Conference Paper, Published Version

Sundaravadivelu, R.; Selvakumar, R.; Ravikumar, M.; Ramasamy, R.; Subramanian, Sp.

Design of Barrage Style Tidal Water Power Plant Structure to Reduce Sediment Accretions in Approach Channel, Entrance, Harbour and Backwaters of Cannanore Port, Kerala

Proceedings of ninth International Conference on Hydro-Science and Engineering (ICHE 2010), IIT Madras, Chennai, India.
2 - 5 August 2010

DESIGN OF BARRAGE STYLE TIDAL WATER POWER PLANT STRUCTURE TO REDUCE SEDIMENT ACCRETIONS IN APPROACH CHANNEL, ENTRANCE, HARBOUR AND BACKWATERS OF CANNANORE PORT, KERALA

R. Sundaravadivelu, R. Selvakumar, M. Ravikumar, R. Ramasamy and SP. Subramanian

Abstract: *Kuppam and Valapattinum Rivers form an extensive backwater lagoon near Kannur Town, Kerala. The Port constructed at the mouth of these rivers by a private company is often silted by sediments brought by the rivers and by entry of littoral drift driven tidal waters into the backwaters. Huge quantities of depositions of silt are to be dredged to maintain the port and it creates huge expenditure. In order to minimize the siltation a special type of structure is proposed as a remedial measure. The structure includes with construction of two parallel training walls of 360 m interval for a length of 2000 m with a construction of underwater barrier wall of 15m breath and 12 m high above ground surface on the sea-bed. Two sliding doors of 35m on either side as part of a sluice gate opening side wards at the mid portion of barrage are to be erected. This underwater barrage is to be located at 200m inside from the outer termination of the training walls. The opening height of sluice gate 70m length is 1 m above ground level of the channel bed. The entire harbor basin, turning circle, the approach channel for a length of 3 km from the mouth will be dredged and deepened to 14 m depth from mean low-tide level. The top of the barrage is always immersed in seawater at a depth of 1 to 3 m below the low tide level. The length and breadth of the channel is 5:1 which protects the approach channel silting of sand is removed by rip currents in front of the under water barrier wall. By this means, the siltation in harbor basin and backwater lagoon beds will be prevented to a considerable extent minimum 5 to 4 times of the cost of annual dredging and maintenance. Installation and operation of such types of sluice gate bearing underwater barrier to be the first time of proposal in India. Such types of sluice-gate structures are installed in many international river channels and sea-ports. The impact of geological processes on this structure is dealt in detail. The barrage may be improved with addition of "Pamban Type Bridge" at the top to regulate tidal waters to rise up to a height of 16 m above sea-bed, to set up a tidal power plant of 80 MW capacities. Continuously tidal water flows into the basin or seaward. Further the barrage lying between two groins like training walls will protect coastal erosion even during heavy monsoon period*.

INTRODUCTION

At the confluence of Kuppam and Valapattinum Rivers, a stretch of backwater lagoon is formed with a tidal rise and fall of 1.3m near **Cannanore** (Kannur) Town 11^{o}52'27"N; 75^{o}22'13"E of Kerala State (Port of Cannanore 2010). The lowland coastal tract is a narrow stretch comprising of rivers, deltas and coastal plains. Six rivers drain Kannur, the longest being the Valapattanam river with a length of 110 km. Other rivers flowing through Kannur region are Kuppam, Mahe River, Anjarakandi, Thalassery, Ramapuram and Perumba. The main tributaries of the

