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Ancient technology of jetties and anchoring points along the west coast of India

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The Indian coast, with a long history of maritime activities, has been dotted with several ancient ports. The evidence for this exists in port-related structures on the shore and in relics lying in the sea adjacent. Marine archaeological explorations have revealed the existence of jetties at Dwarka, Rupen Bandar and Porbandar, and offshore anchoring points at Bet Dwarka, Miyani, Visawada and Somnath on the Gujarat coast. The preferred anchoring points fall in a water depth of 5–7 m. This communication also discusses the effect of tide when using jetties and loading points along various parts of the west coast India.

Keywords: Anchoring points, ancient jetties, ports shipping, stone anchors.

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MESOPOTAMIAN texts vividly described the existence of docks in the 3rd millennium BC. For example, king Sargon the Great boasted that boats of Dilmun, Magan and Meluhha anchored at the docks of Agade, which was his capital[1]. An ancient Sanskrit text, the *Arthasastra*[2] of Kautilya, finds the description of a Superintendent of Shipping (Navadhyaksha), who was in charge of the ocean-going ships and strictly enforced the rules framed for the management of ports. He was empowered to kill pirates and punish those who did not follow the rules. The owner of the ship had to pay taxes before leaving the port. Further, the anonymous author[3] of *The Periplus of the Erythrean Sea* dating back to the 1st CE, has mentioned a chain of ports along the Indian coast. Ancient texts, including Indian (such as Tamil Sangam literature, Persian literature) and foreign sources (Ptolemy's *Geography* and Arian's *Indica*) have also made ample references to the existence of harbours and ports along the Indian coast during the historical and the medieval periods. Further, 'Pattana' is a Sanskrit term for the word port, that has been used in various ancient texts, appearing as two types, namely 'Samudrapattana', i.e. port on the coast of a sea and 'Jalapattana', i.e. port on the bank of a navigable river[4].

de Kerchove[5] defines a port as 'a place for the loading and unloading of vessels recognized and supervised for maritime purposes by the public authorities'. Further, he expands on the differences between a port and harbour thus:

> 'A port may possess a harbour, but a harbor is not necessarily a port. Any natural creek or inlet on the seashore with adequate depth of water and sufficient shelter for ships fulfills the essential conditions of a harbor. To make it a port, in the accepted sense of the word, there must be in addition accommodation and facilities for landing passengers and goods and some amount of overseas trade.'

One of the facilities for landing or loading passengers and goods is the jetty and it is described by de Kerchove as 'an engineering structure projecting into the water, of the nature of a pier, dike, embankment, constructed of timber, earth, stone or a combination thereof'[5]. Here we use the term jetty in a generic sense and where the construction is known, it will appear described as timber jetty, stone jetty and so on.

In an archaeological context, structures associated with ports and jetties have been discovered along the Mediterranean coast, including Carthage and Thapsus on the Tunisian coast[6], Caesarea on the Israeli coast[7], etc. The excavation at Ur on the bank of the river Euphrates had revealed a massive brick structure, identified as a harbour[8], the oldest remnant of any port structure in the world. Similarly, archaeological studies of the oldest known civilization of the Indian subcontinent, namely the Indus Civilization,

indicate the existence of port structures at Lothal[9] and Kuntasi[10]. Further, underwater explorations along the Indian coast during the last two decades have yielded a large amount of data on the existence of ancient ports, jetties and anchoring points. In the last case we refer to places where vessels are known to have moored, i.e. to sit at anchor offshore. An important artifact for identification of a port and anchoring point is the anchor itself, and usually these are lost having parted from the parent boat through a break in the cable or other accidents such as being abandoned due to the sudden onset of storms or being caught on the seabed. These lost anchors are amply found all along the Indian coast.

We deal with some elements of the underwater archaeology of ports, jetty and anchoring points along the Indian coast, with special mention of the Gujarat coast as an example of the nature of this resource (Figure 1). The important antiquities mentioned include underwater and onshore timber and stone structures, and stone anchors recovered during the marine archaeological explorations. A comparative study has also been made with modern traditional jetties found all along the Indian coast.

Offshore explorations have been carried out with the standard Self Contained Underwater Breathing Apparatus (SCUBA) diving system, which allows the diver to move freely to search for relatively shallow-water archaeological remains that lie undisturbed on the seabed. The artifacts found in this process were documented with the help of drawing and photography. Onshore explorations were undertaken at several places and important findings were documented. Traditional jetties used for modern fishing trawlers and small boats were visited and documented for comparison.

