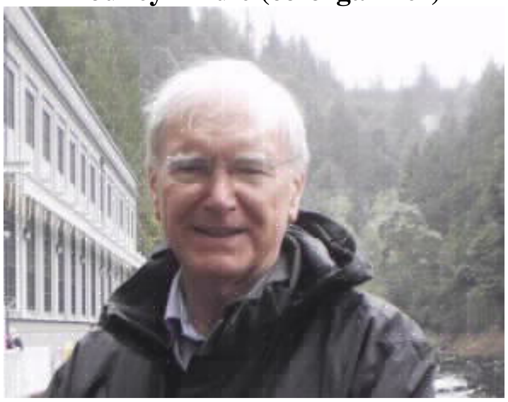
Presenters and Presentations

Rodney Bridle (co-organizer)



Rodney Bridle, Civil engineer, Dam Safety Ltd, specialist consulting engineer in earth and earth-rock dams, internal erosion and risk. UK Member, ICOLD Technical Committee on Embankment Dams. Editor and part-author of the two volumes of ICOLD Bulletin 164 on Internal Erosion. Regular attendee at ICOLD and ICOLD Internal Erosion Working Group (EWGIE) meetings. Former Chair, British Dam Society. More information at www.damsafety.co.uk.

Overview of internal erosion mechanisms

Internal erosion is a process of erosion in which the hydraulic forces imposed by water flowing through openings or seeping through the pores in soils in water-retaining embankments and their foundations are sufficient to overcome the resistance to erosion of those soils. It has parallels to scour and erosion on river beds. The hydraulic forces are usually greatest when water levels are high as floods pass through reservoirs or along waterways, consequently the probability of the water level causing failure can be estimated from the flood hydrology for use in risk analysis (because risk = probability x consequences). If internal erosion initiates, progress to failure will likely be rapid, unless the erosion is stopped by filters – in designed filter zones or in fill zones of a grading capable of filtering - trapping eroded particles and preventing the continuation of erosion after no-, some- or excessive erosion. Unzoned (often called 'homogeneous') embankment dams and levees are more vulnerable to internal erosion than zoned embankments because there are no more-or-less vertical zones that might arrest erosion.

ICOLD Bulletin 164 provides a comprehensive qualitative understanding of internal erosion and the means to quantify the hydraulic forces that will cause failure through the four internal erosion mechanisms: concentrated leak erosion, suffusion, backward erosion and piping, and contact erosion. It gives methods to assess the filtering capability of filters and fills; guidance on investigations and engineering analyses, and on remediation and surveillance. Recent research has added to the usefulness of the Bulletin, notably in backward erosion and piping, as a case history shows. An important conclusion is that it is not possible to anticipate the onset of internal erosion to failure through surveillance and monitoring; and as failure occurs rapidly, the critical hydraulic load, water level, should be predicted by investigations and engineering analysis, and remediation completed if necessary, before large floods occur.

Internal erosion workshop - closing

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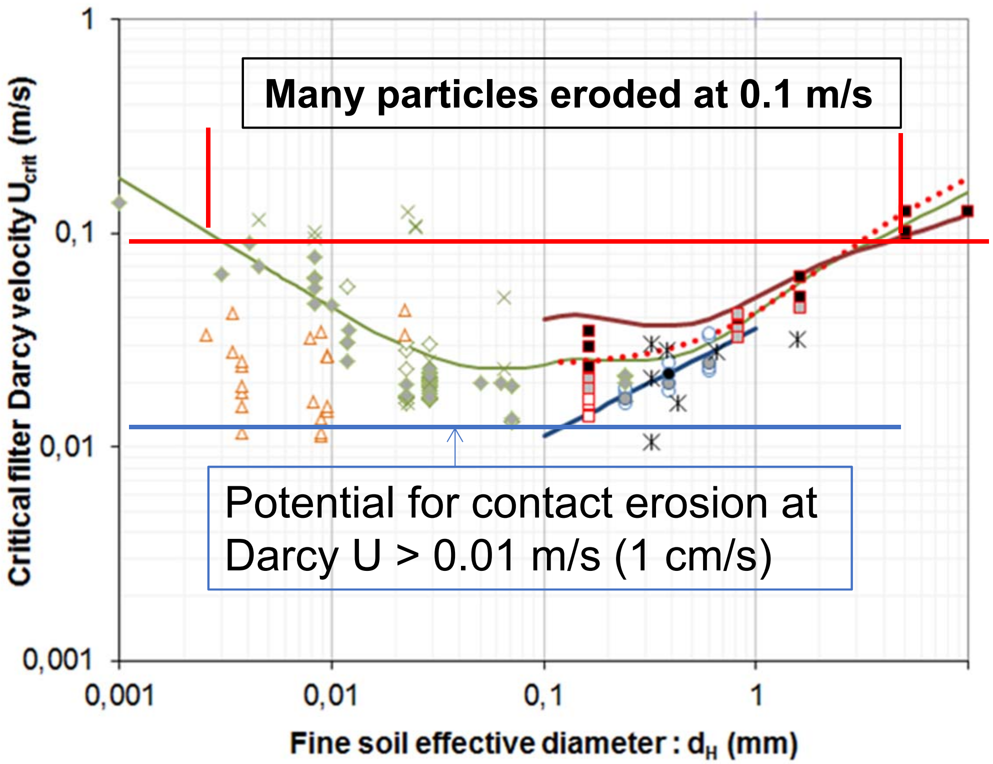
ICOLD Ottawa, Friday 14 June 2019

