SOME ENGINEERING PROBLEMS IN THE CONSTRUCTION AND MAINTENANCE OF MARINE CULTURE PONDS AT MANDAPAM

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ABSTRACT

A major problem concerning the construction and maintenance of marine culture ponds at Mandapam has been that dykes are subject to easy erosion and damage because of the incohesiveness and porosity of earth, which chiefly consists of sand, fragments of corals and molluscan shells. Crests and slopes of dykes are liable to be washed off easily in rains, and dyke bases are eroded by wave action in the ponds. Experiments showed that dykes when built in a proportion of 5-6 m basal width to 1 m height are capable of resisting these damages considerably. To protect dykes' bases and to maintain their slopes, turfing is found to be most effective and long lasting. Also, when a strip of the original ground is left as it is all along the inner edges of ponds, the dykes tend to remain free of damage. A grass belonging to the genus *Chloris*, which has shown a high rate of propagation and a good earth-binding quality, is found to protect the dykes well against the local climatic and soil conditions. It is also found that, by allowing enough time for the dykes to season and consolidate and for the pond bottom to become compact, seepage can be reduced by 75%. Further reduction up to 96% is possible by covering the slopes and dyke bases with protective linings made of locally available cheap materials. Structural work of a simple culvert type sluice, successfully designed and constructed for free flow of water to the ponds, is explained.

INTRODUCTION

The earliest attempt scientifically to construct marine ponds for culture in Krusadai Island and Cochin was reported by Pillay (1947, 1948). Later, Chacko and Mahadevan (1950) described an improved version of ponds in the former locality. Tampi (1960) gave an account of the method and constraints of pond construction at Mandapam. Jhingran et al (1972) dealt with the design and construction of ponds in Lower Sunderbans. Continuing the work of Tampi (1960), Central Marine Fisheries Research Institute took up in 1979 in Mandapam work to develop a low-cost technology for construction of marine ponds. The present paper gives the problems encountered during this attempt, as well as the techniques that were evolved to overcome them. The area where the experiments were conducted is the same in which Tampi (1960) had constructed ponds earlier. The ponds in which the studies were carried out are shown in Fig. 1. A-K.

