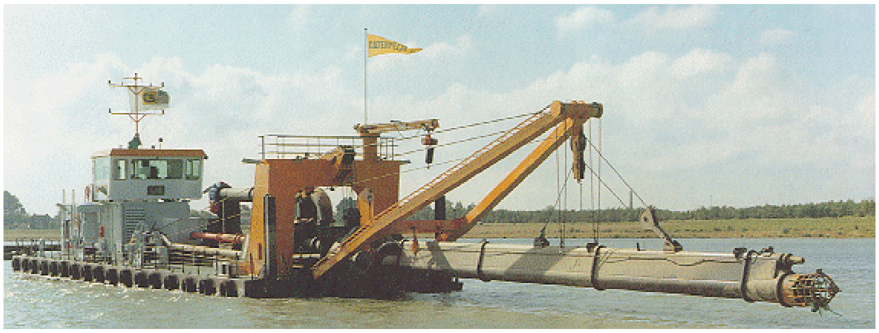
Breaching Process



OE 4626

Prof. Dr. ir. C. van Rhee

12 December 2008

Sectie Offshore & Dredging Engineering

TU Delft
Delft University of Technology

Contents

- Equipment
- Production limits
  - Pit
  - Vacuum
- Theory of breaching process

Plain or deep suction dredger

- Stationary
- No mechanical excavation
- Primary Production process results from slope instability
- Dilution with water jets
- Suction towards water surface
- Pumping to reclamation
- Or Barge loading

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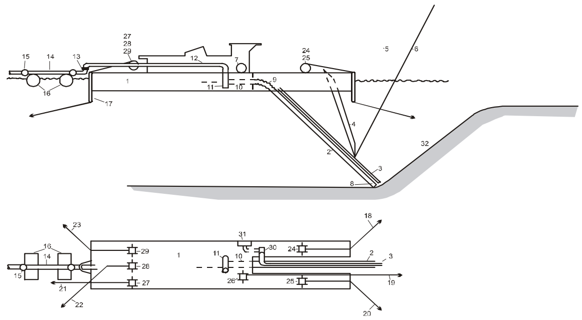
Standard method



Standard plain suction dredger

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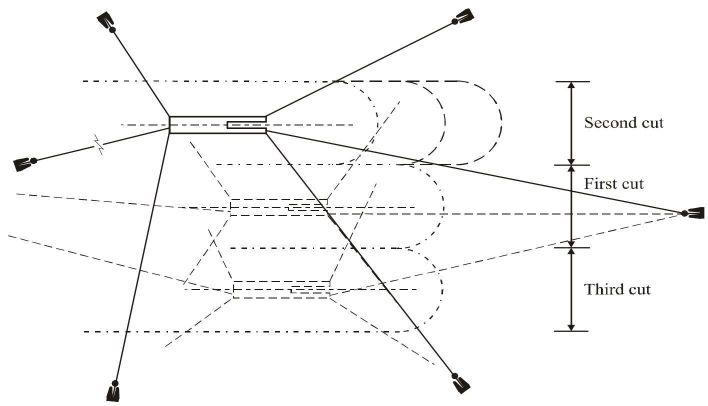
Horizontal cuts



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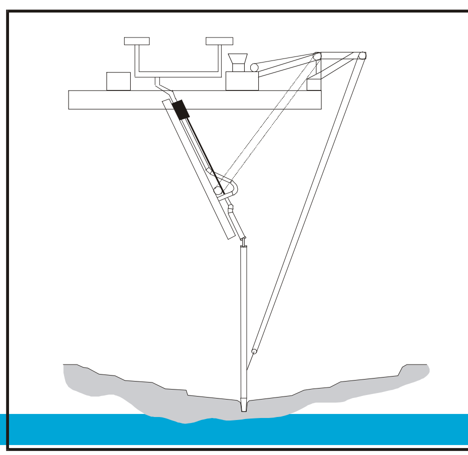
Deep suction dredger



