CHAPTER 50

SHORELINE ADVANCEMENT BY SEA WALL AND GROYNES AT COCHIN

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1. INTRODUCTION

In the paper "Some coastal engineering problems in India" presented at the VIth Conference on Coastal Engineering, a mention has been made about experimental protective measures consisting of one mile long sea wall and groynes adopted for giving protection to the coast near Cochin. The protective works mentioned in the above paper are now in operation for the last five years. As there are no major rivers there is very little littoral drift along this coast. The material eroded from the coast forms the main source of littoral transport.

The data regarding high water and low water marks along the coast have been recorded, and statistically analysed to assess the efficiency of these measures in respect of shoreline advancement. Results are discussed in the paper.

Some experiments have also been carried out in the prototype for a sea wall with bituminous grouting. Behaviour of this type of sea wall has also been discussed in the paper.

Since the construction of the experimental measures, protective measures in the shape of either sea wall or sea walls with groynes have been further extended to a 10 mile long reach of the coast. The results of these new works, experiments carried out in a model for evolving the design of protective measures and model limitations have also been included. Fig. 1 shows the plan of the sea wall and groynes in one mile experimental reach.

2. ANALYSIS OF DATA

Since December 1955, among other observations, high water (HW) and low water (LW) distances have been recorded from a fixed base line along the protected coast, at three positions, viz - centre, north and south extremities of each of the nine compartments formed by ten groynes.

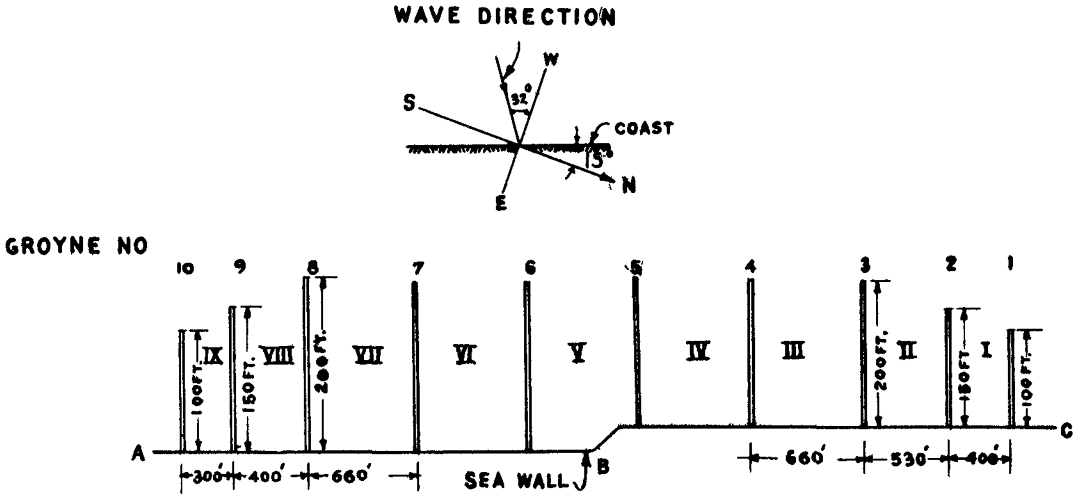

Fig. 1. Plan of sea wall and groynes in a one mile experimental reach; portion A B is masonry wall over sand core and A C is rubble mound sea wall.

Monthly averages of LW and HW distances in each compartment have been first computed. Fig. 2a shows a plot of LW-distance averages and indicates the rising trend particularly in compartments II to VII. Similar tendencies are also observed for the HW-distance averages though to a lesser extent (Fig. 2b). During the months of May to August the sea is generally rough. It is interesting to note that there is an appreciable tendency of recession during these months. In order to draw conclusions about long term trends liberated from usual tidal and seasonal variation features, namely, effect of semi-diurnal, diurnal and semi-lunational tides, effects of monsoon and fair weather water edge distances corresponding to only the fortnightly lowest LW or highest HW levels were selected.

The twelve monthly averages obtained for the Central locations in all the nine compartments are plotted in Figs. 3a and 3b for LW and HW, respectively. It is interesting to note that compartments IV to IX show relatively more width of sand cover than compartments I to III. Visual examination of these plottings also indicates a slow but unmistaken rising trend of accretion in about all the compartments except compartments VI to IX.

