

## **Ancient Indians (Harappan settlement) were aware of tsunami/storm protection measures: a new interpretation of thick walls at Dholavira, Gujarat, India**

**R. Nigam, R. Dubey\*, R. Saraswat, Sundaresh, A. S. Gaur and V. J. Loveson**

National Institute of Oceanography, Dona Paula, Goa 403 004, India

**Dholavira is a Harappan city in Gujarat, India whose fortification, with maximum wall thickness of up to 18 m is extraordinary. The probable cause of such a massive protective wall is yet to be addressed. Based on (i) the location of Dholavira along tsunami/storm-prone coast; (ii) climatic scenario during the mid-Holocene with special reference to higher sea level and (iii) lack of proto-historic military evidences, we hypothesize that the walls may have acted as defence against tsunami/sea storm. The presence of extremely thick protective walls thus implies that the Dholavirans were probably aware of the magnitude of destruction caused by tsunami waves/storms.**

**Keywords:** City fortification, Dholavira, Harappa, sea storms, tsunami.

KHADIR, is a small island approximately at the centre of the Great Rann of Kuchchh, Gujarat, India. The northern part of Khadir is elevated as a result of upliftment caused by a fault in the area. The western and southern sides of the island slope into the Rann<sup>1</sup>. Archaeological excavations on Khadir Bet led to the discovery of Dholavira<sup>2,3</sup>. Located in the northwestern corner of Khadir Bet (Figure 1), Dholavira is the second largest Harappan settlement known in India. According to Bisht<sup>2</sup>, 'it was, perhaps, the best planned Harappan city with several divisions and many new features hitherto unknown'<sup>1</sup>.

The gradual growth and slow decline of Dholavira is categorized into seven distinct stages<sup>2,3</sup>. Stage I marks beginning of the civilization (3000–2900 BCE) with the construction of a citadel which was zealously guarded<sup>2</sup>. The citadel walls were strengthened and the settlement was extended northwards during stage II (2900–2800 BCE). Stage III (2800–2500 BCE) was eventful. It witnessed a catastrophe and elaborate construction of a fortified middle town, north of the citadel. The lower town was built east of the preceding structures within city wall<sup>2</sup>. Stage IV (2500–2100 BCE) was inactive as far as construction was concerned. The civilization suffered slow downfall during stages V (2100–2000 BCE) and VI (1950–1800 BCE). De-urbanization preceded abandonment in stage VII (1500–1450 BCE)<sup>2</sup>.

The Dholavira fortalice is unique. The architectural framework comprises citadel (castle + bailey), middle town and lower town (Figure 2 a) confined within massive defensive walls known as main city fortification<sup>2-4</sup>. Individual sections inside the city are also fortified. Such extensive circumvallation makes Dholavira a unique articulately fortified settlement<sup>2</sup>. Initially it was suggested that the castle wall is more than 15.5 m thick<sup>3</sup>. A later report<sup>2</sup> provided the inner and outer lengths of the castle wall (Figure 3); accordingly it is 13–18 m thick, which seems to be more accurate. The thickness of the outer wall that encloses the entire city is not mentioned. From the published site plan of Dholavira<sup>2</sup>, the city wall thickness is estimated to be 7 m (without salient) and 14 m (with salient) (Figure 2 a).

The fortalice style of Harappan architecture is evident at a few other sites, such as Kalibangan, Banawali, Rakhi-garhi, Harappa and Lothal<sup>5-9</sup>. Archaeological evidences suggest that the 12–13 m thick wall at Harappa and Lothal served as a flood-protection measure, as the settlements occupied flood-plains of rivers Indus and Sabarmati respectively<sup>10</sup>. On the contrary, Dholavira is located on the banks of small ephemeral channels, namely Mansar in the north and Manhar in the south. Even though there are several other much deeper channels in the area, with comparatively large water-carrying capacity, choice of the much smaller Mansar and Manhar for settlement, points towards their suitability for water harvesting. These streams bear evidence of damming in the form of huge rock-cut pieces and boulders belonging to different geological formations that are too heavy to be transported by floodwaters<sup>2</sup>. The construction of dams on other bigger channels would have been relatively difficult. The water-harvesting expertise of Dholavirans is also well exhibited in the form of reservoir systems, deep dug wells, storage tanks and storm channels built in and around citadel. The extensive water storage structures were supposed to be built in view of limited seasonal availability of water, and therefore suggest lack of perennial freshwater source around Dholavira<sup>2</sup>. Additionally, Bisht<sup>2</sup> suggested that it was a well thought-out decision to build the city on the banks of such a small channel, as it can be dammed. Therefore, it is highly unlikely that the Mansar and Manhar channels posed any flood-related risk to Dholavira. The elevation of Dholavira settlement is sufficiently high to be under any risk of flood disaster (Figure 2 b).

