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Mayurkumar Tandel
Fisheries Engineering and Technology, Dr. B.S.K.K.V., Dapoli, Maharashtra, India

Dr. RK Sadawarte
Fisheries Engineering and Technology, Dr. B.S.K.K.V., Dapoli, Maharashtra, India

Dr. VB Mulye
Fisheries Engineering and Technology, Dr. B.S.K.K.V., Dapoli, Maharashtra, India

Dr. JM Koli
Fisheries Engineering and Technology, Dr. B.S.K.K.V., Dapoli, Maharashtra, India

Dr. BR Chavan
Fisheries Engineering and Technology, Dr. B.S.K.K.V., Dapoli, Maharashtra, India

Bhavika Tandel
College of Fisheries Science, Kamdhenu University, Veraval, Gujarat, India

Corresponding Author
Mayurkumar Tandel
Fisheries Engineering and Technology, Dr. B.S.K.K.V., Dapoli, Maharashtra, India

Study of brackish water shrimp farm design and engineering aspects of farm in higher tidal amplitude region

Mayurkumar Tandel, Dr. RK Sadawarte, Dr. VB Mulye, Dr. JM Koli, Dr. BR Chavan and Bhavika Tandel

Abstract
Engineering and design aspects of brackish water farm is an important aspect for development and sustainability of brackish water aquaculture. There were 54 operational brackish water farms were selected by random sampling from six different research sites (OS1, OS2, OS3, OS4, CS1, CS2) of Surat district. All sample farms were divided into tide fed, tide cum pump fed and pump fed farms, they were also divided into small (<2 ha), medium (2-5 ha) and large (>5 ha) size farm. Design aspects such as pond area, length, width, depth, bottom slope, peripheral and partitional dike were measured. Some other engineering aspects such as feeder canal, subsidiary canal, drainage canal and sluice gate of the ponds were measured during this study. Soil characteristics like pH, electrical conductivity, water retention capacity, bulk density and soil moisture of the farms were ranged 7.6 to 9.3, 3.2 to 24.0 dS/m, 21 to 66%, 0.3 to 1.4 g/cm^3 and 9.6 to 41.2% respectively. The observed soil texture varied from clay loam, sandy clay loam to sandy clay. Proper design and engineering aspects are recommended for better production and for reducing the erosion effects by tidal amplitude, construction of berm is recommended outside the peripheral dike.

Keywords: Brackish water farm, tide fed, pump fed, tide cum pump fed, soil

1. Introduction
Recently aquaculture farms are built with traditional earth work but for successful farm operation, favourable topography, good site, enough water and constructive soil are essential (Jayanthi, 2007) [11]. Shrimp farming is becoming more popular as a result of its high value, strong market and short culture period. As it expands, several critical elements such as appropriate site selection, efficient farm design and the environmental condition may be overlooked, resulting in higher production costs and lower production. So, proper topography and site selection is an important aspects as per farm design point of view (Homziak *et al.*, 1993, Biswas, 2012, Chandrakant, 2003, Jayanthi *et al.*, 2017, Pillay and Kuttey, 2005, Bhakat, 2009) [10, 4, 8, 20, 3].

Aquaculture engineering focuses on aquaculture systems, management techniques, aeration systems, filtration, and water management, thus having a good understanding of the subject can help you to solve site selection and farm design issues. Generally 50-60% of total capital cost are used in engineering and constructions of farm from which 35-50% of cost only used in earthwork of ponds, canals and dikes (Chamberlain *et al*., 1985) [7] so, adequate knowledge of proper design and farm management farmers can reduced the cost of construction and increase their productivity.

On the western side of India, strong congregating channel is found from Mumbai known as Gulf of Khambhat (GoK) with highest tidal amplitude recorded with a spring tide range from 8.8-10m near Bhavnagar (Mitra *et al*., 2020) [14]. Costal brackish water farms are exposed to extensive damage caused in the form of erosion by higher tidal amplitude (Mukherjee and Basu, 1988 and Biswas, 2012) [17, 4]. Some other factors viz. wind, wave action, burrowing animals are also responsible for dike erosion (Pillay and Kuttey, 2005) [20]. To reduce such environmental impacts, proper constructions with planning and designing is very important (Ravichandran and Jayanthi, 2006) [22]. Apart from this good soil with enough clay content is essential for best result in construction of embankment which tightly sealed and hold pond water (Biswas, 2012) [4] because lack of knowledge about suitable soil properties of aqua farms will leads to unsuccessful shrimp farming (Muralidhar *et al.*, 2018) [19].

