APPENDIX A

FILL QUANTITY ESTIMATION

CONTENTS

APPENDIX A FILL QUANTITY ESTIMATION

A.1 GENERAL

This Appendix describes the methods of estimating the fill quantity in beach nourishment. Designers may use all these methods to assess the potential range of required fill volume, and should not infer that coarser materials will necessarily last longer than native material when adopting these methods. For more details, reference should be made to CIRIA (1996).

A.2 EQUILIBRIUM PROFILE METHOD

The Dean's equilibrium method (Dean, 1991) determines the volume of recharged sand of a given grain size to increase the width of dry beach by a given amount. Dean proposed that beach profiles develop a characteristic parabolic equilibrium profile given by :

$$d = Ax^{2/3} \tag{A1}$$

where d is the depth below still water for any given horizontal distance, x, from the shoreline, both measured in metres.

A can be expressed as :

$$A = 0.21\, D^{0.48} \tag{A2}$$

where D is the grain size (mm).

Three different types of profile depending on the relative values of A for the native sand and fill material are shown in Figure A1. The intersecting profile intersects the native profile before the closure depth d_{oc}. The non-intersecting profile, steeper than the native profile, does not intersect before the closure depth. For the sub-merged profile, the fill material is finer than the native material and insufficient volume has been added to increase the dry beach width.

The procedure of determining the fill volume is given as follows :

(1) Determine the closure depth d_{oc} as :

$$d_{oc} = 1.75\ H_s \tag{A3}$$

where H_s corresponds to the significant wave height being exceeded only 12 hours per year.

(2) Select a berm crest height R_c and required increase in dry beach width Y.

(3) Determine A_R and A_N from Equation A2 for the fill and native material respectively.

(4) Determine whether the profiles are intersecting or non-intersecting using Equation A4 :

$$\begin{aligned} &Y\left(\frac{A_N}{d_{OC}}\right)^{3/2} + \left(\frac{A_N}{A_R}\right)^{3/2} < 1 \qquad \text{intersecting profile} \\ &Y\left(\frac{A_N}{d_{OC}}\right)^{3/2} + \left(\frac{A_N}{A_R}\right)^{3/2} > 1 \qquad \text{non-intersecting profile} \end{aligned} \tag{A4}$$

(5) Calculate the volume of fill V required per metre run of the beach to advance the shoreline by a distance Y :

If the profiles are intersecting, V is given by :

$$V = R_C Y + \frac{A_N Y^{5/3}}{\left[1 - \left(\frac{A_N}{A_R}\right)^{3/2}\right]^{2/3}} \tag{A5}$$

If the profiles are non-intersecting, V is given by :

$$V = R_C Y + \frac{3}{5} d_{oc}{}^{5/2} \left\{ \left[\frac{Y}{d_{oc}{}^{3/2}} + \left(\frac{1}{A_R}\right)^{3/2} \right]^{5/3} A_N - \left(\frac{1}{A_R}\right)^{3/2} \right\} \tag{A6}$$

A.3 EQUILIBRIUM SLOPE METHOD

The equilibrium slope method by Pilarczyk, van Overeem and Bakker (1986) bases the recharged profile on the present native profile. However, if the grain size of the fill material is different from the native material, the profile steepness is altered according to the following relationship :

$$l_R = \left(\frac{w_N}{w_R} \right)^{0.56} l_N \qquad \text{(A7)}$$

where w = fall velocity.
l = distance offshore of a given depth contour.
N = subscript to denote native material.
R = subscript to denote fill or recharge material.

For common beach sand of diameter D between 0.15 mm and 0.85 mm, the following approximation for fall velocity w may be used (in cm/s) :

$$w = 14D^{1.1} \qquad \text{(A8)}$$

where D is in mm.

If the fill material is coarser than the native material (i.e. $w_R > w_N$), the profile of the nourished beach will be steeper than the original profile as shown in Figure A2. The opposite effect applies to fill material finer than native material.

The above profile is used down to a cutoff depth d_c of the active beach defined by :

$$d_c = 1.75\, H_s \qquad \text{(A9)}$$

where H_s is the nearshore significant wave height.

