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Tanjung Pelepas Port: From Jungle to Malaysia's Newest Container Port

Abstract

The new port development at Tanjung Pelepas is from its inception to its hand-over an excellent example of a fast-track project:
Under the auspices of the Malaysian Government's VISION 2020, Malaysia's blueprint to become a fully developed nation by the year 2020, the port is to be developed in five phases and scheduled to have 12 berths completed by the year 2020. The Ministry of Transport allowed privatisation, awarding a 60-year concession to Seaport Terminal (Johor) and supporting the development by encouraging Malaysian banks to arrange financing. The syndicate of banks agreed to a RM 2 billion loan. The 800 ha port was also granted Free Zone Status.
The decision-making process by Pelabuhan Tanjung Pelepas Sdn. Bhd., a subsidiary of Seaport Terminal Sdn. Bhd., was also fast track. They shortened the time required for feasibility studies without reducing quality. Moffatt & Nicol Consultants were employed to prepare these studies using tested computer simulation techniques. These consultants were supported by the Malaysian consultants EEC, with an impressive track record on port construction and well conversant with the local situation.
The time to select competent competitive contractors was short.
Contract Conditions were drafted to avoid potential cost and time overruns. Although these conditions were onerous towards contractors, the limitation of cost and time overruns increased the Bank's comfort to provide financing.
The project execution programme contained numerous intermediate milestones or partial completion dates. This allowed close monitoring and adherence of progress, minimising delays and financial risks.
In order to avoid heavy liquidated damages the Contractor had to mobilise substantial extra production capacity for site clearing, dredging, reclamation and soil improvement. This turned the river and mangrove area at its peak in 1998 into one of the world's most equipment-intensive dredging projects, with some 12 large dredging vessels being employed in total.

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David Kinlan

Introduction

The first phase of one of Malaysia's most ambitious new port facilities came on stream in January 2000. Its location: Malay peninsula's most southern tip in the State of Johor, close to the new Malaysia-Singapore Second Crossing, a new 1800-metre bridge linking Singapore with Malaysia's main traffic artery.

In less than five years the area stretching from the state capital Johor towards the west along the Johor Straits, has rapidly changed from a quiet oil palm plantation area into a totally new area to be developed with excellent infrastructure, housing facilities and new areas for industrial development.

