Rehabilitation of the Beach at Teluk Cempedak, Pahang, Using Pressure Equalisation Modules (PEM) System

by **Engr. Tan King Seng,** M.I.E.M, P. Eng. , **Engr. Nor Hisham bin Mohd. Ghazali,** M.I.E.M, P. Eng. and **Engr. Ong Hon Lim,** M.I.E.M, P. Eng.

Beautiful and wide sandy beaches do not last forever. They need maintenance against erosion. Here the authors share their experience doing one such 'make-up'.

THE beach at Teluk Cempedak, Pahang, is a pocket beach between the headlands of Tanjung Pelindung Tengah and Tanjung Tembeling, with Sungai Cempedak draining into the northern end of the bay. The bay has been fully developed for public recreation as well as for local and international tourism.

The beach is classified as stable under the National Coastal Erosion Study 1985. However, Teluk Cempedak has a history of severe erosion. Remnants of a failed seawall recorded past attempts to protect the area. In order to overcome the erosion problems, the Department of Irrigation and Drainage (DID) has decided to implement a pilot project to rehabilitate this sandy beach using the 'Pressure Equalisation Modules' (PEM) system and sand nourishment.

The overall objective of this project is to physically and environmentally restore the beach at Teluk Cempedak. In particular, the project aims to create a more erosion-resistant beach.

INTRODUCTION

The beach at Teluk Cempedak is divided into the northern part, which includes the public recreational areas, and the southern part where the Sheraton and Hyatt Hotels are located. The beach is about 1.1km long and is aligned almost perpendicular to the waves from the northeast direction of the South China Sea (Figure 1).

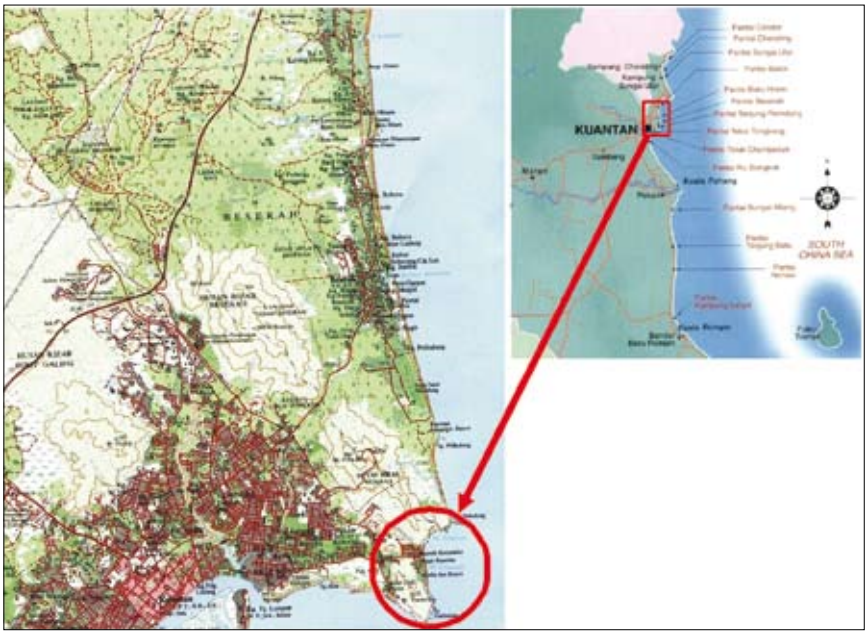

Figure 1: Location of Teluk Cempedak, Kuantan, Pahang

The morphology of the beach in the undisturbed areas shows two levels of beach cusp. This is due to the difference in sea level and wave energy of the two monsoons. The sand is yellowish and coarse-grained, reflecting the nearby source of alongshore sand from the eroding headlands.

Teluk Cempedak has undergone slow and steady erosion that has resulted in the narrowing

Figure 2: Official testing ground of PEM at GI Skagen, Denmark

(To be continued on page 20)

Figure 3: PEM system at Novel Strand, Lonstrup, Denmark

of the beach area, which affected recreational and tourist activities. The average retreat rate is estimated at the time to be around 0.8 meter per year. If protective measures are not taken, the beach will eventually endanger public amenities along the beach front.