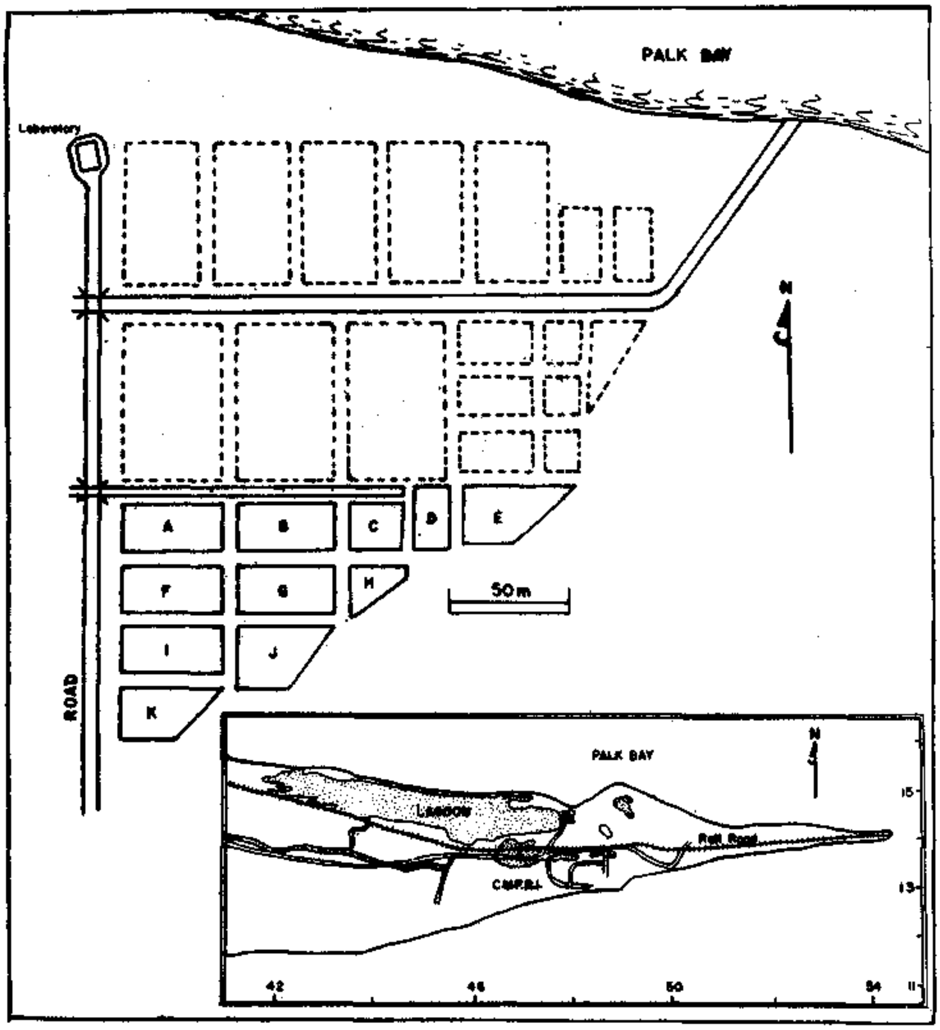

FIG. 1. Lay-out of the ponds A to K which were constructed during 1979-83 for the experiments. (The ponds indicated by broken lines were constructed before 1979. The dark triangle in the map below shows the location of the pond site.)

Problems Encountered

The main problems encountered in the construction and maintenance of of ponds during 1979-80 are as follows:

Poor Physical Quality of Soil

Tampi (1959) had described the soil in the locality as an admixture of calcareous sand, small quantities of fine clay, shells of molluscs, coral pieces and formanifers. In the present work, samples of earth were analysed for studying the physical qualities. Also the ground was excavated at places 10 m apart to a depth of 2 m to understand the soil profile in the locality. The soils were classified based on size of the grains, as given by Rahim (1968), into: "clay" (smaller than 0.002 mm), "silt" (between 0.002 and 0.50 mm), "sand" (0.50 and 2.00 mm) and "gravel" (larger than 2.00 mm).

The excavations have shown that, up to a distance of about 100 m inside the coast, the upper 90 cm of the ground is sand with high percolating quality. For about the next 90 cm it is silt, and for the next 90 cm it is watertight clay. Between 100 and 300 m interior, a layer of the upper most 30 cm or so of earth is clay plus gravel, which is resting on a layer of about 70 cm thickness made up of an admixture of coral pieces, molluscan shells, etc. Below this level the ground is made up of silt. A dyke constructed with this earth in the proportion of 3 m base : 1 m height had collapsed after 69 days (Fig. 2).

FIG. 2. Damage undergone by a dyke built in a structural ratio 3 m base : 1 m height.

Another dyke constructed in the ratio of 4 m : 1 m lasted only for 121 days. These dykes even when reinforced with turf or granite stones on slopes collapsed sooner or later.

Erosion on Crests and Slopes

Although the annual rainfall at Mandapam is not more than 38 to 99 cm (data obtained from the Meteorology Department of Government of India at Pamban), it nonetheless causes erosion of the earthern dykes (Fig. 3). To assess the intensities of erosion and subsidence due to rains, dykes constructed in four different proportions of base to height were exposed to rainfall during the N.E. monsoon (October to December) of 1980. The four proportions were, in metres, 3 : 1, 4 : 1, 5 : 1 and 6 : 1. Dyke heights were measured before and after the rains following the method adopted by Jhingran et al (1972). The number of breaches on the inner and outer slopes of dykes, their lengths, widths and depths were recorded. The quantity of earth lost was then calculated from the means and expressed in cu. m|m length of the dyke.

From Table 1 it may be seen that, in the dyke with 3 base : 1 height, erosion cum subsidence on crest was 30 cm when a rainfall of 21 cm was recorded. But, with increase in the width of bases, this has decreased to 21 cm in a dyke of 4 : 1, to 12 cm in a dyke of 5 : 1 and to only 5 cm in a dyke of 6 : 1. Volume of earth lost from crests showed a linear decrease from 0.70 cu. m|m in the first case to 0.21 cu. m|m in the fourth. From the slopes the volume of earth eroded was 0.00128 cu m|m in the dyke of 3 : 1; but, with