This study also indicates that:

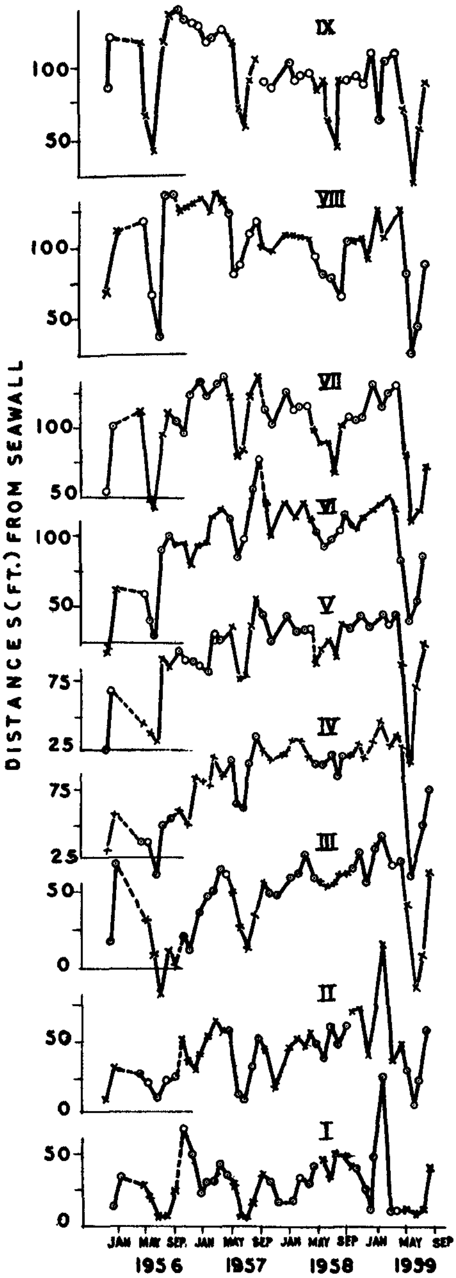

Fig. 2a. Monthly averages for low water levels of 1 ft. above L. W.O.S.T.

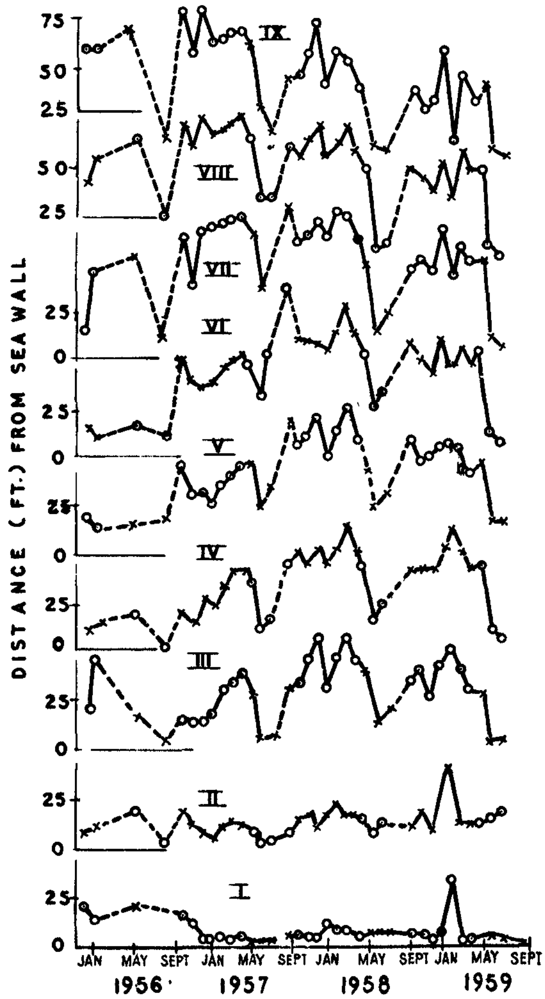

Fig. 2b. Monthly averages for high water levels of 3 ft. above L.W.O.S.T.

