CoastCare HBS System

Soft Engineering Coastal Solutions

Hydrodynamic Beach Stabilisation

Background

Soft engineering solutions for coastal protection such as Beach Management System (BMS) and Pressure Equalisation Modules (PEM) installed in the beach matrix have been known for a while.

However some disadvantages inherent to both systems has recently led to the development of a system based on Hydrodynamic Beach Stabilisation (HDB). HDB is a new approach towards an enhanced and cost-effective method to combat beach erosion without disturbing the natural aesthetic beauty of beaches and the environment in general.

The BMS system requires comprehensive engineering work with large wells, energy consuming pumps and a complex pipe system regulated by valves. The theory is to drain the intruding seawater from the beach matrix. The costs of implementation, operation and maintenance are known to be very high.

The PEM system comprises vertical steel header pipes extended with water abstraction screens of plastic, placed in a matrix along the coastline and in the swash zone. The steel header pipes protrude above the beach surface and can pose a safety hazard to beach-walkers and bathers. According to SIC, who market the PEM system, the filters equalise the pressure of the ground freshwater basin to increase circulation of seawater in the coastal profile.

However scepticism of the theory behind the PEM system and heavy engineering of the BMS system led our engineering department to use time and effort into the development of the CoastCare System (Hydrodynamic Beach Stabilisation system).

The CoastCare System is designed as a discrete low cost simple technology solution to enhance the infiltration / ex-filtration rate of the beach face to increase sediment entrapment and retention.

Function

The hydrodynamic stabilisation principle is based on reducing the time interval required for the pressure gradients created by the effects of retreating seawater after permeating the swash zone.

This allows the sand to settle and stabilise earlier so that the sediment transported away from beach by the retreating seawater in the swash zone is reduced, while at the same time increasing the ability of the beach to trap a part of the sediment washed in by wave action. This basic property of the system promotes sedimentation of materials along the coastal profile where it is implemented.

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 again increases the depositing of materials on the foreshore, thereby building up the beach from the sediments transported along the coast.

Over time the new materials in the coastal profile are increasingly coarse, due to the higher speed of the underlying water in the coast profile.

The CoastCare System©

The CoastCare System is a hydrodynamic stabilisation system. It is a stand-alone system, but can also be implemented as a complimentary solution in conjunction with sand nourishment or groyne solutions, etc.

Where sand nourishment has been carried out to combat erosion, the CoastCare System can be applied to stabilise the beach, since beach nourishment in itself is not a measure to stop erosion, but a compensating measure to replace lost sediment.

The CoastCare System promotes infiltration rate in the swash zone as it compensates for the minor conductivity in beach profiles composed of fine sand particles, by reducing the capillary effect (negative pore pressure) within the beachface to improve the horizontal and vertical flow through the beachface to promote uprush sediment transport.

The CoastCare System is a passive beach stabilisation system regulated by the natural hydraulic forces generated by waves and tides. This system is radically different from dredging, sand nourishment, groyne, dewatering etc., methods. It makes the lowest impact on the aesthetic beauty and environment of a beach area and does not require large structures or energy consumption.

The CoastCare System inhibits the rate of loss of beach sediment due to erosion by stabilising the beach swash zone, while at the same time promoting entrapment of the sediment transported by the sea on to the beach.

Major features of the CoastCare System

Environmental aspects	**Safety aspects**	**Aesthetic aspects**	**Financial aspects**
Very low impact of implementation (category C - White project)	Specially developed for public beaches to take into account public safety	No visible parts on the beach	Cost-effective
No energy consumption	No hazard to public visiting the beaches or swimming	Discrete installation (virtually invisible)	Significant savings compared to conventional options
Nuisance free (no noise, odour, etc.)	No structures of the system are above the beach surface (except the collective aeration well)		Low implementation costs
Does not produce energy related pollution	All components in the system are in compliance with the DS 2077 norm		Favourable leasing package comprising: • Engineering. • Establishing. • Training. • Maintenance. • Land-based monitoring.
Does not disturb benthic habitats			
Does not create offshore sinks			
Does not create land-based borrow pits			
Does not increase the turbidity in the near-shore environment			

Theory

Tide range has a role in shaping coastal landforms. In places where there is a large tide range the difference between low tide and high tide can exceed 10 metres, water crosses a very broad area of inter-tidal zone, and wave energy weakens considerably by the time it reaches the shore. Where tide range is small (under 2 metres), there is more consistent wave action thus greater coastal erosion. Extreme events such as storms combined with very high tides may cause severe coastal erosion, depleting beaches and threatening buildings and other structures near the shore.

