USE OF FIBREDRAIN IN DREDGED CLAY RECLAMATION PROJECT

S. L. LEE, K. Y. YONG
Department of Civil Engineering
National University of Singapore

A R SOEHOED
P T Puri Fadjar Mandiri, Jakarta

ABSTRACT

Land was reclaimed at the waterfront in the Pluit area of Jakarta for a 90ha residential-cum-recreational development. The reclamation works involve construction of permanent and temporary dykes, fill placement, soil improvement, dredging of internal canals and marina, and construction of canal revetment. The site lies on 16m to 18m thick soft seabed deposits. Settlement of the reclaimed areas will result as a consequence of consolidation of the soft underlying sediments. In order to reduce post-construction settlement to within acceptable levels, a system of vertical drains and preloading was adopted. This paper describes the use of Fibredrain, a prefabricated vertical drain made of jute and coir fibres developed at the National University of Singapore, in the soil improvement works and a secondary use in the construction of perimeter dykes for the reclamation works. The construction of the perimeter dyke must be carried out in such a way that slope stability is ensured. Bamboo rafts and bamboo clusters with Fibredrain inserted, and stage construction were employed to improve stability during the dyke formation for the Pantai Mutiara project.

INTRODUCTION

Pantai Mutiara, a residential-cum-recreational development, was constructed on land reclaimed at the waterfront in the Pluit area of Jakarta. The project site is located immediately north of metropolitan Jakarta, east of the power station and adjacent to the fishing port development as shown in Fig. 1.

The size of the development is approximately 90ha, extending about 1500m from the old shoreline and spanning a width of 650m to 750m as shown in Fig. 2. The external layout of reclamation is such that flow from existing canals and rivers is not inhibited and that navigational approaches to the fishing port are not affected. The internal layout was designed to ensure a certain degree of tranquility and acceptable flushing characteristics within the marina. Part of the existing site had been reclaimed for approximately 400m from the original shoreline during the period 1979 to 1981. Areas beyond this reclaimed land was reclaimed in three phases to the proposed formation level of El +2.6m (Elevation is with respect to Port Datum zero ACD). The seabed varies from about El 0m at the shoreline to about El -5m at about 1.5 km from the shoreline. Geologically, the site lies on 16m to 18m thick soft deposits and the coastal geomorphology suggests that the area is subjected to deposition of the fine grained sediment transported into the bay during wet seasons (Cameron McNamara, 1986).

Phase IA of the reclamation works consist of filling an area designated as `Block R' (Fig. 2) during the period end 1986 to 1988 where the seabed varies from El 0m to El -1.2m. Phase IB of the reclamation works consist of filling Block S and Block Z using dredged clay where the seabed varies from El -1.5 to El -2.5m. This phase of the works was completed in 1994. Phase II, consisting of Blocks T, U, V, W, X and Y, started in August 1994 and was completed in 1997. In each phase, the sequence of reclamation work involves construction of perimeter dykes, placement of fill, soil improvement comprising vertical drains and surcharge, dredging of internal canals and marine and construction of canal/marina revetment. Temporary dykes were also constructed to allow phase development of the project.

Settlement of the filled areas will result as a consequence of consolidation of the soft underlying sediments. To provide construction stability during fill placement and to minimise post-construction settlement to an acceptable magnitude, a system of vertical drains and

