**Sandy Beach Morphodynamics**

**Relationship between sediment size and beach slope**

Figure 2. shows data from other scientists who measured beach slopes and sand grain sizes. Graph from Wiegel, R.L., 1965. *Oceanographical Engineering*, Prentice-Hall, 531 pages.

Longshore Sorting - Willard Bascom

Beach Slope, Grain Size, and Wave Energy

Beach at Sandwich Bay, Kent, UK – near the Straights of Dover
What sets the slope of the beach face?

The beach face slope is controlled by the asymmetry in intensity of wave-swash uprush vs. return backwash:

(1) The shoreward uprush tends to be stronger than the seaward backwash because of water percolation into the porous beach sediment.

(2) "This asymmetry moves sediment onshore until a slope is built over which gravity supports the backwash and enhances offshore sediment transport."

(3) When seaward sediment transport (via the backwash) equals landward sediment transport (via the uprush), the beach face slope is steady and the profile is in a state of dynamic equilibrium.

(4) The value of the slope at equilibrium is controlled (at least in part) by the percolation of uprush. Coarse, angular gravel, for example, has much greater permeability than medium-to-fine, poorly-sorted sand. So on the gravel beach, the return backwash is relatively weaker, being compensated for by a greater slope than on the sandy beach.

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Beach Slope, Grain Size, and Wave Energy – Results of Field Studies

Two dependencies visible:

(1) Beach face slope decreases with decreasing grain size, or increases with increasing grain size.

(2) The influence of wave energy – high energy beaches tend to have lower slopes for a given grain size than low energy beaches.

Figure 7-16 The beach-face slope as a function of the median grain size of the beach sediment. Also shown is the difference between U.S. west coast and east coast beaches, which reflects the importance of the overall wave-energy level as a control on the beach slope. [Adapted with permission of American Geophysical Union, from W. H. Bascom, The Relationship Between Sand Size and Beach Face Slope, Transactions American Geophysical Union 52, p. 872. Copyright © 1951 American Geophysical Union and with permission of Prentice-Hall, Inc., from R. L. Wiegel, Oceanographical Engineering. Copyright © 1964 Prentice Hall.]
Results of Field Studies – Half Moon Bay, CA

At one site, Willard Bascom was able to illustrate the effects of sheltering vs. exposure on both the beach slope and the corresponding trend.

North end of Half-Moon Bay, California - headland blocks bulk of wave energy and orientation of coast is such that the deep-water wave approach angle must be refracted through >90° - causes a very low refraction coefficient forcing incident wave heights at the north end to be small.

At south end, beach well exposed to open ocean and oriented more closely to orthogonal to orientation of deep water wave rays. Waves incident to south end beaches lose little wave energy flux to refraction-driven "wave crest stretching".

Result = gently-sloped fine grained beaches at sheltered, north end & steeply-sloped coarse grained beaches at exposed, south end.

When plotted on the compilation diagram, Half-Moon Bay data set spans both Pacific (high energy) and Atlantic (low energy) regions.

Empirical Relationship for Beach Slope as f(wave steepness)

\[ S_0 = 0.30 \left( \frac{H_\infty}{L_\infty} \right)^{-0.30} \]

Rector's (1954) study suggested as waves steepen, beach slope decreases.

This relationship is not in disagreement with the observation that storms (characteristically generating steep waves) are responded to by beach flattening.
Empirical Relationship for Beach Slope as f(Dean Number)

Dalrymple and Thompson (1976) attempted to relate the beach slope to the dimensionless settling velocity (Dean Number), in addition to wave conditions.

Recall that the Dean Number is a “measure of whether a sedimentary particle lifted into suspension by a passing wave can fall to the bottom during the time when its net displacement is shoreward.”

Data show inverse relationship between slope and particle size, but it is not yet resolved whether this is due to sediment movement within a wave orbital (Dean explanation) or if it is due to percolation considerations.

Beach Water Table

Figure 7-19 A compilation of laboratory data to relate the beach-face slope to $H_w/T$, where $w_s$ is the settling velocity of the beach sand. [Adapted from Study of Equilibrium Beach Profiles, R. A. Dalrymple and W. W. Thompson, Proceedings of the 15th Coastal Engineering Conference, 1976. Reproduced with permission from the American Society of Civil Engineers.]
What's the berm? The nearly horizontal portion of the exposed beach.

Berm elevation coincides with wave runup height (Bagnold, 1940)

Takeda and Sunamura (1982) related berm elevation to wave conditions

Bascom’s (1953) explanation of berm formation:

“After a wave breaks, the water rushes forward up the beach face, carrying sand with it, losing velocity as it goes because it is opposed by gravity and friction and because of water losses through percolation. As the beach builds seaward, it leaves a nearly horizontal berm that corresponds to the elevation to which sand had been carried by the swash runup.”
Berm Formation

Uniformity of wave height and rapid berm growth allows the berm elevation to reflect tidal variations (Strahler, 1966).
Large waves bring sediment over the crest and deposit atop the berm -- can produce landward sloping berm if crest grows seaward.
High storm waves cut back and destroy the berm, but under certain conditions are the agents responsible for sediment delivery high on the beach, hence can cause the berm to grow -- an interesting paradox worthy of a simple numerical model.
A storm may leave a high "marker" berm, and if progradation is rapid enough, a beach may display a series of abandoned storm berms -- documenting the storm history witnessed at that site.

Bar Migration and Welding

Inner bar can show great variability

During onshore movement, bar height increases and trough is constricted

Eventual welding onto the beach foreshore

Primary means of “recovery” after a storm moves upper beach material offshore and performs the “flattening”
Beach Cusps