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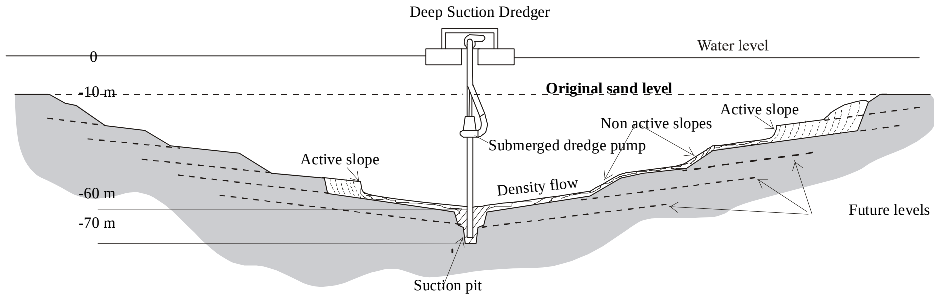
Practice



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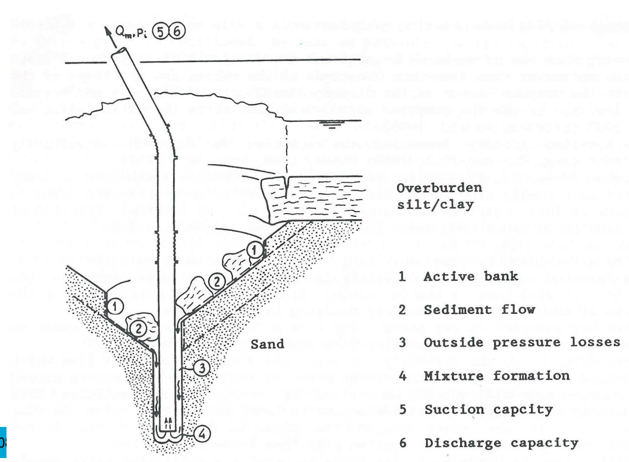
When dredging under an overburden



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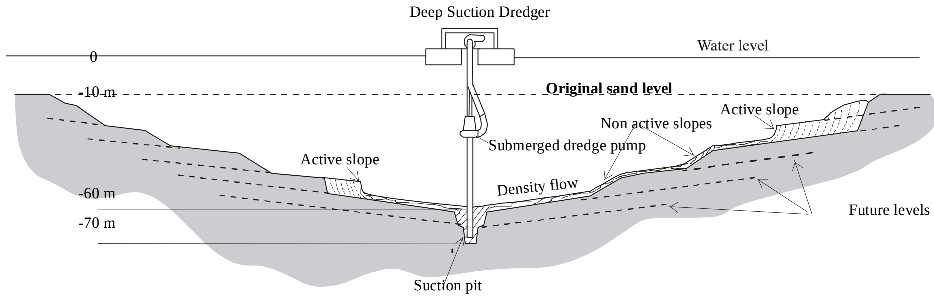
Practice



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Production Limits

- Equipment
  - Pumping power / head available
    - Pumping distance
    - PSD
  - Vacuum limit
    - Suction depth
    - Depth of (underwater) pump
- Production of the pit

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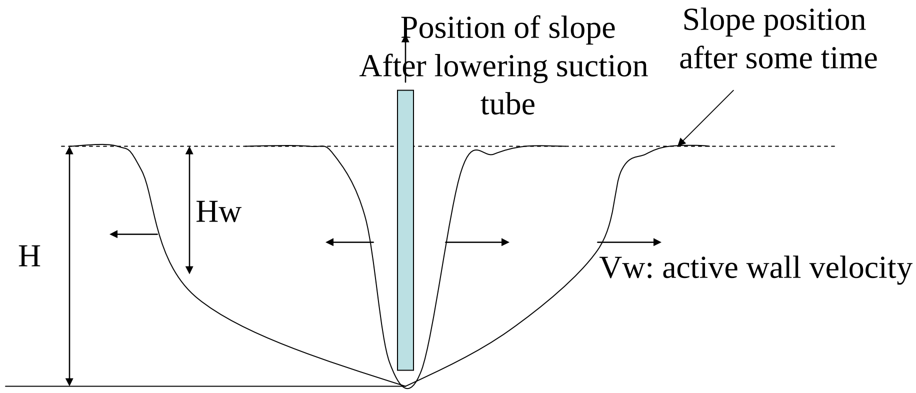
Pit production



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Pit Production

- Production per unit width $P = H_w v_w$
- Total prod (circular pit) $P = \pi D H_w v_w$
- D= Diam pit is proportional with H and Hw is proportional with Hw
- Hence P :: $v_w H^2$
- Vw depends on the permeability of sand: v_w::k