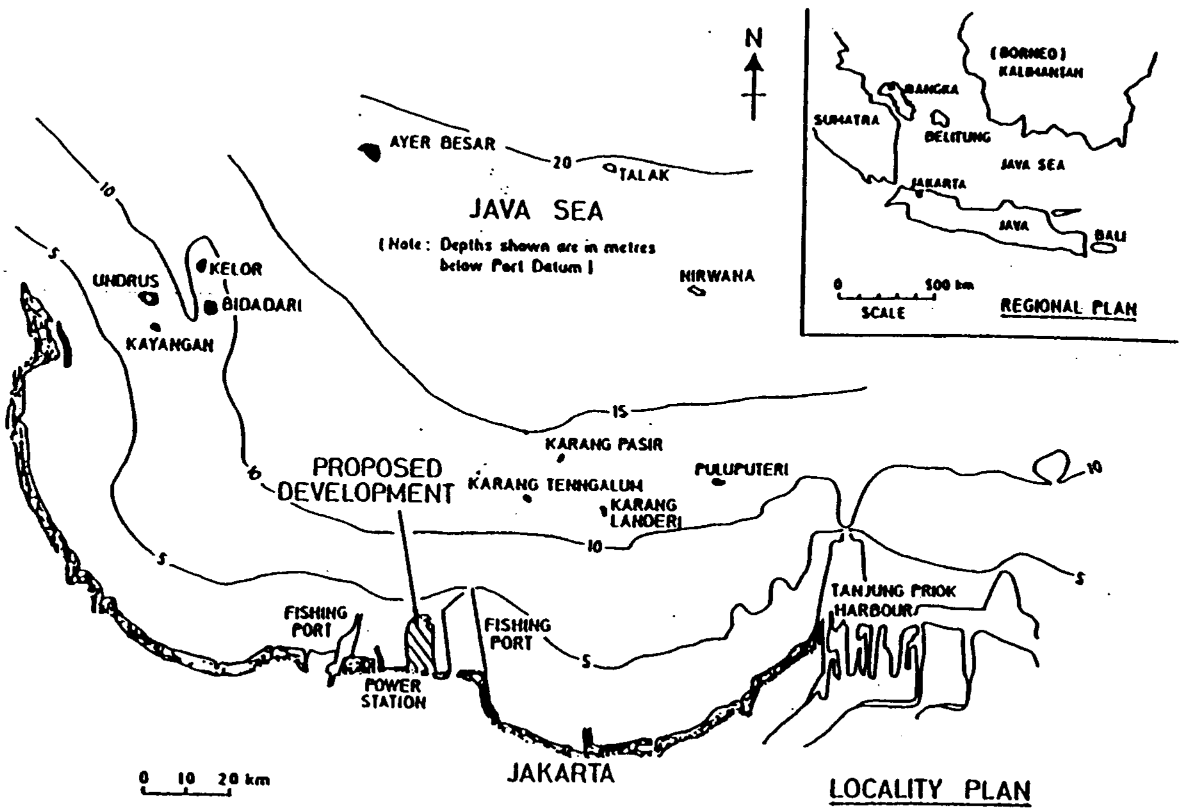


Fig. 1: Location of Pantai Mutiara Waterfront Residential Estate

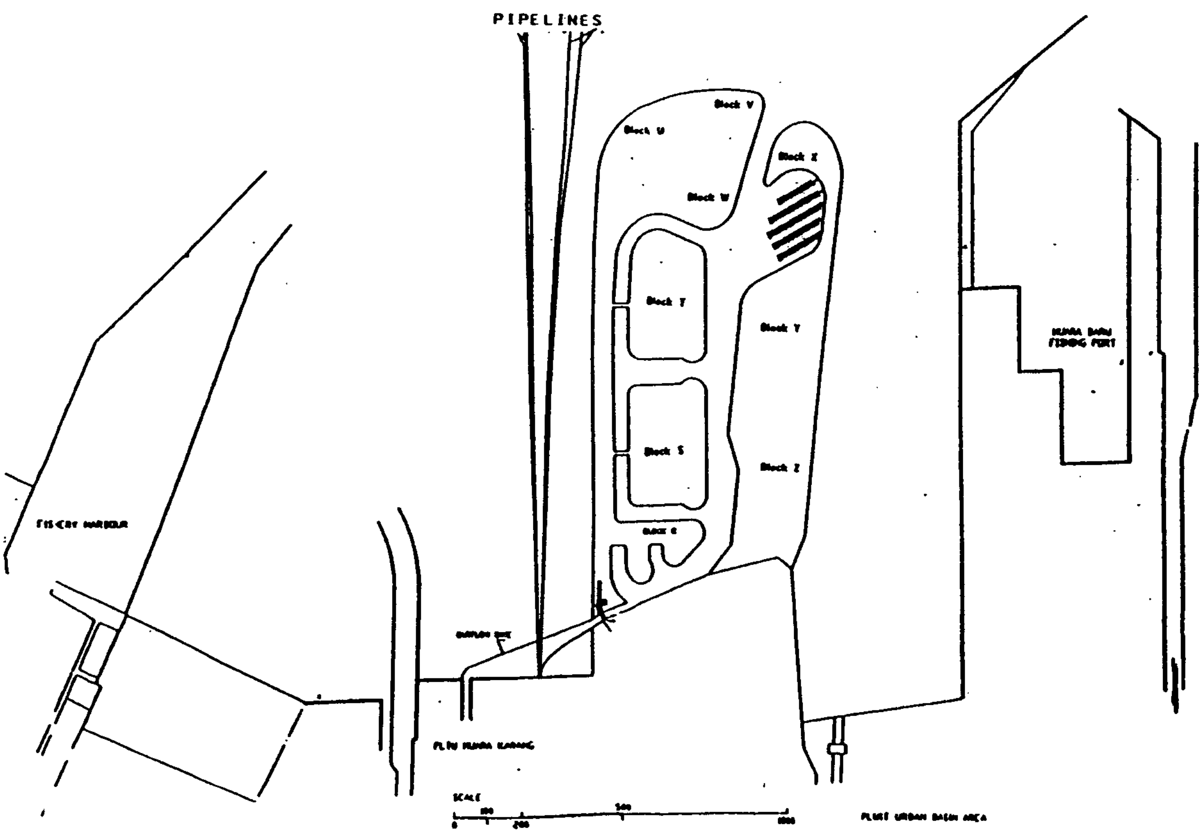


Fig. 2: Layout of Pantai Mutiara Development

preloading was adopted. Drains installed at 1.4m square grid spacing to a depth of about 16m to 18m achieved over 80% consolidation in about 4 months. The drains used were `Fibredrain', an environmentally-friendly drain made up of organic fibres extracted from jute and coir. Details on the development of the Fibredrain are given by Lee et al (1987) and the performance of the Fibredrain in Phase IA of the Pantai Mutiara project was reported in Lee at al (1988).

SOIL CONDITION

A typical soil profile across the north-south direction of proposed development is shown in Fig. 3. The seabed at the site varies from El 0m to El -5m and the proposed formation level is El +2.6m. The site is underlain by a 16m to 18m thick layer of very soft to medium stiff silty clay followed by interbedded layers of silts and sands of dense to very dense consistency and very stiff silty clays.