The fortification is also related to military defence in both the historical and pre-historical studies<sup>11</sup>. The wall thickness at Dholavira exceeds the functional (protection from Harappan weapons, namely sling shots/bow arrow) and investment (in terms of material and labour involved at the times of limited resources) limits of military protection<sup>11</sup>. Even the 3rd century BC Great Wall of China is 4.6–9.1 m thick at the base and tapers to 3.7 m at the top<sup>12</sup>. Moreover, discovery of gunpowder<sup>13</sup> and its

\*For correspondence. (e-mail: rdubey@nio.org)



**Figure 1.** Location map of Dholavira, Gujarat, India (image modified from Google Earth). A–B is the line along which elevation has been measured in the study.

introduction in India<sup>14</sup> was much later than the timing of the Dholavira settlement. The bastion and gateways in the wall at Dholavira need an explanation as well. Bastions could have served the purpose of conveying important public warnings apart from providing strength to the walls. The gateways being flanked-type<sup>2</sup> served the purpose of public movement for trade and commerce, since such gateways are considered vulnerable to military attack<sup>15</sup>. In short, these wall structures which are in general associated with military defence did not serve the same purpose at Dholavira. Instead, they served some social purpose<sup>15,16</sup>.

Dholavira, being close to the sea could have been vulnerable to oceanic calamities. Does unusually thick walls provide any clues for the same? The answer requires an understanding of mid-Holocene sea level and the vulnerability of the area to oceanic calamities. The Holocene sea-level changes are well-documented for the western coast of India. The sea level was higher at ~6000–4000 years BP (ref. 17). The past high sea stand is contemporaneous with the timing of the Dholavira settlement. Other than this, the terrain of Dholavira settlement dips in southwest–northeast direction and elevation ranges from 12 to 28 m with respect to the mean sea level. The citadel area is around 18 m amsl and the terrain dips seaward. In comparison to the middle town and lower town, the citadel area is at a lower elevation (Figure 2 b). From the different architectural stages of devel-

opment, we understand that the citadel came up much before the general city fortification and its wall thickness is more than that of the city wall. The lower elevation of the citadel seems to be another reason for the extra thick walls guarding it. The terrain pattern in terms of elevation set up, suggests that the citadel area being nearer to the coast, could be the first structure where any marine extreme event would strike, if it occurred. The strategic coastal location and elevation of Dholavira settlement on an island suggests its convenience as being a favourable port city in the past, but also its possible vulnerability to any oceanic calamities.

Being on the Makran coast, the area is prone to tsunami-like events<sup>18,19</sup>. The coastal geomorphology of Kutch region indicates that inland portions of the coastline have features which amplify the effect of tsunami waves when they get coupled with high tide, thus becoming fatal<sup>20,21</sup>. Morpho-dynamic and tsunami simulation studies<sup>22</sup> have concluded that tsunami wave height along the Gujarat coast ranges from 2 to 10 m. Evidences of palaeostorms/paleotsunami at 8000–7000 years BP are known from the region<sup>23</sup>. A 3.5 m high tsunami wave reportedly<sup>24</sup> hit the Gujarat coast around 2000 years BP. There is a traditional history of tsunami waves and strong storms hitting the Gujarat coast. The historical tsunami event dates back to 326 BC (ref. 25). Therefore, we hypothesize that the massive walls of the Dholavira might have been a protective measure against possible tsunamis/storms.

