


SLOPE FAILURES: REPAIR OPTIONS

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Slope Failures

- Global & Structural Failures
- Erosion
- Piping and Undermining
- Mudflow

Global and Structural

- Often a result of a design error or oversight.
- Involve failure of soft ground under embankments.
- Failure of retaining wall and/or bridge structures.
- Require extensive engineering evaluation and design for repair.
- $$$

Global and Structural

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Erosion

- Not considered a design issue.
- Common in sandy soils, newly placed or cut slopes.
- Caused by water flowing over surface.
- Control with vegetation, management of surface drainage.
- Erosion control blankets, mulch, compost.

Erosion

Erosion

Piping and Undermining

- Concentrated water flowing under structures.
- Common problem at bridge ends.
- Consider using Cement Stabilized Sand behind abutments.
- Often not obvious until structure collapses.
- Can be detected with inspection.

Piping and Undermining

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Piping and Undermining

- Early detection is key. Small problems are easy to repair.
- Use Flowable Fill (Item 401) to fill voids.
- Maintain seals and divert water when possible.
- Minor voids can became major problems quickly.
- Large, open areas can be filled with aggregate or cement-stabilized sand.

Piping and Undermining

“Mud Flow” Failures

- Slopes composed of highly plastic clay.
- May take considerable time to fail.
- Water is always a culprit.
- May not be preventable. (For Maintenance Forces).
- Designers can solve this problem for future generations!!

“Mud Flow” Failures

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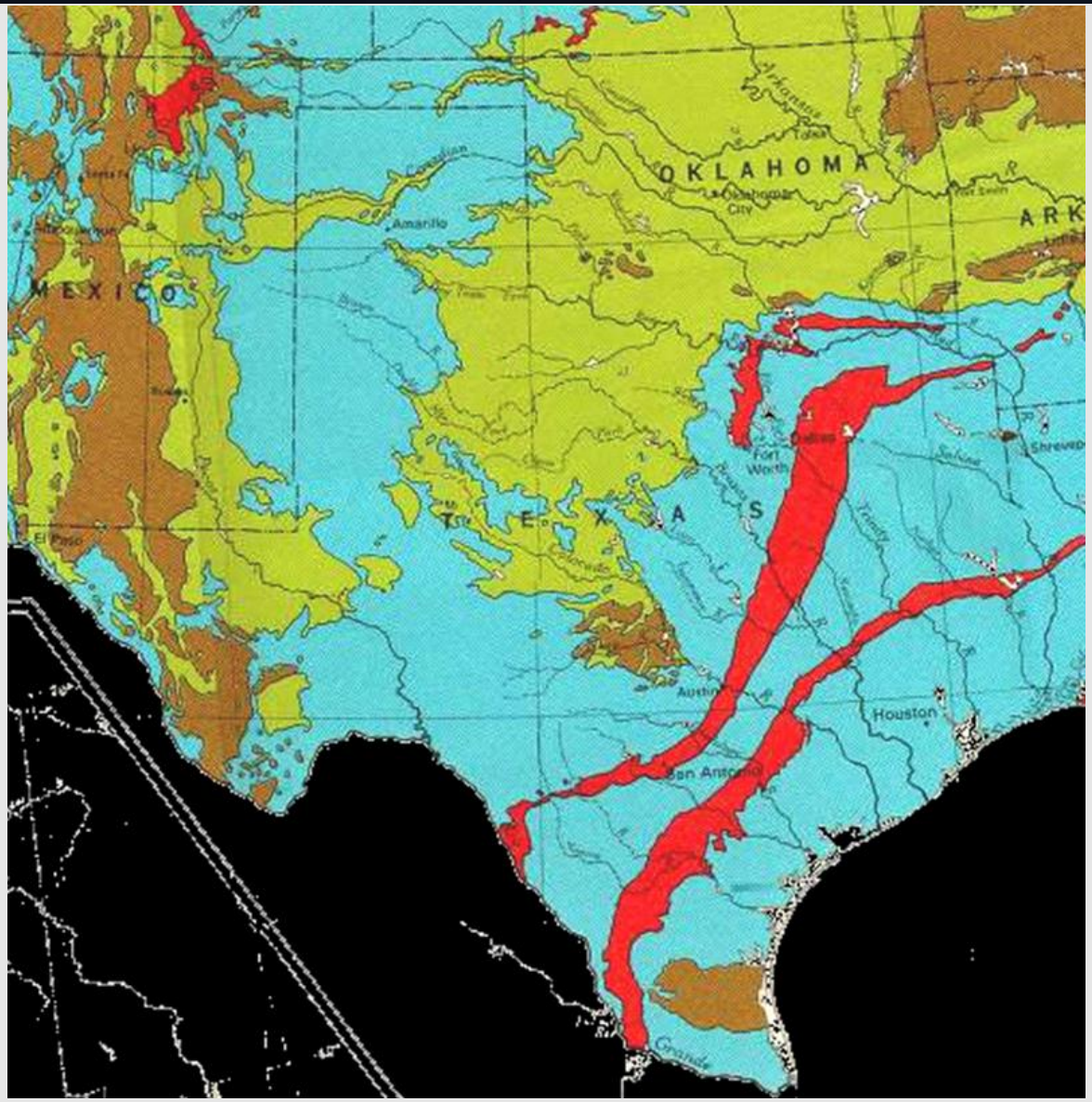
High Plasticity Clay

