Current Deflecting Wall: A Promising Structure for Minimising Siltation in Semi-Enclosed Docks

A. A. Purohit, A. Basu, K. A. Chavan, M. D. Kudale

***Abstract*—**Many estuarine harbours in the world are facing the problem of siltation in docks, channel entrances, etc. The harbours in India are not an exception and require maintenance dredging to achieve navigable depths for keeping them operable. Hence, dredging is inevitable and is a costly affair. The heavy siltation in docks in well mixed tide dominated estuaries is mainly due to settlement of cohesive sediments in suspension. As such there is a need to have a permanent solution for minimising the siltation in such docks to alter the hydrodynamic flow field responsible for siltation by constructing structures outside the dock. One of such docks on the west coast of India, wherein siltation of about 2.5-3 m/annum prevails, was considered to understand the hydrodynamic flow field responsible for siltation. The dock is situated in such a region where macro type of semi-diurnal tide (range of about 5m) prevails. In order to change the flow field responsible for siltation inside the dock, suitability of Current Deflecting Wall (CDW) outside the dock was studied, which will minimise the sediment exchange rate and siltation in the dock. The well calibrated physical tidal model was used to understand the flow field during various phases of tide for the existing dock in Mumbai harbour. At the harbour entrance where the tidal flux exchanges in/out of the dock, measurements on water level and current were made to estimate the sediment transport capacity. The distorted scaled model (1:400 (H) & 1:80 (V)) of Mumbai area was used to study the tidal flow phenomenon, wherein tides are generated by automatic tide generator. Hydraulic model studies carried out under the existing condition (without CDW) reveal that, during initial hours of flood tide, flow hugs the docks breakwater and part of flow which enters the dock forms number of eddies of varying sizes inside the basin, while remaining part of flow bypasses the entrance of dock. During ebb, flow direction reverses, and part of the flow re-enters the dock from outside and creates eddies at its entrance. These eddies do not allow water/sediment-mass to come out and result in settlement of sediments in dock both due to eddies and more retention of sediment. At latter hours, current strength outside the dock entrance reduces and allows the water-mass of dock to come out. In order to improve flow field inside the dockyard, two CDWs of length 300 m and 40 m were proposed outside the dock breakwater and inline to Pier-wall at dock entrance. Model studies reveal that, during flood, major flow gets deflected away from the entrance and no eddies are formed inside the dock, while during ebb flow does not re-enter the dock, and sediment flux immediately starts emptying it during initial hours of ebb. This reduces not only the entry of sediment in dock by about 40% but also the deposition by about 42% due to less retention. Thus, CDW is a promising solution to significantly reduce siltation in dock.

***Keywords*—**Current deflecting wall, eddies, hydraulic model, macro tide, siltation.

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I. Introduction

MANY harbours in the world are developed to provide sheltered areas for safe berthing of ships, easy maneuvering in the dock areas irrespective of phase of tide as well as smooth plying of ocean going vessels through navigational channel. These harbours are developed either on open coasts or in estuarine regions. The primary requirement for both types of harbours is to have tranquil condition for safe berthing of ships. The harbours constructed on open coast require construction of breakwaters to achieve tranquil condition as wave phenomenon being dominant, while those in estuarine region require attention to account for tidal/ riverine hydrodynamics as well as consideration for siltation. Since centuries, many harbours have been used to cater the need of waterborne transport, and most of them were developed in an estuarine region. The reason for developing such harbour facilities in estuaries is to have natural tranquil conditions at berth by avoiding construction of breakwaters, which was not possible due lack of technology/equipment's for constructing them in those days as well as being a costly affair. Such harbours built in olden days were developed with either closed or semi-enclosed type of docks. Over a passage of time, ships requiring higher drafts were built all over the world, and in order to accommodate these new ships in the existing docks, they were deepened along with deepening and widening of navigational channel. One of such docks built on west coast of India about six decades ago in Mumbai harbour area is now-a-days facing a problem of heavy siltation due to various reasons either manmade or natural.

The development of Mumbai harbour was carried about 150 years ago, and it was developed by reclaiming the area between seven group islands known as Salsette/Mumbai Island. The port facilities in the form of docks, jetties, wharfs etc. were developed on the leeside of this artificially developed island to achieve desired tranquil conditions at berth. The Mumbai being on west coast of India, south-west monsoon is dominant, and waves from Arabian sea approaches from south-west quadrant. Thus, for waterfront facilities immediately on the leeside of the island, waves do not create any problem to the ships berthed in the docks. However, the tidal flow phenomenon governs design criteria for the layout of waterfront facilities in Mumbai harbour. In addition to this, the siltation is also an important consideration.

Amongst the various docks in Mumbai harbour, one of semi enclosed dock is facing the problem of heavy siltation. The location of this dock in Mumbai harbour is given in Fig. 1.