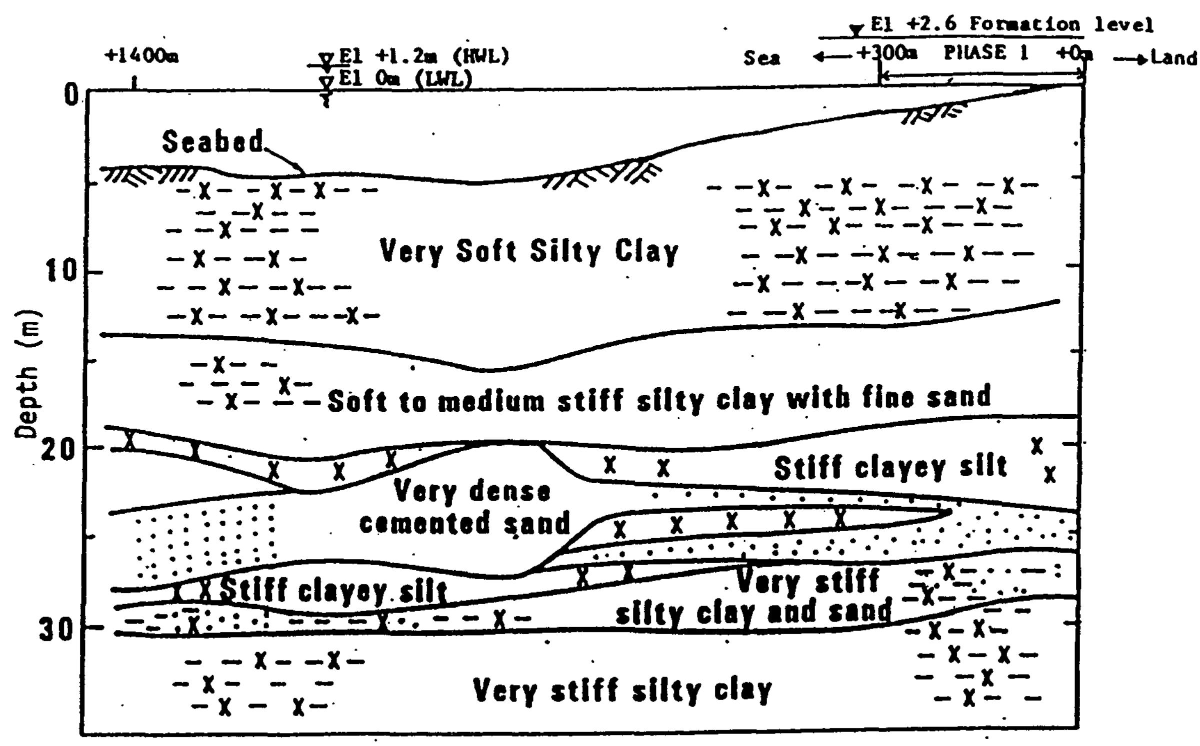


Fig. 3: Typical Soil Profile from Pantai Mutiara Development

The top 12m deposits are highly plastic silts and organic clay with natural water contents varying from 70% to 150%, liquid limit values ranging from 60 to 130 and plasticity indices ranging from 30 to 70. High void ratios of between 1.5 and 3.5 and compression indices, C_c, of between 0.7 and 1.2 were obtained for this very soft silty clay layer. Between El -12m and El -18m, the soft to medium stiff silty clay is relatively less compressible with water content between 50% to 90%, void ratio of about 1.7 and compression index of about 0.5.

The SPT values are zero in the very soft silty clay and increase from about 2 to 15 blows/30 cm in the soft to medium stiff silty clay layer to a value greater than 50 blows/30 cm in the dense to very dense sand/silt strata. The cone resistance rarely exceeds 1 MPa until a depth of 12m is reached (Fig. 4). The reading then increases to about 2 to 3 MPa between 12m and 18m, and exceeds 3 Mpa below 18m depth. The vane shear tests indicate shear strengths increasing from 2 kPa near the seabed to about 14 kPa at 10m depth. Between 12m and 18m depths, the shear strength values vary from 20 to 40 kPa and below 18m depth, the soil was too stiff for vane shear tests to be conducted.

Because of the depositional pattern of the sediments in the flood water and brackish water, most of the silty clay soils are likely to be normally consolidated. This has been confirmed by the preconsolidation pressures obtained from consolidation tests which indicates that the clayey soils are mostly normally consolidated with c/p ratio of about 0.22 to 0.25.

GENERAL RECLAMATION WORKS

The outline of reclamation works is given in Fig. 5. After site preparation works, dykes are constructed to retain the fill materials inside the reclamation areas and provide protection against wave forces. The speed of fill placement with dredged clay should not exceed the speed of construction of permanent perimeter dykes and temporary dykes built-up by sand-bags. The basic reclamation is carried out until the level of fill has reached El +1.60m. On top of the finished base, a sand blanket of about 0.4m to 1.0m thick is placed on the fill to facilitate movement of equipment to install Fibredrain to depths of about 16m to 18m below El +0m. Earth surcharge is placed on the treated area until the required degree of consolidation and gain in shear strength are achieved. At the end of the maintenance period, the reclaimed area is graded to elevation El +2.60m.