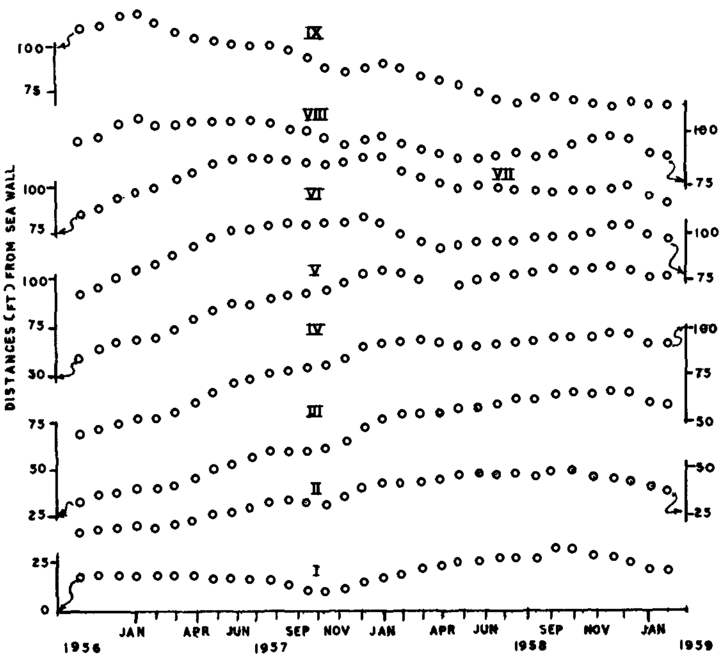

Fig. 3(a). Moving average distances (centre) for lowest low water level.

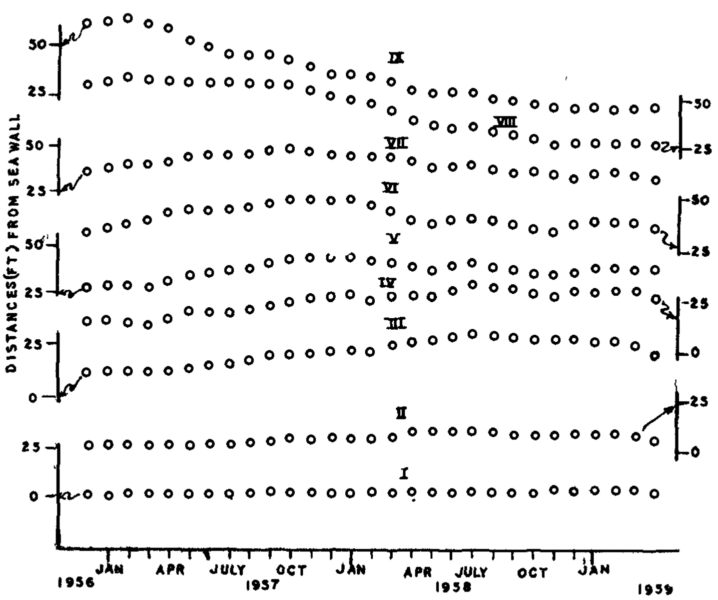

Fig. 3b. Moving average distances (center) for highest high water level.

Fig. 4. Damage to sea wall constructed with bituminous grouting.

Fig. 5. Recession of the coast with sea wall alone.

Fig. 6. Accretion taking place in the groyne field. Notice also the damage to the sea wall.

Fig. 7. Groyne being constructed with coconut piles.

(i) The total distances, by which the sea receded over different periods in different compartments, vary considerably due to the small amount of fresh bed material available to fill the eroded coast. The effect has been particularly small in compartments I and II.

(ii) The low water line in compartments I to V has been receding rather slowly. The reverse trend noticed in compartments VI to IX is possibly due to the sea wall in that portion having been constructed with a sand core. The stretch of this sea wall has been damaged by wave attack during storms which probably retarded the accretion process.

(iii) The HW data, on the other hand, do not bear out any steady or similar evidence. Continuing proximity of the HW edge to the sea wall makes vigilance in maintaining the sea wall-groyne structure imperative.

3. DAMAGE TO GROYNE LENGTHS

The seaward ends of the groynes 1 to 5 were reported to have been damaged in June 1957. These groynes settled in lengths of 24, 34, 39, 29 and 25 ft leaving lengths of 76, 116, 161, 171, 175 ft respectively. In January 1960, three years after these observations were made the lengths of the groynes were 75, 95, 160, 165 and 165 ft respectively. In 1957 very little damage was reported for groynes 6 to 10. In January 1960 the groyne 6, 7, and 8 were 170, 160 and 180 ft against 200 ft of their original length; and groynes 9, 10 were 130 and 80 ft against 150 and 100 ft of their original lengths. Groynes 1 to 5 situated on the northern side were damaged more than groynes 6 to 10 situated on the south.

