
 - X-Band radar (with automatic radar–plotting aid)
 - VHF sets (one of them with digital selector calling)
 - MF and HF sets
 - Inmarsat Mini C monitor
 - Oceanographic data monitor
 - Loading arm position monitor
 - ESD panels

These facilities provide real-time information to the shipmaster and port captain about the approach speed, direction, wind, current and tide information (and so on) of the ship, in the final critical stages of maneuvering the ship to jetty. This information reduces the berthing time significantly.

Additional steps to enhance berth availability at Dahej

Petronet continued to work along with the LNG ship-owners, its port operator and other LNG chain partners to identify and implement measures that would further enhance the availability of the LNG berth, and ensure safe and reliable operations. One of these measures was to conduct additional studies to improve moorings, which was done by Tension Technologies Incorporated UK. These studies showed that increasing the flexibility in the system further reduces loads on the mooring lines. In light of this, tail ropes were changed to polyester/propylene compound. The length of tail ropes were shortened to 22m from 11m for all lines, except spring lines in the monsoon season; and an additional quality check was implemented on mooring lines and the use of new lines before monsoon.

Additionally, the following operational measures are in place for safe berthing:

- Cargo deliveries are planned in an annual program, to avoid berthing on days when the tidal difference is very high, during monsoon period.
- The weather is continuously monitored, to avoid berthing operations on days when the weather forecast exceeds the limits considered for safe berthing. Petronet arranged weather forecasts from two reputable independent sources to improve its preparation for adverse conditions.

- Petronet has adopted conservative threshold limits for safe shipping operations, in consultation with the ship-owner.
- The port operations staff is regularly trained at simulators installed in India, and possible approach and departure runs for ebbing and flooding tides are conducted to determine the optimal maneuvers. Emergency departure scenarios are also covered, as well as failure of tug ropes or the engine.

Conclusion

Any LNG terminal operator would always like to have a sheltered, calm water berth to receive and berth LNG carriers, but this is not always possible for various reasons. The location of Dahej in Gujarat was optimal in commercial terms, due to its proximity to a fully developed gas market and existing pipeline network. However, the location had challenges for the design of port facilities because of its unique site conditions, which included hostile met-oceanic data.

Based on initial studies and data at Dahej, Petronet also considered conventional concept of a sheltered port with a breakwater. However, assimilation of correct data and studies by the experts, incorporating site-specific met-oceanic conditions, opened up the opportunities for different concepts and the elimination of the breakwater.

Petronet's experience at Dahej demonstrates that it is possible to berth LNG ships even at exposed berths in open seas. However, it calls for close monitoring of met-oceanic parameters, provisions in the design to provide flexibility in mooring, and closer monitoring of the mooring lines (for loads during operation, health conditions etc.).

More importantly, it is the shippers who need to be convinced. PLL faced a little resistance from shippers to adapt to the new concepts, but were eventually able to persuade them about the changed scenario. It is therefore felt that the more open-minded the shipping industry is, the easier it becomes for terminal operators to meet the new challenges that lie ahead.

All things considered, PLL has been successful in setting up the Dahej port facilities with latest technological innovations. All the technical challenges posed by site-specific conditions such as high tidal currents, large inter-tidal variations, length of trestle, deep-water jetty and the characteristics of seawater were eventually overcome.

What is more, Petronet LNG Limited, with all the support from the sponsoring companies and Government of India, successfully completed the project within cost and schedule. And, with the help of its partners in operation, has provided India with a clean and environmentally friendly source of primary energy. LNG is now playing an important role in the energy basket of the country.

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.