- Absorbs large amounts of water (when available).
- Swells and softens when wet.
- Shrinks and cracks when dry.
- Simple lab test to determine Plasticity Index (PI).
- PI > 30 is troublesome.

High Plasticity Clay

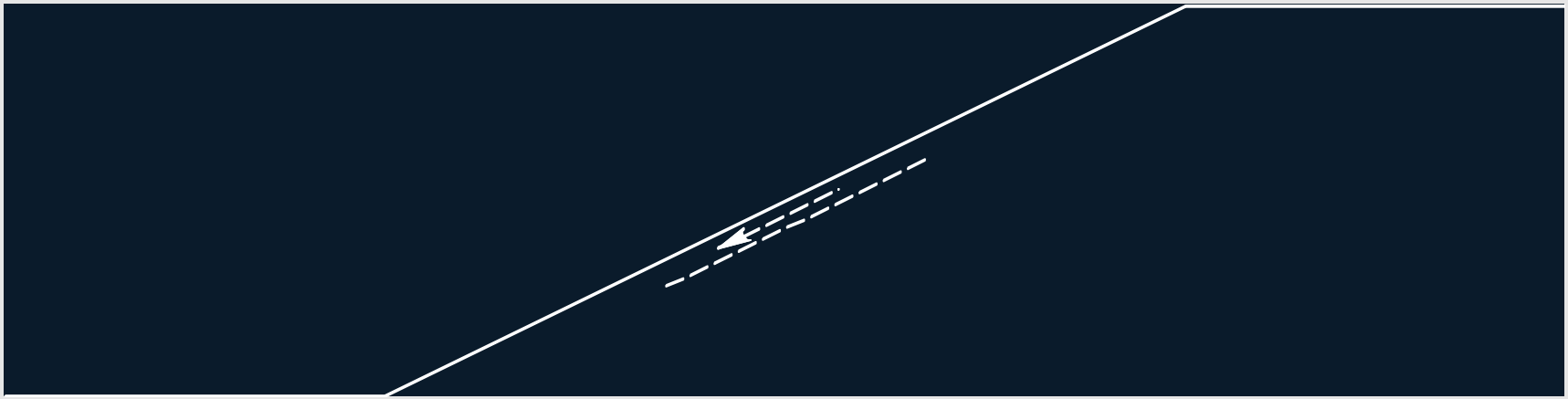


Why Do High PI Slopes Fail?

- As constructed, material is dry and well compacted.
- Surface immediately begins to absorb water, swell and soften.
- During dry periods, material s shrinks and cracks.
- During next wet cycle, rain penetrates more deeply, clay material swells and softens further.
- Finally, material can no longer hold its own weight, and flows down the slope.

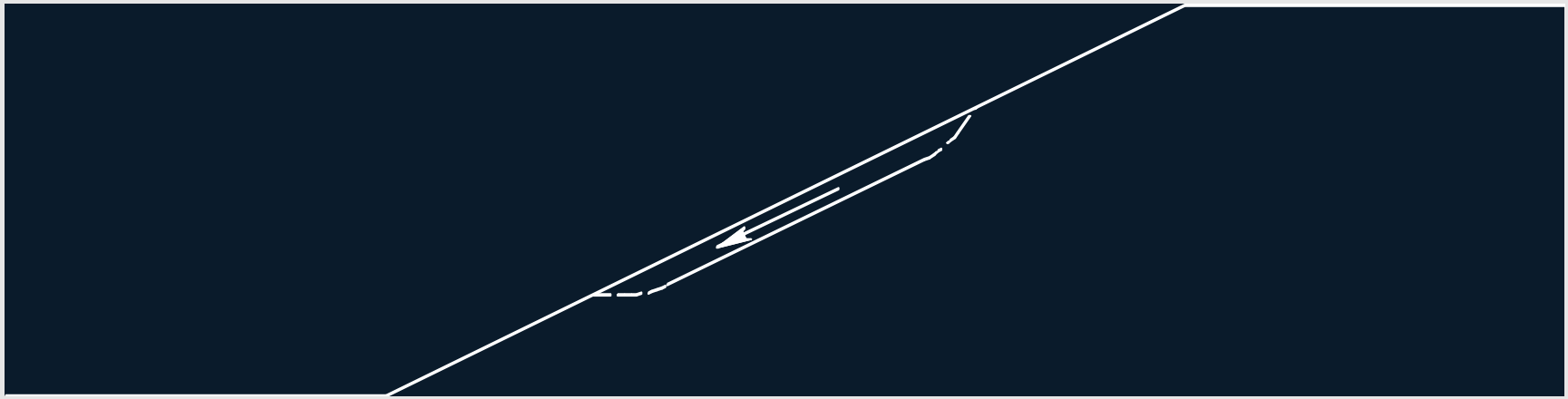
Mudflow (1)