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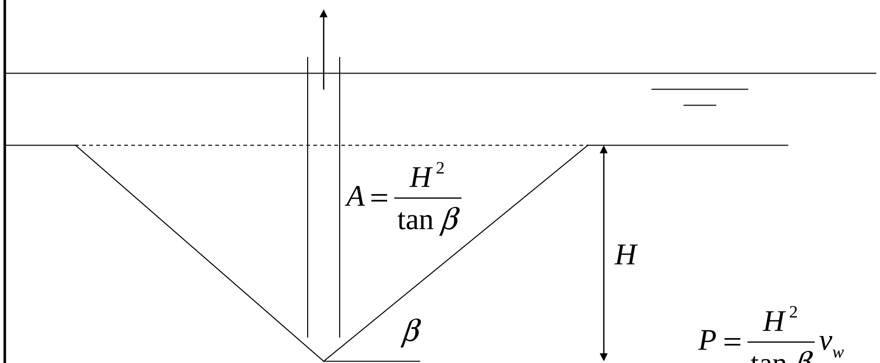
Production for horizontal stepping



$$P = \frac{H^2}{\tan\beta} v_w$$

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Vacuum limit

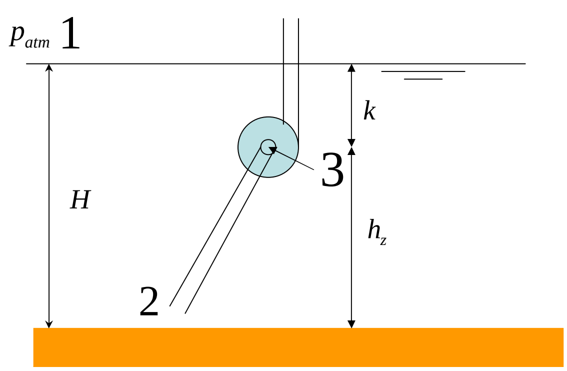
- 1: Water surface

  p_{atm}

- 2: Suction Inlet

  $p_{atm} + \rho_w g H$

- 3: Suction side pump



$$p_s = p_{atm} + \rho_w g H - \rho_m g\left(H - k\right) - \xi \tfrac{1}{2} \rho_m u^2$$

$$p_s = p_{atm} + \rho_w g H - \rho_m \left(g h_z + \xi \tfrac{1}{2} u^2\right)$$

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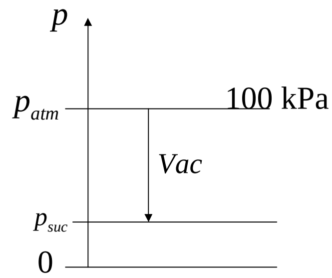
Vacuum limit



•Or:

$$\rho_m = \frac{p_{atm} + \rho_w g H - p_{suc}}{g h_z + \xi \frac{1}{2} u^2}$$

•'vacuum'

$$p_{suc} = p_{atm} - Vac$$

$$\rho_m = \frac{Vac + \rho_w g H}{g h_z + \xi \frac{1}{2} u^2}$$

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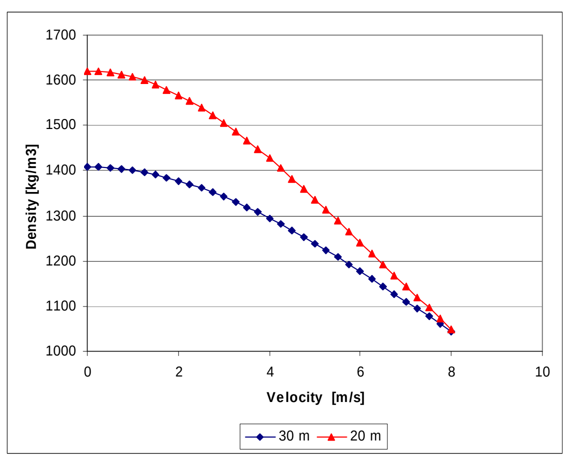
Max density as a function of velocity

•Vac = 85 kPa
•K= 2 m (depth pump)
•Ksi =3



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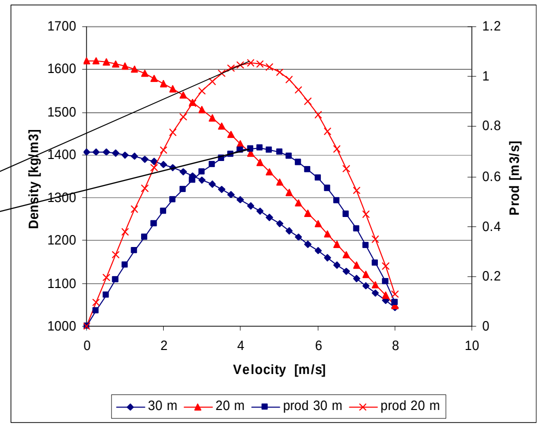
Vacuum Production

