MAJOR RECLAMATION SCHEME FOR MARINA CITY, SINGAPORE

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SUMMARY

One of the most ambitious coastal reclamation projects in the Republic of Singapore to reclaim 360 hectares is now in progress and, when completed in 1985 at an estimated cost of S$385 million, will provide a major portion of the lands required for the development of Singapore's new city centre to be known as Marina City. This paper describes the various activities involved in the planning, design and construction of the project.

INTRODUCTION

The island republic of Singapore with a very small land area of only slightly over 600 square kilometres saw rapid industrial and housing development in the early 1960's. This prompted the government to embark upon an intensive reclamation programme to provide new lands to meet the urgent needs.

Following a small pilot scheme reclamation in 1963 the East Coast Reclamation Scheme was launched and the following phases were executed (Figure 1):-

(i) Phase I reclamation of 405 hectares commenced in April 1966 and was completed in April 1970 at a cost of S$45 million. (Unit cost approximately S$11 per sq metre)

(ii) Phase II continued westwards from Phase I to reclaim 53 hectares. Work commenced in April 1970 and was completed in May 1971 at a cost of S$10 million. (Unit cost approximately S$19 per sq metre)

(iii) Phase III to reclaim 67 hectares commenced in March 1971 and was completed in December 1975. The project cost was S$23 million. (Unit cost approximately S$34 per sq metre)

(iv) Phase IV reclaimed 486 hectares from May 1971 to February 1976 at a total project cost of S$44 million. (Unit cost approximately S$9 per sq metre)

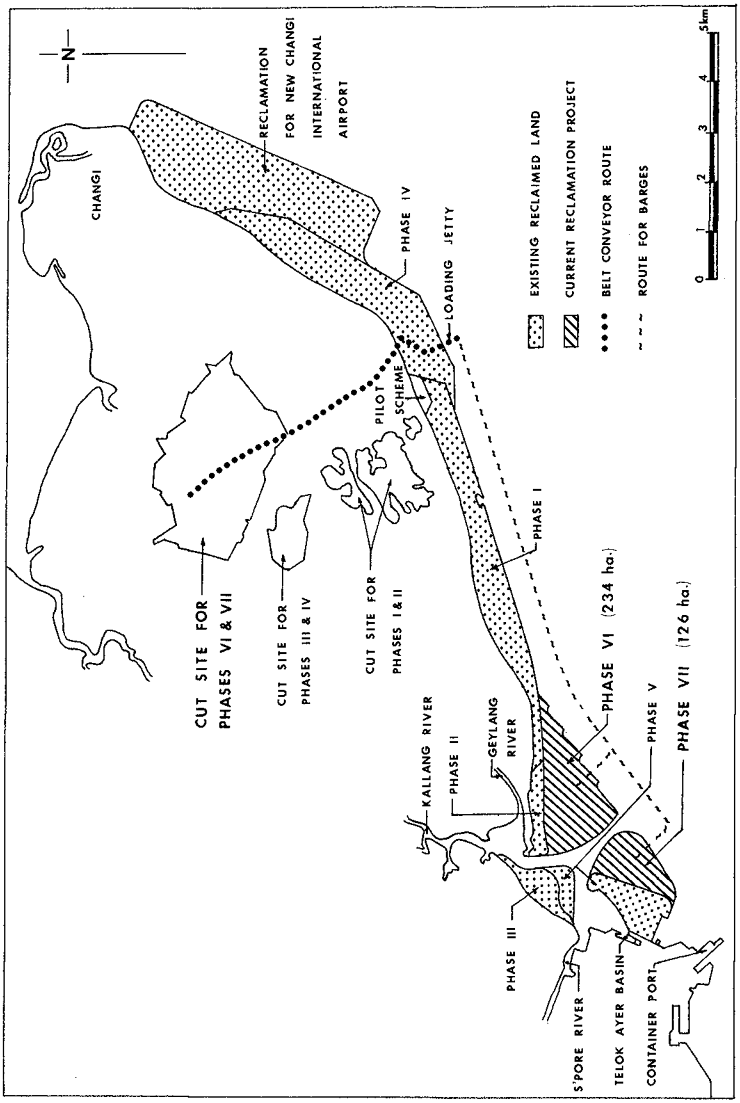

Figure 1 PLAN SHOWING THE LAYOUT OF VARIOUS PHASES OF EAST COAST RECLAMATION SCHEME, SINGAPORE.