One of the reasons why beachface erosion occurs is due to a complex interaction of sea and beach in the swash zone. The sea encounters a steep gradient in the swash zone resulting in an uprush and a subsequent downwash cycle with cyclic infiltration- exfiltration and sediment transport across the beach face. If the offshore sediment transport during the backwash exceeds that of the uprush, then beachface erosion occurs.

Infiltration of water into the beach occurs primarily during the wave uprush, whereas exfiltration of water out of the beach mainly occurs during the backwash. The net water circulation is characterized by net infiltration over the swash zone and net exfiltration seaward of the swash zone. The effect of swash infiltration is mainly to reduce the duration and velocity of the backwash flow and does not have much effect on the uprush phase of the swash. This results in an increase in the onshore flow asymmetry and promotes onshore sediment transport and results in the development of steeper equilibrium gradient.

The ensuing swash asymmetry between uprush and backwash influenced by infiltration-exfiltration enhances onshore sediment transport and a steepening of the beachface until a gradient is attained whereby the onshore force due to swash asymmetry is balanced by the offshore gravity component. The resulting gradient, referred to as the equilibrium beachface gradient, increases with the amount of swash infiltration.

Swash infiltration increases the onshore asymmetry in the swash flow, thereby enhancing onshore sediment transport and resulting in relatively steep beachface gradients. However, the accretionary effects of swash infiltration are only evident when the rate of infiltration is sufficiently large, i.e., when the total infiltration volume over a wave cycle exceeds c. 2% of the uprush volume. According to recognised studies, this limit is attained when the hydraulic conductivity exceeds 1 cm/s, which is approximately equivalent to a grain size coarser than 1.5 mm.

This leads to two critical parameters: critical sediment hydraulic conductivity K à 1 cm/s and grain size D50 à 1.5 mm. Therefore, swash infiltration has negligible effects on sandy beaches where the sediment grain size is usually less than 1 mm. The correlation between the beachface gradient and sediment size at these beaches is due to other mechanisms, rather than swash infiltration.
For gravel beaches, however, swash infiltration is likely to be the dominant factor in controlling the beachface gradient.

On tidal beaches, swash infiltration depends largely on the tidal stage with infiltration predominantly occurring during the rising tide when the beach is relatively dry. However, if tidal action is ignored, the amount of water infiltrating into the beach during swash action depends primarily on the hydraulic conductivity / permeability of the beachface. The permeability of the beachface increases with sediment size and to a lesser degree with sediment sorting. Cyclic infiltration- exfiltration is associated with individual swash events. At the timescale of individual swashes, vertical pore-pressure gradients within the beach face are much greater than horizontal pore-pressure gradients (Darcy's law).

The relationship between sediment size, swash infiltration and beach gradient is widely recognised. The larger the sediment size the greater the amount of swash infiltration, and the steeper the beach.

In layered geologic media, where alternating fine and coarse layers can contribute to the horizontal migration, it follows that this natural variability in sediments and resulting sedimentary rocks imparts variations in the hydraulic properties of the sediment.

For example, a very fine-grained sand layer below coarser sand can retard the downward vertical movement. Flow fingers develop because the fine material can't supply sufficient water to fill the underlying larger pores. Thus flow occurs at discrete points along the boundary and not over the entire surface. Flow fingers are preferential pathways of flow through which the water continues to migrate.

Beach matrix infiltration and surface loss caused by tidal dynamics and waves involve many different processes at different scales of observation. The most basic of the processes is the infiltration of seawater into the beach matrix, which is mainly conducted into the capillary zone. The capillary zone above the groundwater table is characterised by a lower pressure than the atmosphere, which leads to upwards infiltration/percolation of rising seawater through the beach matrix.

As the volume of infiltrated seawater increases, the infiltration capacity of the beach matrix decreases to a minimum rate equal to the beach matrix's saturated hydraulic conductivity. The saturated hydraulic conductivity is a proportionally constant between hydraulic gradient and flow in Darcy's law for saturated flow in porous media and is assumed to be a characteristic of the beach matrix.

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