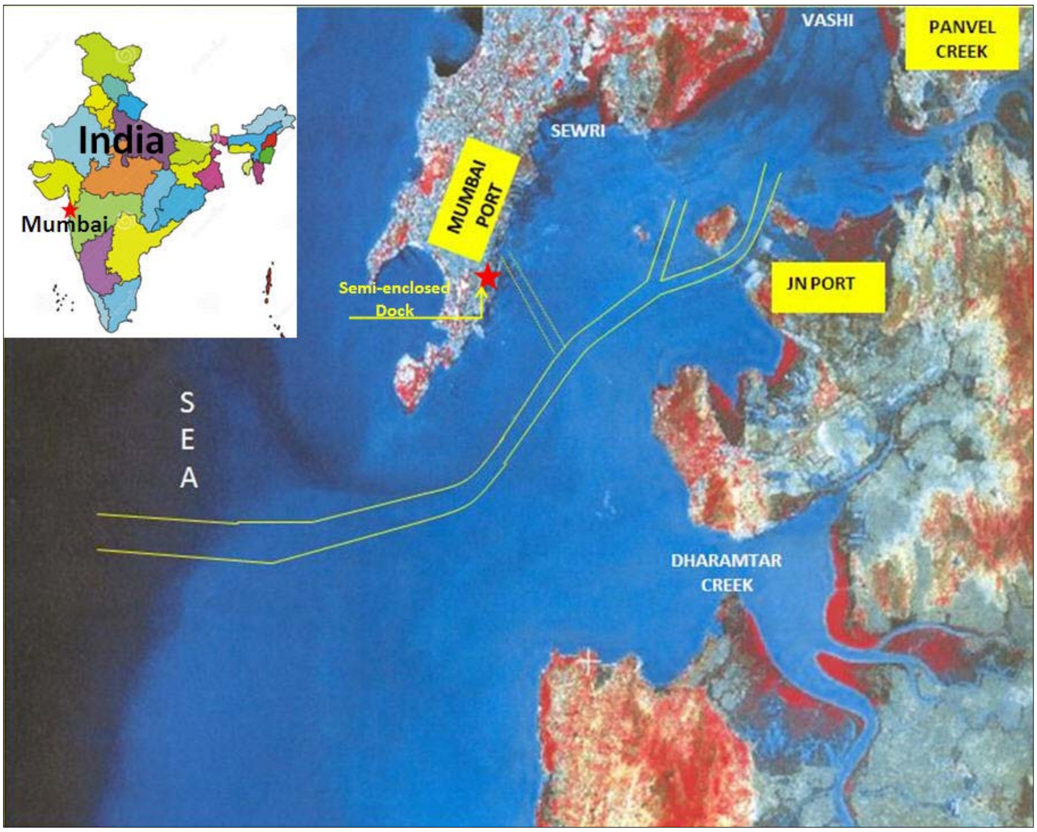


Fig. 1 Location plan of semi enclosed dock in Mumbai harbor

II. Characteristics of Mumbai Harbour and Dock

A. Geographic and Oceanographic Characteristic

The Mumbai harbour is situated in Thane estuarine region and has complexity in both geographic and oceanographic features. The harbour has wide estuarine entrance of about 10 km and tidal water spreads up to 30-40 km upstream, where it then meets the Ulhas River and Bhasin Creek. In addition to this, two major estuaries, viz. Dharamtar from south-east direction near entrance and Panvel from east side at about 15 km upstream of entrance meet the Mumbai harbour area. Both Dharamtar and Panvel estuaries have shallow depths and are such a region wherein confluence of five different rivers changes the flow conditions significantly during monsoon season. The Mumbai harbour also have a combination of various geographical features such as presence of number islands, viz. Elephanta, Butcher, Middle Ground, Cross Island, Oyster Rock, etc. along with large tidal flats like Sewri and Uran. The main navigational channel maintained to a depth of about 10.8 m for past several decades has recently been deepened to about 14 m below Chart Datum (CD). The main channel has total length of about 32 km and inside the estuary it takes turn at 90^0 towards Mumbai port, while this channel thereafter bifurcates into two branches; one goes towards the waterfront structures of Pir-Pau and the other part goes towards Jawaharlal Nehru Port. The oceanographic characteristics are such that the presence of macro type of tides (5 m range) exchanges large volume of tidal mass in/out of vast estuarine region of Mumbai harbour during tidal cycle. Hence, although many rivers from nearby area debouche the sediment in this region during monsoon season, Mumbai harbour is a well-mixed estuarine region. Thus, there is no stratification in dock/navigational channel region, and the siltation is mainly due to settlement of suspended sediment present in the flow prevailing in the harbour region. In Mumbai Harbour area, sedimentation rates are high near docks of Mumbai. The reason is due to the fact that many developmental activities such as reclamations, bridges, townships, etc. in Thane, Panvel estuarine region, carried out by Governmental/Non-governmental Agencies have resulted in decrease of tidal flux over decades and thereby increase in siltation. Further to this the presence of high suspended sediment concentration (0.5-1.3 gm/lit) as well as deepening of berth pockets/channels to cater the operability of large vessels has also resulted in increased siltation. The data on dredging carried out at various areas in Mumbai region indicate that rate of siltation is maximum during monsoon season. The semi-enclosed dock considered for studies is such that rate of siltation is maximum, and authority has to spend significant amount on maintenance dredging to keep it operable for the entire year.

B. Configuration of Semi-Enclosed Dock

The location of semi-enclosed dock in Mumbai harbour region as shown in Fig. 1 is such that it is located at about 5 km north from the entrance to the harbour. The dock is protected from the furry of ocean waves by 'L' shape breakwater toward south end, while pier wall towards north of entrance to the dock results in formation of semi-enclosed basin. The 'L' shape breakwater consists of two types of sections, viz. rubble mound and caisson type. The portion of the breakwater (740 m) from its root is perpendicular to the coastline and has rubblemound cross-section, while remaining part of the breakwater (690 m) runs almost parallel to the coast and consists of caisson type vertical structure. The harbour area of dock admeasures to about 0.6 km^2 and is shown in Fig. 2.