In order to overcome this threat and also to assist in the development of the tourist industry in the country, the DID has decided to implement a pilot project in mid July 2003 to rehabilitate this sandy beach with the use of the PEM system and sand nourishment.

The PEM system is a new technology from Denmark. It is designed to stimulate the accretion of sand on certain beaches and to slowdown the erosion process on the other beaches. It had been implemented on a number of beaches in Denmark (Figures 2 and 3) as well as in other countries like Sweden and Australia.

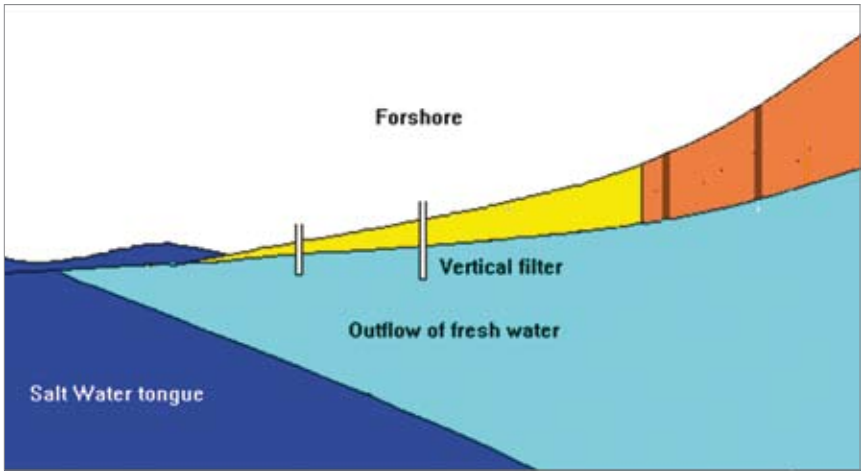

Figure 4: Schematic view of the vertical pipes in a PEM system

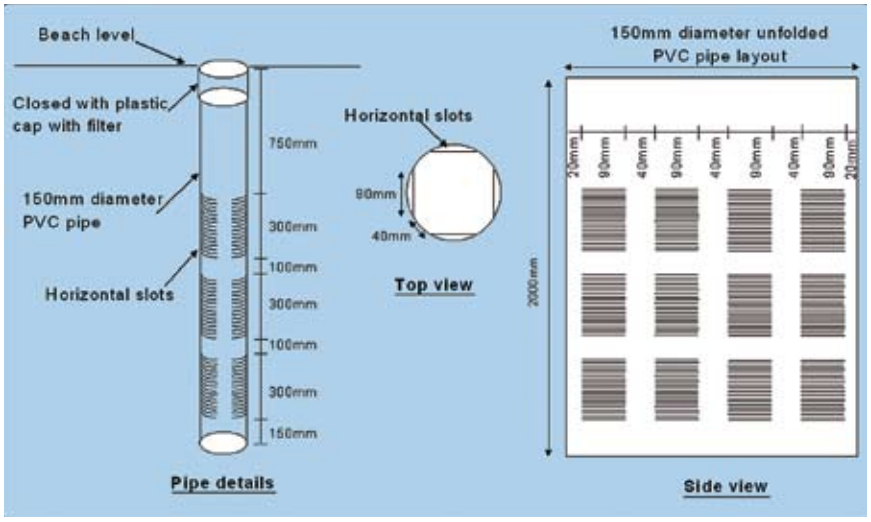

Figure 5: Pipe design for the PEM system

PRESSURE EQUALISATION MODULES (PEM) SYSTEM

Pressure equalisation modules are vertical pipes that are placed in rows forming a matrix along the coastline as shown in Figure 4. Based on previous experience, the PEM system is able to stimulate the accretion of sand on certain beaches and to slowdown the erosion process on other beaches.

Cross-shore sand tongue develops in front of each row of the PEM system. These sand tongues essentially have the same effect as groynes in arresting some of the transported long shore sand, thus building up the sand between the rows. The pipes equalise the pressure in the groundwater zone, and an increased circulation of seawater in the coastal profile will take place thus promoting sedimentation.

