# Half Day Seminar on Construction of Pantai Trunk Sewerage 1

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The Tunnelling and Underground Space Technical Division (TUSTD) of IEM organised a half day seminar on 16 November 2006 at the IEM Bangunan premises. The talk attracted a total of 200 participants. The speakers for the seminar were:

1. Engr. Koh Hwa Nam – Metropolitan Engineer and Builder Sdn Bhd
2. Mr. Adrian Dobbie-Holman – Shimizu Corporation
3. Mr. Jan Dollekamp – Reinders Wessemius Malaysia Sdn Bhd
4. Mr. Gordon Ferrer – RPS Engineering Surveys Ltd

The objectives of the seminar were to present a general overview of Phase One of Pantai Sewer Networks as well as some of the problems encountered and the various methods applied to solve the problems. There were lively discussions between the audience and the presenters during the Q&A sessions. The seminar was adjourned at 1.00 p. m. with a note of thanks to all the presenters.

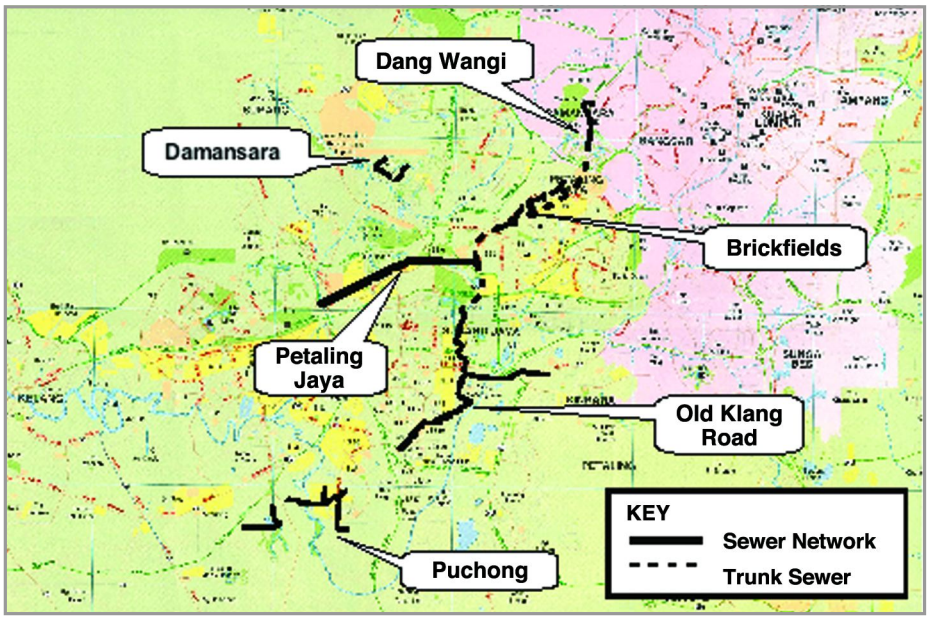


*Figure 1: Sewer networks*

## BRIEF OF PANTAI TRUNK SEWER

The first phase of a major sewerage project was undertaken by Shimizu-Road Builder-Hitachi Plant JV in Kuala Lumpur for the government. The Sewer Networks consisted of over 13km of new trunk sewers and sewer diversions in the Dang Wangi, Brickfields, Petaling Jaya, Old Klang Road, Damansara and Puchong areas (Figure 1). Due to a combination of space constraint, heavy traffic conditions and the authorities' conditions in response to increasing awareness of the social costs of more traditional methods, the pipejacking method was specified to install most of these sewers.

15No remote-control slurry-system TBM's and 3No open-face shields for manual excavation were used to install HDPE-lined reinforced concrete pipes ranging from an internal diameter of 300mm to 1800mm. This was the biggest and most complex pipejacking project ever undertaken in the country. Following six months of planning and investigations, the pipejacking project started in July 2004 and was completed in mid-2007.