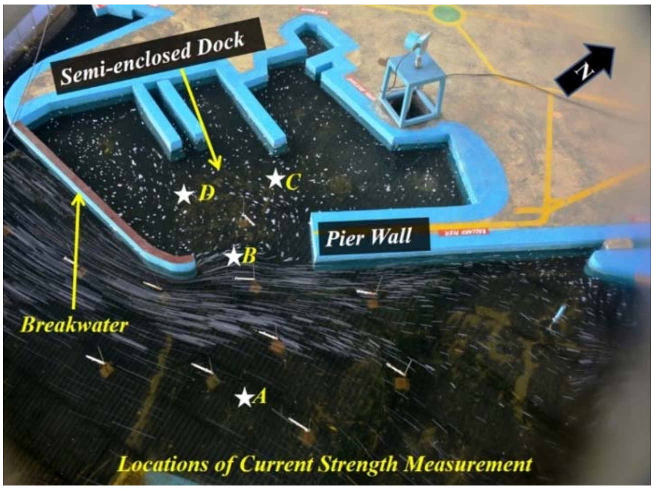


Fig. 2 Layout plan of semi enclosed dock and current measurements

The dock consists of inner/outer tidal basin and is being maintained at 8-9 m below CD. The siltation in the harbour/dock is mainly due to the settlement of suspended sediment which enters inside the dock through its entrance. The alignment of 'L' shape breakwater and the Pier wall being at the acute and obtuse angle with respect to the tidal flow form the entrance to the movement of tidal flux in/out of the dock. The width at entrance is about 340 m and it forms a semi-enclosed basin. The tidal flow enters the basin at right angle to the main flow. Therefore, basin gets filled up during flood tide and gets emptied during ebb phase. The sediment in suspension enters the basin with flood flow through entrance only and dock acts as a silt trap. The data available with CWPRS, Pune indicate that it faces the problem of heavy siltation of about 2.5/3 m per annum. This siltation rate being significantly high, in order keep dock operable, maintenance dredging is inevitable. Thus, it is a recurring expenditure and is a very costly affair. Hence, to minimise the recurring expenditure on maintenance dredging, it is essential to obtain a permanent solution.

C. Solution to Minimise Siltation

The siltation in Mumbai harbour area is increasing due to the reduction in tidal flux as a result of development of various townships, reclamations and other developmental activities in nearby estuarine regions. Further to this, due to the climate change, it causes flash floods and increase in sediment transport into the semi-enclosed dock/ harbour. Hence, there is great need to have some permanent solutions to minimise the siltation. There are two ways to achieve this goal: (a) to understand the hydrodynamic process responsible for siltation inside the dock and mitigate the siltation problem either by providing structure outside the dock or (b) keep water in the dock/berth in agitating condition so that sediment will not settle. The second option requires constant monitoring by operating the pumps, diffusers and is also not effective for large basins.

III. Measures for Mitigation of Siltation

Sedimentation has always been a major problem in tide dominated regions such as estuaries, creeks all over the world and the cost involved in maintenance dredging plays a vital role in the economic functioning of a port. In order to minimize siltation in harbours/basins, mainly three methods such as i) Keep Sediment Out (KSO), ii) Keep Sediment Moving (KSM) and iii) Keep Sediment Navigable (KSN) are adopted. The KSO strategy focuses on minimizing penetration of sediment laden water into the basin and this method does not require any energy or moving parts such as movable gates, locks, flow augmentation, etc. The submerged sills, flow training structures such as CDW [1], etc. are the examples of KSO measures. The KSM strategy focuses on raising the flow velocities in quiescent/quiet areas by means of flow agitation techniques so that the suspended sediment will not settle. This method has been found to be quite effective when there is stratified flow. The KSN strategy takes the advantage of the ability of ships to sail through the low density (less than 1200 kg/m^3) fluid mud often located near the basin/channel bed. In order to minimize the siltation in docks, the CDW has been used in several docks at Parkhafen harbour, Germany [2]. In the present study, the use of physical modeling tool to understand the hydrodynamic flow field responsible for siltation in existing semi-enclosed dock and the effectiveness of CDWs in altering the flow field has been investigated. Based on the measurements on water levels and current/flow velocity made at dock entrance, the percent reduction in sediment transport rate and siltation is computed using semi-empirical formulation developed earlier for Mumbai region. The results/findings are described in this paper.

IV. Hydraulic Model Studies

A. Modeling Principles

Physical hydraulic model has been employed since early century to understand the complex flow phenomena which are not amenable to mathematical analysis or wherein analysis of site specific field data on oceanographic parameters alone does not provide the sufficient information on flow characteristics which vary in space and time. Thus, physical model is a nature in miniature, and reproduction of actual physical process has been used for studying the complex flow processes near the shore such as formation of dynamic eddy, separation of non-uniform unsteady flow, flow separation, determination of siltation prone zones, effect of marine infrastructures on the surroundings, etc. In case of tidal flow, the gravitational and inertial forces are dominant compared to other forces such as viscous force, surface tension force, and pressure force. Hence to measure the tidal flow parameters in the scaled model, Froude's law of similitude is used. The Froude Number is calculated using (1).

$$Froude\ Number,\ F_r = \frac{Inertia\ Force}{Gravitational\ Force} \quad (1)$$

As per the Froude similitude [3], the velocity scale, V_r and time scale, T_r are calculated using (2) and (3), respectively.