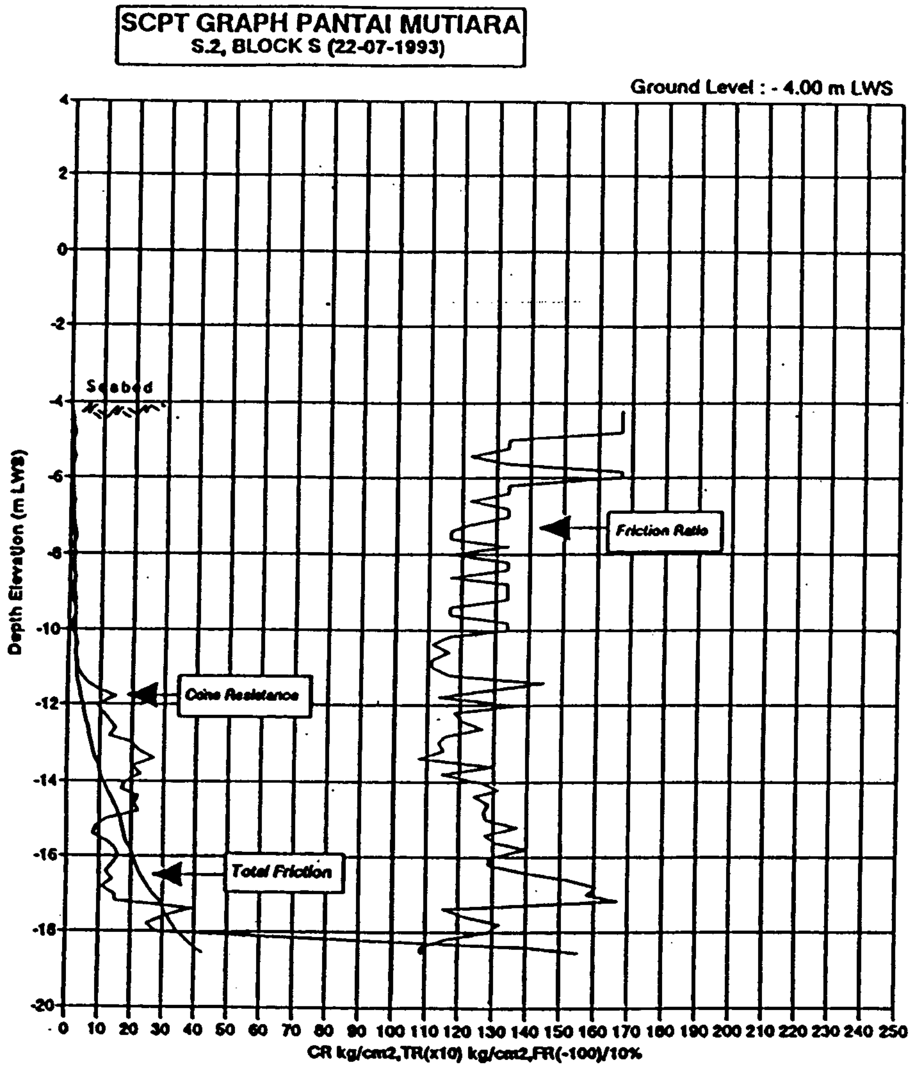


Fig. 4: Typical CPT Measurement

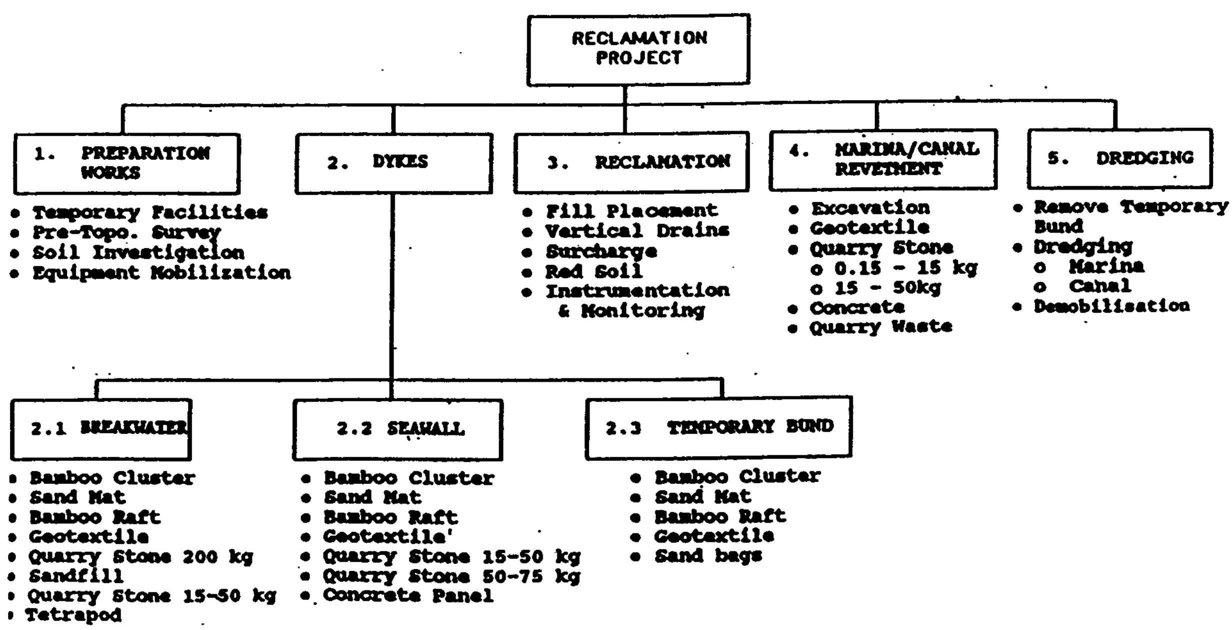


Fig. 5: Scheme of Reclamation Works

In Phase IA, filling was carried out by end dumping and forward placement. The fill material was delivered to the site from sea and land by barge and dump truck respectively. Placement was controlled to minimise disturbance of sediments and creation of mudwaves ahead of the reclamation front. Filling was interrupted by availability of suitable fill materials and took a longer time than expected. In Phase IB, the land was reclaimed hydraulically using dredged clay with organic content not exceeding 4%. Filling work was done in the direction of the open sea, by moving the pipe nozzles gradually forward while filling its designated lanes by fanning the clay slurry. Unwanted fines were flushed out by tidal currents; however, such flushing out of fines should not be extensive as to diminish the purpose and the efficiency of the filling method. This could be effected by constructing small islands of dumped clay in the tidal-current flow to decrease its flushing effect. Phase II was reclaimed by hydraulic sand fill.