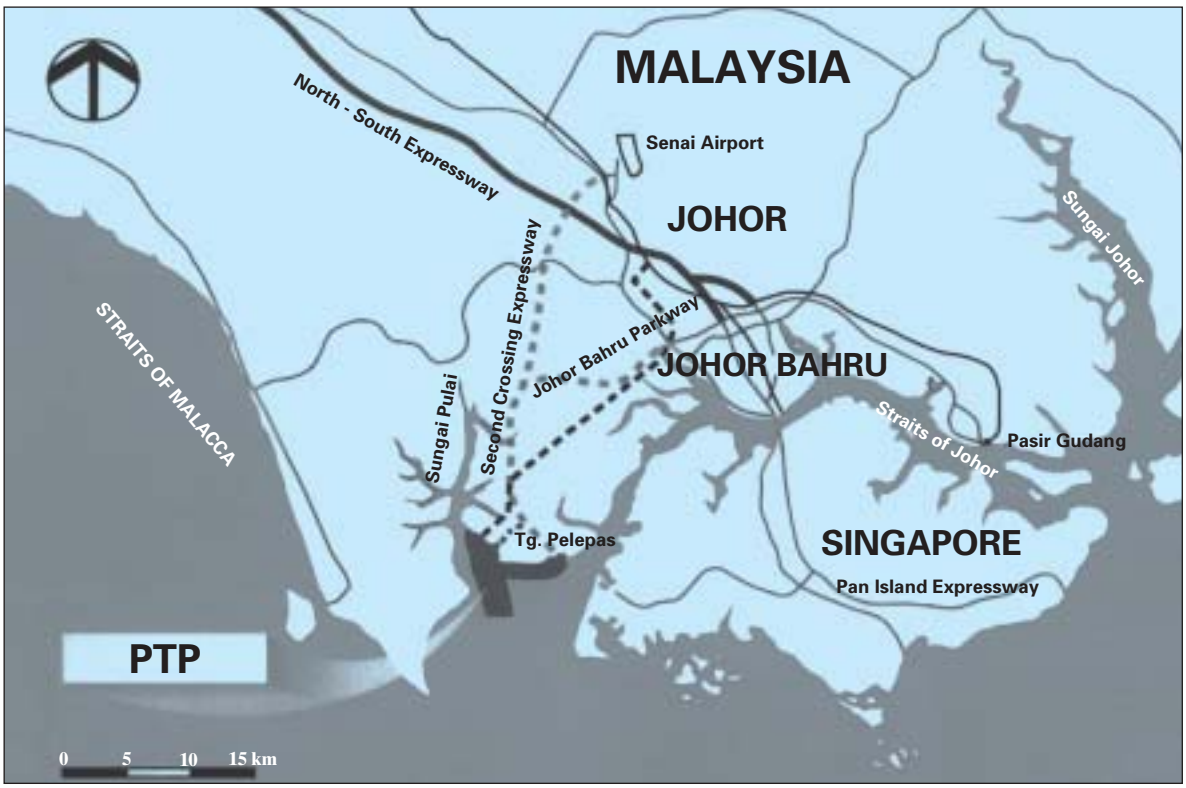


Figure 1. Location map of Port Tanjung Pelepas (PTP) showing the new infrastructure projects, such as the Second Crossing and new airport.

Major infrastructure projects such as the Second Crossing, Johor Airport and the new port development at Tanjung Pelepas at the east bank of the Sungai (River) Pulai, form the cornerstone of the Johor growth triangle west of the city (Figure 1).

Background

Since commencing operations in 1977, the present Johor Port at Pasir Gudang expanded rapidly. Growth predictions showed that the Port would suffer capacity problems by 2000. The Johor Port Authority reached maximum expansion of the Port area with the completion of Phase 4 of Pasir Gudang and began studies in 1990 to identify a site for a new port that would have the capacity to cater to all future demands for cargo traffic. Based on a site selection study, Tanjung Pelepas was selected as the most suitable location for Johor's new port (Figure 2).

On 24 March 1995, the Government of Malaysia and Seaport Terminal (Johor) signed a 60-year concession Privatisation Agreement with the Federal Government setting in motion the development of Pelabuhan (Port) Tanjung Pelepas.

The Port will be developed in Five Phases over a 25-year period up to 2020. Phase 1, comprises the development of 6 container berths or 2 km of quay together with the dredging of an access channel with a draft of 14 metres enabling the Port to cater to post-Panamax vessels (Figure 3).

Preparation of a master plan and preliminary design were done in a very short time in the years 1995-1996, enabling the project to start in 1997 and have its first staged completion in 1999.

The studies were done by Moffatt & Nichol in association with Engineering and Environmental Consultants Sdn. Bnd. (EEC) of Kuala Lumpur. During the execution of the site preparation, dredging and reclamation works, EEC remained the client's consultant.

Moffatt & Nichol's schedule for submitting the master plan did not allow for extensive field measurements normally required for capital projects of this magnitude. Also the client's commitment to have the new port on line within an accelerated timeline required assessment of financial risk and viability in an early stage. Both technical and financial computer simulation studies were carried out based on abbreviated field data and cargo flow projections. This provided the investors with valuable insight into the viability and potential profitability of the project. Critical to this potential profitability was the government's agreement to have the existing port operations at Johor-Pasir Gudang as part of the same concession. Before reaching a confidence level sufficient to proceed with master planning and preliminary

Figure 2. The existing fishing village at Tanjung Pelepas in July 1997, showing the edge of the mangroves which were to be dredged for the new port.

design tasks, over 30 different development and income scenarios were tested.