4. SEAWALL WITH BITUMINOUS GROUTING

Experiments were also carried out in the prototype by constructing a sea wall with bituminous grouting. The work was started in March 1959. The inner core of the sea wall was made up of sand with slopes of 3:1 on seaward and landward sides. The top of the sea wall kept at +11 was, thus, 8 ft above the High Spring Tide Level (+3). The sand core was covered by 9" thick dry rubble casing, consisting of stones 4" to 6" in size. The rubble casing was then grouted, with a mixture of 65% sand, 15% cement (by weight), 20% mexphalt (30/40P). The bottom of the sea wall was taken up to - 4 on the seaward side and +4 on the landward side.

Local beach sand was first heated to 350°F. This was added to sand and mixed well. The filler (cement) was then added to the mixture and thoroughly mixed. Remaining quantity of bitumen was also heated to 350°F. It was added and mixed to form a grout of proper workable consistency. When the mixture was at 350°F, it was taken out and poured into crevices of the stones so as to completely fill the full depth of stones. About 2000 pounds of mixture was required for covering an area of 100 sq ft to a depth of 8". The cost of this wall was Rs. 110/- (equivalent to $22) per running foot.

The sea wall could not withstand the wave attack though waves were only 3 to 4 ft in height. It was considerably damaged within a month and a half after its construction. Fig. 4 shows the damaged conditions of the bituminous grouted sea wall. This type of sea wall did not give satisfactory results in this particular case. It has been, therefore, decided not to use such type of construction for the protection of the remaining coast.

5. EXTENSION OF PROTECTIVE MEASURES TO OTHER REACHES

One mile long experimental sea wall with groynes has proved to be effective in giving protection to the coast under erosion. Protective measures are, therefore, being extended to the south of this reach for a lengh of 10 miles. In order to give immediate protection to the coast and due to availability of limited funds sea walls alone are constructed in 8 mile length of the coast. Considerable damage has taken place to these sea walls. Prototype experience has thus clearly shown that without groynes sea walls are ineffective in affording protection to the coast. Figure 5 shows the recession of the coastline with the sea wall alone. In the remaining two mile stretch of the coast, sea walls supplemented with the groynes are constructed. Though some damage has taken place to the sea wall itself, sand has accreted in the groyne field and the conditions are much better than those obtained with sea walls alone (Fig. No. 6). The results with sea walls and groynes have been found encouraging in these reaches also, and 200 ft long groynes are being immediately added to the sea wall.

The cost of rubble groynes has been found to be high and an alternative type of semi-permeable groyne is, therefore, being tested in the prototype. This consists of two rows of coconut piles which are driven to 7 ft below bed level. Space between the piles is being filled with fascines. The results would be available by the end of August 1960. Figure No. 7 shows the semi-permeable groynes under construction.

6. MODEL TESTS

Previous experiments carried out in 1/40 geometrically similar scale model and described in an earlier paper showed that a sea wall alone required considerable maintenance and it was necessary to supplement it with groynes to give adequate protection to the coast.

Short groynes less than 150 ft in length were found unsuitable to give adequate protection. It was realised that along the coast where the quantity of littoral drift was not considerable and was due to the erosion of the coast itself, groyne tops should be sufficiently high so that the bed material intercepted in the groyne field was not lost by passing over groynes.

Further tests were carried out to ascertain the most effective lengths of, and spacing between, the groynes. Rates of maintenance for sea wall with groynes of lengths 150 and 200 ft spaced at 2, 3 and 4 times their lengths have been observed and compared. With spacing of 4 times, the initial maintenance has been considerably higher for 200 ft long groynes than that required for groynes spaced at two to three times the groyne length. Between 150 and 200 ft length of groynes, the maintenance required for 200 ft long groynes was less for groynes spaced at 2 to 3 times the groyne length (Figs. 8 a & 8b). During the course of these experiments, certain modifications in the design of the sea wall and groynes suggested themselves. In face of the considerable maintenance required, it may be asked whether the maintenance rate cannot be reduced by using heavier stones in the construction of the sea wall; or whether, by placing suitably designed piles at the sea wall toe, the sea wall cannot withstand the attack of storms with less damage. It is likely that a disposition of groynes in a form different from what has been adopted in the previous experiments (groynes normal to the sea wall) may give better protection with less damage. To answer these questions a certain number of experiments were performed, results of which are described below.

7. SEA WALL OF HEAVY STONES

All the previous experiments were carried out with stones weighing 225 lbs. In order to reduce the rate of maintenance of a sea wall armoured with stones heavier than those used previously, experiments were carried out with stones of weights corresponding to 1/2 and 1 ton. Sea wall supplemented with groynes 200 ft long and spaced 400 ft apart was constructed. Larger stones were placed on the seaward face of a core which was composed of 85 lbs and 225 lbs stones respectively, in the proportion of 3:1 by weight.