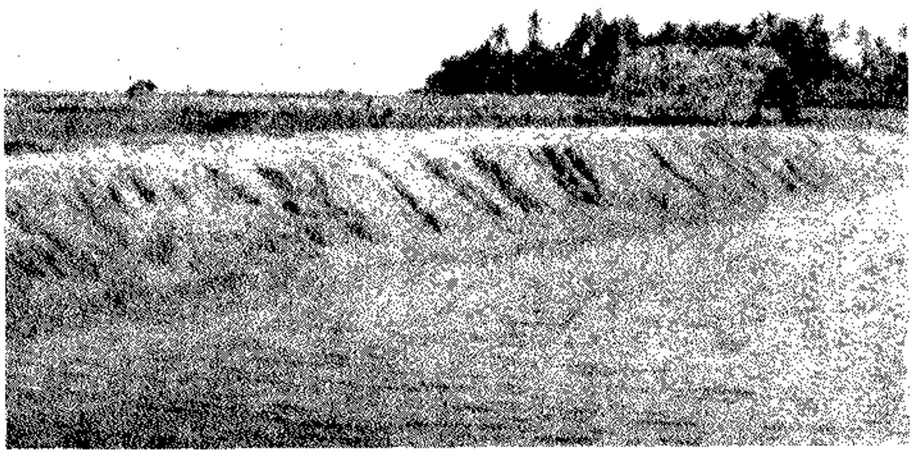

FIG. 3. Erosion on slopes on a dyke during the N.E. monsoon of 1980

increase in basal width this was reduced to 0.000236 cu m|m in the dyke of 6 : 1. The total volume of earth lost declined from 0.70128 cu m|m in the dyke of 3 : 1 to 0.210236 cu m|m in that of 6 : 1, thus registering a reduction of 70%.

Erosion at Dyke Bases

Since it was shown that the dyke in the proportion of 6 base : 1 height was the most durable, a newly constructed dyke in this proportion was subjected to study the erosion at its base due to wave action. As the wind velocity is the main factor inducing changes in the intensities of wave action, the data on wind velocity were collected from the Meteorology Department at Pamban, for correlation. From the observations made, it was found that up to about 6 km|h of wind velocity, the impact of pond water at dyke bases was negligible for a period of 12 h. But, at higher velocities, the mean depth of erosion was: 3 cm at 7 km|h, 5 cm at 10 km|h, 7.5 cm at 17 km|h, 10 cm at 21 km|h and 15.5 cm at 28 km|h. The volumes of earth eroded per 1 m length of the dyke in each case were: 0.0138, 0.0290, 0.0731, 0.2140 and 0.3906 cu m respectively, all per 12 hours duration. It was obvious that if adequate provisions were not made to arrest wave action of pond water at dyke bases, the dykes would get eroded much more, thus leading to caving in and collapse.

Sand Deposition

A cumulative effect of the erosions during rains is deposition of sand on the pond bottom and the corresponding decrease in pond depth. The deposition could be measured by means of a graduated scale kept planted in a sample pond of 1 m depth, spanning 800 sq m area, with dykes in the ratio of 6 : 1. The volume of sand deposited was 520 cu m|ha|3 months, in 21 cm of rainfall during the N.E. monsoon of 1980.

Seepage

The seawater supply to the ponds being effected by mechanical pumping, the volume of water lost from the ponds through seepage could easily be estimated from the difference between the initial depth of water after pumping and the depth after a fixed duration, allowing a nominal margin for evaporation. In a newly excavated pond of 30 x 15 x 1 m with unlined dykes in the ratio of 4 : 1 that was excavated about 200 m inside the coast, seepage was 900 cu m|ha|1h. In another newly excavated pond of 60 x 40 x 1 m keeping the same ratio for dykes, but lined with polyethylene sheets on slopes and not at the bottom, seepage varied from 190 to 280 cu m|ha|1h. Comparing the results, it is obvious that, in the newly excavated ponds, lateral seepage accounts for about 70 to 90% and vertical seepage about 10 to 30%.

Minimising the Problems

For the Durability of Dykes

As seen earlier, a dyke structure of 6 m base and 1 m height has undergone least damage. Such a dyke when lined with turf blocks on slopes has undergone negligible erosion, indicating that for durability of dykes at Mandapam one easy way is to construct them in the above proportion. Further, with a view to preventing pond water from eroding dyke bases, a narrow strip of the original ground was left as it was at the time of excavation all along the

Table 1. *Erosions undergone by dykes in four ratios of Structural Work during October-December*, 1980.