Computer modelling exercises were done to predict potential siltation rates under varying channel and port configurations, with as a main objective designing the channel so that maintenance dredging would be minimised. Although the master plan has since been changed, the initial port and channel layout remained intact; and the design detailed along these basic lines and eventually the dredging and reclamation works were carried out (Figures 4 and 5).

Description of Dredging and Reclamation Contract

The Contract for Dredging and Reclamation Works forms part of Phase 1, which comprises all works required to provide a fully operational Container Terminal by end of 1999. This included contracts for Dredging and Reclamation, Wharves, Port Infrastructure, Cranes and Equipment as well as Port Buildings. For the Dredging and Reclamation Contract the scope comprised the removal by dredging of existing soft material to provide an approach channel, turning basin and bund foundation area. The reclamation works under the contract comprised the construction of the Wharf Bund and filling of the terminal and infrastructure areas to provide a stable platform for the Container Area.

The US$ 158 million Contract was awarded in July 1997 with a contract period of three years. Owing to the Client's fast-track programming with multiple contractors, the dredging and reclamation contract contained numerous sectional completions with heavy liquidated damages for time overruns to ensure critical path activities were adhered to.

Type of contract: Re-measure up to lump-sum "ceiling"

The Contract was drafted and tailored to suit the Employer's Lenders requirement that the overall development budget should not be exceeded at any cost. This "Cap" on the Contract Sum has been used on other large infrastructure projects in Malaysia, most notably the Second Link to Singapore. It had been drafted by Masons, UK lawyers and could be described as onerous by curtailing a number of important provisions.

Figure 3. Aerial view of the Reclamation Area.

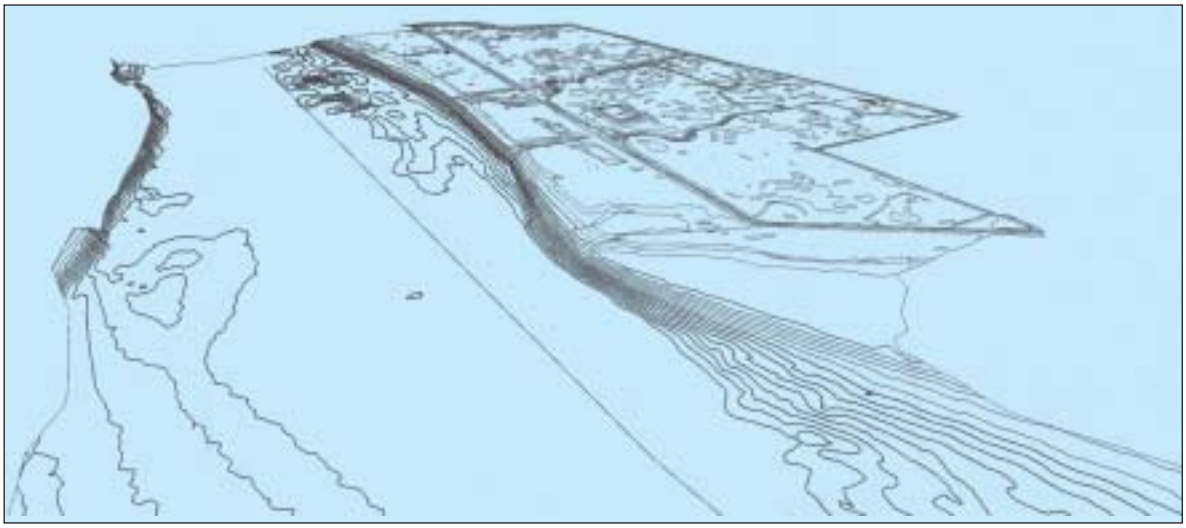


Figure 4. Three-dimensional overview of the original seabed and ground level at the Turning Basin and Land Reclamation Area.

