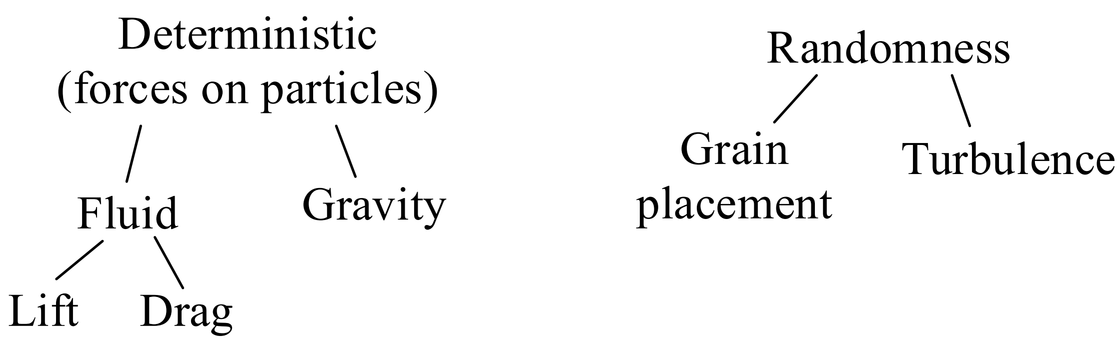
Initiation of Motion

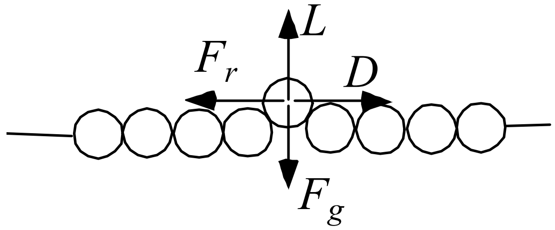
The initiation of movement of individual grains is dependent on a variety of factors, both deterministic and random.



Many models have been developed which attempt to model the LHS. We will discuss one popular model, the Ikeda-Coleman-Iwagaki model. It is extremely similar to Wiberg and Smith (1987).

Assumptions:

1. Unidirectional, uniform, boundary layer flow
2. Forces act on a 'dangerously placed' particle
3. No flow within the 'bed'
4. Turbulent forces are negligible (i.e., $u_*/v_s << 1$)
5. Drag and lift forces act through the center of mass (all other forces are negligible)
6. Boundary effects (i.e., c_D is assumed to be its free-stream value).
7. Roughness height is taken equal to the grain size.



We are interested in the fluid velocity at the top of the particle of interest. It can take two values depending on whether the boundary is smooth or not –

Smooth means that a viscous boundary layer exists; i.e.,

$$\frac{u_* D}{\nu} < 5 \qquad (1)$$

In this case, $u_f = \bar{u}\big|_{z=D/2}$

$$\frac{\bar{u}}{u_*} = \frac{u_* z}{\nu} \qquad \text{OR} \qquad \frac{u_f}{u_*} = \frac{u_* D}{2\nu} \qquad (2)$$

In rough flow, we assume that the particle protrudes into the log-layer and that the velocity of interest becomes

$$\frac{u_f}{u_*} = 2.5\ln\left(30\frac{z}{D}\right)\bigg|_{z=D/2} = 6.77 \qquad (3)$$

Note that these two solutions meet for $u_* D/\nu = 13.5$, therefore we can state

$$\frac{u_f}{u_*} = F\left(\frac{u_* D}{\nu}\right) \tag{4}$$

We also know the forces on the particle, if we assume that u_f represents the free-stream velocity and velocity difference across the particle. They are –

$$F_D = \frac{\rho \pi D^2 c_D u_f^{\,2}}{8} \tag{5a}$$

$$L = \frac{\rho \pi D^2 c_L u_f^{\,2}}{8} \tag{5b}$$

$$F_g = \frac{\rho \pi R g D^3}{6} \tag{5c}$$

$$F_r = \mu F_n = \mu\left(F_g - L\right) \tag{5d}$$

where μ is the Coloumb friction coefficient. The Coloumb friction coefficient is dependent on mineralogy and shape, but is typically ~ 0.8-0.9.