Farmers are currently confronted with issues relating to engineering and adequate soil for farms, putting pressure on researchers to develop a viable farm design for brackish water coastal farms. The current study analyse and finalise engineering factors to improve farm management using existing farm design and soil characteristics.

2. Material and Methods

Operational brackish water farms of Surat district were selected for the present study. Surat district is situated at 21.2629º N and 72.9933º E. It is an economical capital of Gujarat state and situated near the river Tapi. With 83 km coastline it shares 5.2% of the total coast of Gujarat and found near Gulf of Khambhat (GoK). For the present study Surat district were divided into six (OS_1, OS_2, OS_3, OS_4, CS_1, CS_2) different research sites (Fig. 1) as per the six main creeks present in the Olpad and Choryasi taluka of Surat district. Brackish water farms were divided into tide fed, pump fed and tide cum pump fed farm which were further subdivided into small (<2 ha), medium (2-5 ha) and large size (>5 ha).

There were 54 farms selected by random sampling method and data were collected by interview cum data collection method. From these farms, engineering aspects of farm such as pond area, water spread area and depth of pond were collected. Apart from these top width, slope, freeboard and height of the peripheral and partitional dike were also collected. Dike berm, feeder canal, subsidiary canal and drainage canal, sluice gates and aerators information were gathered during this study.

2.1 Sampling procedure

Bottom soil samples were collected from 5-10 equal intervals along transects from edges to centre of ponds. Soil samples were were dried in oven at 105 ºC as per for 24 to 48 hr (Boyd, 1995) [5]. Soil pH were analysed by potentiometric method using 1:2.5 soil-water suspension and same suspension were used for EC determination, where EC determine by conductivity meter (Piper, 1966) [21]. Bulk density and moisture of soil were analysed by standard procedure (Boyd, 1995) [5]. Water holding capacity was determine by Keen's box method (Piper, 1966) [21] and soil texture analysis was determine by hydrometer method (Boyd, 1995) [5]. Water quality parameters such as Total Suspended Solids, pH and salinity were analysed as per the standard procedure (APHA, 1998) [1] while other parameters like water temperature and transparency were checked on the spot by thermometer and secchi disk.

Fig 1: Six research sites in Surat district

3. Results and Discussion

Out of 54 sample farms, there was no tide fed farms were observed in Surat district while 34 pump fed, 7 tide cum pump farms from Olpad taluka and 12 pump fed, 1 tide cum pump fed farms were observed from Choryasi taluka. There were 2 small, 25 medium and 19 large size pump fed farms were found while 7 medium and 1 large size tide cum pump fed farms were found from Surat district. From these distribution of farms it conclude that farmers of Surat district were widely adopted medium size pump fed farms. There were no tide fed farms were reported during the present study. Total farms area were ranged from 2 ha to 50 ha with water spread area ranged from 0.94 ha to 30.99 ha which was contribute 52% to 80% water spread area of farm. Though, water spread area of farms shall not exceed 60% of the total area of the land (CAA, 2005), except large size tide cum pump fed farms, all farms were found within the limit of water spread area.

In the specification of ponds, area of ponds were ranged from 0.02 to 2.00 ha with length ranged 11 to 340 m and width ranged 7 to 200 m. Generally 0.2 to 0.5 ha pond size is good because of easily manageable practices and that size is idea for Indian topography (Biswas, 2012) [4]. Pond depth were recorded 2.0 to 4.8 m which was found higher than the

recommendations because of every year farmers scrapping the upper soil and takeaway it from the farms but they did not add the soil at bottom of the ponds. Pond bottom slope were provided with 1000:0.2 to 1000:2 slope towards the drainage canal or creek while recommended slope was 1000:1 to 1000:5 which indicate that farmers of Surat district were provide lower slope which may leads to inadequate drainage of water (Upadhyay, 1994) [23]. However, many farmers fill or drain their ponds directly by pump, and because they did not built a sluice gate in the ponds, they did not maintain the pond's bottom slope.

During this study two small farms were observed in OS_1 (Olapd Site-1) which indicate that majority of farmers adopted medium and large size brackish water farms. There was no significant difference ($p>0.05$) found in pond size, pond length and pond width within medium size farms of district while pond depth and bottom slope were shown significant difference ($p<0.05$). In large size farms, no significant difference ($p>0.05$) found in pond length while significant difference found in pond area, width, depth and bottom slope of the pond ($p<0.05$).