- Production

$$P = Q\frac{\rho_m - \rho_w}{\rho_{situ} - \rho_w} = \tfrac{1}{4}\pi D^2 u\frac{\rho_m - \rho_w}{\rho_{situ} - \rho_w}$$

Max production decreases
With depth



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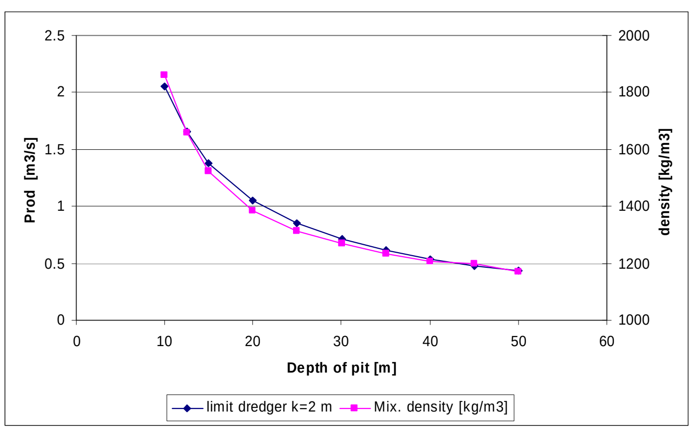

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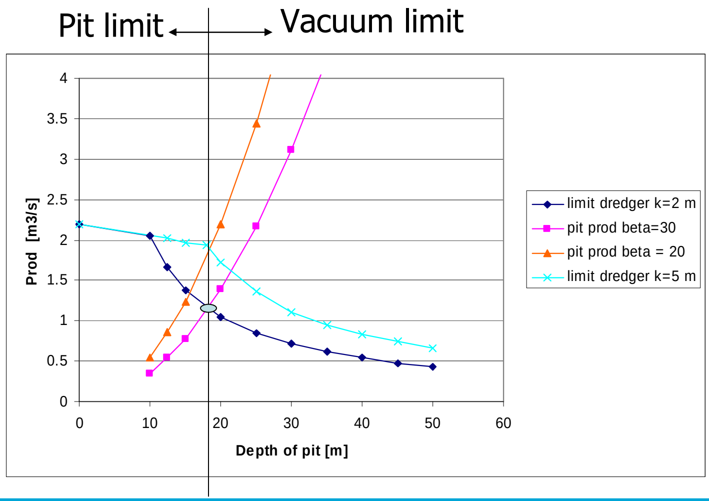
Limits of pit and dredger



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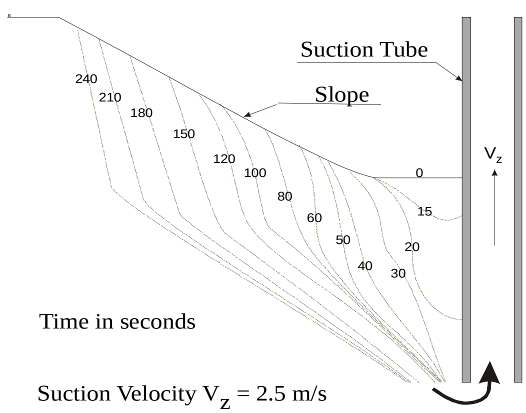
Breaching process



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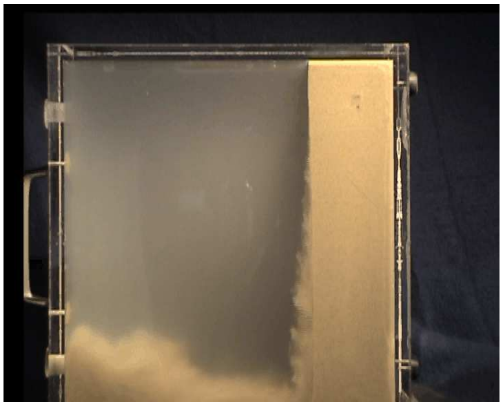