USE OF FIBREDRAIN IN DYKE CONSTRUCTION

Sequence of Construction

A typical section of the western breakwater at the seabed level of El -4.5m is shown in Fig. 6. The dyke is designed to retain fill materials inside the reclamation areas and at the same time protect the reclaimed land from wave forces. Prior to construction of the dykes, bamboo clusters consisting of 7 bamboo poles, length of 8m and a diameter of 80 to 100mm, are inserted vertically into the soft seabed at 1.5m spacing with the aid of a floater guide until the top of the clusters are at the seabed. These bamboo clusters have two Fibredrains wrapped around the centre pole of the cluster (Fig. 7). The bamboos are tied together by `ijuk' (jute) ropes and bamboo pins. A bamboo raft comprising 7 layers of bamboo mat is placed on top of the clusters with the aid of a crane mounted on a pontoon. Each bamboo pole has a nominal 1 ton tensile strength.

Sand is then spread over the rafts, filling the rafts up till 0.30m above the top of the raft. In the case of temporary dyke, sand-bags can be put on top of this reinforced raft-sand layer. In the case of permanent dykes, the raft sand layer is covered by a layer of POLYFELT TS700 geotextile before continuing the build-up with graded quarry stone. Two rock mounds comprising 200 kg quarry stone are constructed gradually with slope of 1:1.5. The next stage consists of placing geotextile on the centre portion between the two rock mounds after which sand is placed until the elevation of El -1.0m is reached. After a period of time for the

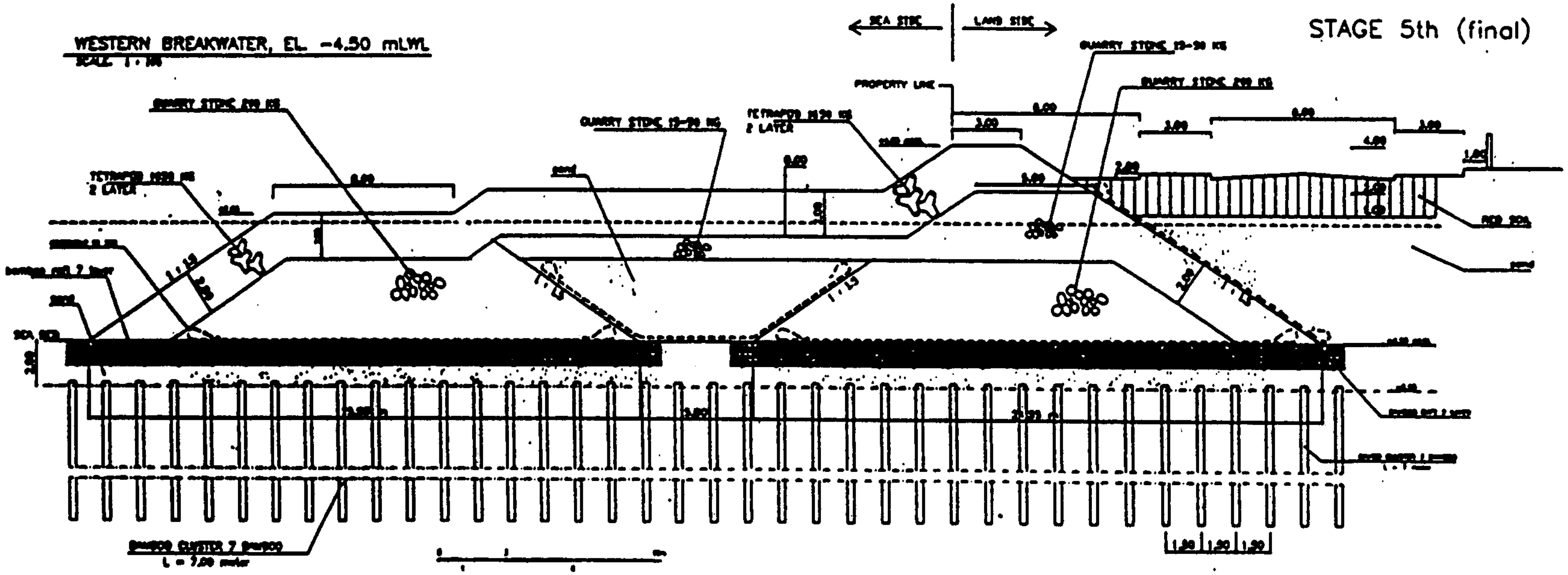
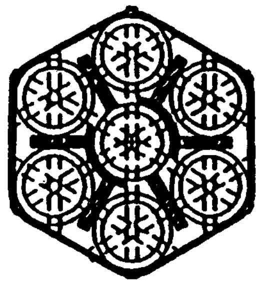


Fig. 6: Cross-section of Dyke (Western Breakwater)
(for Phase II)



