Influence of permeability on the performance of shingle and mixed beaches

Technical Summary: FD1923

Joint Defra / EA Flood and Coastal Erosion Risk Management R&D programme

Background to R&D project

Beach recharge using mixed sand-gravel sediment is a common practice in the UK, used as a means of coastal defence and protection against storm wave attack. Good design for schemes involving such sediment depends on effectively predicting the behaviour of the resulting beach in response to different wave conditions. This in turn depends on our understanding of sediment processes on mixed sand-gravel beaches. The scoping study has taken the form of an extended literature review; theoretical analysis coupled with special purpose laboratory experiments; re-analysis of existing experimental data; numerical modelling with the support of laboratory and field data; and case studies of three current/recent beach recharge programmes. The objectives are as follows:

- to produce a review of existing knowledge of the impacts of permeability on the performance of gravel and mixed sand-gravel beaches;
- to investigate the cliffing problem of recharged mixed sand-gravel beaches;
- to examine the effects of the sand fraction on the permeability and porosity of mixed sand-gravel sediment, and the ways forward in alleviating the problem of cliffing;
- to carry out numerical modelling to improve understanding of the effect of permeability on beach profile response on mixed beaches, including the relative importance of parameters such as hydraulic conductivity, wave friction factor, sediment grading, and groundwater flow;
- to propose recommendations for a framework of field and laboratory studies to advance knowledge of the influence of permeability on beach performance.

Results of R&D project

The literature review found that no standard method is yet available for characterising mixed sediments. A primary difficulty is that mixed beaches exhibit a high degree of variability, both spatially and temporally. However, the percentage of sand and its size relative to the gravel are among the most important parameters associated with the performance of a mixed sand-gravel beach, and thus may be used as key parameters characterising mixed beaches. The literature also indicates that sediment transport is affected by the relative proportions of sand and gravel.

Laboratory experiments show that under the same wave conditions, mixed sand-gravel beaches have reduced volumetric changes, less onshore transport, and more offshore transport than gravel beaches. This may be directly related to the fact that the presence of sand in a mixed beach significantly reduces the permeability of the beach, impairing the water flow within the sediment media. Numerical modelling and laboratory experiments show that the hydraulic conductivity of the sediment and the groundwater level both have significant effects on the evolution of the beach surface. A lower groundwater level leads to increased onshore transport and a higher groundwater level to increased offshore transport for both accretionary and erosional conditions. There is a clear need for improved numerical models specifically designed to deal with mixed beaches.

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The cliffing problem of recharged mixed sand-gravel beaches was firstly investigated by means of a simplified theoretical model of mixed sediment. The theoretical analysis led to a group of simple equations that relate the porosity, hydraulic conductivity and bulk density of the mixed sediment to the percentage of sand in the sediment. A series of laboratory experiments were then carried out which successfully validated the theoretical equations. The hydraulic conductivity of the mixed sediment was shown to be greatly influenced by the presence of sand. The equations also provide an indication of the worst scenario in terms of the likelihood of cliffing, and how compaction affects hydraulic conductivity and cliffing of a recharged sand-gravel beach. Theory suggests that the cliffing problem may be significantly alleviated by controlling the sand percentage, which should not exceed the critical value corresponding to a given sand and gravel size (normally in the range of 30% to 40%). It was also noted that the control of the sand percentage is only required for the upper beach, or just the beach crest, and it is achievable through managed use of sediment sources and/or improved sediment placement techniques.

Case studies included Pevensey Bay in East Sussex, Tankerton in Kent and Hayling Island in Hampshire. The analysis of data collected from these three sites highlights the importance of frequent and focused beach recycling and the widespread problem of cliffing. At Pevensey the volume of material recycled annually is of the same order as that added during the recharge, leading to significantly reduced operational cost, whilst making more efficient use of limited sediment resources. Field data also shows that a high sand percentage coupled with an unnaturally steep beach slope seems to be the core of the cliffing problem. Laboratory and field evidence indicates that a natural slope of a mixed sand-gravel beach is around 1:9, but recharged beaches tend to have a design slope of ~1:7. The experiences from the three sites indicated that reducing the sand percentage on the upper beach had the positive effect of reducing the cliffing problem. The 'modified rainbowing' technique of PCDL (Pevensey Coastal Defence Ltd) is worth more investigation and may be considered for wider applications.

A number of recommendations for future work are produced and these are given in the Project Report. They are grouped in terms of types of work/study and relevant groups of interest, with priorities for the recommended work also suggested.

R&D Outputs and their Use

The main outputs from this scoping study are the Technical Report, a paper at ICCE 2006, a paper at the Defra Conference 2006, a paper at Coastal Sediments 2007, a Defra newsletter (July 2006), and five Internal Project Reports, with journal papers to come. The Technical Report includes an extensive review of the current state of understanding of mixed beach processes, the method of prediction of the cliffing problem, and preliminary advice on good practices in relation to beach recharge programmes.

This R&D Technical Summary relates to R&D Project FD1923 and the following R&D output:

R&D Technical Report FD1923/TR – Influence of permeability on the performance of shingle and mixed beaches. Published March 2008.

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The above outputs may be downloaded from the Defra/EA Joint R&D FCERM Programme website (www.defra.gov.uk/environ/fcd/research). Copies are also available via the Environment Agency's science publications catalogue (http://publications.environment-agency.gov.uk/epages/eapublications.storefront) on a print-on-demand basis.

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