(v) Phase V to reclaim 154 hectares commenced in April 1974 and was completed in December 1977 at a total project cost of S$106 million. (Unit cost approximately S$69 per sq metre)

Altogether, between 1966 and 1977 a total of 5 phases were completed, providing 1165 hectares of new land at a total cost of S$228 million. The Housing and Development Board as agent for the Government carried out the planning, design and supervision of construction of these 5 phases of reclamation.

The proposed shifting of the international airport to Changi by 1982 has lifted planning constraints on areas adjacent to the existing city centre which are now under the flight path. Planners and architects were therefore able to plan a city of the future to meet the Republic's needs for the year 2000 and beyond. As a result, the concept of the Marina City was mooted and it became necessary to reclaim more land to meet the requirements of the proposed development. Thus Phases VI and VII of the East Coast Reclamation Scheme were initiated. When completed in 1985 these 2 phases together with some of the lands reclaimed under earlier phases will provide 660 hectares of new land for the Republic's city of the future.

Figures 1 & 2 show some of the main features of the project.

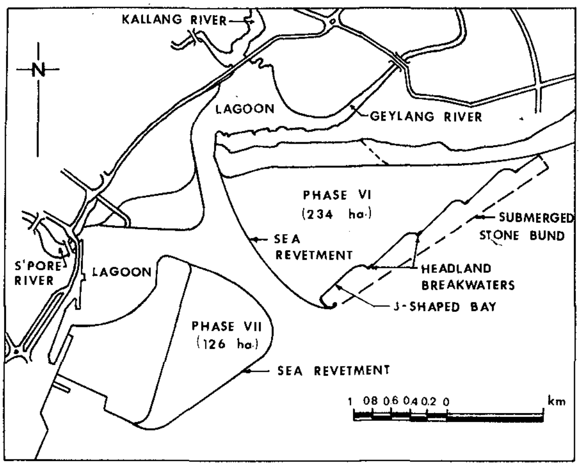

Figure 2 LAYOUT OF EAST COAST RECLAMATION SCHEME PHASES VI & VII

COASTAL PROCESS PARAMETERS

During the implementation of the earlier phases of the East Coast Reclamation Scheme various data such as waves, currents and tides were monitored (1) to enable studies to be carried out on the behaviour of the new coastline (2) as well as to provide information for the planning and design of the new reclamation projects.

From the field investigations it has been established that the southeast coast of Singapore is essentially a low energy coast throughout the year with waves coming from the southeast quadrant and a nett westward littoral drift is present. The area is considered as rather sheltered and winds from the north during the northeast monsoon (December to March) do not have a large influence except through refracted swell from the South China Sea. Higher waves are experienced during the northeast monsoon. Recordings showed a maximum wave height of 1.14 m with a zero-crossing period of 3 seconds and the highest probable maximum wave was 1.37 m.

It was found that the tides are essentially semi-diurnal of a mixed type and the current patterns appear to bear little relationship with the rise and fall of tide. Results of the field measurements also suggest that the tidal current is not a significant factor for distribution and transportation of bed material.

MODEL STUDIES

The data obtained from the investigations just mentioned as well as other data such as peak discharge values, distribution of direct run-off against time and water quality data of several rivers with outlets near the reclamation area were used in subsequent model studies to investigate the following:-

(i) whether the proposed reclamation shapes or modifications thereof would limit the increase of water levels of the lagoons by no more than 5 cm above existing levels after reclamation (taking into account the coinciding of a 5-year flood with the high tide);

(ii) whether adequate flushing of the lagoons would be possible;

(iii) the flow patterns resulting from the proposed reclamation on condition that this should not adversely affect the navigation of vessels leading to the Container Port, smaller craft to Telok Ayer Basin and Kallang Basin and movement of vessels in the general vicinity and

(iv) siltation aspects arising from the proposed shapes of reclamation.