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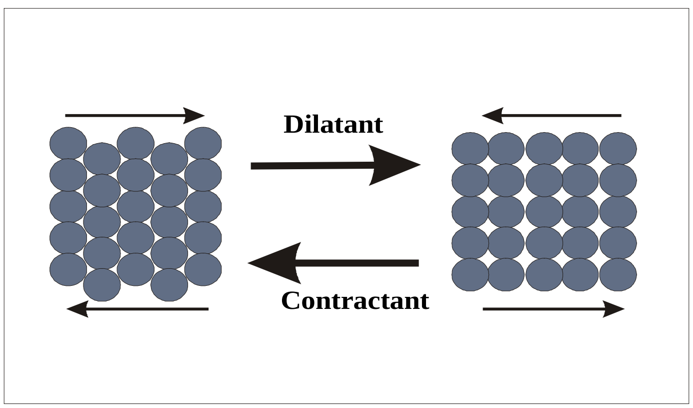
Dilatancy⇔ Contractancy



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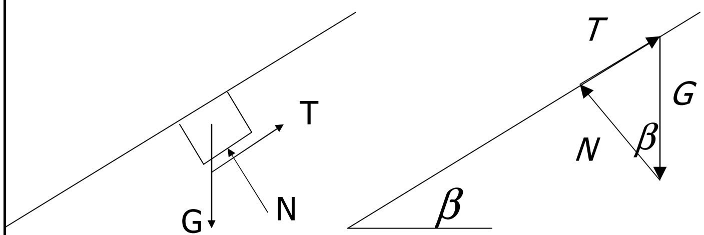
Equilibrium under water slope



$$T = G\sin(\beta) \qquad N = G\cos(\beta) \qquad \frac{T}{N} = \tan(\beta)$$

Soil mechanics: limit $\left(\frac{T}{N}\right)_{\max} = \tan(\phi) \qquad \beta_{\max} = \phi$

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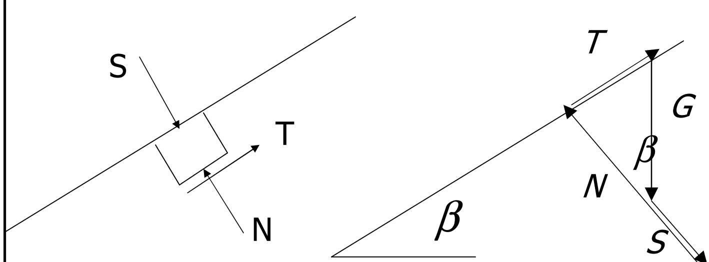
Limit equilibrium under water slope with seepage



$$N = G\cos(\beta) + S \qquad T = G\sin(\beta) \qquad \left(\frac{T}{N}\right)_{\max} = \tan(\phi) = \frac{G\sin\beta}{G\cos\beta + S}$$

$$S = G\left(\frac{\sin\beta}{\tan\phi} - \cos\beta\right) = G\left(\frac{\sin\beta\cos\phi}{\sin\phi} - \frac{\cos\beta\sin\phi}{\sin\phi}\right) = G\frac{\sin(\phi - \beta)}{\sin\phi}$$

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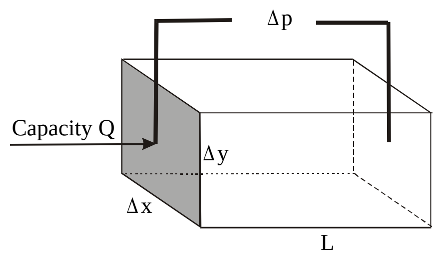
Law of Darcy