Crest or top width of peripheral dike were ranged from 1.58 to 6.70 m which was higher than the recommendation and also decrease cultivable area of farm. Though it may vary as per the topography and soil texture of that specific area. Slope of the peripheral dike ranged from 1.3:1 to 2.8:1 whereas recommended ranged is 1.5:1 to 2:1 (Jayanthi, 2007) [11]. Free board were maintained 0.30 to 1.95 m which is higher than the recommendation. Apart from this height of the peripheral dike were recorded 2.10 to 4.10 m. Peripheral dike located very close to the creek however, it should be located 30 m away from the riverbank for protection against the flood and wave action that cause erosion of outer dike and destruction of the farms (Jayanthi, 2007) [11]. In some farms stone pitching and growing vegetation were observed to minimise wave cations. Although in Surat district farms, crest or top width of the peripheral dike should maintain 3.7 to 4.5 m width that is as per recommendation (Wheaton, 1977) [24].

Partitional dike were found with 0.52 to 3.20 m crest or top width which was found higher than the recommendations, it should be in the range of 1 to 2 m (Mishra and Dora, 2015 and Upadhyay, 1994) [13, 23]. Partitional dikes were used to separate ponds, hold the pond water and easy operation. That type of dike should be strong enough to hold the pond water and for that clay soil is best for constructing such a bundh in the farm (Jayanthi, 2007) [11]. Dike slope of the partitional dike were ranged 1.4:1 to 2.8:1 while height of dike ranged from 1.98 to 3.90 m which was also higher than the recommendation given by MPEDA (1997) [16]. Peripheral and partitional dike should strong enough in flood or cyclone condition especially when it comes under the higher tidal amplitude area such as Gulf of Khambhat (GoK). Dike should also prevent the seepage problems and for that width and flatter slope should as sufficient as the parabolic line of seepage falls within the body of dike. Another major problems were found the digging animals such as crab that can make the whole into the dike and reduced the strength so, to disputed it quick lime can be applied in the borrows (Mline, 1972) [15].

Out of 54 brackish water farms, only 15 farms were found with berm outside the peripheral dike. Berm was recorded in five medium and six large size pump-fed farms while it was not recorded in small size pump-fed farms. In tide cum pump fed farms, three medium and one large size farm were found with berm outside the peripheral dike. During this study it was found that farms with berm had a lower erosion rate of dike than the farms without berm. Although sloping the sides of dikes according to soil properties and grow some grass on peripheral dike were significantly reduce erosion of the dike (Boyd, 1995) [5].

Table 1: Details of pond design, peripheral and partitional dike parameters

Sr. No.	Particulars		Range	Standard parameters/Researchers' findings
1.	Pond area		0.02-2.00 ha	0.2-0.5 ha (Biswas, 2012) [4]
2.	Pond depth		2.0-4.8 m	0.8-1.0 m (Chandrakant, 2003) [8]
3.	Pond bottom slope		1000:0.2-1000:2.0 (Vertical: Horizontal)	1000:1-1000:5 (Upadhyay, 1994) [23] (Vertical: Horizontal)
4.	Peripheral dike	Crest	1.58-6.70 m	3.7-4.5 m (Wheaton, 1977) [24]
		Dike slope	1.3:1-2.8:1	1.5:1-2:1 (Jayanthi, 2007) [11]
		Free board	0.30-1.95 m	0.6-0.7 m (Ravichandran and Jayanthi, 2006) [22]
		Dike height	2.10-4.10 m	3.0-4.5 m (Mishra and Dora, 2015) [13]
5.	Partitional dike	Crest	0.52-3.20 m	1.0-2.0 m (Mishra and Dora, 2015 and Upadhyay, 1994) [13, 23]
		Dike slope	1.4:1-2.8:1 m	2.5:1 (Jayanthi, 2007) [11]
		Free board	0.30-1.95 m	> 0.3m (Jayanthi, 2007) [11]
		Dike height	1.98-3.90 m	0.5-2.0 m (MPEDA, 1997) [16]

Water supply system of the farms are consists canals such as feeder canal, subsidiary canal and drainage canal. These canals were used to fill the water or to drain the water from the ponds. Top width of the feeder canal were ranged from 0.6 to 5.0 m which was found double then the recommendation given by MPEDA (1997) [16], that top width of the feeder canal should be 0.3 to 2.0 m. But it can also vary by size of the farms and width of the partitional or peripheral dike. All farms were found with close subsidiary canal system which was made up of PVC pipes that directly supply the water from feeder canal to ponds. It was regulated by valve. Top width of drainage canal were recorded 2.3 to 32.0 m with 0.8 to 3.7 m depth. Although top width and depth of the drainage canal were depends on pond water volume, time required to drain the water and elevation of the canal (Baluyut and Balnyme, 1995) [2].