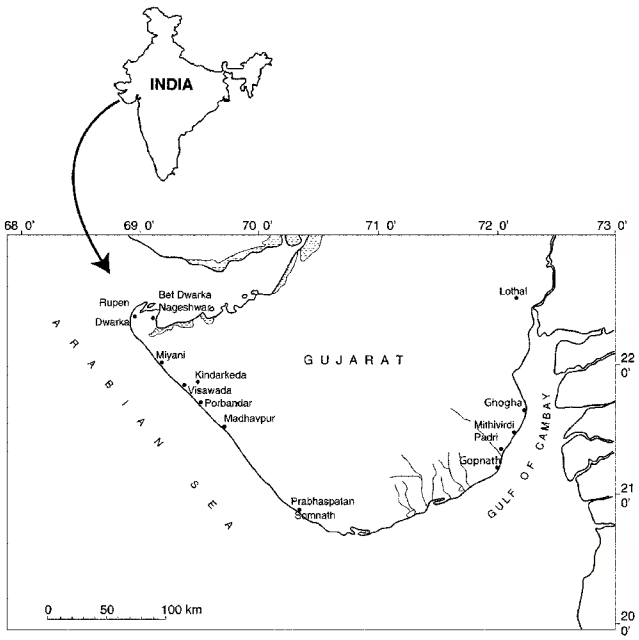

Figure 1. Location of ancient jetties and anchoring points along the Saurashtra coast.

The offshore explorations in Dwarka revealed a large number of stone structures from inter-tidal zone to 5 m water depth[11], to a distance of 500 m from the Samudranarayan temple. The structures are semicircular, rectangular and square in shape and made up of well-dressed limestone blocks (Figure 2). A few complete structures which are circular in shape with 2 m diameter were recorded (Figure 3) in the inter-tidal zone of Dwarka. A detailed study of these structures indicated that they were part of an ancient jetty[12]. This hypothesis is also supported by the presence of stone anchors in the vicinity of the structures.

Rupen Bandar, a fishing harbour 2 km north of Dwarka, also has the remains of a jetty that is 100 m when measured from the high water line. Here, evidence suggests that wooden logs were secured in a stone pillar. With time, parts of the stone structure were damaged and salvaged for use elsewhere (robbed-off). Though this appears to be a common phenomenon, presently three rows of wooden logs (jetty piles supporting the deck beams and the deck itself) remain strongly secured deep in the sediment (Figure 4). The oral history indicates that this jetty is at least a century old.

Figure 2. Collapsed structure of an ancient jetty off Dwarka.

Figure 3. Base of a Pillar of an ancient jetty, exposed during low tide off Dwarka.

A few jetties considered to be at least a couple of centuries old were reported to the investigators on the bank of Porbandar creek[13]. They were found to be made of well-dressed limestone blocks. Though at high tide boats can reach up to a kilometre upstream in the creek, as was the case at one of the jetties noticed in this area, with the emergence of a new harbour at the junction of the creek and the sea, these structures ceased being used and fell in disrepair.

The study of the existing traditional jetties along the west coast of India suggests that the Gujarat coast does not have jetties built of wood, while going down to the Maharashtra and Karnataka coasts, wooden jetties are found, many still operational, particularly in backwater areas by local fishing trawlers and canoes. Indeed, the presence and absence of a jetty at a recognized port could well be connected with tidal variations as Gujarat coast by and large experiences a higher tidal range and the gulf areas further more. The tidal curves of Okha and Porbandar, for example, suggest a comparatively higher tidal range of 0–4 m and 0–3 m, respectively, whereas the southwestern coast of India has lower tidal range of 0–2 m at Karwar and 0–1 m at Cochin[14] (Figure 5). Where the higher tidal range results in the exposure of a larger beach area, it is apparent that jetties are not necessary. After anchoring offshore to await the incoming tide, fishermen take their boat as far inshore as possible, right up to the high water line during the high tide. During low tide, as the water recedes their boats rest on the sandy beaches and they carry out loading and unloading and also small repairs of the boats, if necessary, without the need of any kind of structure. This appears to be an old tradition in Gujarat, because a large number of stone anchors from inshore (Figure 6 *a* and *b*) as well as inter tidal zones of Dwarka and Bet Dwarka, and one each at Armada, Tukda and Gopnath have been recorded. However, moving down the coast the tidal variations reduces significantly and falls in the range of 1–2 m. This does not allow the large exposure of land during low water. Where there is minimal tidal range, boats need to be continuously afloat, necessitating landing as well as loading and unloading points. In these cases timber jetties provide as affordable solution. Tidal currents also need to be considered in these circumstances, for if it is weak, the boat may not be able to propel back to the sea, especially if it lies on the shore and the breezes are contrary.

Figure 4. Remains of an ancient jetty at Rupen Bandar exposed during low tide.