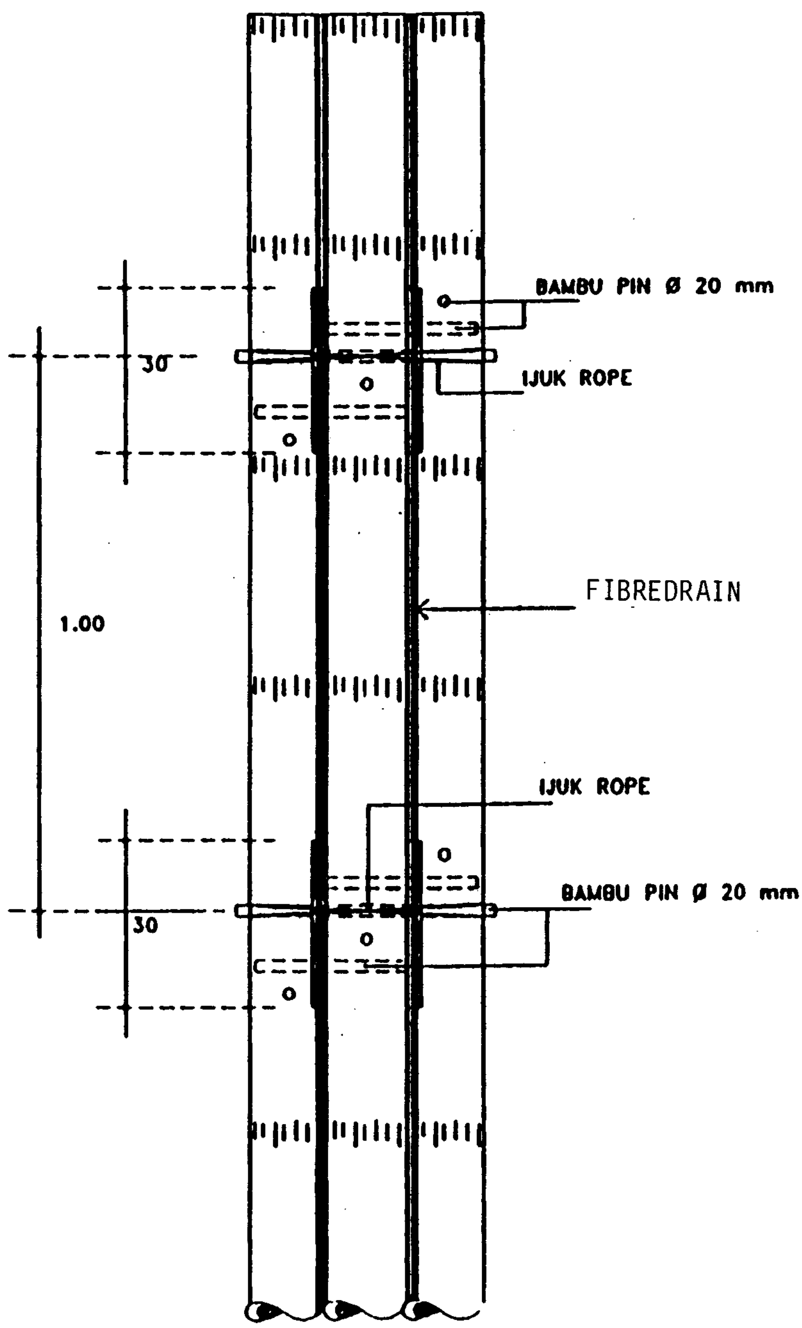


Fig. 7: Details of Bamboo Cluster

underlying soft clay to gain strength from dissipation of excess pore pressure through Fibredrains wrapped in the bamboo clusters, quarry stones of 15 to 50 kg are placed in a configuration shown in Fig. 6. To provide protection against wave forces, a 2m thick layer of precast tetrapods are placed on the external sides of the dyke up to a crest height of El +4.0m. There is a time lapse between each stage to allow the underlying soft clay to gain strength.

Stability of Dyke

During the construction of the dyke, the bamboo raft acts as a tension element underneath the slopes, increasing the dyke stability. The main influence of the bamboo clusters is the increase of the length of a potential rupture surface during the fill operation and the Fibredrain is to accelerate the gain in strength of the underlying soft clay. Stability analysis is carried out for each stage and the minimum factor of safety is 1.10 for a deep-seated failure. This factor of safety will increase gradually with time due to consolidation of the underlying clay layers. The stability of the dyke with the reclamation fill behind it was also analysed and the minimum factor of safety was found to be about 1.20.

Settlement of the Dyke

During the initial stages of construction, the bamboo clusters will support the dyke. At the later stages, the weight of the dyke will exceed the bearing capacities of the bamboo clusters. The latter will subside and the surrounding clay will commence the consolidation process with consequent increase in shear strength. From previous measurements of completed dyke, the settlement is estimated to be in the order of 1.5m to 2.0m.

PERFORMANCE OF FIBREDRAIN IN SOIL IMPROVEMENT

Phase 1A (Block R)

In Phase 1A of the development, more than 350,000m of Fibredrains were installed in 1.4m square spacing to a depth of 16m to 18m over an area of about 4 ha. Degrees of consolidation of 80% and 90% were achieved in about 4 months and 6 months respectively together with a significant increase of shear strength. The high flow rates through the Fibredrain and the rate of ground settlement at different depths observed in the field indicate that the ground responded well to the soil treatment. Filling operations were interrupted by availability of suitable fill materials and the reclamation works stretched to more than 15 months. During this period, field measurements showed that the Fibredrains continued to function effectively.

Details of the performance of Fibredrain for this phase of development have been reported by Lee et al (1988, 1996). This phase of work was completed in 1988.

Phase 1B (Blocks S and Z)

Phase 1B of the reclamation works consist of filling Block S and Block Z. This phase of works which started in January 1992 was completed in October 1994. The sequence of reclamation works are as follows:

Activity	Date Commenced
Clay Filling to +1.6m	31-01-92
Sand Blanket	19-08-92
Red Soil	12-05-93
Fibredrain Installation	03-08-93
Surcharge	01-10-93

A typical sequence with the increase in height of fill with time at Block Z is shown in Fig. 8. Also shown is the settlement of the seabed with time and the significant increase in undrained shear strength at El -6m after installation of Fibredrain and surcharge placement. The general increase in shear strength with time for the depth of soft clay is shown in Fig. 9. In this phase, over 800,000m of Fibredrains were installed in about 20m length.