The PEM system is simple in design but is based on a relatively difficult phenomena under the principle of soil drainage. The swash zone is the area of the beach where waves crash and run up along the beach slope. The seawater than returns down the beach face but at the same time permeates into the profile. Simply put, the PEM system provides a faster passage for the water within the verticle profile of the swash zone to drain. During the high tide, the sea water extends further up the beach which means pressure is built up in the layers underneath where there is also a freshwater tongue originating from the hinterland. The drainage passage created by the PEM system thus equalises the pressure within the upper and the lower profiles.

When the water level is low on the coast during the period from low tide to high tide, the water circulation in the swash zone increases which, in turn, increases the depositing of materials on the foreshore, thereby building up the beach from the sediments transported along the coast. In beaches lacking in sediment transportation, the PEM system will instead slowdown the erosion rate of the beach.

(To be continued on page 22)

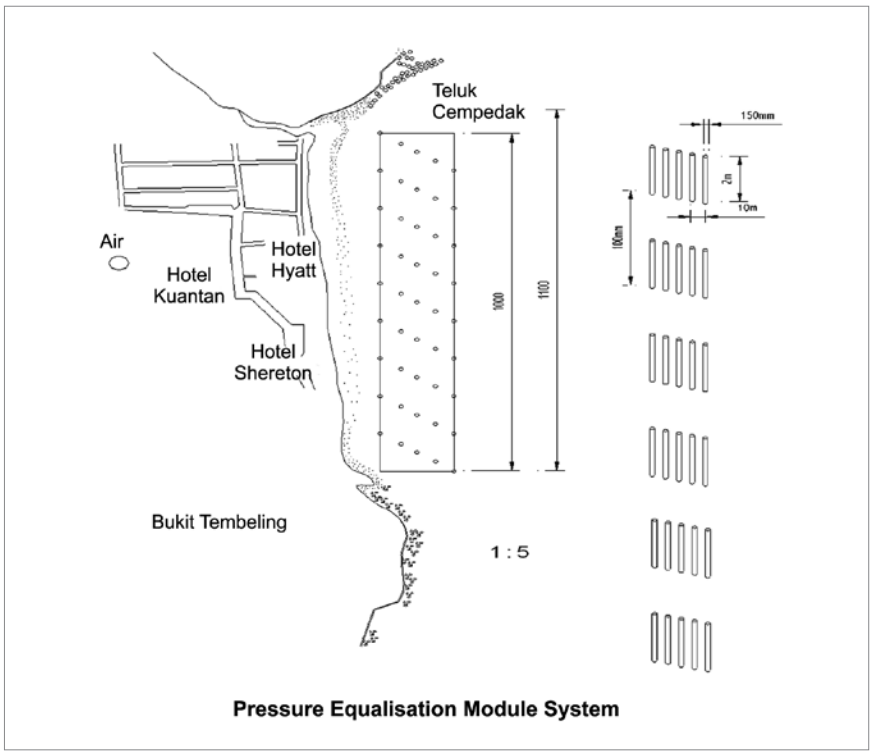

Figure 6: Layout of the PEM system at Teluk Cempedak

Figure 7: Installation of PEM system

Figure 8: PEM system and sand nourishment at Teluk Cempedak completed in July 2004

The beach at Teluk Cempedak lacks sediment transport because maintenance dredging at the Port of Kuantan is cutting off the supply of sediment. Beach nourishment is required for the application of the PEM system to rehabilitate the beach. In this case, the PEM system will function to reduce the erosion rate.

PEM PIPE DESIGN

The drainage pipes of the PEM system are made of PVC and are characterized by the following features:

i) Length of pipe is 2.0m
ii) Pipe diameter is 15cm
iii) Pipe wall thickness is 3mm

Each vertical drainage pipe is perforated with horizontal slots arranged vertically in sections along the length of the pipe. Each section is 30cm long and consists of horizontal arc slots cut into the pipe at 1mm apart, each arc slot at 90mm long and a width of not more than 0.2mm. The distance between each section is 10cm (Figure 5).

The top of the pipe is closed with a plastic cap with filter and covered with sand so that they do not present obstacles to users of the beach. The cap is made of hard PVC 2-3mm in thickness and of an easily observable colour.