This article will cover the many technical aspects of the project. This includes an overview of the sewer alignment, soil investigation, jacking pipe design, pipejacking equipment selection, construction focusing on pipejacking equipment and process, as well as other important factors such as safety, utilities, soil stabilisation, shaft construction and instrumentation. It concludes with an overview of the successful application of modern trenchless technology, and how the difficulties encountered have been overcome.

## ALIGNMENT

The existing sewer system for a large portion of Kuala Lumpur was built in the 1950s. One major 1.5mØ trunk sewer runs along the flood channel of the Klang River, through the city centre to the existing Pantai Sewage Treatment Plant (STP). This sewer had become blocked and damaged in places and was heavily overloaded. This had resulted in untreated sewage overflowing into the river.

Phase One was divided into several sub-projects. The Pantai Trunk Sewer was a sub-project consisting of a new 5km long segmental tunnel sewer, 2.5mØ and 2.8mØ internally, which would carry sewage to the Pantai STP, and the upgrading and expansion of the latter which forms another sub-project. The Pantai Sewer Network sub-project, totalling about 13 km in length, consisted of the following five sections:

- Dang Wangi Sewer Diversion
- Brickfields Sewer Diversion
- Petaling Jaya Trunk Sewer
- Damansara Sewer Diversion
- Old Klang Road Trunk Sewer

With the exception of the Damansara Sewer Diversion, all the other sewers were connected to the new Trunk Sewer. The Sewer Diversions would intercept the existing sewer branches before they reach the 1.5mØ trunk and divert the flow into the new Trunk Sewer. The main purpose of the Petaling Jaya (PJ) and Old Klang Road (OKR) Sewers was to provide a point at which future diversion projects in those areas would be directed. The Puchong Sewer Network sub-project would include about 2km of pipejacking and divert the existing flow to several small local STP's into an existing pumping station.

Initial soil investigations were carried out in 2001. This information helped the

designers to determine suitable manhole locations and pipejacking lengths.

Local authorities in the country were increasingly specifying that trenchless methods be adopted for new works. This was the case for this project, therefore, pipejacking was specified for the majority of the Sewer Networks. In any case, the depth of the sewers (up to 21m, but typically 5-13m) and the congested nature of the urban environment would make open-cut methods impractical and/or prohibitively expensive (See Figure 2).

*Figure 2 – A jacking shaft in Dang Wangi*

Several curved alignments with radii as low as 200m were required to thread past a variety of sub-surface structures supporting elevated road, rail and light transit systems. There were several drives 250-340m in length. The longest was a 371m long 1800mmØ curved drive in Dang Wangi. This would be the longest pipejack ever carried out in Malaysia.

## PIPEJACKING EQUIPMENT SELECTION

The most important consideration when selecting pipejacking equipment was that the TBM must be well-suited to the ground conditions. The choice of methods for spoil transportation and separation was also important. Other considerations includes availability, speed, cost and minimum shaft size. With the exception of the connections into existing sewer manholes and a small number of drives less than 30m in length, slurry systems were used.

### 2.1 Overview of Modern Remote-Controlled Slurry-System Pipejacking

Although the systems used on the project were from four different manufacturers from Europe (Herrenknecht and MTS) and Japan (Rasa and Iseki), they all shared many similar fundamental characteristics (See Figure 3). Each system comprise the following component parts:

- TBM
- Jacking Frame
- Circulating slurry system (pipes, pumps and pit bypass valve)
- Control Cabin
- Guidance laser
- Hydraulic Power Pack
- Generator
- Soil Separation Plant
- Lubrication Plant

To complete the entire process, product pipes, lifting equipment and spoil removal trucks were required. The selected TBM's was characterised by a rotating cutting face forming the front of a cone-shaped slurry chamber through which excavated material passed into the slurry pipes to be transported to the surface for separation. The face cutting tools could include teeth, scrapers, discs and rollers. Excavated material was crushed as it passes through a gap between the rotating shaft and the cone. In Iseki Unclemole heads, the cutting head travelled along a trochoidal path. In the MTS2000 system used in Dang Wangi, it was possible to move the crusher cone forward and backward to adjust the crusher gap size to suit varying ground conditions.

