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Coastal Engineering Technical Note

FALL VELOCITY OF BEACH SANDS

PURPOSE: To present an improved method for estimating the terminal fall velocity of any beach sand. Fall velocity is used in predicting the occurrence of accreted (berm) or eroded (bar) nearshore profiles; see Section 4.525c of the *Shore Protection Manual*. Although definitive methods for engineering application have not yet been established, the fall velocity is expected to figure in the dimensions of bed forms and in the sediment transport.

BACKGROUND: Standard guidance on the value of fall velocity is provided for spheres of a given material in a given fluid; for example, Figure 4-31 of the SPM presents the fall velocity of quartz spheres in freshwater at several temperatures. A recent review of available measurements resulted in a set of simple equations giving fall velocity for common angular sediment grains. This more general and convenient guidance will be summarized here, and an example calculation presented.

GIVEN GUIDANCE: To estimate fall velocity, V_f, the following material characteristics must be specified: ρ_s = sediment density; ρ = fluid density; υ = fluid kinematic viscosity; and M_d = sediment median grain diameter. To determine which of the three equations should be used, the grain buoyancy, A, must be determined using the following equation:

$$A = \frac{(\rho_s - \rho) g M_d^3}{\rho \upsilon^2}$$

where g = acceleration of gravity. The fall velocity equations and their ranges of applicability are:

$$V_f = \frac{(\rho_s - \rho) g M_d^2}{18 \rho \upsilon} \quad , \text{ for } A < 39 \qquad (1)$$

$$V_f = \frac{\left[\frac{(\rho_s - \rho) g}{\rho}\right]^{0.7} M_d^{1.1}}{6\ \nu^{0.4}} \quad \text{, for } 39 < A < 10^4 \qquad (2)$$

$$V_f = \left[\frac{(\rho_s - \rho) g\ M_d}{0.91\ \rho}\right]^{1/2} \quad \text{, for } A > 10^4 \qquad (3)$$

Any consistent units may be used in these relationships. Common values of ρ and ν for freshwater and for 33 parts per thousand (ppt) saltwater are listed in the table. The value of g is 981 cm/sec^2. Common values of ρ_s are 2.65 gm/cm^3 for quartz and 2.7 to 2.8 gm/cm^3 for shell material. Equation (2) will usually be applicable in freshwater or saltwater for fine to coarse quartz sand, i.e., M_d between 0.125 and 1 mm.

Table. Common Fluid Characteristics

Temperature °C	Freshwater		33 ppt Saltwater	
	ρ, gm/cm^3	ν, cm^2/sec	ρ, gm/cm^3	ν, cm^2/sec
5	1.0000	0.0151	1.028	0.0157
10	0.9997	0.0130	1.027	0.0135
15	0.9991	0.0114	1.026	0.0119
20	0.9982	0.0100	1.025	0.0105
25	0.9969	0.0089	1.024	0.0095

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GIVEN: Quartz sand of M_d = 0.02 cm (0.20 mm) in 20°C freshwater;

FIND: The value of fall velocity, V_f.

SOLUTION: Using values from the table, the value of A is computed as:

$$A = \frac{(\rho_s - \rho) g\ M_d^3}{\rho \nu^2} = \frac{(2.65 - 0.998)\, 981\, (0.02)^3}{(0.998)\,(0.0100)^2} = 130 \ ,$$

so that Equation (2) is appropriate, and

$$V_f = \frac{\left[\frac{(\rho_s - \rho) g}{\rho}\right]^{0.7} M_d^{1.1}}{6\ \nu^{0.4}} = \frac{\left[\frac{(2.65 - 0.998)\, 981}{0.998}\right]^{0.7} (0.02)^{1.1}}{6(0.0100)^{0.4}} = \begin{array}{l}2.51 \text{ cm/sec or} \\ 0.082 \text{ ft/sec}\end{array}$$

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REFERENCES:

HALLERMEIER, R.J., "Terminal Settling Velocity of Commonly - Occurring Sand Grains," *Sedimentology,* 1981, Vol. 28, No. 6, Dec 1981, pp. 859-865.

Shore Protection Manual. 1984. 4th ed., 2 vols, U.S. Army Engineer Waterways Experiment Station, Coastal Engineering Research Center, U.S. Government Printing Office, Washington, D.C.