Beyond the cutoff depth d_c, the nourished beach thickness is assumed to decrease linearly within a transition zone until it intersects the original profile at an intersection depth d_i, given by $d_i \sim 3H_s$ as shown in Figure A2.

A.4 OVERFILL RATIO METHODS

A.4.1 Krumbein and James Method

Krumbein and James (1965) established a method for estimating the additional quantity of fill material required if the fill and native sediment are dissimilar. The method involved multiplying the required volume of beach material, assuming a natural grading, by a critical overfill ratio R_{crit} to determine the quantity of fill material over and above that required by the absolute dimensions of the proposed nourishment works. R_{crit} is given by :

$$R_{crit} = \frac{\sigma_{\phi R}}{\sigma_{\phi N}} \exp\left[-\frac{(M_{\phi N} - M_{\phi R})^2}{2(\sigma_{\phi N}^2 - \sigma_{\phi R}^2)}\right] \qquad \text{(A10)}$$

where ϕ = $-\log_2 D$ (D = mean sediment diameter in mm).

$M_\phi = (\phi_{84} + \phi_{16})/2$, larger values of M denote finer material.

$\sigma_\phi = (\phi_{84} - \phi_{16})/2$.

ϕ_{84} = the particle size in phi unit that is exceeded by 84% (by dry weight) of the total sample.

ϕ_{16} = the particle size in phi unit that is exceeded by 16% (by dry weight) of the total sample.

R = Subscript to denote fill or recharge material.

N = Subscript to denote native material.

The overfill ratio R_{crit} determined by the Krumbein and James Method cannot be applied to all the possible combinations of fill and native sediment grading, which are summarized as follows :

(1) Fill material finer than native material $M_{\phi R} > M_{\phi N}$

If the fill material is more poorly sorted than the native material ($\sigma_{\phi R} > \sigma_{\phi N}$), the best estimate of the required overfill will be given by R_{crit}.

(2) Fill material coarser than native material $M_{\phi R} < M_{\phi N}$

If the fill material is more poorly sorted than the native material ($\sigma_{\phi R} > \sigma_{\phi N}$), the required overfill ratio may probably be less than R_{crit}.

(3) Fill material finer than native material $M_{\phi R} > M_{\phi N}$

If the fill material is better sorted than the native material ($\sigma_{\phi R} < \sigma_{\phi N}$), the distributions cannot be matched. Loss of fill cannot be predicted and will probably be large.

(4) Fill material coarser than native material $M_{\phi R} < M_{\phi N}$

If the fill material is better sorted than the native material ($\sigma_{\phi R} < \sigma_{\phi N}$), the distributions cannot be matched but the fill material should be stable. Scour of native material fronting toe of fill may be induced.

A.4.2 Dean Method

The Krumbein and James Method is only applicable if the native material is better sorted than the fill material. If the fill material is better sorted than the native material, this method simply does not apply. Secondly, the Krumbein and James Method assumes that the portion of the fill material retained on the beach after sorting by waves and current will have exactly the same size distribution of the native material. This implies that both the fine and coarse portion of the fill will be lost. This feature is not consistent with the knowledge of sediment transport process as the coarser portion of the fill will likely remain on the beach without being carried away by waves and currents (Dean, 1974; also Dean and Dalrymple, 2002). The overfill ratio by the Krumbein and James Method will tend to be overestimated.

Dean (1974) addressed the above shortcomings by assuming that only the finer portion of the fill will be winnowed away by prevailing wave condition leaving the mean diameter of altered distribution of fill material to be at least as large as the mean diameter of native material. Dean defines the overfill ratio as the required replacement volume of fill material to obtain one unit of compatible beach material and uses the ‘phi’ unit to describe the size of sand particle, given by :

$$\text{Size in phi unit} = -\log_2 D \qquad \text{(A11)}$$

If the mean diameter in phi unit and the standard deviation in phi unit of both native and fill material are known, the overfill ratio can be determined from Figure A3.

A.5 REFERENCES

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LIST OF FIGURES