The shields were articulated, enabling them to be steered horizontally and vertically. The usage of three or four hydraulic steering jacks was common. The jacks were fixed across the articulation point which allowed the operator to control the direction of the shield. The sewer alignment tolerance for the project was 75mm horizontally and 25mm vertically and this was achievable under normal circumstances.

The OD of the shields was greater than that of the pipes. This was to create an annular space around the pipes, to reduce friction, and on larger diameters, to allow the injection of a lubricant. This 'overcut', typically 10-20mm, was very important. It was initially created by the perimeter cutting tools of the TBM. It was, therefore,

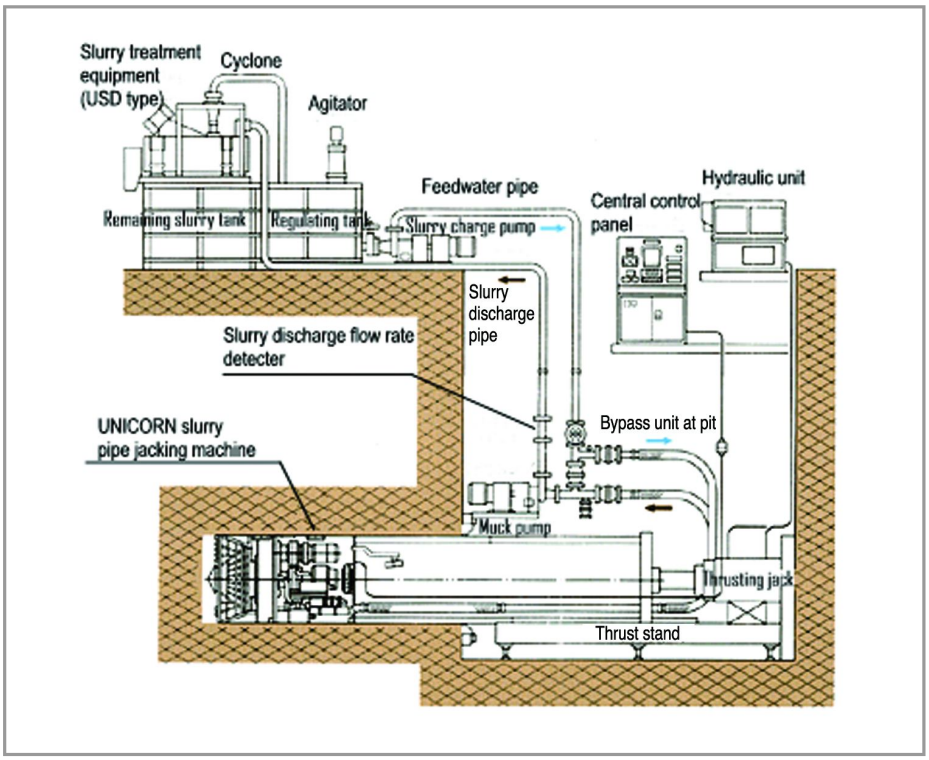


*Figure 3 – Typical remote-control slurry system pipejacking (Schematic)*

very important that the over-cutting ability of those teeth be maintained for the entire drive. In the OKR Sewer, TBM1200#1 experienced unusually high jacking pressures early on in the drive. It then encountered hard sandstone and, at a chainage of 154m, the jacking force became so high that the drive could not continue. The TBM was recovered and it was found that the perimeter teeth had worn away to the extent that no overcut was being created.

The stability of the soil face was provided by a system of pressurised slurry. The slurry used could be water but additives such as bentonite or polymer were often added for improved performance. The slurry was circulated to and from the TBM using charge and discharge pipes, typically 3"-6"Ø. Flow was provided by a charge pump at the surface and a discharge pump in the thrust shaft. A bypass valve in the TBM just behind the face allowed the slurry circulation to be maintained whilst excavation stopped. The pressure of the slurry was maintained at a level to suit the soil conditions and water pressure. The pressure had to be high enough to prevent collapse of the face into the face chamber, which might cause surface settlement or block the slurry pipes, and low enough not to cause a heave or an excessive loss of slurry. The slurry pressure was measured by gauges in the chamber and displayed in the control cabin.