The items (i) to (iv) above were carried out on the Singapore Tidal Model at Pôona (3). Horizontal and vertical scales of 1:700 and 1:120 respectively were used.

It was observed that of the different stages of flow viz. east-going ebb, east-going flood, west-going ebb and west-going flood, with and without freshet discharge, two flow conditions viz. east-going ebb and west-going ebb produced the bad flow conditions. Accordingly results of east-going ebb and west-going ebb when rivers carry their peak freshet discharge are considered.

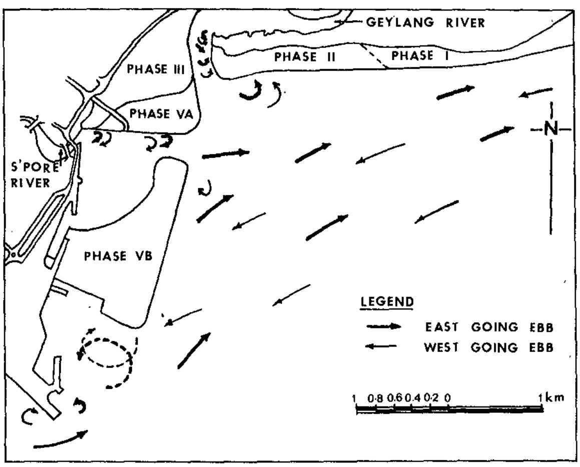

Figure 3 FLOW PATTERN FOR EXISTING CONDITION

Figure 3 shows the flow pattern for existing conditions, ie with the completed Phase V reclamation. Eddies were observed near the entrance to the new basin off the mouth of Singapore River and also near Kallang River mouth and south of Phase II. Eddies were also observed at the east and west of the Container Port for both east-going and west-going flows.

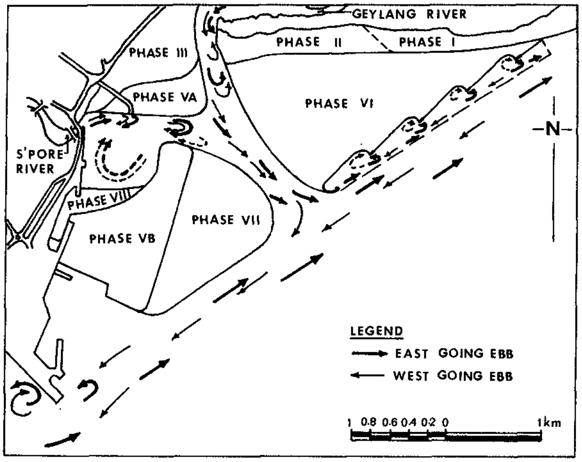

Figure 4 FLOW PATTERN WITH PHASES VI, VII & VIII

Figure 4 shows the flow pattern with Phases VI, VII & VIII. Phase VIII, incidently is not being implemented under the current project. It was observed that the flow pattern along the seaward faces of Phases VI and VII as well as in the channel between Phases VI and VII was good. However eddies were observed near the entrances to the new basin and Kallang Basin during the ebb phase of the tide. Eddies were also formed to the east and west of the Container Port during both east-going and west-going flows. The eddies in front of the Container Port which were observed for existing conditions (Figure 3) were not seen after similating Phases VI, VII & VIII on the model.

With slight modifications introduced to the proposed reclamation profiles the flow pattern improved, as shown in Figure 5.