The critical condition for motion to occur will be if the drag force F_D is just balanced by the resistive force F_r. Setting (5a) and (5d) equal, we find

$$\frac{u_f^{\,2}}{RgD} = \frac{4}{3}\frac{\mu}{c_D + \mu c_L} \qquad (6)$$

Remembering (4)

$$F = \begin{cases} \dfrac{1}{2}\dfrac{u_* D}{\nu} & for \quad \dfrac{u_* D}{\nu} < 13.5 \\ 6.77 & for \quad \dfrac{u_* D}{\nu} > 13.5 \end{cases}$$

$$\tau_c{}^* = \frac{u_{*c}^{\,2}}{RgD} = \frac{4}{3}\frac{\mu}{c_D + \mu c_L}\frac{1}{F^2} \qquad (7)$$

Where F is the function described in (2) & (3) and τ^* is the Shields stress, or Shields parameter. It can be defined alternatively as

$$\tau^* = \frac{\tau_b}{\rho RgD} \qquad (8)$$

Shields (1936) first proposed the general relationship based purely on dimensional analysis. Some of his data is plotted along with 'recent' data from Miller *et al*. (1977)

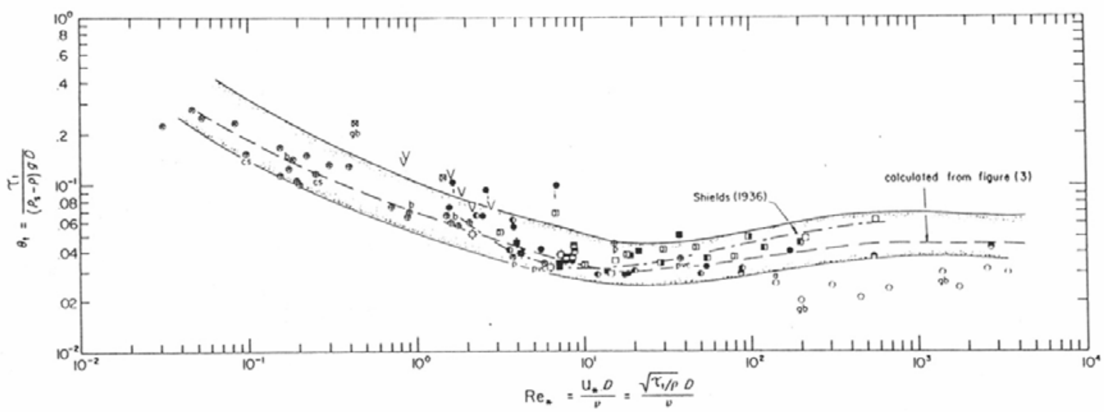


Fig. 2. The proposed modified Shields curve of θ_t versus Re_* based on additional carefully selected data. See Table 1 for identification of the symbols.

Another problem with the Shields curve is that it is an implicit relation. That is, it requires knowledge of the critical shear velocity u_{*c} in order to calculate the critical Shields stress τ_c*.

Mixtures

Laboratory modelers typically use well-sorted materials to constrain *D*. However, natural sediments are often poorly sorted. Recently have there been efforts to account of the effects of the grain-size distribution. These formulations generally take the form –

$$\tau_{ci}{}^* = \tau_{cg}{}^* \left(\frac{D_i}{D_g} \right)^{\beta} \qquad (9)$$

where D_i indicates the grain size in the ith size range in the mixture. D_g indicates the geometric mean grain size ($\overline{\Phi}$) of the 'surface layer'.

β takes a value of about -0.9 (Parker, 1990). Because beds typically **armor** themselves, a well-developed flow will often move sediment according to the shear stress of the largest material within the flow. This effect is often referred to as **hiding**.

Fine Sediments

The Shields diagram and the theory outlined above is implicitly derived for sandy to gravelly beds. There are several assumptions that are often invalidated with fine sediment –

a. Fine sediment tends to be more poorly-sorted
b. Electrostatic forces become important (grain-grain cohesion and mineralogy dominate)
c. Definition of the 'bed' is more difficult
d. Turbulence and its structure strongly regulate movement (i.e., u_*/v_s becomes larger).

As a result, initiation of motion is complex and dependent on several new factors. They are:

a. Sediment concentration
b. Degree of consolidation
c. Degree of flocculation