DESIGN PARAMETERS AT TELUK CEMPEDAK

The beach front at Teluk Cempedak is approximately 1,000m long between the two adjoining headlands. The existing or native sand grain size (median) is around 0.3 to 0.5mm (the finest sand is in the northern part of the area), and the sand nourishment grain size is 0.5 to 1.0mm.

The existing average slope of the beach is one in 60 and the designed slope is one in 45. Based on experience from other installations, the PEM system shall be configured in a 100m x 10m grid, with a total of 11 columns and five rows. The installation plan is shown in Figure 6.

(To be continued on page 24)

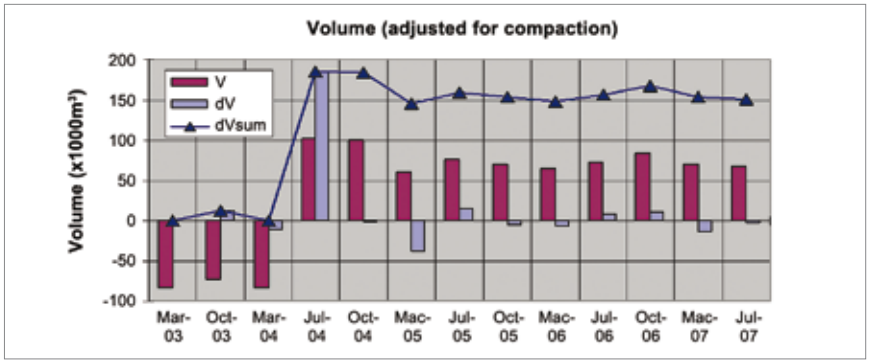

Figure 10: Survey summary graph (Volume)-adjusted for compaction

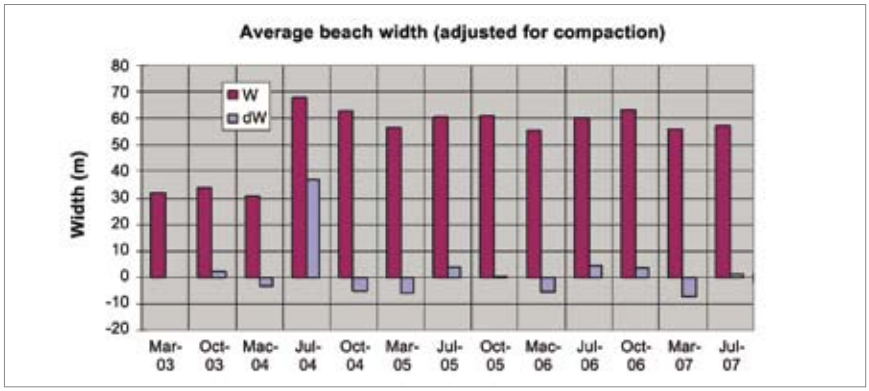

Figure 11: Survey summary graph (Beach Width)-adjusted for compaction

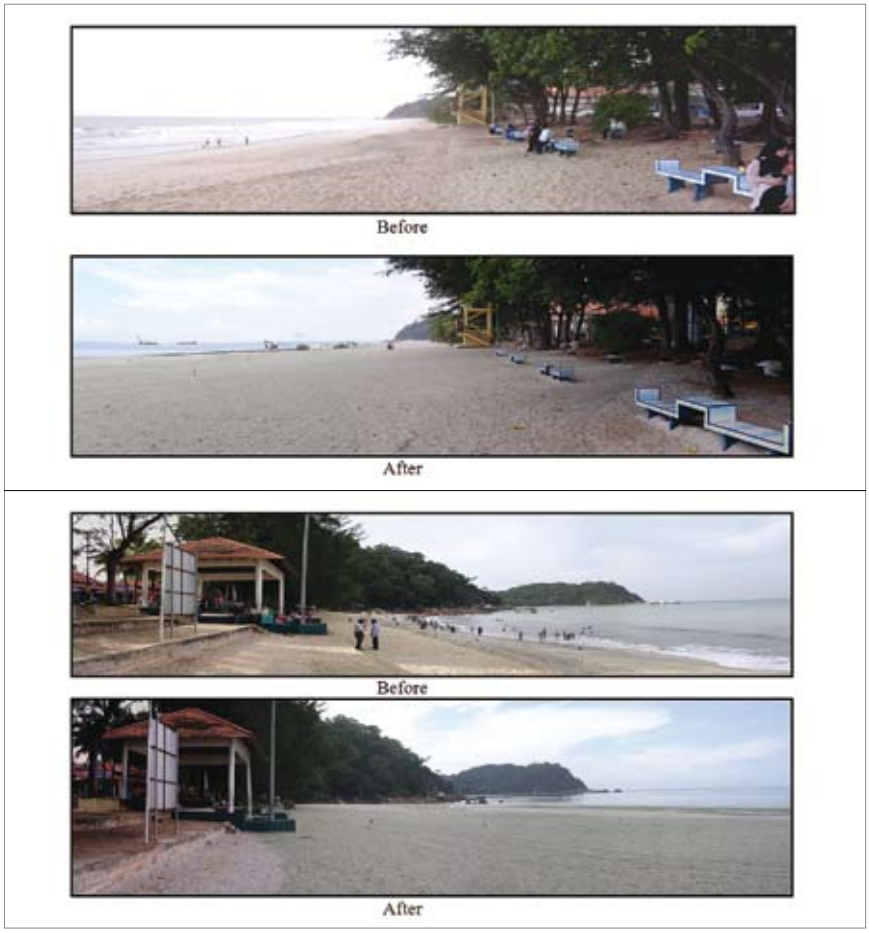

Figure 12: Before and after beach rehabilitation works at Teluk Cempedak

Installation of the PEM system is generally done in two steps. Installation of the Basic PEM system is to drain the existing beach and prepare for sand nourishment. Vertical 2m long drain pipes are located in a 100m x 10m matrix from the surface of the beach face to the groundwater table (Figure 7). The effect of the Basic Installation is to increase the drainage capacity of the active zone initially, and then to transport silt away from the beach thus further accelerating the drainage capacity.

Installation of the Off-set PEM system after sand nourishment with 2m long drainpipes (shifted 20m along the shore direction) will result in the development of cross shore sand tongue in front of each row of the PEM. These sand tongues essentially have the same effect as groynes, which arrest some of the sand transported by the long shore current, thus resulting in the buildup of sand between the rows (Figure 8).

BEACH SURVEY EVALUATION (MONITORING)

In order to adequately monitor and evaluate the effect of the PEM system, and to operate and maintain the system satisfactorily, a Post Project Monitoring Programme is implemented. The Post Project Monitoring will start prior to the commencement of filling (pre-nourishment survey) and will continue over the entire Defect Liability Period (two years after completion) and Maintenance Period (three years after completion).

Since the project commenced on March 2003, a number of beach surface elevation, *i.e.* sand volume, and 12 surveys have been conducted in order to follow the morphological changes at Teluk Cempedak as a result of the project implementation:

i) Basic PEM installation on March 2003 (first baseline)
ii) Sand nourishment in July 2004
iii) Installation of the second PEM system in July 2004 (second baseline)