$$v = k \cdot i = k \frac{\Delta p}{\rho_w g L}$$



$$\frac{\Delta p}{L} = \frac{v}{k} \rho_w g$$

$$S = G \frac{\sin(\phi - \beta)}{\sin \phi}$$

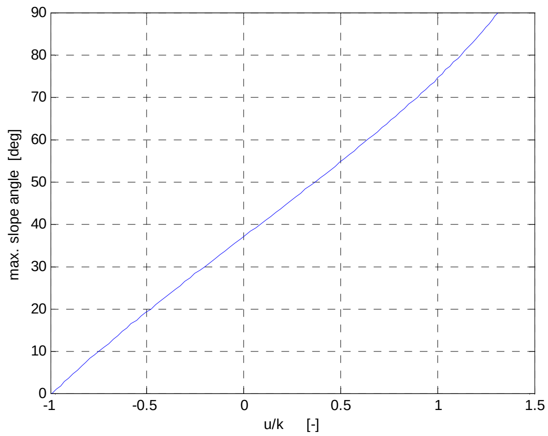
At limit of equilibrium

$$G = (1 - n_0)(\rho_s - \rho_w) g$$

$$S = -i_w \rho_w g = -\frac{u}{k} \rho_w g$$

$$\frac{u}{k} = -(1 - n_0) \Delta \frac{\sin(\phi - \beta)}{\sin \phi}$$

Max slope angle with inflowing water

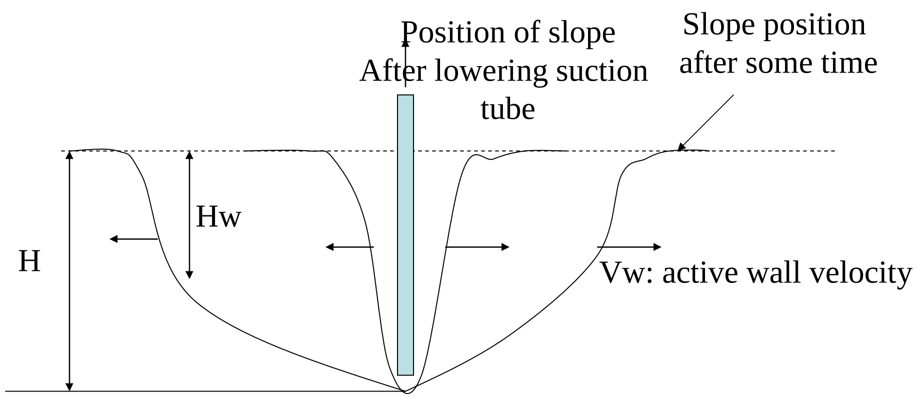


$\phi = 37^0$

Summary slope stability analysis

- Stability of a slope is influence by in- or outflowing water
  - Inflowing: Steeper than friction angle
  - Outflowing: Less steep
- How can we determine v_{wal} with this knowledge?

Pit production



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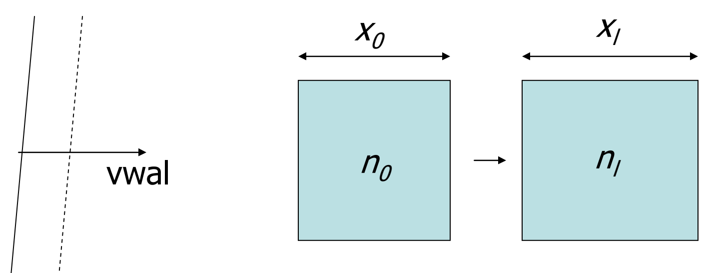

Porosity must increase at surface

Volume change $\Delta V = n_l x_l - n_0 x_0$
(per unit width and height)

Conservation of sediment $(1-n_l)x_l = (1-n_0)x_0$

$$\Delta V = n_l x_0 \frac{1-n_0}{1-n_l} - n_0 x_0 = x_0 \frac{n_l - n_0}{1-n_l}$$

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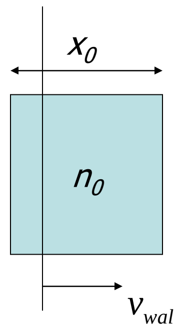


$$\Delta t = \frac{x_0}{v_{wal}}$$

$$u\Delta t = \Delta V$$

$$u\frac{x_0}{v_{wal}} = x_0 \frac{n_l - n_0}{1-n_l} = x_0 \Delta n \qquad v_{wal} = \frac{u}{\Delta n} = -\frac{k_l}{\Delta n} i_w$$

$$v_{wal} = \frac{u}{\Delta n} = -\frac{k_l}{\Delta n} i_w \qquad i_w = -(1-n_0)\Delta \frac{\sin(\phi-\beta)}{\sin\phi}$$