The entire Bill of Quantities was marked "provisional" and was measured during and on completion of the Works. The Tenderer was allowed to submit an amount to cover for the risk that the re-measure could be greater than the maximum allowable Contract Sum. This was titled "Provisional Value Adjustment Item" or PVAI for short. A sum was included in the Summary of Tender by the Contractor as representing the difference between the Total Value of Re-measured Works and the maximum amount payable to the Contractor for the execution of the Re-measured Works.

This meant that the Contractor had to accept the risk of increased dredging and reclamation quantities and it ensured that the Employer's Ceiling Value would not be exceeded.

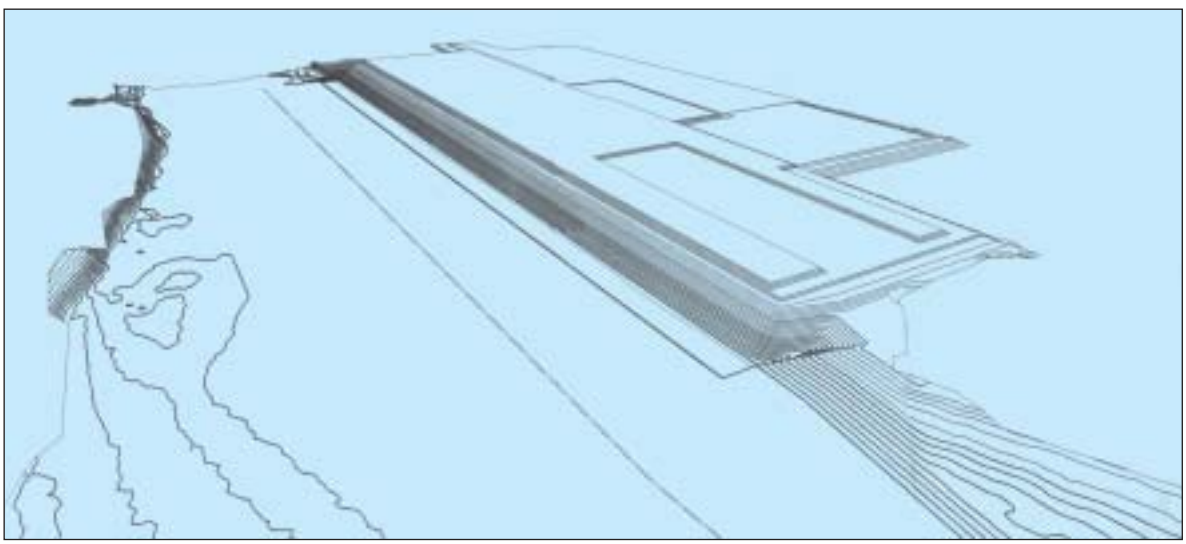
From the commencement of the Contract, the Employer revised the layout of the reclamation adding or omitting work from the contractual scope. Whilst omissions of scope reduced the overall Contract Sum, the additions (at the artificial unit rate) were outside the Ceiling Value and paid against actual quantities.

Summary of work: Main quantities

The specific work can be summarised as follows:

- 200 hectares of Site Clearance, mangrove and bush clearing;
- additional Site Investigation;
- dredging of the 9-km long approach channel and turning basin, approximate volume 16,000,000 m^3;
- dredging to foundation level below Wharf Bund, approximate volume 5,500,000 m^3;
- constructions of the Wharf Bund, approx. volume of sand 4,000,000 m^3;
- installation of 20,000,000 metres of wick drains as ground treatment;
- reclamation and surcharge of Phase 1 Area,

Figure 5. Three-dimensional overview of the dredge and fill design of the Turning Basin and Land Reclamation Area.



amounting to 14,000,000 m3 of sand fill including Settlement; and
– remove and reuse as fill 4,000,000 m3 of surcharge.

Principal contract parties
In 1997 the Employer, Pelabuhan Tanjung Pelepas Sdn. Bhd. (PTP), formed a management company titled Upper Plus Sdn. Bhd. (UPSB) to manage and supervise the design and construction activities. This organisation was replaced by PTP Management Sdn. Bhd. (PMSB) in October 1998 when the design tasks were completed.