Ratios of dykes, base: height (m)	3 : 1	4 : 1	5 : 1	6 : 1
Volume of earth before rainfall (cu m|1 m length)	2.3	2.8	3.3	4.05
Reduction in height after 21 cm rainfall (cm)	30	21	12	5
Volume of earth eroded from crests (cu m|m length)	0.70	0.59	0.40	0.21
Volume of earth eroded from slopes (cu m|m length)	0.00128	0.000587	0.000499	0.000236
Total volume of earth lost (cu m|m length)	0.70128	0.590587	0.400499	0.210236
Percentage of reduction in total loss from the dyke of 3 base : 1 height		16	43	70
Remarks	Collapsed after 69 days	Collapsed after 121 days	In good shape after one year	

inner edges of the ponds, as may be seen from Fig. 4. At the same time, the dykes were also reinforced along their middle portions with cores of hard earth taken from the surface of the area at which the pond was excavated. Six ponds

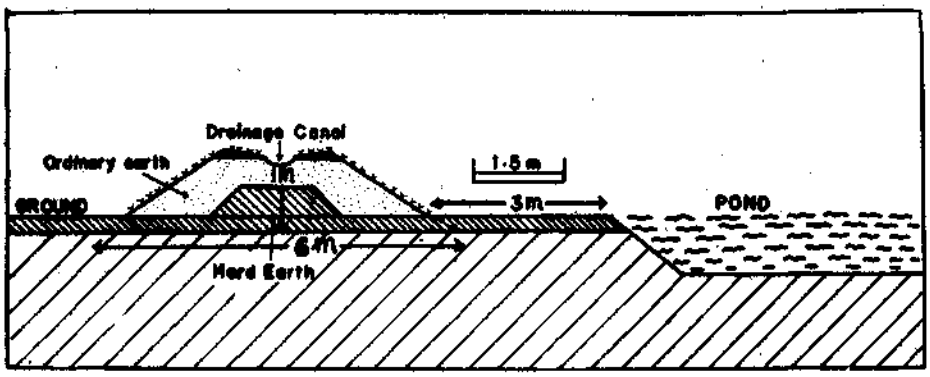

FIG. 4. Structural design of a dyke. (Note the strip of the original ground along the margin of the pond.)

TABLE 2. *Experiments on ponds constructed with a strip of original ground unexcavated on inner sides.*

Area of Pond (m²)	504	813	600	293	690	266
Excavated depth (m)	0.7	1.0	0.9	1.0	0.9	0 9
Water depth (m)	0.3-1.2	0.5-1.2	0.5-1.2	0.3-1.0	0.3-1.0	0.3-1.0
Initial mean width of the strip (m)	3.0	2.0	2.0	1.5	1.5	1.0
Mean width of strip after 2 years (m)	2.5	1.2	1.1	1.1	0.9	0.6
Initial mean height of the strip (m)	0.7	0.9	0.9	1.0	0.9	0.9
Mean height of strip after 2 years (m)	0.5	0.8	0.4	0.8	0.8	0.9

were constructed under this design (Fig. 1: D, E, H, I, J and K), but with four widths for the strips, viz, 3 m, 2 m, 1.5 m and 1 m, as given in Table 2. Observations during 1981-82 showed that erosion of the strips ranged between 0.1 m and 0.2 m height and 0.5 m and 0.9 m width. All the same, the dyke bases remained unaffected on all the sides all through the year.

For Protection of Dyke Slopes and Bases

For protecting slopes and bases of dykes from erosion, five experiments were conducted with inexpensive linings, namely, turf blocks, palmyrah leaves with stalks, coconut leaf thatches, palmyrah leaf stalks, and bamboo mats. Turf blocks measuring 20-25 cm length and width and 7-10 cm thickness were brought from a nearby meadow. At dyke bases the blocks were laid 5 to 8 layers deep and rammed into a pitch. On dyke slopes the blocks were spread evenly in a single layer. In the case of dried palmyrah leaves and coconut thatches these were laid at the bases and slopes of dykes and fixed firmly with coir ropes fastened to pegs. For lining with the bamboo mats, the mats were mounted on bamboo frames and were laid to cover the bases and slopes. Lining with dried palmyrah leaf stalks was given by driving the stalks partly into the substratum and then covering the slopes and bases by the exposed portions. The stalks were held in position with the aid of wires.