[4]Dept of Ocean Engineering, Indian Institute of Technology, Madras, Chennai-36

Valapattinum River are Valiapuzha and Aralampuzha. Kuppam river drains an area of 539 sq.kms. The length of river is 82kms. The other rivers in the district are Mahe (54kms.), Anjarakandi (48kms.), Thalassery (2kms.), Ramapuram (19kms.) and Perumba (51kms.). The Kuppam river and other west flowing rivers are used for navigation (Tomy, 2008) The Sultan canal constructed in 1766 is 3.8kms long, the Valapattinum river (55km) and Ancharakandy river (23 km) are used for navigation purpose. The annual average rainfall is 3438 mm and more than 80% of it occurs during the period of South-West monsoon. The rainfall during July is very heavy and the area receives 68% of the annual rainfall during this season. The geological formations in the region are of Archaean and recent age. The Archaean formations comprise of granite gneisses and charnockites. Recent formations are alluvium and laterite. Thin seams of lignite are exposed along the coast. China clay is found in abundance in Thaliparamba and Kannur. Laterite is quarried for bricks. Beach sands containing ilmenite, rutile, sillimanite monazite, Zircon, and thorianite occur along the coast, especially to the south of Valapattinum river mouth and near Azhikode. Many occurrences of bauxite deposits have been discovered in this region. Lime-shells used for the manufacture of white cement and for industrial purposes are found in the backwaters of Eranholi river, Dharmadampuzha, and Anjarakandi river around Thalassery and Dharmadam as well as Valapattinum river in the east of Azhikkal ferry.

Siltation

Siltation at the mouths of Kuppam and Valapattinum rivers are due to deposition of sediments brought by the rivers in the deltaic region. The entry of tidal waters also brings sand particles and deposits in the lagoon and backwater regions. The littoral drift caused by the movement of prevailing winds also deposits huge quantities of sediments at the mouth (11^o56’39”N; 75^o17’48”E) of these rivers. The slow and steady rise and fall of tidal water entering and retreating from the backwater lagoon also cause deposition of sand in considerable amount. The confluence of these rivers at a single mouth is widened for 360m. A private company was permitted to construct a port in this area. It has extensively constructed training walls all along the lagoon basin for a total distance of 2721km length protecting a lagoon having a maximum dimension of 710m with average widths ranging between 274m and 360m. The lagoon extends to Valapattinum River having a mean breadth of 684m and the Kuppam river side width is 400m. The entry of 1.3 m tidal water oscillation with slow movements of tidal currents enter into the rivers to a considerable distances for more than 18km in the north and 9km in the east along the river channel backwaters during heavy monsoon period. The 360m widened-mouth allows huge quantities of tidal water rise along with sediments inside the backwaters (Fig. 1). The velocity of tidal current in this area after studying the adjoining area is very high during heavy monsoon period is 0.5 m/s and decreases to <0.01 m/s during the slack time. In Beypore lagoon, the mean tidal current estimated is 7 cm/s (Dinesh Kumar et.al. 2004). According to them tidal currents are different at the surface and bottom waters, suggesting baroclinic nature of tide and currents subjected to diurnal and semidiurnal signals. Further they are influenced by seasonal dominance of freshwater discharges in this region. Considering the geological features of the Kannur Port area, the mean tidal current velocity may vary around this estimation. Therefore the dredged harbor basin is frequently silted within a few months after dredging the basin. The Google Earth pictures show that presence of several parallel shoal bands of considerable dimensions trending in NNW-SSE directions parallel to the coastline.

Shoals

About 8 shoal bands formed in varying lengths and widths are seen at present stage. The shoals appear to be formed sea within a few months of duration prior to the Google imaging the site after the construction of the training walls projected into the sea. All these shoal bands are uniquely have steep wave front faces with gentle leeward slopes towards shoreline.. The slope gradient varies from 1: 4 to 1: 25. The vertical height appears to be varying from 5m to 1m from sea die to near shore area. Some of the shoal bands appear to be continuous more than 1 km distance. After that they tapering at the end or diffuse and disappear. Some shoal bands appear to be bending just in front of the training walls, indicating that the construction of training walls appears to be a barrier for littoral drift movement and sedimentation of the sandy materials. The shoals are considered to be temporary features and are dynamic in their configurations due to the action waves induced by the prevailing wind movement perpendicular to the trend of coastline in this area, gravitational force, quantities of sediments brought by the rivers and configurations of coastline and bottom topography. The steepness of the vertical height of the shoal bands is high towards inshore regions at wave breaking zones indicates the direction of deposition of sandy materials towards the coastline. The shoal bands appear to be well-formed at the middle portions with sharp steepness and the leeward side a gentle slope gradient is seen. These portions are considered to be effective zones of wave-breaking and are often less than 5 m in depth during low tide period. Their vertical height also significantly reduced towards shore-line forming very flat shoal bands. The shoal bands though appear to be very similar to ripple marks formed on the river bed, have alternate crests and depressions with wavy pattern. The intervals between two adjacent shoals at middle portions relatively high (160 m) in the middle portions compare to the adjacent shoal bands intervals near the shore (70 m) and at far-inshore regions (60m). In between any two large shoal bands, there are a number of many small sized shoal bands with a dimensional width less than 1m and length greater than 30m. Wavy depressions are seen between any two adjacent shoal band ripples.