$$V_r = \sqrt{d_r} \quad (2)$$

$$T_r = \frac{L_R}{\sqrt{d_r}} \quad (3)$$

B. Description of Hydraulic Model of Mumbai Harbour

Over past several decades, Central Water and Power Research Station, Pune (India) has played a pivotal role in the field of coastal engineering to finalize the layouts of major ports, navigational channel, alignment of jetty/berths, etc. The hydraulic modeling techniques which are used to solve these coastal engineering problems work based on the principles of Froude's similitude. The Mumbai Port model at CWPRS is a permanent physical model which covers portions of Thane, Panvel, Dharamtar estuarine regions as well as part portion of Arabian Sea. This well-established permanent physical model is being used for several decades to study the developmental proposals of various waterfront facilities, and based on the studies, the layouts are finalised and recommended. The tidal model of Mumbai Port is a distorted model having horizontal scale 1:400 and vertical scale 1:80. The total model area is about 150 m x 90 m and it is a rigid bed model. The water supply to the model is of recirculation type, and three pumps of 75 HP each with total discharging capacity of about 1500 lit/sec supply the water. The part area of the model is covered by a shed of size 70 m x 45 m, representing an area of about 11 km x 7 km in proto. The covered portion includes main area of interest, e.g. Mumbai, Jawaharlal Nehru harbour areas, Karanja, etc. and is shown in Fig. 3.

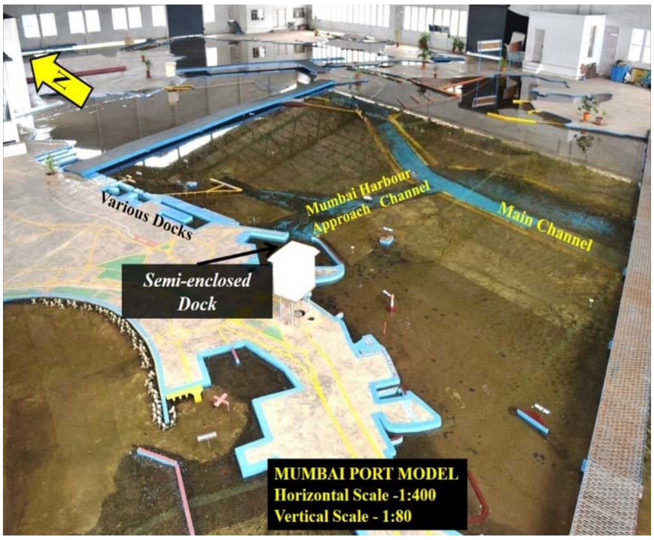


Fig. 3 View of Mumbai Port Model and semi enclosed dock

Fig. 4 Automatic tide generation system

C. Generation of Tide

The Mumbai Port model is well equipped with an Automatic Tide Generating (ATG) system which can generate pseudo as well as mixed tides of required amplitude and period. The generation of tide is controlled by ATG system. The model is fitted with balanced radial gates resting on weirs and is connected to a common shaft as shown in Fig. 4.

The common shaft is connected to a gear box, which is driven by a stepper motor. The movement of stepper motor is controlled by motor drive, which is in turn connected to the computer. The computer is fed with the required water level, while the actual water level in the model is measured by a pressure transducer known as rose mount sensor. At every time step, the computer compares the actual water level with required level in the model.

D. Calibration of Model

The flow conditions, when in tidal model and prototype, are in proportion, then model is considered as calibrated [4]. The physical model of Mumbai Port was calibrated in terms of tide data measured at Apollo Bundar both for spring and neap tides. The comparison of typical measured tide data at model with that of Proto for spring tide is shown in Fig. 5. The velocity measurements were carried out by digital image processing technique. In this technique, paper confetti were spread on the water surface, and confetti travel with the flow velocity and snapshots of the flow are taken by digital camera at specified time interval. The movement of confetti in known time provides information on magnitude of the velocity, while its direction with respect to North gives bearing. The tide in model is about 95% in agreement with prototype tide, and as model has latest bathymetry, velocity also matches with site.

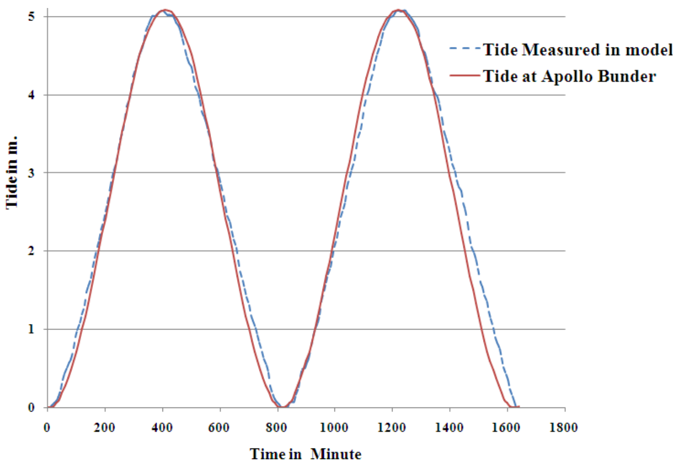
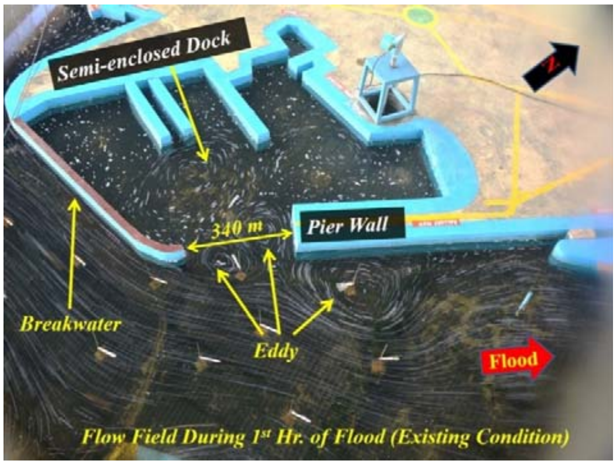