In certain areas of Block Z, the degree of consolidation was slow, about 50 to 60%, and not according to the expected 90 to 100% consolidation. Detailed probing with several CPTs and field vane measurements indicate that at these locations, there were no sand blanket between the clay fill and red soil. The top of Fibredrains terminated at El +1.6m in the red soil and hence dissipation of excess pore water was retarded. It was decided to "stitch-in" additional Fibredrains from the existing level of about El +3.8 to provide drainage continuity with the previously installed Fibredrains. Within 2 months after the "stitch-in", all the retarded areas achieved close to 100% consolidation under the fill and surcharge.

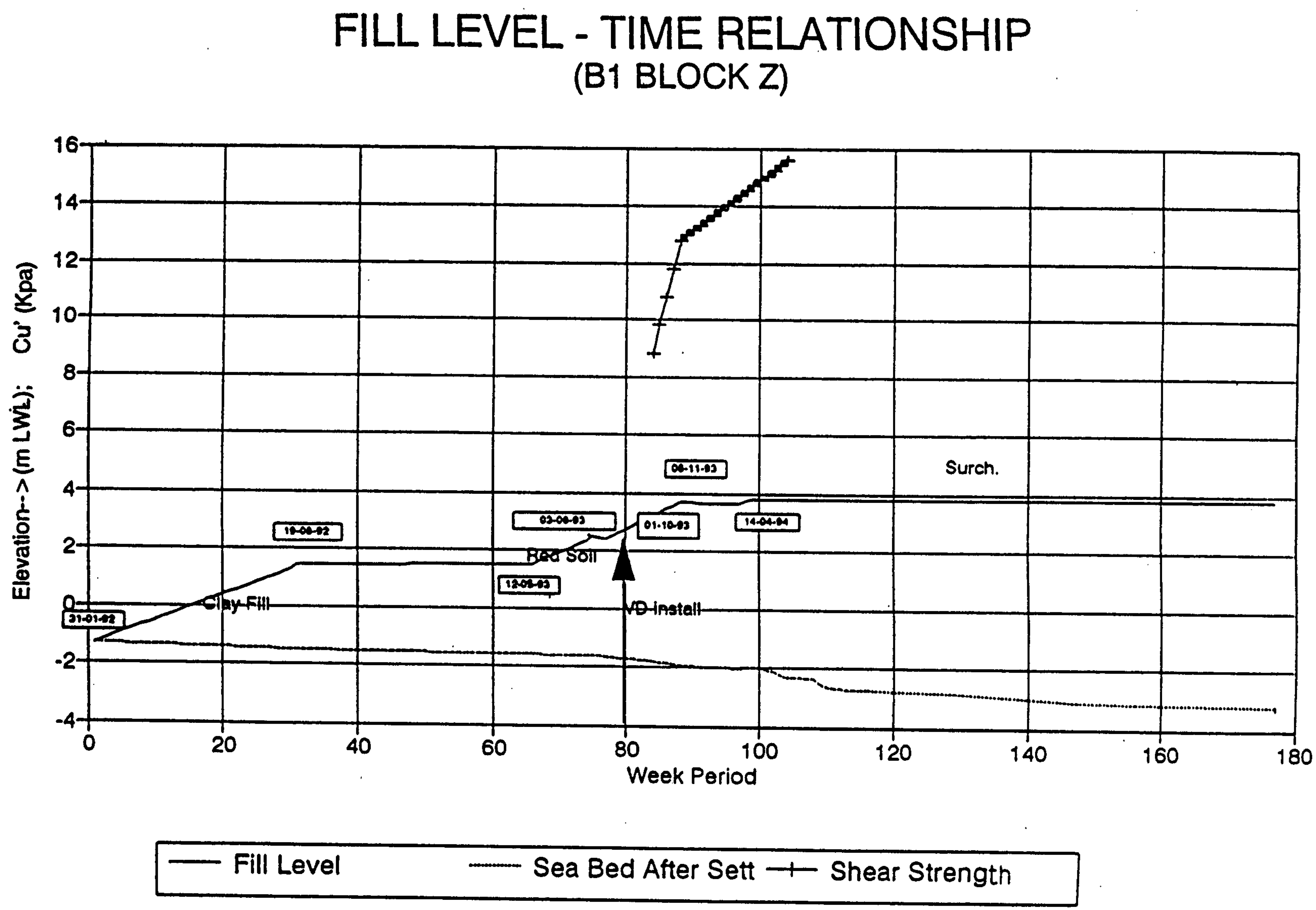


Fig. 8 Increase in fill level with time and change in undrained shear strength after Fibredrain installation and surcharge placement

UNDRAINED SHEAR STRENGTH (Cu)