The sand particles lifted and bounced over to the elevated crest and rolled down along the leeward side to the bottom by saltation process. By accretion at the bottom depression, new crest forms and the ripple structure again migrates towards the shore and then by rip currents back into the sea. By oblique movements by backwash currents, the sand particles displaced to new place. Within the harbour basin longitudinal shoal bands are formed by the entry and retreat of tidal waters into the basin. Some of the shoal bands are curvilinear owing to fluctuation and circulative currents developed during the tidal water movement and other topographical features. The breadth of such bands is less than a meter in dimensions. A continuous movement of sand particles promotes a littoral drift of the sediments. This causes siltation in the bottom of river or backwater. Further perpendicularly cross-cutting laminations of sandbars are also produced perpendicular to the direction of tidal water flow. The length and breadth of these laminations are widely varied depending upon the configuration of the harbour basin and its walls enclosed. Significant accumulation of shoal bands are seen just south of the southern training wall, indicating the net littoral drift causing depositional environment prevails at the southern portion and erosive environment prevails just north of the northern training walls constructed in this area (Sundar, 2004 and Chandrasekara Iyer, 2004). These features indicate that the geological processes trying to close the mouth by depositing sand in the form of parallel shoal bands. The littoral drift zone extends to 1.1km from the shore line and it expands to 1.7km from the mouth. The littoral zone generally lies in the near shore region lying below a depth of 5m at low tide level.

Concept of design of structures

The concept of structural design is to reduce siltation at the mouth and in backwater lagoons, as the same tidal rise and fall would not be affected any way by construction. The regulation of entry and retreat of tidal waters is controlled by construction of training walls on either side of the mouth. The training walls already constructed in the port is not sufficient to regulate tidal waters and also to arrest or minimize siltation in the harbor basin and approach channels. The ratio of length and width of the two training walls is very low (0.58). The northern wall is hardly 210m long (Fig. 1) from the low tide level, while the southern wall is 400m long. Since the interval between the two walls is 360m, rip current in the littoral zone is not effective. Formation of more numbers of shoal bands just south of the longer southern training wall is seen. The breaking of waves is introduced more than a km distance from the sea-shore, the energy is dissipated at the mouth, where the depth of water column is less than 5 m and it is often less than 1m. Hence, the backwash is not effective to remove the sand particles. Further entry of high tide water passing through Kuppam and Valapattinum rivers influence quite a long distance. The continuous dynamic tidal ingress or retreat is suppressed the tidal current flow in this estuarine system. Hence depositional process is active during entry of tidal waters in the harbour basin rather than effective erosive action during the retreat of tidal waters during low tide period. Hence, net accumulations of sediments are promoted in the harbour basin.

Design structure

Training walls constructed at both sides of the mouth of Kannur Port should be extended to 2000m length (Fig. 2). An underwater barrage of 360m long 15m breadth and 12 m high from low tide level will be constructed at about 200m inside of the training wall from the outer terminal. A 70 m long sluice gate consisting with sideward moving two sliding doors of 35 m length and 12 m high attached with a thickness of 30cm will be installed at the mid portion of the barrage. The sliding doors will be open only during the entry of ship into the harbour basin, the remaining time it will be closed. The tidal water freely enters into the basin and retreats back into the sea without any obstruction. Installation of 80 turbine-units directly on the top of barrage can produce electricity under varying velocity of flow of tidal waters (Fig. 3). Barrage style of tidal plant work with constant flow of tidal waters enhances power production significantly. Design and installation of "Pamban-Type" of lifting bridges and 70 m sluice gates below are to be opened up simultaneously during for entry of ship (Fig. 4 and Fig. 5).