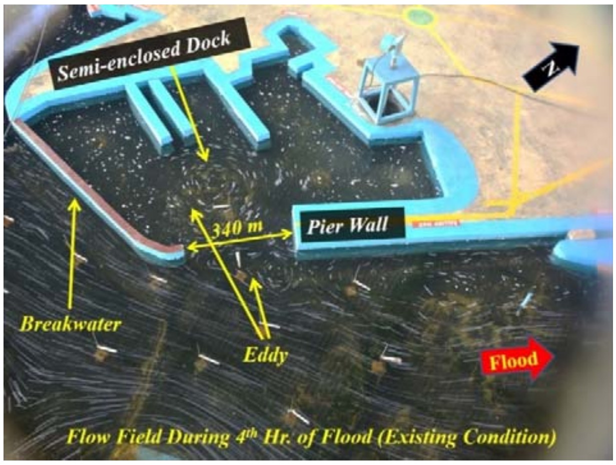
Fig. 5 Comparison of Proto and Model Tide Data

E. Model Studies without CDW (Existing Condition)

The Hydraulic model studies were carried out by generating the tide prevailing in Mumbai harbour both for spring and neap conditions to assess the flow patterns inside and around the existing semi-enclosed dock (without CDW). The maximum tidal range for spring is 5.05 m, while for neap tide it is 2.35 m. The flow patterns were visualized by capturing the snaps using digital image processing technique. The model study reveals that during flood phase of tide, flow remains parallel and hugs to the breakwater during initial hours of flood. The flow then starts entering the dock with formation of several eddies near the pier wall as well as inside/entrance and north of entrance. Subsequently, flow leaves the breakwater due to separation and results in picking of current strength with larger eddy formation inside the dock/pier wall. The diameter of all these eddies formed during three hours of flood tide inside the dock vary from 130-200 m (prototype scale). The eddy which gets formed inside the dock has current strength varying from 0.05-0.1 m/sec. The flow field which was observed during flood tide is given in Figs. 6 (a), (b). At the latter hours of flood, dock starts filling laterally with no formation of eddies.



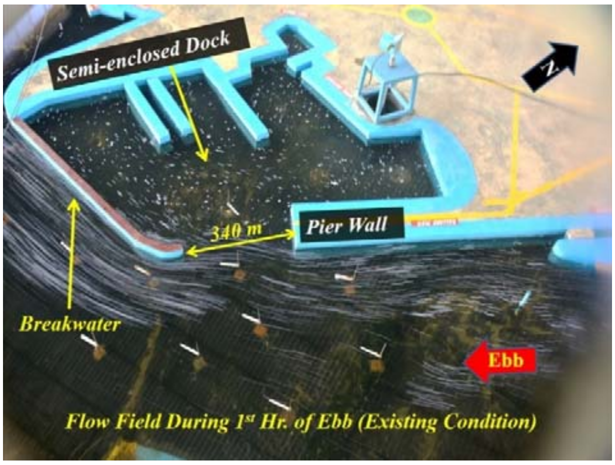
(a)



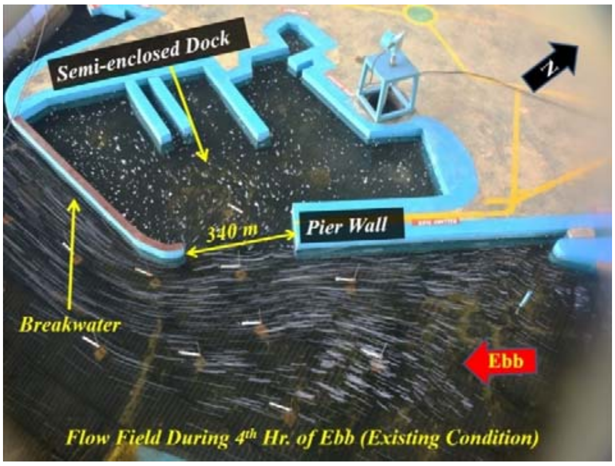
(b)

Fig. 6 Flow field for existing condition during (a) 1st (b) 4th hr. Flood

In addition to this, the formation of eddies at the entrance as well as inside the dock whirls the sediment, and the trapped sediment gets settle down in the dock. The flow at latter hours of ebb starts coming out; however, by that time, the trapped sediment remains inside due to significant depth of about 9 m below CD. This indicates that complex hydrodynamic process is responsible for major siltation in the dock and as such to change this process, it is necessary to have modification in flow pattern inside and outside of the semi-enclosed dock. Thus, application of CDW to divert the flow entering in dock through entrance and reduction in formation of eddies is the only solution to minimise the siltation.



(a)



(b)

Fig. 7 Flow field for existing condition during (a) 1st (b) 4th hr. Ebb

F. Model Studies with CDW

In order to improve the flow field inside as well as in the surrounding area of the Dock, two CDWs of length 300 m and 40 m were proposed outside the breakwater and also in line with the pier wall, respectively. The curved shape CDW of 300 m length starts near roundhead portion of breakwater and gap between the breakwater, and the CDW varies from 100 m at the northern end to 30 m at its southern end. The layout of CDW is shown in Fig. 8.