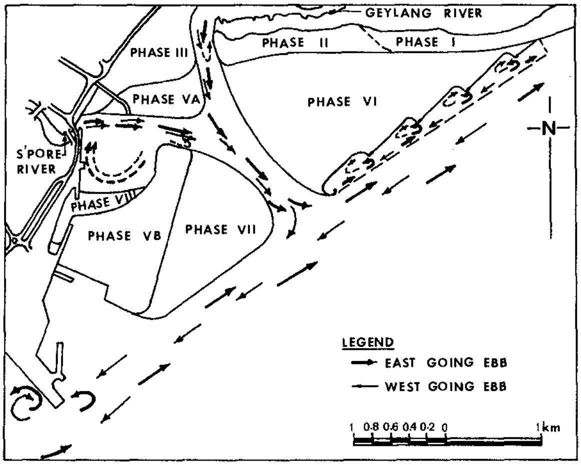

Figure 5 FLOW PATTERN WITH PHASES VI,VII & VIII (with slight modifications)

From float track observation it was found that the average current velocity along the seaward face of Phase VII during east-going ebb was of the order of 0.36 to 0.38 m/sec. while that along the seaward face of Phase VI beyond the submerged stone bund was of the order of 0.42 to 0.47 m/sec. During west-going ebb the average current velocity along the seaward face of Phases VI & VII was of the order of 0.41 m/sec and that in the channel between Phases VI & VII was from 0.35 to 0.40 m/sec. The average current velocity between the submerged stone bund and the J-shaped bays of Phase VI varied from 0.17 to 0.23 m/sec.

It is however not practicable to modify the existing Phase V revetment because it had already been completed and the modification cost would be very high. In any case the flow pattern is no worse than that for the existing conditions, ie without Phases VI & VII.

To study the flushing characteristics of the lagoons, experiments were conducted on the tidal model by injecting fluorescent water soluble dye in the lagoons. A solution of fluorescent dye of known strength representing the pollutant was injected at a known uniform rate in the rivers and its dispersion under tidal activity with and without freshet discharge was studied over a period of 4 consecutive tides. It was observed that the strength of pollutant in the lagoons remained constant. Further experiments were conducted on the model by polluting only the lagoon water by fluorescent dye and its dispersion was studied with and without freshet discharge. It was observed that tidal activity equivalent to a 1-day duration for a tidal range of 3 m without freshet discharges from the rivers provided a dilution ratio of 5.5 in the new basin at Singapore River mouth and 23 in the Kallang Basin. With freshet discharge from rivers dilution ratios of 13.8 and 43.2 respectively were achieved at the end of a period equivalent to 1 day.

Results of the studies can be summarized as follows:-

(i) Rise of water level in the lagoons caused by discharge (5-year flood) of various rivers coinciding with high tide would only be slightly over 3 cm. This was not measured on the tidal model because of the small vertical scale of the model. Instead the result was obtained by computation.

(ii) Flushing characteristics of the lagoons would be satisfactory as indicated by no accumulation of pollutant in the model tests.

(iii) Flow patterns would be satisfactory.

(iv) Siltation characteristics would not change significantly with the construction of the proposed reclamation.

DESIGN OF SEABED STABILIZATION & REVETMENT

Because of the presence of thick soft marine clay strata at the reclamation site it is necessary to carry out seabed stabilization works in the form of dredged and sand filled trench, ie sand key.

Dimensions of sand key and ancillary components of stone bund and sea revetment were obtained by the method of slip circle analysis using the Bishop equation.

With known soil strength parameters obtained from offshore soil investigation and the trial dimensions for a given section as inputs for using a proprietary computer programme (Bishop method) numerous analyses were carried out to obtain a design with a minimum factor of safety of 1.30 against slip failure.

Final design sections adopted have factors of safety slightly over 1.30 and are founded on firm clay layer between upper and lower marine clay strata. An example of the results of one actual slip circle analysis is shown in Figure 6.

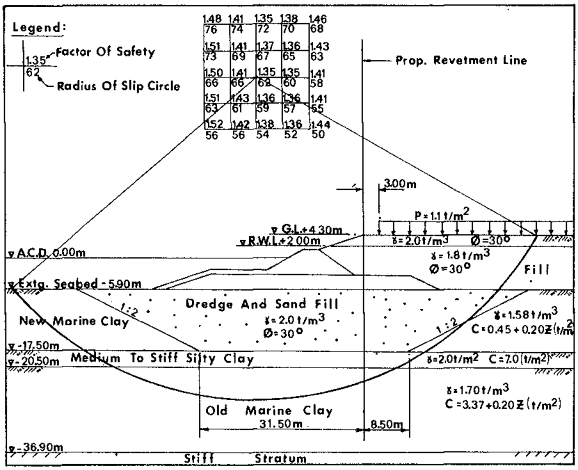

Figure 6 EXAMPLE OF SLIP CIRCLE ANALYSIS

Typical design sections for the stabilization works are shown in Figures 7 & 8.