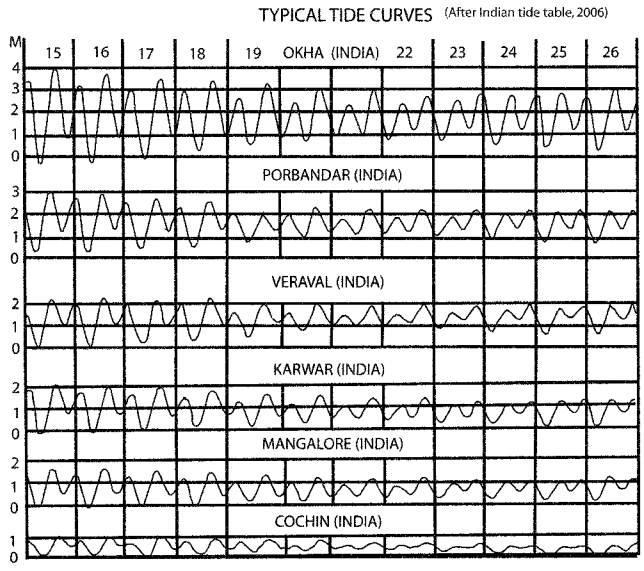

Figure 5. Typical tide curves at various places along the west coast of India.

A jetty is fashioned by employing a trestle arrangement similar to that of a light-weight bridge on a small river using strong forest wood. Normally piles are sunk vertically into the seabed or into a rock support. Selection of wood log depends on its straightness. The distance between a pair is normally 0.5 m, which allows at least two planks of 0.25 m width to rest between. The distance between two rows varies from 0.75 m to 1.5 m. On the two rows, wooden planks are found resting, that are used for loading and unloading of the vessels (Figure 7). This type of jetty has been noticed right from Ratnagiri in the north to Kerala in the south.

To approach a port in the creek, often ships or boats used to anchor at the open sea, where the creek merges with the sea at suitable water depth. Generally, the anchoring points have a rocky seabed as the anchor needs to hold the boat firmly. Underwater investigations on the Saurashtra coast have clearly demonstrated the presence of ancient anchoring points at a water depth of 5–7 m (Figure 8). These observations correspond well with those of traditional anchorage points all along the Indian coast[15]. Underwater observations revealed that the seabed topography between Bet Dwarka on the extreme west and Somnath on the east, is almost less variant, particularly at Dwarka, Miyani, Visawada, Porbandar, Tukda and Somnath. The seabed topography is comprised of rocky formations with numerous channels filled with fine sand. Stone anchors

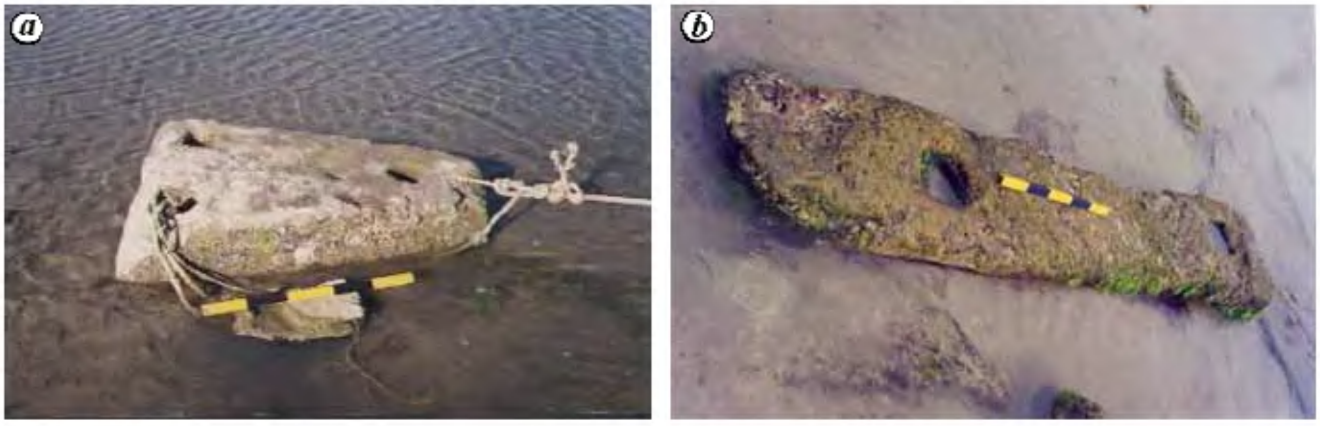

Figure 6. Stone anchor lying in inter-tidal zone of Aramda (*a*) and Dwarka (*b*) in Okhamadal area.

Figure 7. A fishing boat anchored along the wooden jetty at Mangalore port.