Sluice gates of ponds plays a vital role in aquaculture farming practices. It is used to fill, drain and exchange the water. It is constructed with RCC walls or columns that stretch from the pond bottom to above the planned water level and have a hume pipe of suitable scale (Mishra and Dora, 2015) [13]. Width of the sluice gates were ranged 0.27 to 2.50 m in the farms of Surat district. Although it depends on pond size and daily rate of water exchange (Ravichandran and Jayanthi, 2006) [22]. It was observed that total 4 to 12 aerators were used in a single pond for aeration and mean distance of aerators from dike were ranged 1.6 to 9.0 m. But during this study it was found that if distance between aerators and dike were

higher than 4.2 m, it did not affect the inner dike. Inner dike erosion were frequently observed by the aerators generated wave action and wind generated wave action (Boyd, 1995) [5]. In the brackish water farms of Surat, Soil pH and EC value were ranged 7.6 to 9.3 and 3.2 to 24.0 dS/m, respectively. Water retention capacity of soil were 21 to 66% which is depend on the clay and sand percentage of the soil while bulk density of soil were ranged 0.3 to 1.4 g/cm^3. Soil moisture content in soil were ranged from 9.6 to 41.2%. Soil quality parameters of small, medium and large pump fed farms were given in Fig.2 while medium and large tide cum pump fed farms were given in Fig.3. Normally to reduce the seepage from the bottom and dikes, hard clay deposited in layers with good compactions and mixed chemical sealant such as sodium polyphosphate with soil (Jayanthi, 2007) [11]. Soil texture of the district were observed clay loam, sandy clay loam to sandy clay in the different area. For aquaculture mostly sandy clay, sandy clay loam and clay loam are suitable texture (Muralidhar and Saraswathy, 2006) [18]. Physical and chemical properties with soil texture analysis are used to determine the suitable soil for building the ponds (Hajek and Boyd, 1994) [9].