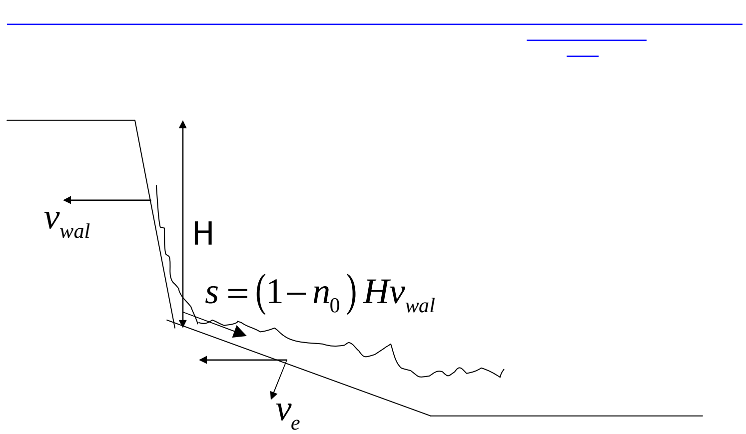
$$v_{wal} = \frac{k_l}{\Delta n}(1-n_0)\Delta \frac{\sin(\phi-\beta)}{\sin\phi}$$

Vertical slope: $\beta = \frac{\pi}{2}$

$$v_{wal} = \frac{k_l}{\Delta n}\frac{\rho_{situ}-\rho_w}{\rho_s-\rho_w}\frac{\rho_s-\rho_w}{\rho_w}\frac{\sin\left(\phi-\frac{\pi}{2}\right)}{\sin\phi} = \frac{k_l}{\Delta n}\frac{\rho_{situ}-\rho_w}{\rho_w}\cot\phi$$

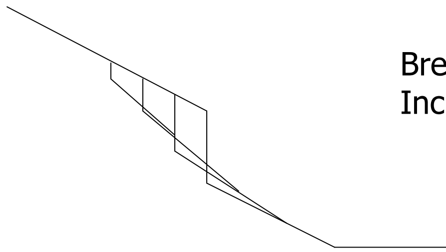
Influence of erosion
Stable /unstable breaching

- Influence height of the breach
- Erosion of slope



Erosion due to density current

Stable breaching



Breaching height decreasing
Increasing slope angle at toe

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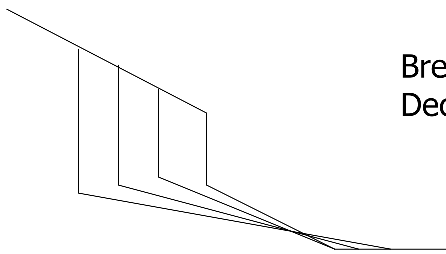
Unstable breaching



Breaching height increasing
Decreasing slope angle at toe

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•Slope angle at toe decreases with flow velocity over the slope
•Flow velocity increases with production

$$i_{slope} = \tan\beta = 0.0049 D_{50}^{0.92} s^{-0.39}$$

$$s = (1 - n_0) H v_{wal}$$

$$i_{slope} = 0.0049 D_{50}^{0.92} \left((1 - n_0) H v_{wal}\right)^{-0.39}$$

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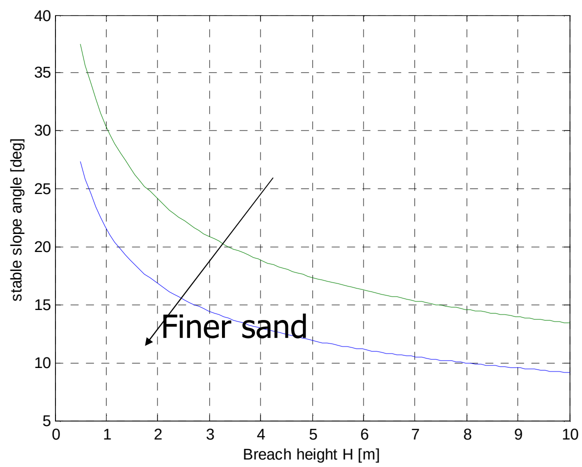

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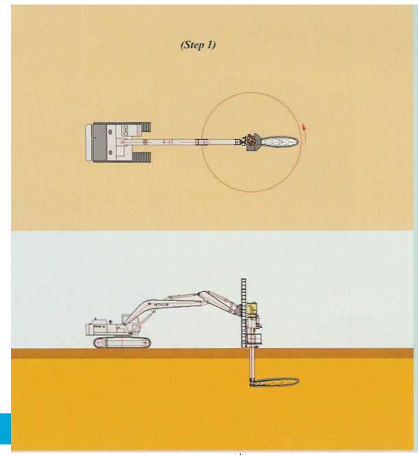
Dredging under an overburden

The method:

Suction tube is set to the full depth.

The jet or jets turns slowly around the vertical axes.

The sand descends as a cylinder to the suction mouth.



Dredging under an overburden

- A jet system rotates slowly around the vertical axes