Tidal Power Plant

A Tidal Power Plant may be constructed by spending additional amount of a few hundred crores rupees, so that the barrage style tidal power plant promotes its ability both to protect the harbour from siltation and coastal erosion and supplies at least power supply of 80 MW with installation of 8 farms with 10 units each producing 1 MW / unit (Mary Bellis, 2010). The height of the barrage is increased to 16m from the sea-bed. At the end of the barrage two channels regulating tidal waters into the power plant and allowing the used waters into the basin and in to the sea. Though it was suggested at least 5 m tidal rise and fall is required to install a power plant, the mean tidal water volume encountered for this operation is 17.64 m^3/s, feeding 220 l/s. Turbine wheel of 20 rpm gets impact force of 660 kg / rpm. The authors estimated that volume of water subjected to rise and fall for a distance of 360 m with a mean tidal current velocity as 0.07 m/s is sufficient to operate 80 MW tidal plants for 24 hours a day operating at high tide and low tide periods. During flood season, excess tidal water is allowed to discharge freely.

Environmental Impact Analysis

The construction of underwater barrage of 12 m from sea bed at low tide level does not disturb the entry / retreat of tidal water. Therefore no environmental damage to biological or ecological aspect will be incurred. It protects the harbour basin, approach channel and backwater lagoons from siltation. The turbines spin much more slowly than wind turbines at just 10 to 20rpm and so there is little impact on marine life. Each machine will generate around 1MW of power and 10 to 20 machines will be grouped in 'farms' under the sea where currents are high. On the other hand, completion of the dike, outflow water discharged from the sluice gates has longer residence times due to the weakened tidal current. The construction of a barrage style tidal power plant may do harm when imbalances occur between the entry of tidal waters into the basin and the retreat of tidal water in to the sea after utilizing the water for power generation. Prolonged residential time of damming up the water in either side of the barrage will collapse the equilibrium of natural estuarine environment and may lead to adverse biological or geological processes of degradation. Construction of barrage increases the extreme amplification tidal water level causing inundation of adjoining parts (Kang, 1999). Controlling the discharge and gate-opening timing can partially mitigate these impacts on the marine environment (Seok Lee et.al. 2008). For this tidal water storage in the basin / sea should be regulated to an optimum condition.

CONCLUSION

Movement of coastal inlets, silting up on entrance, mouth and basin and for perfect mixing of tidal prism with river water and seawater to create optimum estuarine condition for aqua-cultural activities, it is necessary to construct an underwater barrage at about an optimum distance from the mouth or port-entrance to regulate clear tidal waters entry or retreat. This will prevent sedimentation in the harbour area. The same structure may be further developed for installation of tidal power plant producing significant quantity of electricity. In present case, it is possible to generate 80 MW power by installing 8 farms each containing 10 units of 1 MW capacity. The tidal rise is limited to 1.33 m (mean value 0.7 m) for a length of 360 m length with a mean tidal current flow of 0.07 m /s along the barrage can operate 80 units of power generation to rotate 20 rpm turbine wheel with energy of 660 kg/s for 24 hours of continuous work both at low and high tide levels. The advantages of barrage style tidal plant, it is possible to regulate and to make the tidal water steady flow into the power generation turbine by avoiding the diminish flow in the slack time tidal effect. Therefore, a continuous generation of electric power is possible. The feasibility of installation of such structures in every artificial seaport in India may be explored.

REFERENCES

Chandrasekara Iyer, J., (2004) Coastal Erosion & protection – A National Perspective in Workshop on Coastal Protection Measures 5-6 Nov. 2004.