The hydraulic model studies carried out with CDWs in position reveal that, due to 300 m long CDW during the flood phases, the flow gets channelized and bifurcated. The major part of flow which hugs the outer boundary of CDW (300 m long) is diverted towards the pier wall, while remaining flow enters the basin through the opening between the CDW and breakwater. Study reveals that, during the initial hours of flood tide, no eddy gets formed inside the dock and the strength of current at the entrance of basin has also reduced. However, eddies of varying diameter (180 m to 200 m) formed near the pier wall during the initial few hours of flood disappear in the third hour of flood tide and afterwards. The flow field which was observed during flood tide is given in Figs. 9 (a), (b).

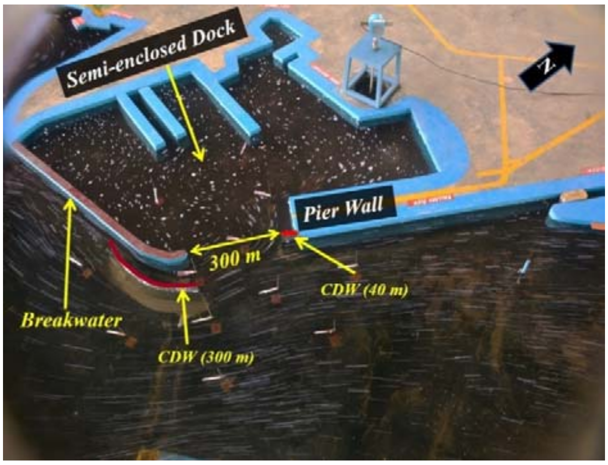
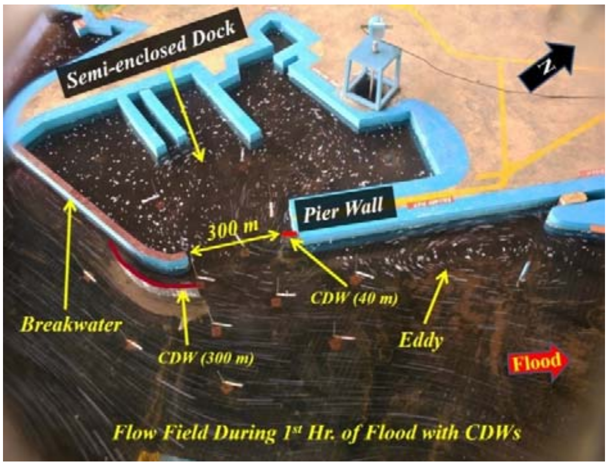


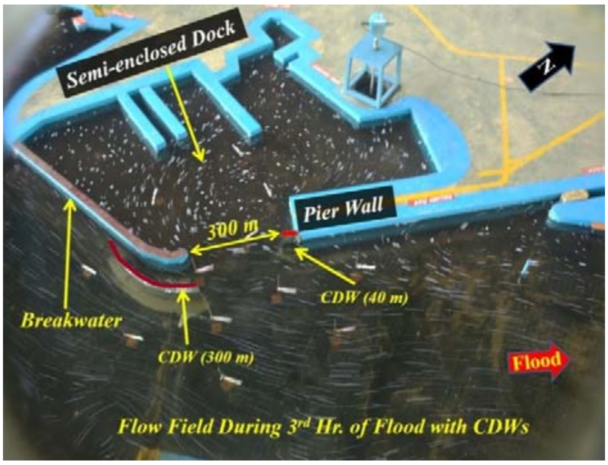
Fig. 8 Locations of CDW near Dock

During ebb tide, the flow reverses and it remains parallel to the pier wall, CDWs and the breakwater. During the initial hours of ebb tide, the current strength outside the dock remains stronger as compared to the inside strength. The study reveals that, due to the proposed 40 m long CDW near the pier wall, no eddy gets formed inside/entrance of the dock during the ebb tide. The major part of flow passes either through the opening between the breakwater and 300 m long CDW or hugs the outer face of the 300 m long CDW. The flow patterns are shown in Figs. 10 (a), (b). The water mass from the dock starts coming out immediately from the first hour of ebb tide and the rate increases from the second hour of ebb. As such overall current strength inside the basin during ebb tide has also increased as compared to the existing condition. It would result in less stagnation of sediment inside the dock, and due to no eddy formation during flood tide there is further reduction in settlement. In order to get information about current strength at the entrance of the dock and outside the dock, the measurements were carried out for both the conditions, viz. without CDW (existing dock scenario) and with both CDWs in position.

The comparison plots indicate that, due to the proposed CDWs, the current strength outside the mixing zone has increased by 10-15% (Location- “A”) and this indicates that more amount of water is being deflected away from the entrance of dock. The plots also indicate that, during initial hours of flood tide due to the proposed CDW, the overall current strength at the dock entrance has decreased by almost by 40% (Location-“B”), and during ebb tide due to CDW, the strength of current inside the dock has increased by 30-35%. This will not only decrease the carrying capacity of suspended sediment into the harbour (during flood tide) but will also increase the rate at which the tidal water leaves the dock during ebb tide. Hence, it can be concluded that the water exchange rate for the dock gets modified due to the proposed CDWs, and the modified hydrodynamics of the harbour/dock will result in reduction of the siltation in harbour/dock.