With such a sea wall, rate of maintenance especially in the first critical HW runs was considerably smaller than the corresponding rate for 225 lbs stones (Fig. 8c).

As an experimental measure the functioning of a sea wall, constructed with 1/2 ton and 1 ton stones, i.e. without a hearting of smaller stones was further tested. Rate of maintenance of the sea wall increased due to the effect of suction caused by the receding waves which resulted in removing the material from behind the sea wall. This caused a further sinking of sea wall stones. A well packed hearting besides being

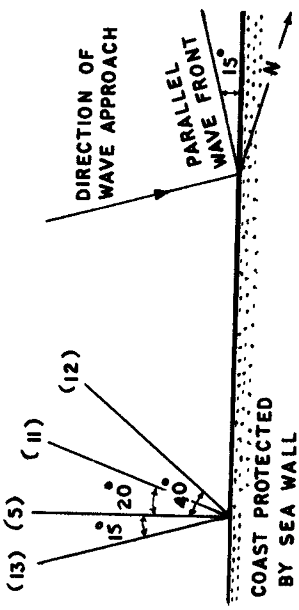

Fig. 9. Groyne directions.

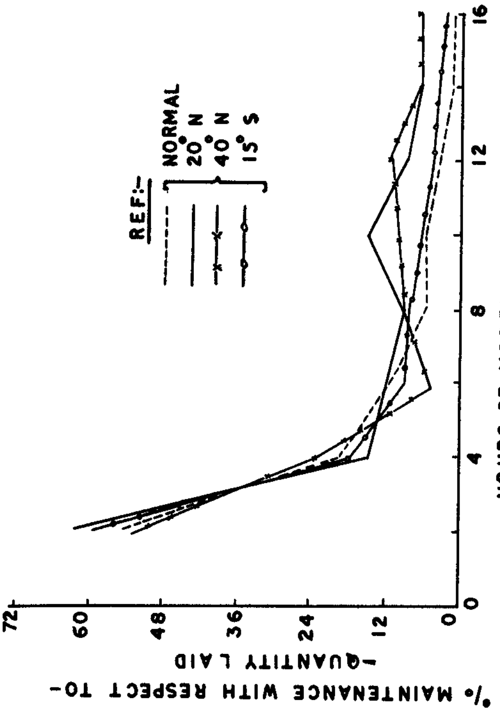

Fig. 10. Comparison of rates of maintenance of seawall supplemented by inclined groynes. Groyne length 200 ft. spacing 600 ft.

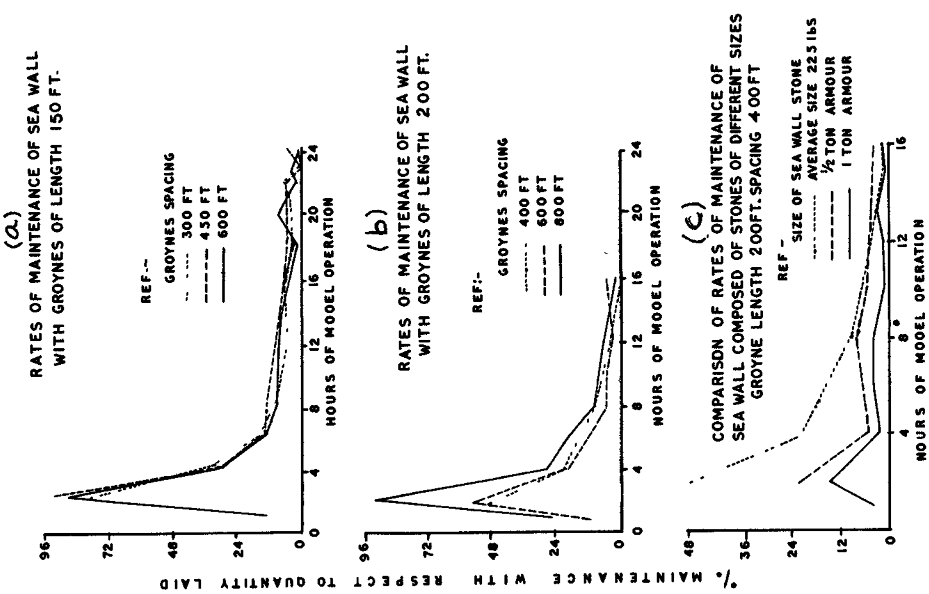

Fig. 8

cheaper avoids this and is therefore necessary.