Dinesh Kumar, P.K., Srinivasm K,. and Anil Kumar, N. (2004) Seasonal variability of tidal and non-tidal currents off-Beypore, SW Coast of India, METOC

Kang, J.W, (1999) Changes in Tidal Characteristics as a Result of the Construction of Sea-dike/Sea-walls in the Mokpo Coastal Zone in Korea, Estuarine, Coastal and Shelf Science, v. 18, (4) 429-438.

Mary Bellis,(2010)- How Tidal Power Plants Work About.com Guide, inventors.about.com/od/tstart inventions/a/**tidal_power**.htm

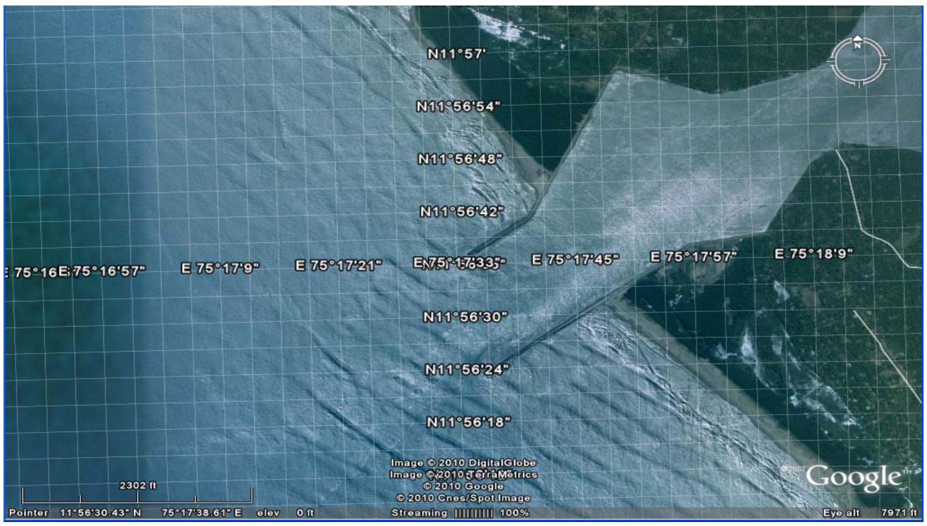
Seok Lee , Heung-Jae Lie, Kyu-Min Song, Cheol-Ho Cho and Eun-Pyo Lim(2008) Tidal modification and its effect on sluice-gate outflow after completion of the Saemangeum dike,
South Korea, Journal of Oceanography, 2008, v.64 (5), pp. 763-776

Sundar, R. 2004, Coastal erosion and protection. Workshop on Coastal Protection Measures 5-6
Nov. 2004.

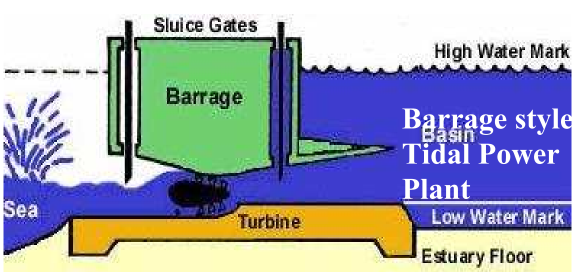
Tomy, P.J. (2008) The Kerala Coast- Causes of its' ruin and methods for revival pp. 1-25 www. KeralaCoastfate.com.

www.worldportsource.com/ports (2010)/IND Port of Cannanore_1849.php 2.