Erosion mechanics – general

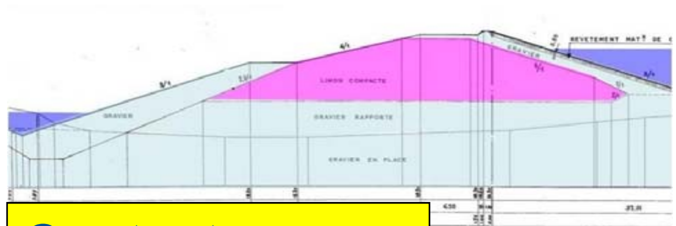


1. Curves similar to Shields 1936: Similarity mechanics in sediment movement on river beds
2. Higher velocities erode larger and smaller (clay) particles
3. Accelerating erosion as water level (and seepage velocity) rises during floods – erodes a larger range of particle sizes and larger volumes of particles
4. Erosion at normal pool level shows that erosion is occurring. It will accelerate when pool level rises - don't ignore, <u>investigate and remediate if necessary</u>

Probability and risk of internal erosion failure

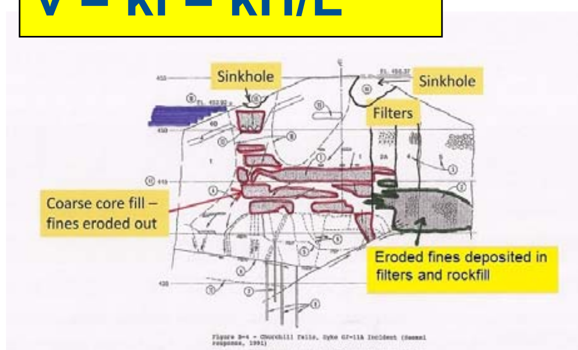
Concentrated:

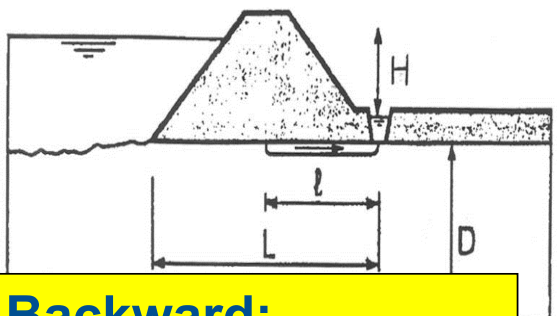
$$\tau = \rho_\omega \frac{gH_f d}{4L}$$



Contact:

$v = ki = kH/L$





Backward:

$H/L = 1/c = F_R * F_S * F_G$

Suffusion:

Critical hydraulic gradient can be less than 1

1. H = water level that causes internal erosion failure
2. Annual probability of occurrence of H from flood hydrology
3. Risk = Probability x Consequences

Bridle R (2018). Estimating the risk to dams from earthquakes, floods and internal erosion. *Trans. 26th ICOLD Congress, Vienna,* Q101, R3, 33-43

Further reading and internal erosion references

Bridle (2019) ICOLD Symposium paper gives many references:

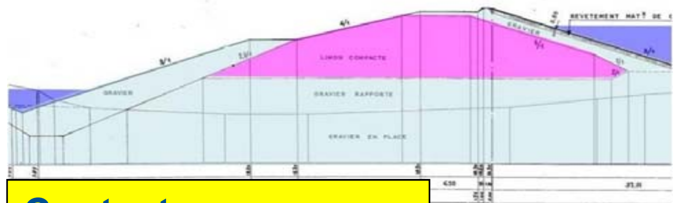
- ICOLD Bulletin 164 on internal erosion - how to estimate the loads causing internal erosion failures in earth dams and levees

- Please contact me if you have queries about internal erosion:
- **rodney.bridle@damsafety.co.uk**
- **www.damsafety.co.uk**

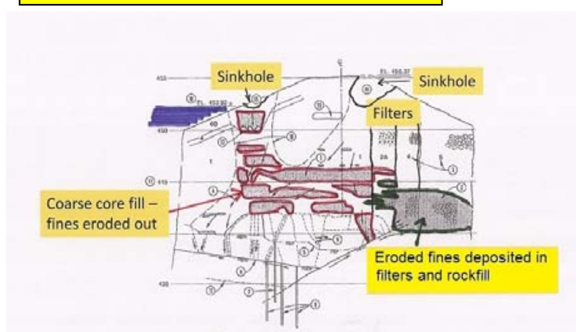
Internal erosion - summary and recommendation

Concentrated leak:

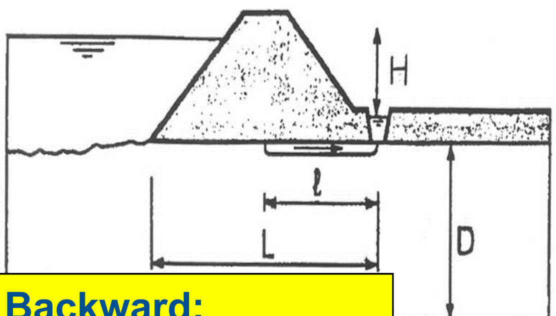
$$\tau = \rho_\omega \frac{gH_f\, d}{4L}$$



Contact:
$v = ki = kH/L$



Suffusion:
Critical hydraulic gradient can be less than 1



Backward:
$H/L = 1/c = F_R*F_S*F_G$

1. **H = water level that causes internal erosion**
2. **H_{max} occurs during floods - cannot be reduced**
3. **Investigate potential for IE failure NOW – before a large flood occurs**

Farewell

- Thank you for attending, presenting and asking questions
- We hope you feel well informed about internal erosion and engineering to protect dams from it
- MAY YOUR INVESTIGATIONS FIND YOUR DAMS TO BE FREE OF INTERNAL EROSION