BLOCK Z

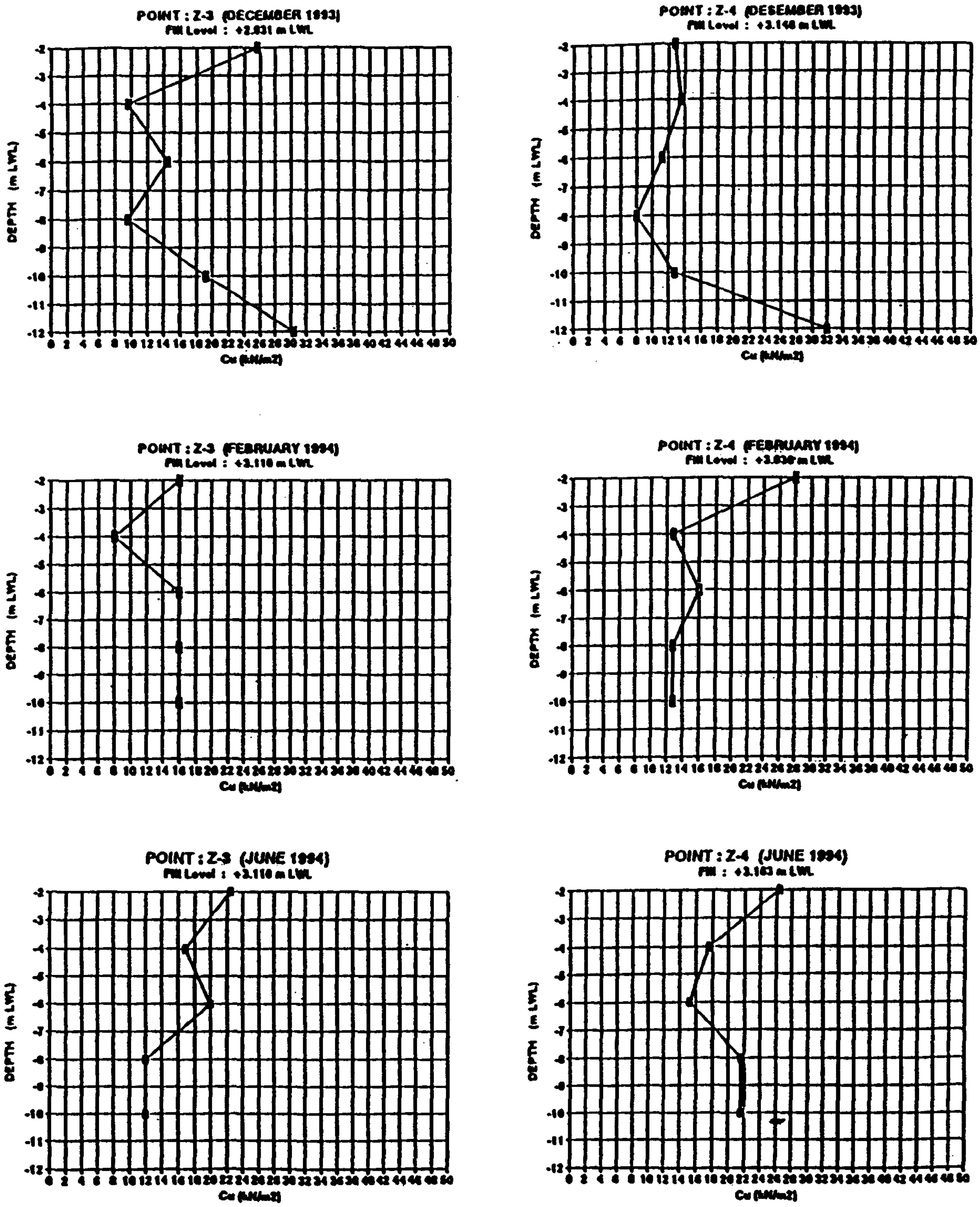


Fig. 9 Variation of shear strength with depth at different time

CONCLUDING REMARKS

The most important requirements governing the performance of vertical drains are that they should not become clogged with time and that their discharge capacity must not be reduced due to kinking as settlement occurs [Lee et al (2000)]. This is particularly pertinent at this site where delay in fill placement in one phase extended the reclamation works to more than 15 months. During this period, Fibredrain continued to function effectively. The relatively high flow rates through the Fibredrain and the rate of ground settlement at different depths observed in the field for both Phase 1A and Phase 1B indicate that the ground responded well to the soil treatment method.

Bamboo rafts consisting of several layers of bamboo mats and bamboo clusters with Fibredrain inserted, and stage construction were employed successfully to construct dykes over soft seabed. The minimum factor of safety obtained for the dyke construction is 1.1 a the final stage. To achieve the desired safety factor of 1.2 for temporary condition, the spacing of the bamboo cluster with the Fibredrain can be reduced or the time lapse between construction stages can be increased, both methods to gain higher strength increment, hence higher factor of safety.

ACKNOWLEDGEMENTS

The co-operation of the owner, P T Taman Harapan Indah of Dharmala Group; the Fibredrain manufacturer, P T Indonesia Nihon Seima; and the contractor of Phase II, P T Jaya Obayashi are gratefully acknowledged.

REFERENCES

Cameron McNamara (1986). Geotechnical Report for Pantai Pluit Indah Canal Development at Pluit, Jakarta, Report No. 84-1704A, May.

Lee S L, Ramaswamy S D, Aziz M A, Das Gupta N C and Karunaratne G P (1987). Fibredrain for Consolidation of Soft Soils, Post-Vienna Conf on Geotextiles, Singapore, 238-258.

Lee S L, G P Karunaratne, K Y Yong and A R Soehoed (1988). Performance of Fibredrain in Pantai Mutiara. Short course and Seminar on Ground Improvement Application to Indonesian Soft Soils, Cawang, 23-26 August, pp 1-24.

Lee S L, G P Karunaratne, M A Aziz, K Y Yong and T Inoue (1996). Fibredrain and Its Application in Land Reclamation and Ground Improvement. NUS-Fukken Seminar, National University of Singapore, 16 July 1996.

Lee S L, G P Karunaratne, M A Aziz and K Y Yong (2000). Fibredrain Development, Design and Performance. Proc. IS Yokohama 2000.