www.kannurairport.com/ -Official Web site of Kannur International Air Port A



Tidal Power Plant **Present view of Kannur Port Kerala**



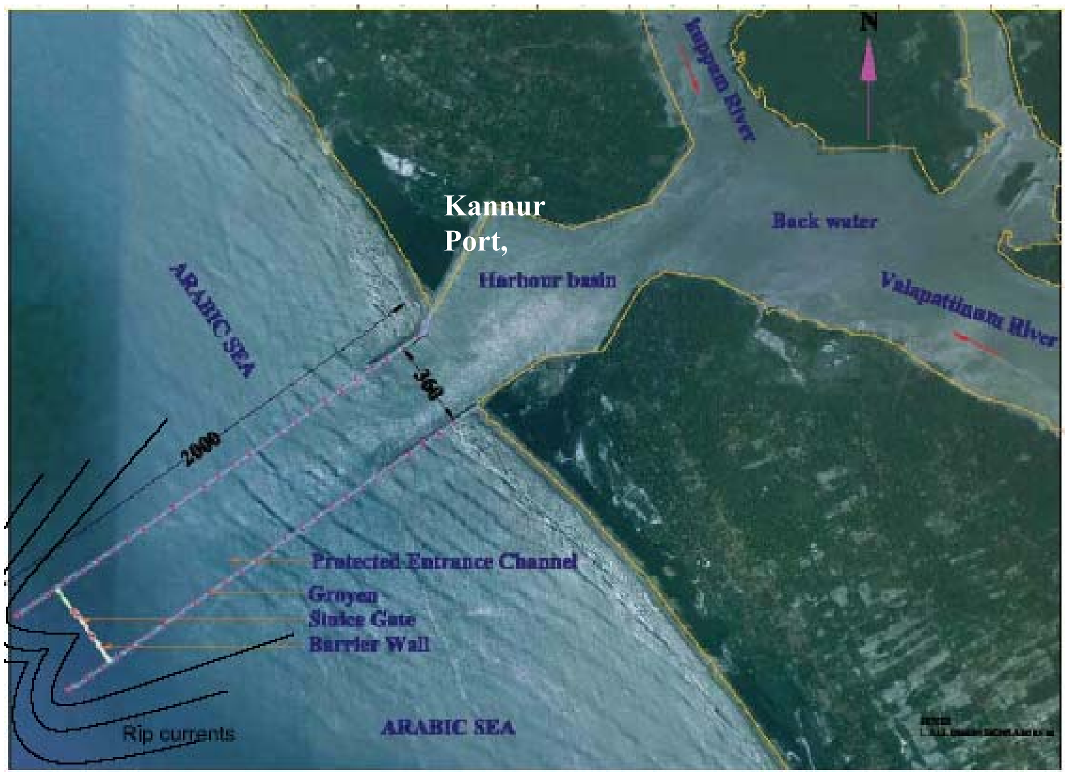


Fig. 1 Kannur Port, Kerala and the design structures to be installed

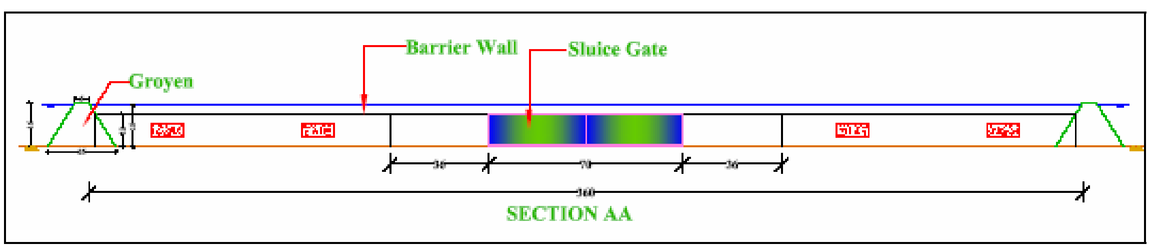


Fig. 2 Underwater barrage between two training walls of 2000 m long and 360 wide barrage