Results of the experiments are given in Table 3. In the experiment with turf blocks durability of the dykes was more than 37 months. After 37 months, covering three N.E. monsoons, all the grass growing on the lower half of the slopes (which were fully in contact with seawater) and 20% of those growing on the upper half (partly in contact with seawater) perished. Nevertheless, the slopes and bases continued to be stable and firm for more than five years. The palmyrah leaf stalks had a maximum durability of 31 months, also covering three monsoons. After this period, the leaf stalks decayed all on a sudden. Palmyrah leaves lasted for a maximum of 30 months, with decay setting in after 18 months. Coconut thatches and bamboo mats lasted for 29 and 15 months, respectively.

Countering Adverse Effects of Rains on Crests

For preventing the damages due to rain on dyke crests, the step taken was turfing. On the crests where drainage was desirable turfing was done up to the edges, leaving a strip of 30-50 cm width and 7-10 cm depth in the middle (Fig. 5). For drainage of water from crests, grooves were provided at strategic locations. The grooves, measuring 25-30 cm wide and 7-10 cm deep, were lined with turf. After these preventive steps, rains, during N.E. monsoons of 1980, 1981 and 1982, amounting to 21, 50 and 88 cm, respectively, did not cause any erosion or damage to the dykes. But, at the same time, the dykes which were not given this protection have undergone considerable erosion and damage.

TABLE 3. *Experiments on lining the slopes and bases of dykes during* 1980-83.

Length (m)	40	40	40	40	20
Width (m)	20	20	20	20	20
Depth (m)	1	1	1	1	1
Water depth (m)	0.6-1.0	0.3-1.0	0.1-1.0	0.3-1.0	0.2-1.0
Lining on slopes and bases	Turf and pitching at bases	Palmyrah leaves	Coconut thatches	Bamboo mats	Palmyrah petioles
Date of lining	Feb 80	Mar 80	Apr 80	Oct 80	Aug 80
Durability without decay (months)	37	18	15	10	28
Durability with part decay (months)	37*	30	29	23	31
Standardised cost for a pond of 40 x 20 x 1 m (Rupees)	1,284	2,235	1,710	2,792	2,842

* In April, 1985, even after a period of five years, the slopes and bases have remained.

Propagation of Earth-Binding Grasses

Since propagation of earth-binding grasses is an inexpensive method for protecting dykes, the different species of grasses available at Mandapam were incidentally experimented with for their propagation potentialities. One species, locally called *"Karatti Pul"* (*Chloris* sp.), is partly salt-resistant and the most flourishing grass in the locality, constituting about 70% of the grass population. Transplantation experiments showed that, though this grass may naturally grow throughout the year except during the summer months of April-July, its ideal period of growth is the monsoon season. Another species called *"Arugam Pul"* (*Cynodon* sp.) is equally good but is scarce in Mandapam (5%). A third species *"Korai Pul"* (*Cyperus* sp.), although available (constituting 20% of the population), needs freshwater for survival.

To find out the rate of propagation of *Chloris*, the choice grass, in relation to the rains at Mandapam, turf blocks containing the species were transplanted on a 42-sq-m ground bereft of grass. After the first monsoon rains of

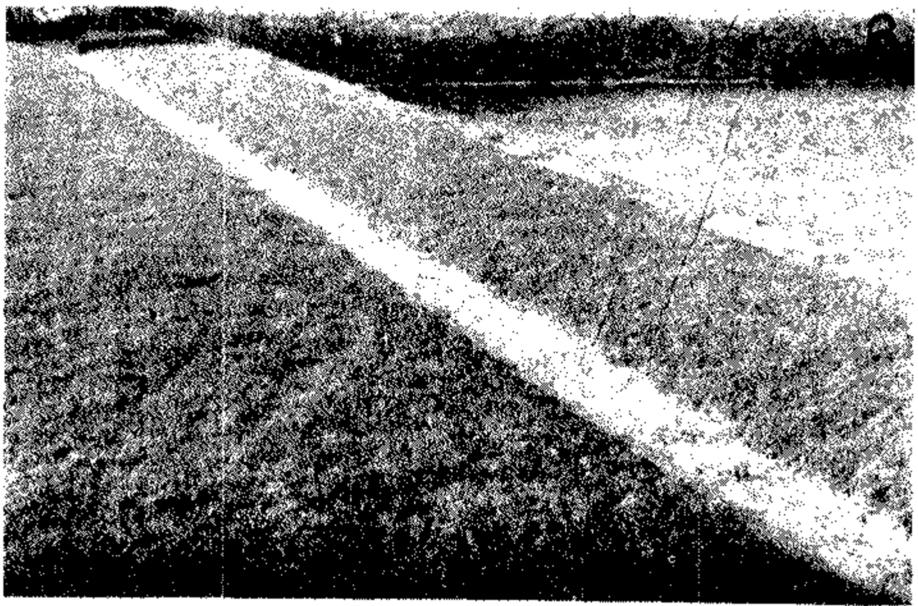

FIG. 5. Above: A portion of the crest with grass turfing on both margins and a drainage channel in the middle. Below: Flow-out channels on slopes at strategic points.