Environmental and Engineering Consultants Sdn. Bhd. (EEC) was appointed by PTP to directly supervise the construction activities on Site. Ballast Nedam-SKS Joint Venture executed the contract. Ballast Nedam Dredging and Dredging International Asia Pacific carried out the main dredging and reclamation works.

The dredging of the trench forms a part of the soil replacement to construct a total of 2.16 linear km of Wharf and was dredged to a maximum depth of –19 m CD and executed mainly by the cutter suction dredgers.

The dredged material was pumped into the deeper part of the Turning Basin and removed by the hopper dredgers. The Turning Basin and Access Channel were dredged by hopper dredgers. At the end of the dredging works high spots were removed with a sweep bar.

The Project required the importation of some 18,000,000 m3 of marine sand. This material was won from the vicinity of Karimun (Indonesia) from two separate locations. The sand was dumped directly in the dredged trench or pumped directly into the reclamation area via floating pipeline.

Figure 6. A large fleet of dredging vessels were used simultaneously: Seen here, trailing suction hoppers Rigelstar (left) and Amsterdam (right) were joined by cutter dredgers such as the Hector (center).

Description of the work
The construction, completion and maintenance of the Dredging and Reclamation Works involved the dredging of 16,000,000 m3 of soft and stiff material to form a 12 km Access Channel and Turning Basin, together with the dredging of 5,500,000 m3 of soft to medium material from a trench to form the base for the new Wharf Structure.

The initial activity concentrated on dredging an access of 12 metres deep, 100 metres wide and approx. 5000 metres long (pre-dredging depth only approximately 4 metres by low tide) to allow the jumbo hopper dredgers to reach the Site.

Dredging Works

Trench dredging
The trench dredging commenced from the most northern location, working southwards. Prior to commencement the Department of Environment (DOE) raised concerns about the re-handling of marine clay. Modifications were implemented such as extending the discharge pipe to 12 metres below the water level and daily water monitoring to ensure that release of fines was minimised.

The re-handled material placed in the Turning Basin by the cutter dredgers *Vlaanderen XI* and *Hector* was removed by hopper dredgers and dumped at the designated dumping ground in the Malacca Straits. Whilst removing the re-handled material, existing material in the Turning Basin was dredged at the same time.

Figure 7. Overview of Work Area showing sand winning ground and dumping ground.

The cutter suction dredgers suffered considerable stoppage time owing to blockages. These were caused by mangrove roots clogging the cutter head and/or dredge pump, thus decreasing their efficiency.

Access channel

Initially, the TSHD *Amsterdam* sailed single mud trips, but after some weeks, she began sailing "combi" trips taking out soft material in the Access Channel and re-handled material from the dredged Trench whilst bringing in sand from the concession area in NE and SW Karimun. For this activity TSHD *Amsterdam* was joined by TSHD *Pearl River*.

The work of the jumbo dredgers *Amsterdam* and *Pearl River* were supplemented by the medium trailing suction hopper dredgers, *Wado*, *Gogland* and *Rigelstar* (Figure 6). As the material in the shallow areas of the approach channel could not be taken away by the hoppers, cutter dredgers were used to dredge the material and dump it in the deeper parts of the channel, from where the hopper dredgers could remove the same and dump it at the designated dumping ground in the Malacca Straits. For this purpose the cutter dredgers *Hector*, *Rubens* and *Wombat* were used.

Combination trips

Hopper dredger production is dependant on the cycle times of round trips. For the Pelepas Project, the hoppers executed two major activities:

– the removal of unsuitable dredged materials; and
– the importing of suitable fill material for reclamation.

These activities were combined in round trips lasting 8 to 9 hours, executed mainly by Ballast Nedam's trailer *Amsterdam*. Sources for suitable sand were identified in EEC's EIA (Environment Impact Assessment) study, indicating sand winning grounds around the island of Karimun, Indonesia. Deep-sea disposal areas for unsuitable dredged material were identified at deep water off Pulau Kukup, roughly 80 km northwest of the site in Malaysian waters (Figure 7).