Details of revetment are designed in accordance with the methods given in the Shore Protection Manual of the U.S. Army Corps of Engineers (4). The design wave height used is 1.7 m (25-year probable maximum height) (2) with a 5-second wave period.

Typical details of revetment are shown in Figure 9.

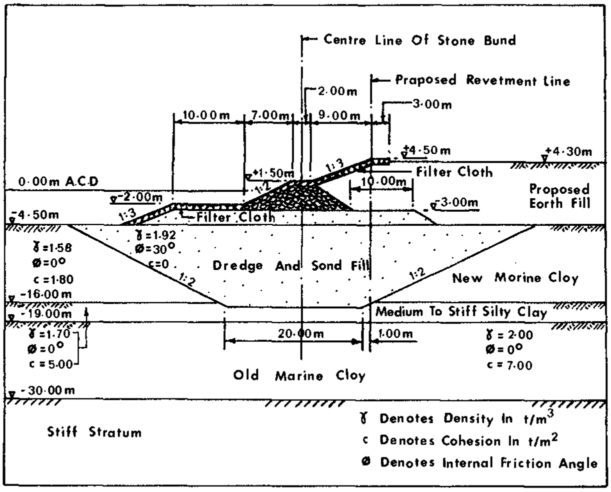

Figure 7 TYPICAL SECTION OF SEA REVETMENT

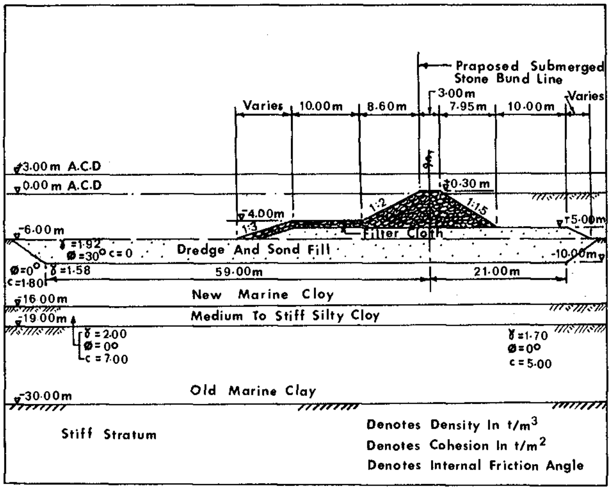

Figure 8 TYPICAL SECTION OF SUBMERGED STONE BUND

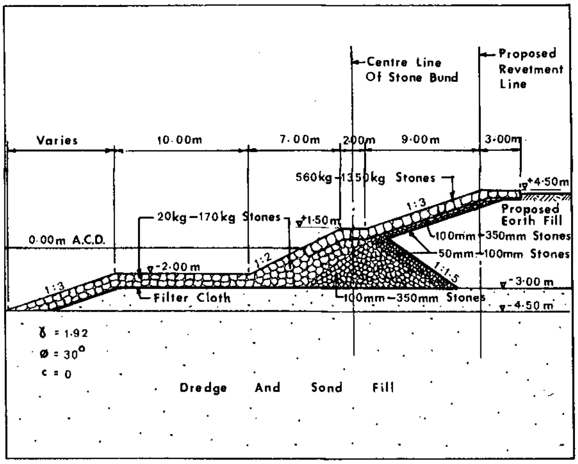

Figure 9 DETAILS OF STONE BUND AND REVETMENT

It can be seen that the sizes of the armouring units of granite blocks are generally somewhat bigger than those required by the design calculations. The reason for this is that the sizes adopted are those normally produced by local granite quarries and it would be uneconomical for contractors to break down the supplied sizes to the calculated sizes.