1980, the grass spread over 20% of the area. After the rains of 1981 and 1982, additional spreads of 25% each of the area were observed. Thus, in terms of availability, acclimatization and growth, *Chloris* was found to be the apt species for turfing.

Seepage Control

As it has been mentioned above, the soil conditions in Mandapam are such that, in a newly excavated pond, the seepage is apt to be major problem. But leaving the dykes and the pond bottom undisturbed for about six months prior to the actual utilization a reduction in seepage to about 75% is found possible. Kraatz (1977) had pointed out that seepage decreases with age, because the earth compacted by itself during this period, especially when it consists mainly of clay and silt, is liable to become sufficiently waterproof.

In my studies it was found that the bottom of a pond, when left undisturbed for about six months, underwent accretion of sand to about 15-20 cm thickness (Fig. 6). The reduction in seepage after the ageing was apparently due to this factor. Besides, a comparison of the rates of seepage in a pond provided with lining and in another pond without lining showed that there was a mean reduction of 96% seepage in the former compared to the latter.

Control of Sand Deposition

Measuring the sand deposition after protecting the ponds with linings, during 1980 it was found that the amount of sand deposited was only about

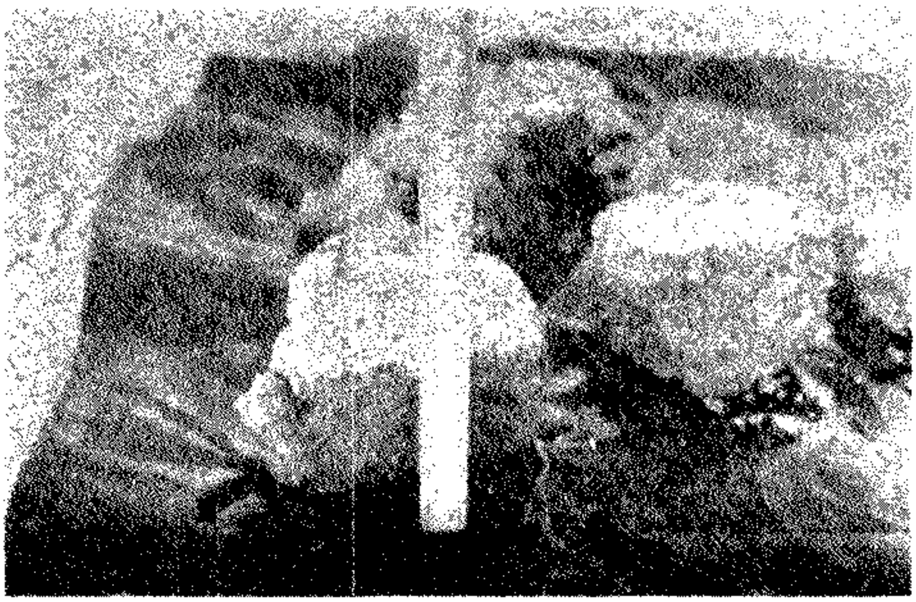

FIG. 6. Part of the pond bottom excavated showing the accretion of sand due to compaction.

150 cu m|ha|3 months in the face of 21 cm rainfall. This was about 85% reduction compared to the sand deposited in a pond without lining. Thus, for reducing sand deposition, too, lining of the ponds is helpful.

A Sluice for Flowing Water

For flowing water to ponds, a culvert type of sluice was designed (Fig. 7) and constructed experimentally between ponds "G" and "J" (Fig. 1). Since water flow has to be controlled and undesirable organisms have to be prevented from entry into the flow-in pond at the outset, provisions were made for operating a shutter and for filtering the water. The sluice consisted of a hume pipe of 0.3 m diameter provided with R.C.C. collars at both ends (Fig. 8) and placed above concrete supports. In the flow-in pond a concrete structure of 1.25 m length, 1 m width and 0.75 m height was constructed with two sets of grooves for operating a shutter and|or mesh screen. Since meshes could be tied around both ends of the hume pipe and mesh screens could go in the grooves, filtration of undesirable organisms could be effectively accomplished.