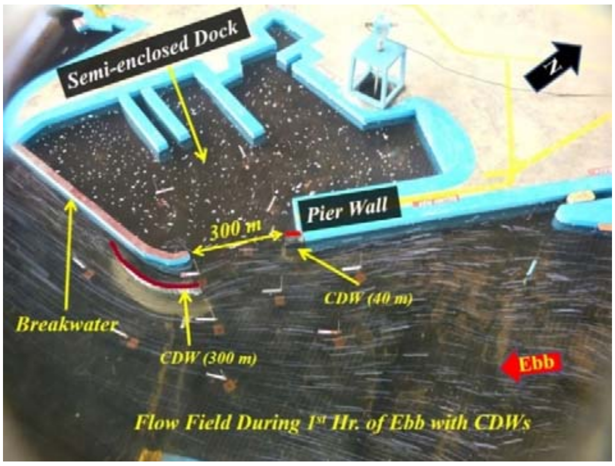


(a)

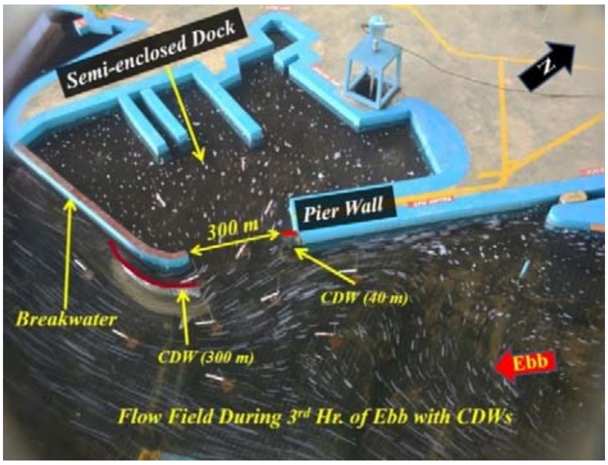


(b)

Fig. 9 Flow field with CDW during (a) 1st (b) 3rd hr. Flood

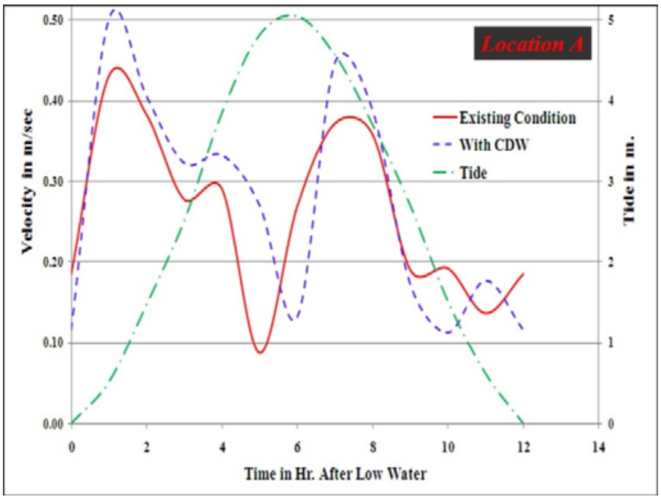


(a)

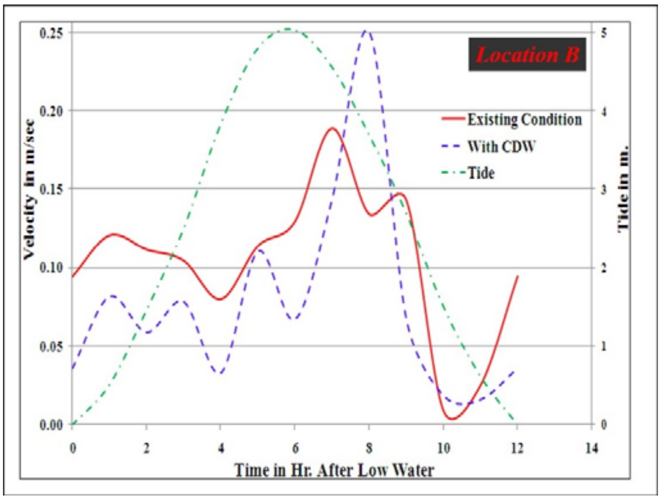


(b)

Fig. 10 Flow field for CD Walls during (a) 1st (b) 3rd hr. Ebb



(a)



(b)

Fig. 11 Comparison of current strength with and without CDW at (a) location "A" (b) location "B" during flood and ebb tide

The comparison plots for current are shown in Figs. 11 (a), (b).

G. Estimation of Siltation

The area of dock being in macro tidal region, method developed at CWPRS by Gole et al. [5] for the prediction of siltation in harbor basins was adopted to estimate the siltation. This method considers the analysis of the prototype and model data, theoretical and analytical studies. A coefficient `K' evolved indicates the ratio of actual siltation to the effective silt load entering the area of development and is evaluated from the known dredging and other data of existing ports. The siltation expected in a harbour/channel is a function of the physical dimension, viz. length, breadth and deepened depth, the tidal range, the velocity of flow in and across the harbour/channel (magnitude and direction), the spatial distribution of silt charge and its gradation, salinity and salinity gradients both longitudinal and vertical, characteristics of the bed material and wave parameters such as direction, period and height. Prototype data supplemented by hydraulic model studies play important role in the prediction of siltation in harbour channels and basins. For prediction of siltation, silt charge at the location of development area of the harbour plays a vital role to understand the flow field under existing conditions, while hydraulic model data provide information about the flow pattern after the deepening of the harbour basin, additions of breakwaters and CDW, etc. As such combination of the prototype data, results of hydraulic models, theoretical and analytical studies, it is possible to estimate the probable siltation in harbour by semi-analytical method.