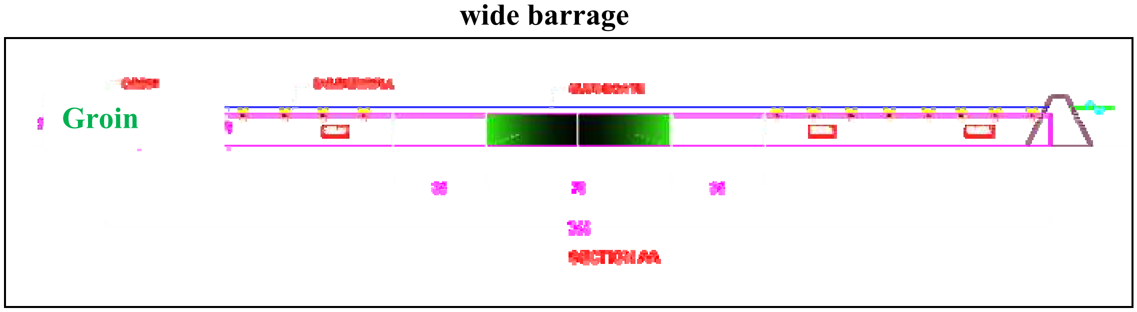


Fig. 3 Tidal Plant with 80 units on an underwater barrage of 12 m high, bottom depth of 14 m below low tide level

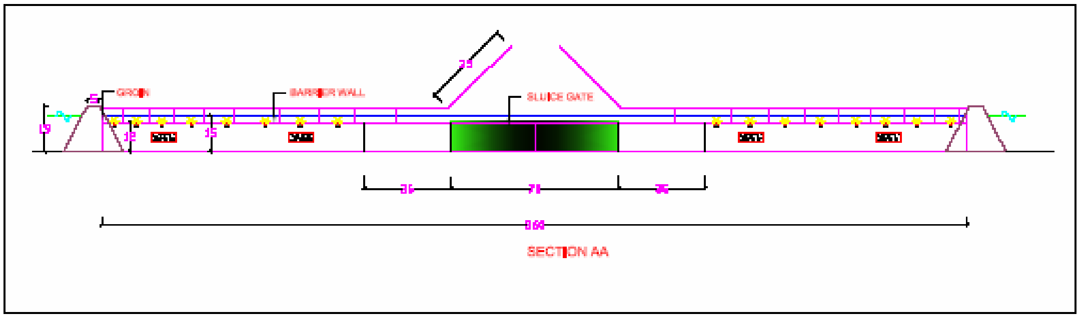


Fig. 4 Barrage style of Tidal water Plant with Pamban Type of bridge and sluice gate to open for the entry of a ship (values in m)

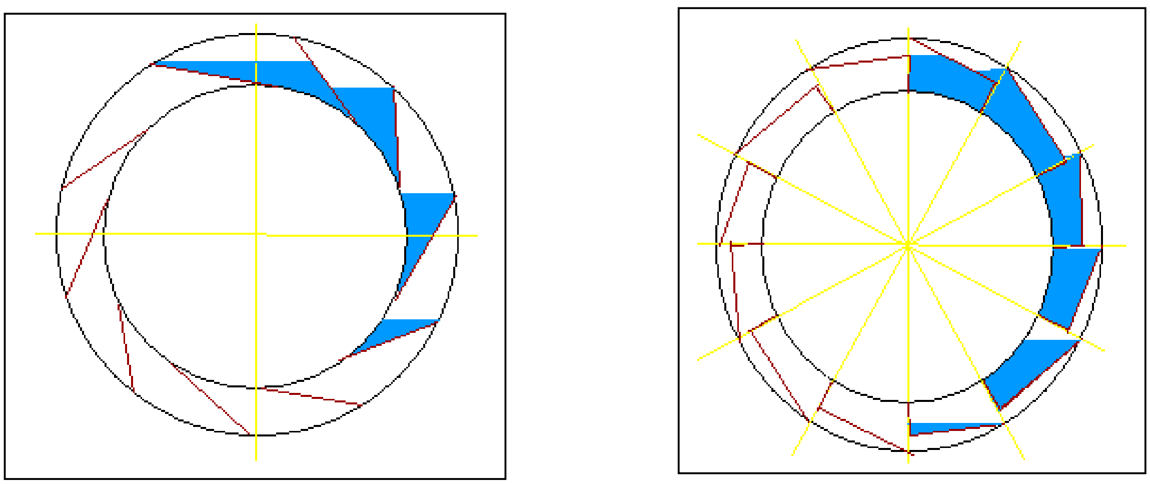


Fig.5 Turbine wheels to produce electric power by rotation due to inflow of tidal water