- Surface soils soften and begin to creep



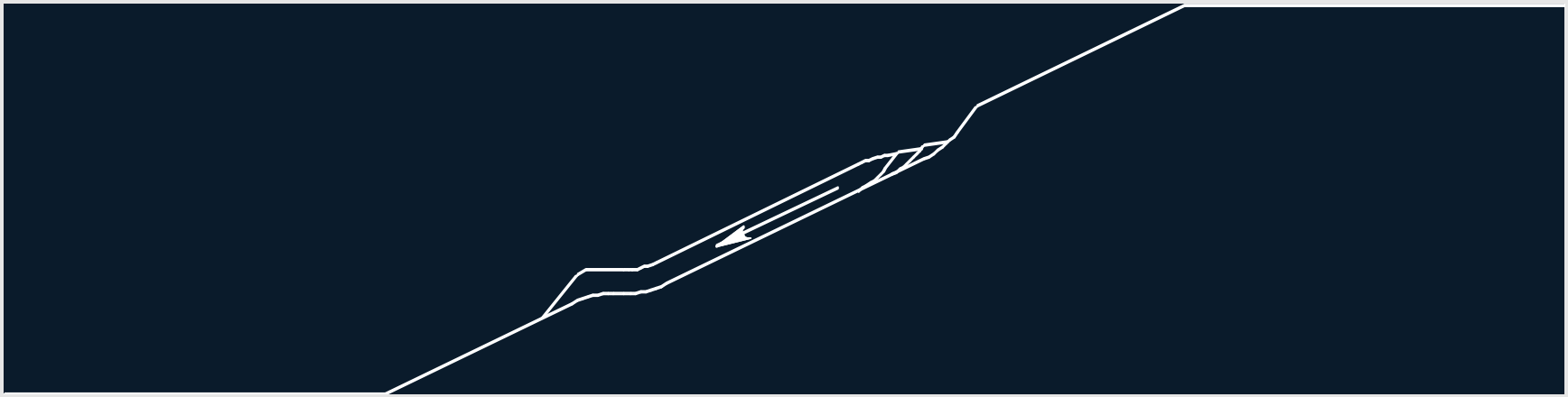
Mudflow (2)

- Eventually a complete failure plane forms



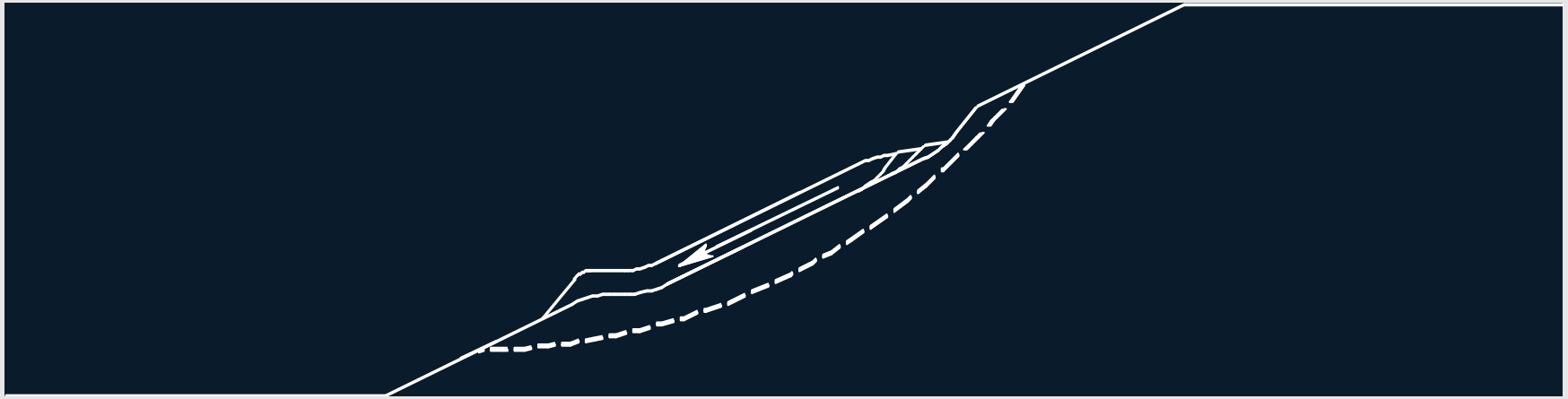
Mudflow (3)