Reclamation Works

Site clearance

The initial activities on site included the clearing of 210 ha of mainly mangrove vegetation. All vegetation more than 15 cm above the existing ground surface had to be removed. This caused a substantial migration of snakes, monkeys and large monitor lizards. Mangrove root systems were left in place to serve as a natural reinforcement of the top layer of the very soft marine clay on which the first layer of hydraulic fill could be placed. The mangrove roots made installation of the vertical drains more difficult, but there were clear advantages to leaving them in place.

Trench filling

Although suitable sand sources were known in Indonesia, a large sand search investigation was initiated, which was concentrated around the designated dumping ground in the Malacca Straits northwest of Karimun and along the coast of Pontian up to 120 km from the

site. Some small pockets of sand were found, but these were exhausted by the end of 1997. From January 1998 the sand was won from Karimun southeast.

Filling of the trench was done partly by direct dumping. First the jumbo hopper dredgers dumped as much as possible until they were limited by their draught. Then the medium-sized trailers dumped their loads until they were also limited. After this the remaining filling of the bund was achieved by hydraulic filling via pipelines.

The final slope and the berth pocket were trimmed by a cutter dredger to the required profile. Excess material was pumped into the reclamation. The TSHD *Wado* proved to be a very efficient medium-sized hopper with limited draught to dump the top layers of the bund, achieving a much higher density compared to hydraulically placed fill via pipelines.

Slopes designs

During tender evaluation, it was noted that the designs of slopes of 1:2 as specified on the Contract Drawings were not stable. A comment to such effect was included in the Method Statement advising that a revision was required for which a variation order should be issued (Figure 8).

Following Contract award the slopes were revised to 1:3,5, however given the soft underlying material there remained a risk that such slopes were still not stable. The Consultant was of the opinion that a rest period of 3 weeks between each lift was required (although there was no requirement in the Specification) and rejected the Quality Plan for reclamation works on this basis.

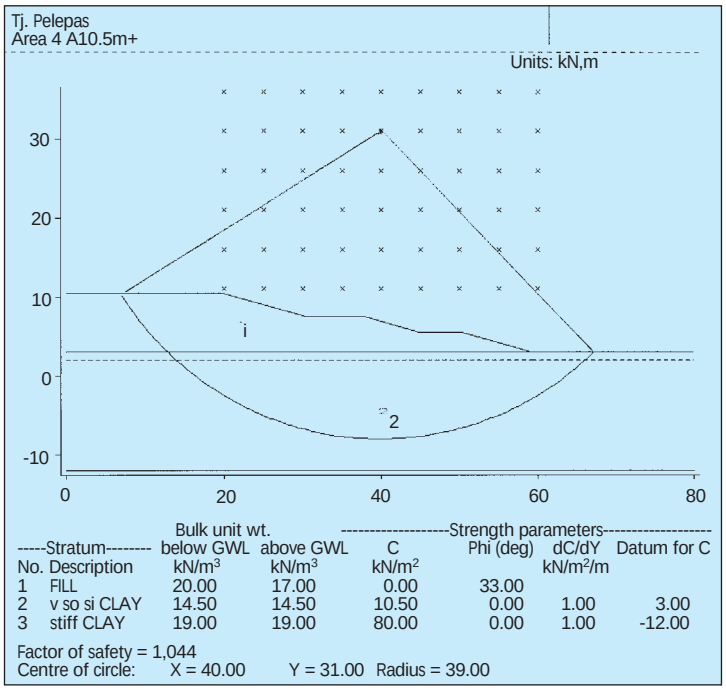
This waiting time was impossible to achieve given the tight hand over dates and no further revision to the design slopes was issued. On different dates in April and June 1998, seven large slip failures occurred during filling operations.