Reason for the lower rate of maintenance for the sea wall in the case of bigger stones appears to be two-fold: firstly heavier stones are less vulnerable to direct wave action, and secondly, even when the stones are pulled down the sea wall face, they do not lend themselves to littoral transport as easily as do the lighter stones. This comparison apparently of little consequence in the model assumes considerable importance in the prototype, when much bigger stones are required to be used. Economic considerations prevail in such a case. Perhaps it may be cheaper to use smaller stones and replace them in the first two years as maintenance reduces considerably thereafter, once sand cover forms in front of the toe of the sea wall. As use of stones heavier than 500 lbs is precluded in this case because of economic considerations, stones less than 225 lbs in weight have been used for sea wall construction.

8. SEA WALL WITH PILE LINE AT THE TOE

One experiment was performed to ascertain whether sea wall protected by a pile line at the toe effected a reduction in the rate of replenishment of the sea wall. Results, however, showed that during the initial run bed material lying against the seaward face of the pile began to be eroded away speedily, leaving the pile face exposed and unprotected. Experiment did not show any material advantage for sea wall with the pile line at the toe.

9. INCLINED GROYNES

In all the previous experiments groynes were kept normal to the coastline. A series of experiments were performed to verify whether any advantage accrued from inclined groynes. Groynes were placed respectively 20° N, 40°N and 150° S of the perpendicular to the coast protected by a sea wall (Fig. 9). Direction of groynes 15° south was parallel to the direction of waves. Lengths of and spacing between groynes were 200 and 600 ft respectively, and other experimental conditions were identical. Figure 10 shows the respective rates of maintenance of the sea wall for the above inclinations compared with the corresponding rates for groynes, normal to the coastline. Comparison does not indicate any amelioration in the replenishment of the sea wall resulting from inclined groynes in the initial stage. On the contrary there is a tendency for the rate of maintenance to be higher than that with normal groynes in the last stage. Experiments did not also indicate any better performance in the degree of protection afforded to the coast. It appears that on the coastline like the one on the West Coast of India where direction of waves swings from NWW to WSW, perpendicular groynes are likely to give better results.

10. MODEL LIMITATIONS

Before drawing any conclusions, it may not be out of place to restate the limitations of a model study of littoral drift in a problem of coastal erosion. The results of the present series of experiments show that quantities of stone required for the maintenance of the sea wall are considerably greater in the model than in the prototype. The reason for this discrepancy is due to the fact that, during the initial hours of model operation, sea wall stones tend to sink in the model sea bed formed of coarse coal powder, which would not usually happen in the prototype. That such a contingency can, however, occur in nature is proved by the complete and rapid disappearance of some of the lengths of sea wall not supplemented by groynes, within a short time after their construction.

Experience of the behaviour of the experimental sea wall on the prototype showed that considerable damage had taken place to the sea wall in the first year. About 16 per cent of the stones used for the sea wall were lost. The sea wall was repaired in the third year after its construction. Very few stones have since then been lost to the sea. In the model the initial high rate of maintenance of the sea wall diminishes within a few hours of run to only a small fraction; this latter rate remains practically constant throughout the rest of the period of model operation. The initial maintenance rate in the model is however much higher than that observed in the prototype. Figures of damage of experimental sea wall in the last two years after repairs of the sea wall confirm model behaviour in respect of subsequent low maintenance required for the sea wall.

Another limitation of the model investigation is that, whereas in the prototype a coast eroded during the storms gets replenishment in the fair weather season from offshore bars of sand removed during the storms; no such two-way process is possible in model experiments. This shows that the model errs on the safe side in subjecting the protective structure to a considerably greater wave attack than in nature.

11. CONCLUSIONS

(i) Groynes of length 200 ft are to be preferred to groynes of length 150 ft.

(ii) Spacing between groynes should not exceed 3 times the groyne length.

(iii) Heavy stones, used as sea wall armour on a core of smaller stones, result in considerably decreased rate of maintenance.

(iv) Piles at toe of sea wall do not give extra protection to the sea wall.

(v) Inclined groynes do not commend themselves for adoption on this coast.

Along the west coast of India where these groynes are constructed littoral drift is very small as there are no major rivers contributing to the sediment transport by littoral drift. The material eroded by wave action forms the main source of the littoral drift.