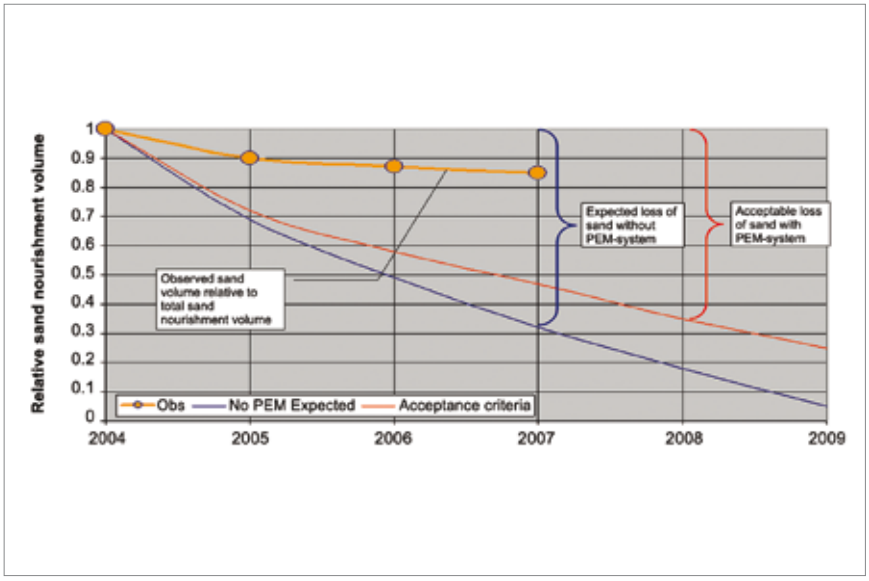

Figure 13: Evaluation of the PEM system

According to the DID requirements, the interim surveys shall be taken at intervals of approximately three months, but should coincide with pre and post monsoon events throughout the period of monitoring. The purpose of conducting a series of beach surveys is to follow the morphological dynamics of the beach at Teluk Cempedak and to provide empirical assessment of efficiency of the PEM system in relation to beach protection (Figures 9 to 11).

The results strongly indicate that the PEM system has enhanced the sand retaining properties at Teluk Cempedak. There is a clear seasonal variation in the beach width, however, with a stable average level some 20-25m wider than the original beach. (Figures 11 and 12)

VOLUME ACCEPTANCE CRITERION

After sand nourishment, it is the general experience that a portion of the sand will be redistributed and/or transported further offshore during the first monsoon period. According to the acceptance criteria described in Figure 13, this phenomenon is expected. As part of the analysis, the 'natural' erosion situation was analysed from survey data and numerical simulations were done to project the sediment loss over time. The projections show that 30% of the added sand volume will be lost over the first year, primarily during the first monsoon.

Here, the term 'loss' refers to the situation where sand is transported outside the beach influence zone, with a low probability of returning to the beach when the weather conditions change. The July 2007 survey result has been plotted in the PEM evaluation acceptance diagram (Figure 13) and shows that the status of the volume development after three years clearly lies in the acceptance region above the full red line (around 85% of the sand is retained on the beach).

CONCLUSION

The results of the survey have shown that, in the three consecutive years, the erosion rate at the newly sand nourished Teluk Cempedak is significantly less than what would be expected if the PEM system were not installed. The empirical survey thus supports the hypothesis that the PEM system works and slows down beach erosion. The PEM System has succeeded in arresting the erosion and preserving the beach at Teluk Cempedak. It is part of the DID's program to introduce innovation in solving coastal erosion problems along recreational sandy beaches. ■

REFERENCES

[1] Jan Agerholm Hoybye, 2007. Final Assessment Report on Beach Survey Evaluation at Teluk Cempedak, Pahang.

[2] Jurukur Perunding Sdn Bhd, 2007. Report on "Kerja-Kerja Ukur 'Topographic and Bathymetric' bagi Projek".

[3] *Perintis Pemulihan Pantai Pelancongan dengan Menggunakan* 'Pressure Equalisation Module' (PEM) di Teluk Cempedak, Kuantan, Pahang Darul Makmur.

[4] Department of Irrigation and Drainage Malaysia, 2003. *Dokumen Kontrak Cadangan Projek Perintis yang Menggunakan Teknologi* 'Pressure Equalisation Module (PEM)' *untuk Pemulihan Pantai di Sepanjang Pantai Teluk Cempedak*, Pahang Darul Makmur.

[5] MRCB Environment Sdn Bhd, 2003. Planning and Rehabilitation of the Beach at Teluk Cempedak, Pahang using PEM System.

[6] MRCB Environment Sdn Bhd, 2003. Detailed Design Report (Vol. I) *Projek Perintis Pemulihan Pantai*.

[7] *Pelancongan Menggunakan* 'Pressure Equalisation Module' (PEM) di Teluk Cempedak, Kuantan, Pahang.

[8] MRCB Environment Sdn Bhd, 2003. Detailed Design Report (Vol. II) *Projek Perintis Pemulihan Pantai*.

[9] *Pelancongan Menggunakan* 'Pressure Equalisation Module' (PEM) di Teluk Cempedak, Kuantan, Pahang