With the prototype and hydraulic model data, total suspended load crossing the channel/harbour entry is given as:

$$S_t = L \times v \times c \times t \times d \quad (4)$$

where S_t : total silt load, L: length of the channel, v: velocity of currents across the channel, c: silt concentration, t: time, d: depth of flow.

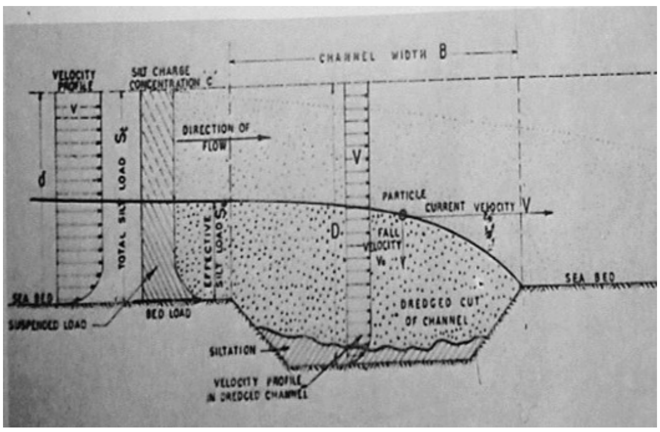


Fig. 12 Diagram to estimate siltation in basin/channel [5]

The total suspended load crossing the channel is computed by integration over time. The fall velocity of the particle (vo) is determined considering particle diameter. The effective silt load which can contribute to the siltation of the basin/channel [5] is computed, and the parameters are given in Fig. 12.

$$\text{Effective Silt Load } (S_e) = (S_t) \times \frac{(B \times v_0)}{V \times d} \quad (5)$$

B = width of the basin entrance/channel = 340 m
v_o = fall velocity of the particle = 0.001 m/sec
V = velocity in the basin portion = 0.06 m/sec
d = depth outside the basin/ channel = 7 m below CD

$$\text{Net Siltation } (s) = K \times (S_e) \times \left(1 - \frac{V^2}{v^2}\right) \quad (6)$$

where ` K' is a coefficient

$$\text{Net Siltation } (s) = K \times (S_e) \times \left(\frac{D^2 - d^2}{D^2}\right) \quad (7)$$

$$(s) = K \times (L \times v \times c \times t \times d) \times \frac{(B \times v_0)}{V \times d} \times \left(\frac{D^2 - d^2}{D^2}\right) \quad (8)$$

The value of `K' for basin was 0.61, while for channel it was 0.245. The studies carried out reveal that, due to CDW, the average flux entering the dock gets reduced by about 40% with that of existing dock layout. The sediment getting transported inside the dock being a function of velocity at the dock entrance, water depth and suspended sediment concentration, there is net reduction in siltation rate by 42% due to decreased retention period and non-formation of eddies.

V. Conclusion

The siltation in estuarine harbours is a major problem faced by many countries in the world, and India is not an exception. The Mumbai harbour and various docks are facing the problem of siltation due to many developmental activities taken place in macro tidal region. The maintenance dredging is inevitable to keep semi-enclosed docks operable and it is a costly affair. One of semi-enclosed dock in Mumbai harbour faces high rate of siltation of about 2.5/3 m per annum.

A permanent solution to minimise siltation in such dock is need of time. There are two ways to achieve this goal: (a) to understand the hydrodynamic process responsible for siltation inside the dock and minimise the entry of sediment laden water inside the basin or (b) keep water in the dock/berth in agitating condition so that sediment will not settle.

The option of agitating water in dock requires constant monitoring by operating the pumps, diffusers and is also not effective for large basins. As such in a semi-enclosed dock, the effectiveness of CDWs for modifying the water exchange into the semi-enclosed dock has been investigated in the present study. The physical hydraulic model studies provide valuable information about the flow pattern in such regard. The present study reveals that the exchange of water due to tidal action during flood phase results in formation of eddies at entrance as well as inside the dock. The peculiar shape of dock causes significantly strong flow outside the dock during ebb.

This results in reentry of the tidal flux inside the dock, thereby not allowing water mass inside the dock to go out. The sediment transported inside the dock hence gets trapped for duration of about 7-8 hours of tidal cycle, and the trapped sediment further whirls in the eddies and causes settlement of sediment. Thus, keeping the sediment away from the dock, minimisation of formation of eddies inside the dock and reducing the retention time of sediment are the solution to minimise the siltation.

The application of CDW outside the dock (300 m) and in line with pier wall (40 m) at north end of entrance studied reveals that, due to the 300-m long CDW, major part of tidal flux during flood phase gets deflected away from the dock entrance, while remaining part enters into the dock through the opening between CDW and breakwater. Also, during initial hours of flood, no eddies are formed inside the dock and current strength at the entrance reduces by about 40%. This ensures the reduction in transport of suspended sediment entering the dock and increase in current strength outside by 10-15%. During ebb tide, due to the 40-m long CDW, no flow enters inside the dock from outside, and therefore, no eddy gets formed at the entrance/inside the dock. This results in water-mass inside the dock to quickly go out during initial hours of ebb and less retention inside the dock. Hence, all the reasons of heavy siltation are overcome by providing CDWs, and siltation estimated reveals that siltation rate can be significantly reduced by about 42%.

Thus, CDW is a promising solution to significantly reduce siltation in semi-enclosed dock**.**

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