Compaction of bund

The most economical filling method for the bund would have been:

- filling up to –6 to –7 CD direct dumping from a hopper dredger;
- from –6 to –7 to +4 CD rainbowing;
- thereafter pumping via pipelines.

From previous experiences at Pasir Gudang Phase IV it was accepted that rainbowing would not achieve the maximum possible density. The operation consisted of initially direct dumping from hoppers, followed by the more expensive method of pumping via floating and shore pipelines. This method did achieve a value of 45% relative density, which was required by the Client's consultants for the later wharf construction (Figure 9).



-----Stratum--------		Bulk unit wt. below GWL	above GWL	----------Strength parameters---------- C	Phi (deg)	dC/dY	Datum for C
No.	Description	kN/m³	kN/m³	kN/m²		kN/m²/m	
1	FILL	20.00	17.00	0.00	33.00		
2	v so si CLAY	14.50	14.50	10.50	0.00	1.00	3.00
3	stiff CLAY	19.00	19.00	80.00	0.00	1.00	-12.00

Factor of safety = 1,044
Centre of circle: X = 40.00 Y = 31.00 Radius = 39.00

Figure 8. Reclamation slope. Typical slip circle with the minimum safety factor.

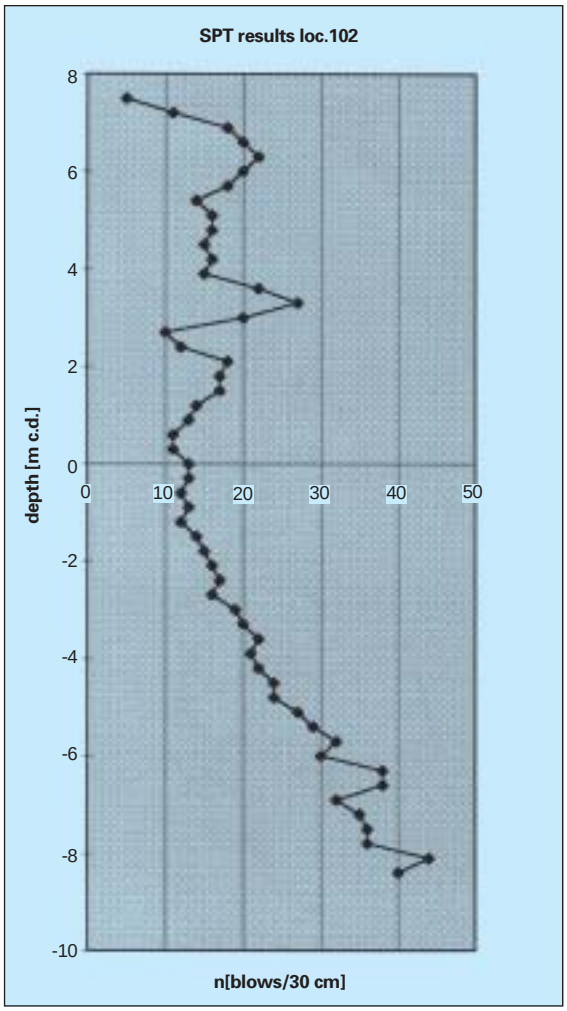


Figure 9. Compaction of bund wall. Typical SPT graph of sandfill.

Reclamation filling

Reclamation was done in principle in 4 layers:

1. First layer up to +3.5 to 4.0 metres CD. This first layer with a thickness of between 0.5 and 1 metre was to facilitate the installation of the vertical drains. These drains were installed in nearly all areas. Because of the relatively thin first layer of sand, jumbo trailers, owing to their high pumping output, could not do this work. Therefore the first layer was done mainly by the medium trailer *Wado* and in the beginning also by the CSD *Vlaanderen XI*, which used the trench as a re-handling pit.