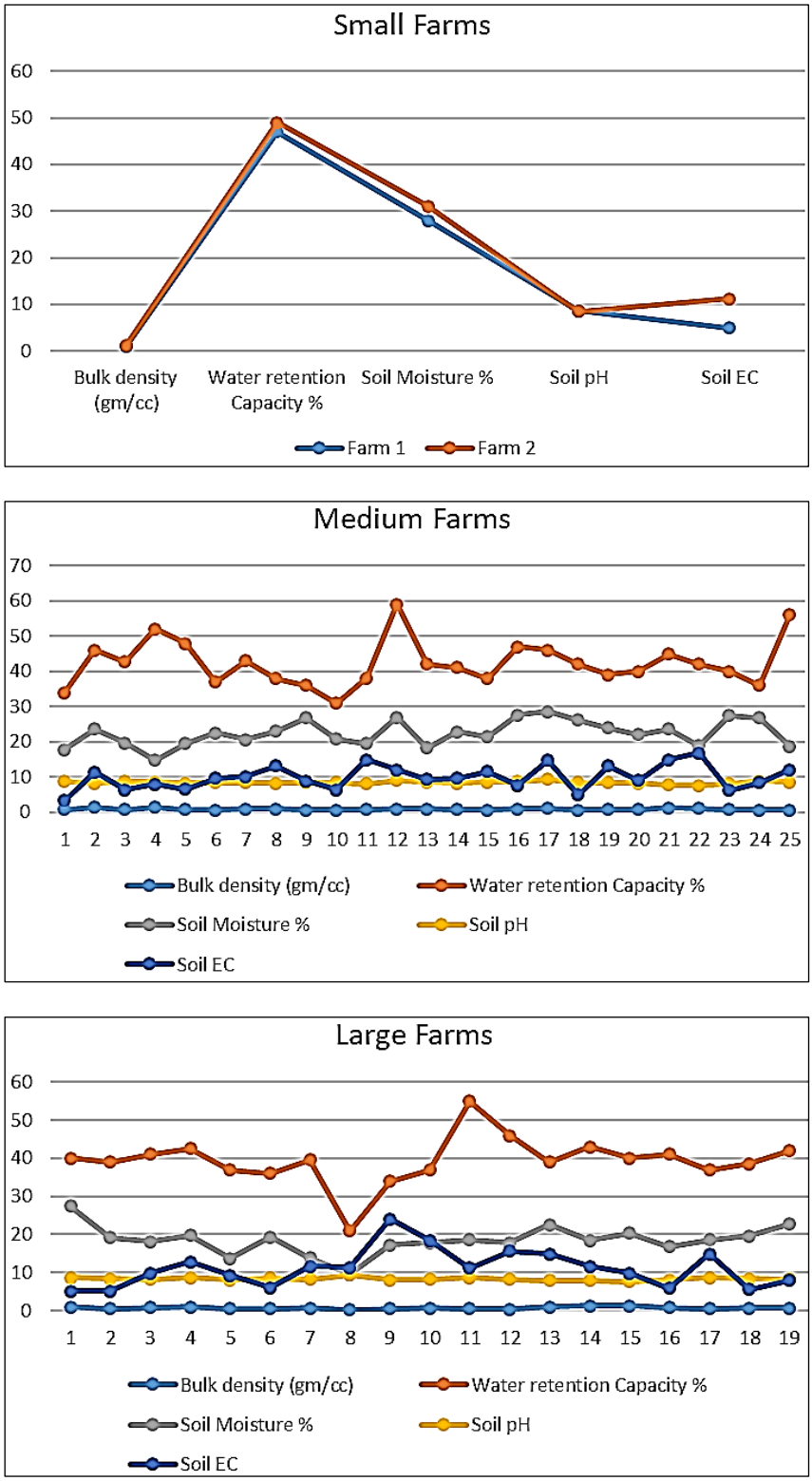

Fig 2: Soil Quality Parameters of Small, Medium and Large size pump fed farms

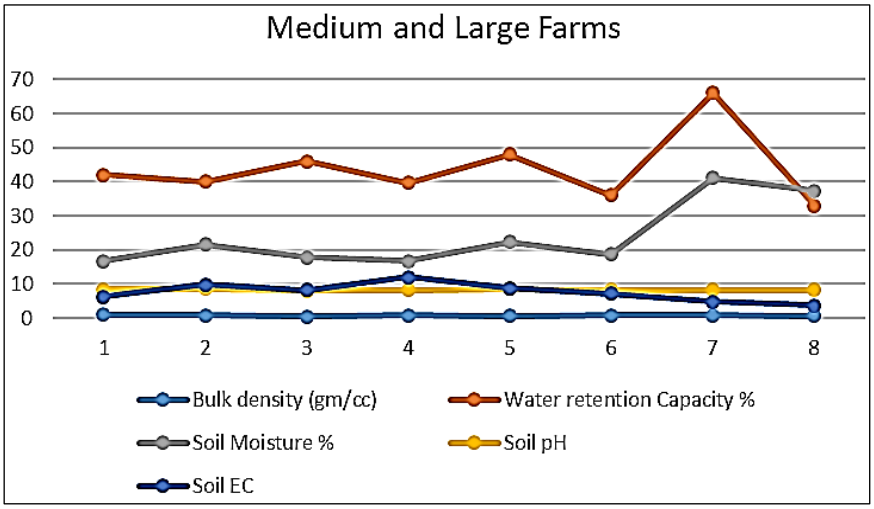

Fig 3: Soil Quality Parameters of Medium and Large size tide cum pump fed farms

Thus, the overall study revealed that the Surat district, with its ideal topography, water availability and soil parameters, has enormous potential to establish brackish water farming sustainably. If farmers follow recommended farms design parameters, it will definitely increase the efficiency and strength of farms and also help to improve the livelihood of the shrimp farmers.

4. Conclusion

Study of different engineering aspects of brackish water farms were help farmer to select appropriate site and planning of site as per Costal Aquaculture Authority guide lines and improve farm design against tidal current. In Surat district there were no tide fed farms observed due to modernisations and improved farming technics. Soil texture is also found good which is suitable for the aquaculture. This study also helps researchers for the further study on brackish water farm designs and its soil parameters according to different locations of Surat district.

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