SHORE PROTECTION

For the whole of Phase VII and the western part of Phase VI shore protection in the form of sea revetment is adopted. However, in order to provide beaches for recreation, the southern edge of Phase VI is designed as an offshore platform with J-shaped bays between rip rap headland breakwaters. This method is based on a new concept (5) of protecting newly reclaimed shoreline by a series of shore-attached headland breakwaters (1), (2) and was first tried out successfully on earlier phases of the East Coast Reclamation further to the east (Plate 1).

Plate 1. Typical J-shaped bay between headland breakwaters (Phase I reclamation).

Plate 2. Bucketwheel Excavator.

EXECUTION OF THE PROJECT

Execution of the current 2 phases of reclamation requires excavation of about 45 million cubic metres of earth from the Cut Site at Tampines (Figure 1). This excavation will pave the way for the development of Tampines New Town which will eventually house 225,000 people.

Excavation is being done by 2 large bucketwheel excavators (Plate 2) and the earth transported about 7 km by belt conveyors to a loading jetty (Plate 3) from which barges are loaded for transportation of the earth by sea over a distance of 12 km to the fill sites. The bucketwheel excavators and the entire conveyor system including the ship loader on the loading jetty are all electrically driven with a total power rating of about 10 MVA. Earthworks by this method has the advantage of very low noise and dust pollution as compared to the conventional method using traxcavators and tipper lorries.

Each bucketwheel excavator has a rated output of about 2,000 tonnes per hour while the conveyor system can handle up to about 5,000 tonnes per hour. Barges of various sizes ranging from 4,000 tonnes to 10,000 tonnes are used for the transporting operation.

The first stage of the construction involved dredging of the trench (Plate 4) for sand key to the design profiles followed by sand filling of the dredged trench. Depths of dredging are in the order of 16 m below A.C.D. (low low water level). A total of 4.5 million cu m and 5.5 million cu m of dredging and sand filling respectively are involved. At the same time the cut site and belt conveyor route preparations were carried out with construction of loading jetty, electrical system, overhead bridges and underpass across existing roads going on simultaneously.

Stone bund (Plate 5) was constructed over the sand filled trench to the design levels followed by temporary works of silt barricade. Two types of silt barricade, one using stone-filled gabions and the other using a floating screen are used to limit siltation in the adjacent port waters. Once a substantial portion of stone bund and silt barricade was completed the reclamation filling commenced, the timing being such that by then the cut site and conveyor system operations were ready.

Excavating, transporting and filling is now being carried out round-the-clock. At present about 60,000 tonnes per day are being executed. Initially direct dumping of fill material is possible until draught limitation necessitates unloading of the barges by reclaimer (Plate 6) and conveyor system on the newly reclaimed land.

Plate 3. Loading of fill material from the belt conveyor onto barges.

Plate 4. Dredging for sand key.

Plate 5. Stone bund at Phase VII reclamation site.

Plate 6. Reclaimer unloading fill material from barge into the sea to form reclaimed land.

The average median size of fill material from the cut site is 0.2 mm. After sorting by wave action it is expected that the average median size at mid-tide level will vary from 0.7 mm to 2 mm based on the results obtained in the earlier phases of reclamation(2).

Filling, grading and compaction to the final levels will be carried out by a combination of conveyor system and conventional equipment. The standard of compaction specified is a minimum dry density of 90% Modified AASHO Density at a level of 1 m below the finished level.

Other items of work such as construction of outlet drains, sea revetment, headlands and landscaping will form the last activities of the project.

CONCLUSION

The current Phases VI & VII of the East Coast Reclamation Scheme is one of the most prestigious and challenging projects ever carried out in Singapore.

Based on the current rate of progress it is anticipated that the Phase VII part of the reclamation will be completed by 1982 while the Phase VI part will be completed by 1984.

By early 1985 Singapore will have another 360 hectares of land on which will be built its city of the future.

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