The excavated material was brought to the surface by the discharge slurry lines, and processed in the soil separation plant. The purpose of soil separation was to remove the excavated material from the slurry, so that the slurry could be re-circulated. This reduced water-use and minimised the volume of material to be removed from the site. Separation equipment included settlement tanks; trommel systems, screens, shakers and hydrocyclones.

The control cabins contained consoles from which the systems were operated and monitored. Information from the TBM was relayed via CCTV (Iseki and Rasa) or via computerised systems (MTS and Herrenknecht). The major features were as follows:

- TBM Steering Jacks
- Alignment of TBM (horizontal / vertical)
- TBM Pitch / Roll
- Cutter Torque and Rotation Direction
- TBM Bypass and Stop Valve indicators
- Face Pressure
- Slurry Flow rate
- Slurry Pressure
- Main and Inter-jacks Force / Pressure / - Stroke Length
- Jacking Speed

With the advent of computerised systems, and in particular, when automatic lubrication systems were used, and complex alignment guidance systems, the control cabins could resemble the cockpits of airliners.

## CONCLUSION

Due to the rapid development of Kuala Lumpur in the two to three years between the tender and construction stages of this project, the greatest and most time-consuming initial challenges were finalising the sewer alignments and obtaining all the necessary approvals to commence work. Some major route revisions were necessary. At the time of these revisions, technical and commercial risk levels had already been assessed and sub-contracts placed so the number and type of pipejacking resources available was limited. The revised alignments were, therefore, formulated to match the anticipated risks and the capabilities of the available resources as much as possible.

Under normal circumstances, this would not be the case. With the use of inter-jacks, drive lengths were only really limited by the impracticality of working along a long tunnel with only one point of access. Drives over 2,000m have been achieved before. TBM's could be made to suit any pipe diameter up to a size where segmental tunnelling became more practical and cutter heads to suit any ground conditions were available. With modern guidance systems, complex alignments with multiple horizontal and vertical curves with radii as small as 15m were possible.

Once construction has started, the greatest difficulties encountered have been associated with shaft construction through relatively soft water-bearing soils, unforeseen ground conditions such as those encountered in the Puchong, OKR and PJ Sewers, and the loss of soil stability upon TBM launch and reception. Shaft construction problems have been overcome by the use of soil stabilisation methods, and the resultant delays have generally been eliminated as the TBM's have all greatly exceeded the conservative production rates on which the work schedule was based. In cases where drives have been halted by obstructions, the TBM's have been successfully retracted. There are now options available to resolve the problems such as modifying the cutter heads, using different TBM's or changing the sewer alignment.

In the absence of unexpected ground conditions, the TBM's are able to perform well and can install pipelines quickly with little disruption compared to open-trench methods, and in cases where such methods would not be possible, such as in busy urban areas, and under major roads, rivers and railways. Over 7km of sewers have been successfully installed so far. However, it must be said that to make the best use of modern equipment and to avoid unnecessary delays and costs, the following are required:

- Careful planning
- Well-maintained equipment
- Correct equipment selection, particularly cutter-head configuration
- Experienced, competent supervision and operation staff
- Highly-accurate setting-out and surveying.

This article cannot speculate as to the use of sewer rehabilitation methods as an alternative to pipejacking for this project. Certainly for installing new sewers in urban conditions at the required depths and diameters, there is no practical alternative to trenchless excavation methods.

With the rapid development of cities like Kuala Lumpur and the awareness of the benefits of trenchless methods improve, the demand for it will increase. This should lead to increased competition amongst contractors thereby lowering costs. With the concurrent development of contractors experience, and of the technologies involved, the demand for and the success of trenchless technologies for such applications can only increase. ■