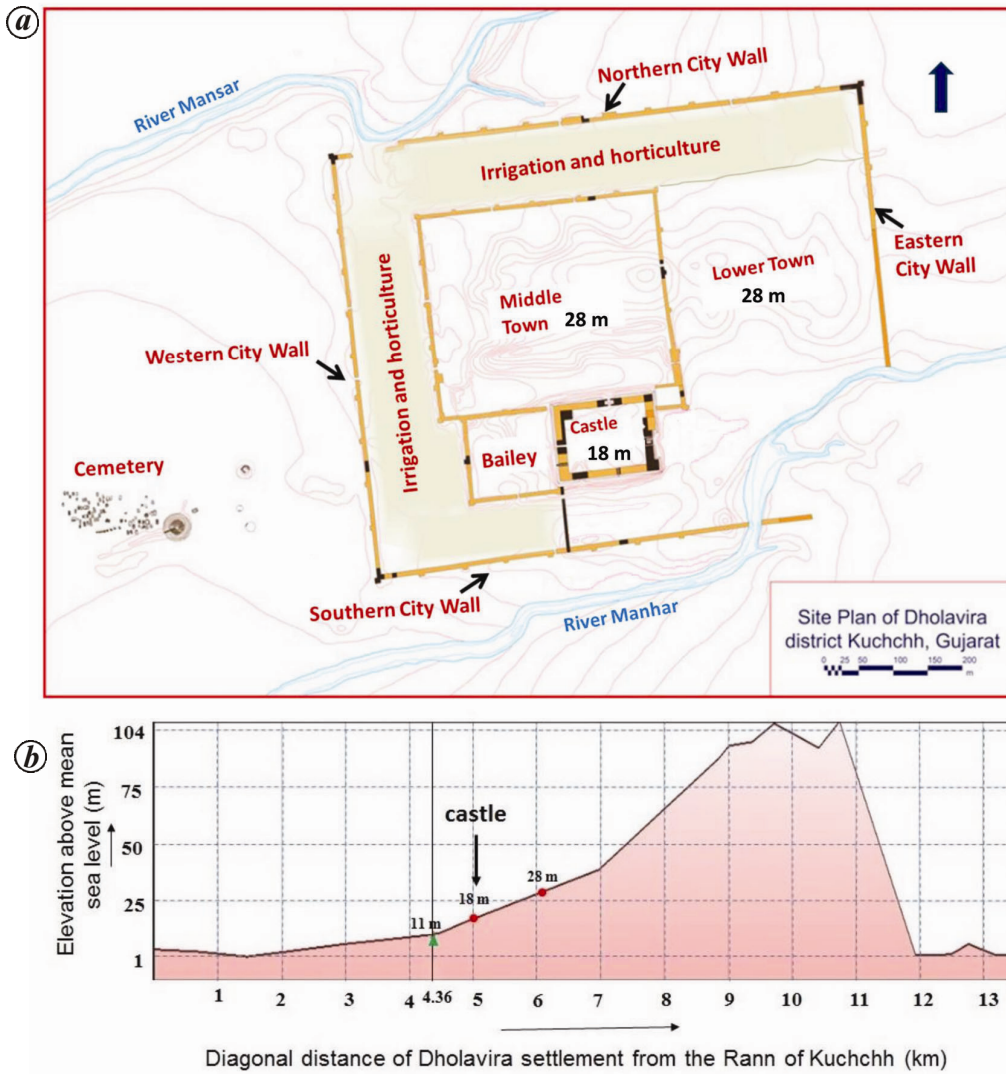


Figure 2. a, Position of various architectural components of Dholavira (modified after Bisht<sup>2</sup>). The values shown are elevations as measured on the field along line A–B of Figure 1. b, Elevation profile of the area under study along line A–B in Figure 1. Arrow marks the elevation of the castle.

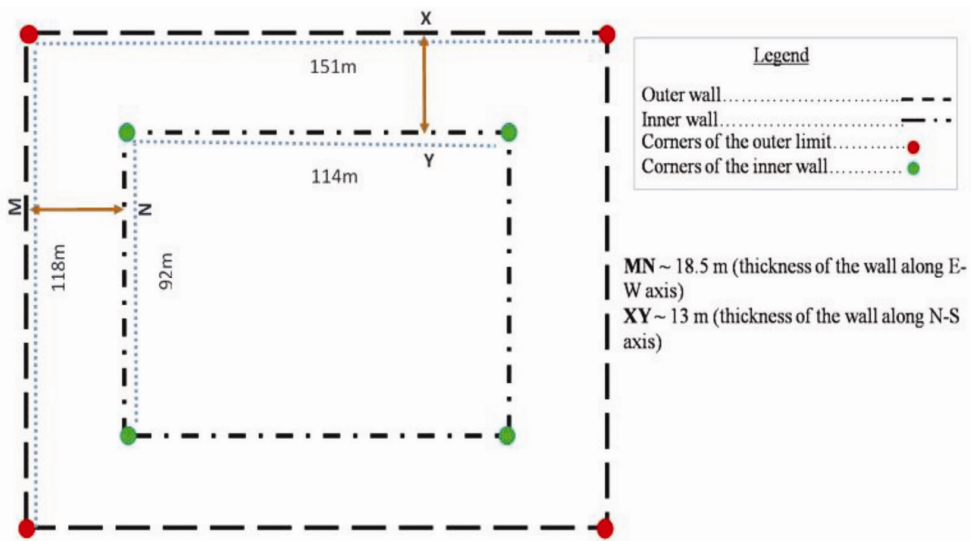


Figure 3. Schematic diagram showing the inner and outer dimensions of the castle wall.

Now-a-days building protective walls is part of the coastal hazard management as adopted in Japan and USA<sup>26-29</sup>. The Dholavira walls are similar to the dimensions of these modern structures. Thus, Dholavira fortification could have reinforced social authority and trade supremacy, but unusual wall thickness served the purpose of protection against tsunamis/storms. In view of the foregoing, tsunami/storm protection measure is the most plausible explanation for the thick walls at Dholavira and the same may also be considered as the oldest record of such measures.

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