2. Second layer by jumbo trailers up to +5.5 to 6.0 metres CD which provided sufficient sand to construct dikes;

3. Thereafter the third layer up to +7.5 to 8.0 metres CD; and.

4. After a waiting period of 3 weeks the last layer up to +10.5 metres CD was placed.

To avoid any delay by the jumbo trailers, two floating pipelines with two connection points were used.
In addition there was also the opportunity to dump the load in the Trench if any problem on the reclamation area or with the pump-ashore facilities of the dredgers arose.

Soil improvement

The consolidation of the wharf bund and reclamation area was done by a combination of vertical drainage (wick drains) and the placing of sand-surcharge (Figure 10).

In total some 20 million metres of wick drains were installed by a specialist subcontractor as soon as the area was accessible for crawler cranes. The drains were installed with a spacing of 1.25 metres and the total length for each drain was between 20 and 30 metres. Output was maximum 1000 M' per day. The total length of the drains exceeded 20,000 000 metres. The placing of the vertical drains started within five months after contract award. The first two areas 1B and 3B required high installation productions. At its peak 21 rigs were operational. In a 7 month period some 13 million metres of drains were installed over 600,000 drainage points.

Prevailing soils (*from*: EEC, EIA study, PTP, January 1996)

Results of sub-surface investigations indicated the following stratifications:

A. On land:

Dessicated firm crust of alluvium:	1.0 m to 1.5 m thick
Very soft to soft alluvium:	up to 18 m thick
Firm to hard residual soils:	15 m to 19 m below existing ground surfaces

B. Over water:

Very soft to soft alluvium:	up to 18 m thick
Firm to hard residual soils:	up to 19 m below existing ground surface

Figure 10. Some 20 million metres of vertical drainage (wick drains) were installed.

Figure 11. Container terminal at Tanjung Pelepas under construction.

The very soft alluvium will consolidate under loads imposed by site filling and high surface loads, resulting in settlement of finished ground surfaces, if such consolidation has not been eliminated by geo-technical engineering means during construction.

Instrumentation
In order to monitor the behaviour of the reclamation area a programme was executed to install geo-technical instruments and obtain field data.

The following instruments were placed:
- Settlement markers or plates (total 236 nos.) to measure site settlement and consolidation.
- Pneumatic Piezometers (total 129 nos.) to measure groundwater pressure, monitoring the de-watering and drainage of the subsoil and to control the safety of the filling operation and degree of consolidation.
- Inclinometers (total 22 nos.), to monitor lateral movements in embankments, bunds and landslide areas.
- Magnetic Extensometers (total 11 nos.), to monitor settlements and heave. Data from the extensometer indicate the depths at which settlement has occurred as well as the total amount of the settlement.

Monitoring of the behaviour of the reclamation area was important to be able to adjust the filling and surcharge removal operations in order to limit landslips and to plan the removal of surcharge after sufficient consolidation.

Slope failures were predicted and indeed occurred. Minor embankment design changes were introduced to further limit failures without the need to redesign the wharf construction.

Surcharge removal and placing
After a waiting period of 6 months, surcharged areas could be excavated to a level of +5.50 metre CD. The material went to areas more land inward and to the future distri-park area. The total quantity to excavate and transport was approx. 4,000,000 m^3. Output was more than 100,000 m^3 per week. For this work hydraulic excavators and articulated dump trucks were used (Figure 11).

Conclusions

The Pelabuhan Tanjung Pelepas Dredging and Reclamation Works have been executed successfully notwithstanding adverse site conditions and strict contractual requirements. The timely mobilisation of sufficient dredging plant and competent local subcontractors greatly reduced time overrun risks. Changes of work were handled with flexibility from all sides. Technical problems were solved with the intention to complete the works in the shortest possible time.

One of the main success factors was the excellent performance of the large fleet of seven trailing suction hopper dredgers. They achieved an overall efficiency of nearly 90%, working continuously around the clock. The lion's share was undertaken by Ballast Nedam's new 18,000 m^3 jumbo trailing suction hopper dredger *Amsterdam* and its crew, working nearly 70 weeks on this project with weekly sand deliveries in excess of 200,000 m^3 per week.