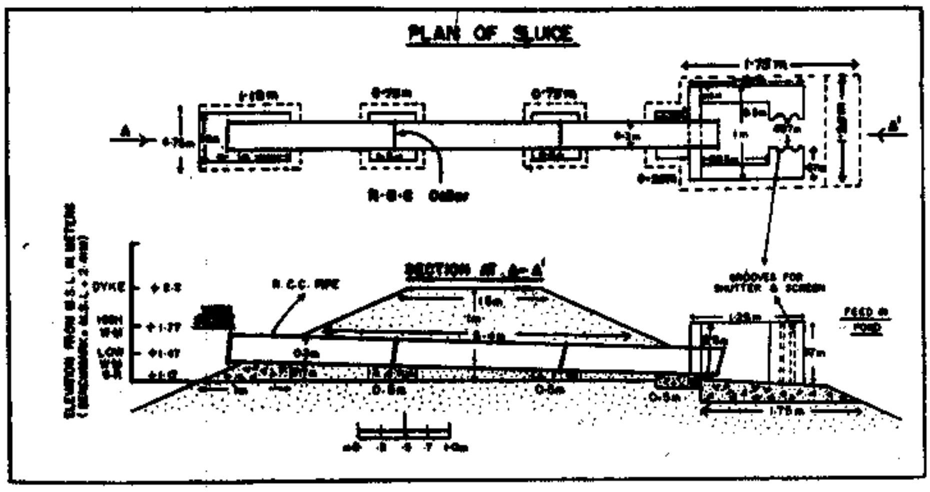

FIG. 7. Structural details of the cluice constructed.

Remarks

The dykes of ponds built by Thampi in late fifties (Thampi 1960) were provided with coral stone pitchings at bases resting on a tow wall and with turfing on slopes. Protecting the slopes and bases this way is essentially similar in idea to protecting them with turfs in the present case. The salient feature of dykes described by Jhingran et al (1972) is the provision of a puddle core wall. Pillai (1962), while giving an account of the construction methods of ponds in southeast Asia, mentions that there should be at least 1.25 to 1.75 m base for every 1 m rise of the dyke. But this was in regard to a locality where the earth

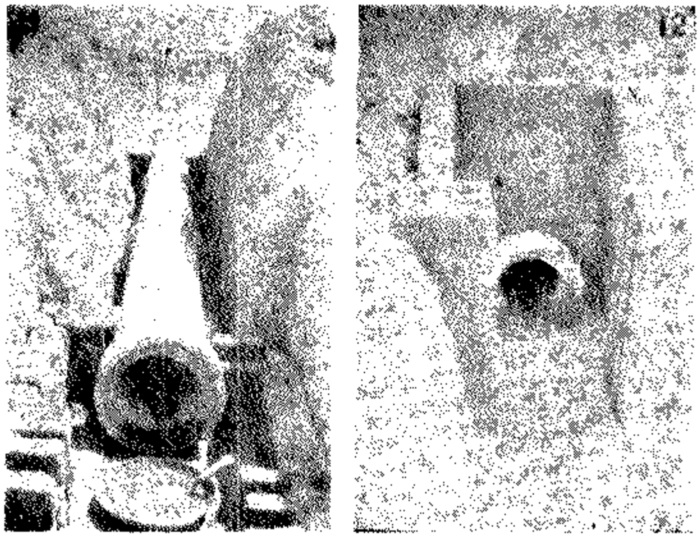

FIG. 8. Left: Construction of sluice under progress; Right: The gooves for operating the shutter or screen.

consisted of mainly clay which is cohesive and hence dykes constructed out of it in such proportions are easily durable. In Mandapam, on the other hand, because of the highly incohesive nature of the soil, a base of about 6 m for every 1 m height is a necessity.

Bardach et al (1972) mention a few methods for maintaining slopes, such as granite pitching, asbestos sheet lining, etc. Chen (1976) suggests lining with bricks over the soil. Apparently, such methods are more expensive than lining with turf.

For controlling seepage, of the methods employed, such as application of bentonite, sodium polyphosphate, etc. (Bardach et al 1972), none is cheaper and more suited to the conditions of Mandapam than the ageing of pond bottom and lining of slopes and bases.

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