Figure 9. A ring stone type anchor lying at 9 m water depth off Somnath.

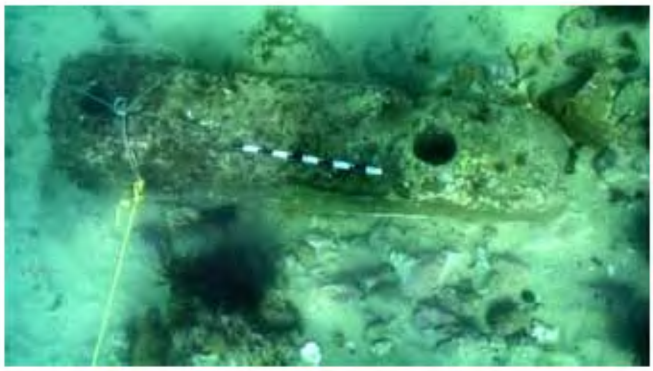

Figure 8. Stone anchor lying at 5 m water depth.

were trapped in these channels and between the rocks, which were suitable for holding big boats like the Arab 'Dhows' and the Indian 'Vahan'. Observations at Bet Dwarka and Porbandar revealed that boats carrying more than 100 tonnes of cargo anchored at a water depth of 4–5 m; sometime they also rested on the sandy beaches during low tide. However, at Somnath most of the anchors were reported from 8 to 12 m water depth. This indicates the anchoring point at Somnath was comparatively at greater depth. This phenomenon could well be connected with low tidal variations at Somnath, where boats need to continuously float. However, majority of these anchors belong to ring stone-type (Figure 9).

The port plays a dominant role in facilitating sea trade. There have been several ports all along the Indian coast since antiquity. A prerequisite for the selection of any port site includes a sheltered place, particularly protection from high wind and rough seas, sufficient water depth for sailing of the vessel and a suitable anchoring point. Besides the structural part of the port, it is also important to keep in mind that the several products from the hinterland reach the port and vice versa. Majority of the ancient ports were situated on the river banks and the backwaters. A few Harappan sites, including Kuntasi[4], Amra, Lakhawavel and Vasai[16] on the northern Saurashtra coast are located on the banks of tidal rivers, where tidal variation is as high as 5 m, this helped mariners to reach the site during the high tide.

Archaeological findings have indicated the existence of several ports, jetties and anchoring points along the west coast of India from the protohistoric period[17]. The discovery of a large number of stone structures and anchors at Dwarka suggests that it was a busy port during the historical and the medieval times[11]. Large limestone blocks have been profusely used for its construction. A later period jetty at Rupen Bandar was made of stone blocks as well as of wooden logs. As some comparison, a similar type of jetty remains has also been reported from Australia dating back to the late 19th century CE. There are also comparative instances, especially in northwest Australia, where the tidal range is often in excess of 10 m. In the 19th century, at places where there are no jetties, even large sailing ships were run aground at high tide in NW Australia. As the tide receded leaving bare sand beneath the ship, passengers and cargo were moved to and fro using large carts drawn by bullocks[18]. This is a direct reflection of the practices referred to above. Though there are no remains of an ancient jetty at Bet Dwarka, the presence of stone anchors in the inter-tidal zone indicates that the high tide was effectively used for anchoring the boats. Conversely, the northwest coast of India has jetties in creeks which are made of limestone blocks, while in the southern side traditional wooden jetties continued to be in use.

Tidal variation and seabed topography played a significant role in the construction of jetties. As stated earlier, the higher tidal variation in Gujarat has been used by navigators to anchor boats in the inter-tidal zone; thus loading and unloading become easier. This has also been confirmed with the discovery of stone anchors from the inter-tidal zone areas of Dwarka, Bet Dwarka and Armada. Stone anchors are the indicators of ancient anchoring points and underwater findings have indicated that the preferred anchoring points on the Saurashtra coast fall between 5 and 7 m water depth.

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Seismic evidences of faulting beneath the Panvel flexure

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Microseismic studies in the Konkan plains encompassing the Panvel flexure, adjoining Mumbai, reveal low seismicity associated with the 150 km long flexure. About 158 earthquakes (*Mc* 1.0–3.6), including 41 events of magnitude (*Mc* ≥ 2.5) occurred along the flexure and its flanks during the period 1998–2005. Historical seismicity indicates the occurrence of about 24 moderate earthquakes of intensity ≥IV in this region. Hypocentres estimated for 20 events reveal that the earthquakes occur at three depth levels – near surface (<2 km), shallow (2–15 km) and deep (>15 km). The near-surface earthquakes occur within the Deccan traps possibly due to failure of the faults flanking the flexure, while the shallow and deep crustal earthquakes

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