- Mud flow begins, forming scarp and toe bulge



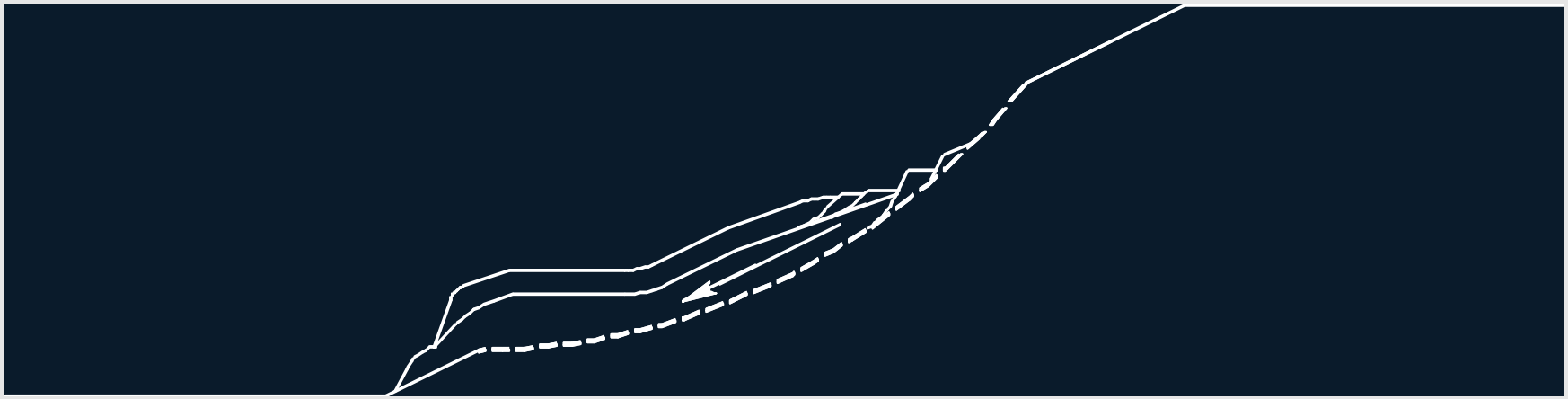
Mudflow (4)

- Moisture penetrates more deeply, and size of failure increases



Mudflow (5)

- Process continues until moisture source is removed or slope is repaired



What Can Be Done To Prevent Failures?

- Control surface water. Avoid concentrated flows onto slopes unless in flumes.
- Maintain vegetation on slopes.
- Avoid rutting that may hold water or impede drainage.
- In some cases, you may not be able to avoid a failure. (For Maintenance Forces).

What Can Be Done To Repair Failures? (Permanently)

- Remove and replace all problem material.
- Flatten slope.
- Install retaining wall.
- Add drainage.
- Combination of above.

Remove and Replace

- All failed material must be removed
- Removal should extend beyond the failure plane.
- Using reinforcement layers will require even deeper excavation to “anchor” the reinforcement.
- Excavation may extend into the roadway.
- Shoring may be required.

Replace with What?

- Import New Material:
  - ✓ Low PI fill.
  - ✓ Reclaimed or “dirty” base.
- Modify existing high PI clay:
  - ✓ Layers of reinforcement (geogrid, steel mesh).

Solving the Problem

- Item 132 “Embankment”
  - ✓ Type C. Material meeting the specification requirements shown on the plans.

- Specify “Type C” and limit the PI.

- Do not allow material excavated on the job to be used as embankment if it does not meet the PI requirement.

Plasticity Index Recommendations

SLOPE (X to 1)	PLASTICITY INDEX (PI)(%)
2.5 to 1	< 5
3.0 to 1	< 20
3.5 to 1	< 35
4.0 to 1	< 55
4.5 to 1	< 85

- Plasticity Index Range for Various Slopes Required for FS = 1.3 in the Long-Term (Drained) Condition

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