When Retaining Walls Fail: The Lessons Learned

Steve Wendland, PE, RG
swendland@kleinfelder.com

March 17, 2011

Why So Many Failing Retaining Walls?

- Water, water, water….
- Interaction between lots of people makes communication difficult
- Other causes < 10% of the time

KLEINFELDER
Bright People. Right Solutions.

Are MSE Walls More Problematic?

MSE = Mechanically **S**tabilized **E**arth

- They are more complex to design, construct, and inspect.
- They are more likely to be designed and built on a low-bid basis by a third-tier contractor.
- There are more firms involved = more complex communication.
- AASHTO vs. NCMA design standards

KLEINFELDER
Bright People. Right Solutions.

Complex Communication

Who is Involved?

KLEINFELDER
Bright People. Right Solutions.

Communication among 9 to 13 Firms / Organizations

- **Civil Engineer** decides wall is needed
- **Geotechnical Engineer** determines geotechnical parameters for design and checks global stability
- **Structural Engineer** or a **Wall Design Engineer** completes design
- **Owner** and/or **Architect** will have input wall appearance
- **Wall Supplier** will provide MSE wall materials
- **Surveyor** figures out where to build it
- **Landscape Architect** may have input too
- **General Contractor** will hire an **Earthwork Contractor** who may hire a **Specialty Contractor** to construct it
- **Inspector** and/or **Construction Manager** monitors the construction

KLEINFELDER
Bright People. Right Solutions.

Case Histories Presented Here

- They are sanitized to protect others. I was at fault at least partially in many of them while working with my current or previous employers.
- “Fault” or “blame” is never black and white
- Other people involved probably disagree with my opinions, analysis, and memories.
- Some are obvious blunders. Some are more complex. Some may not even be a “failure”.
- I have many more case histories, but not enough time today…

KLEINFELDER
Bright People. Right Solutions.

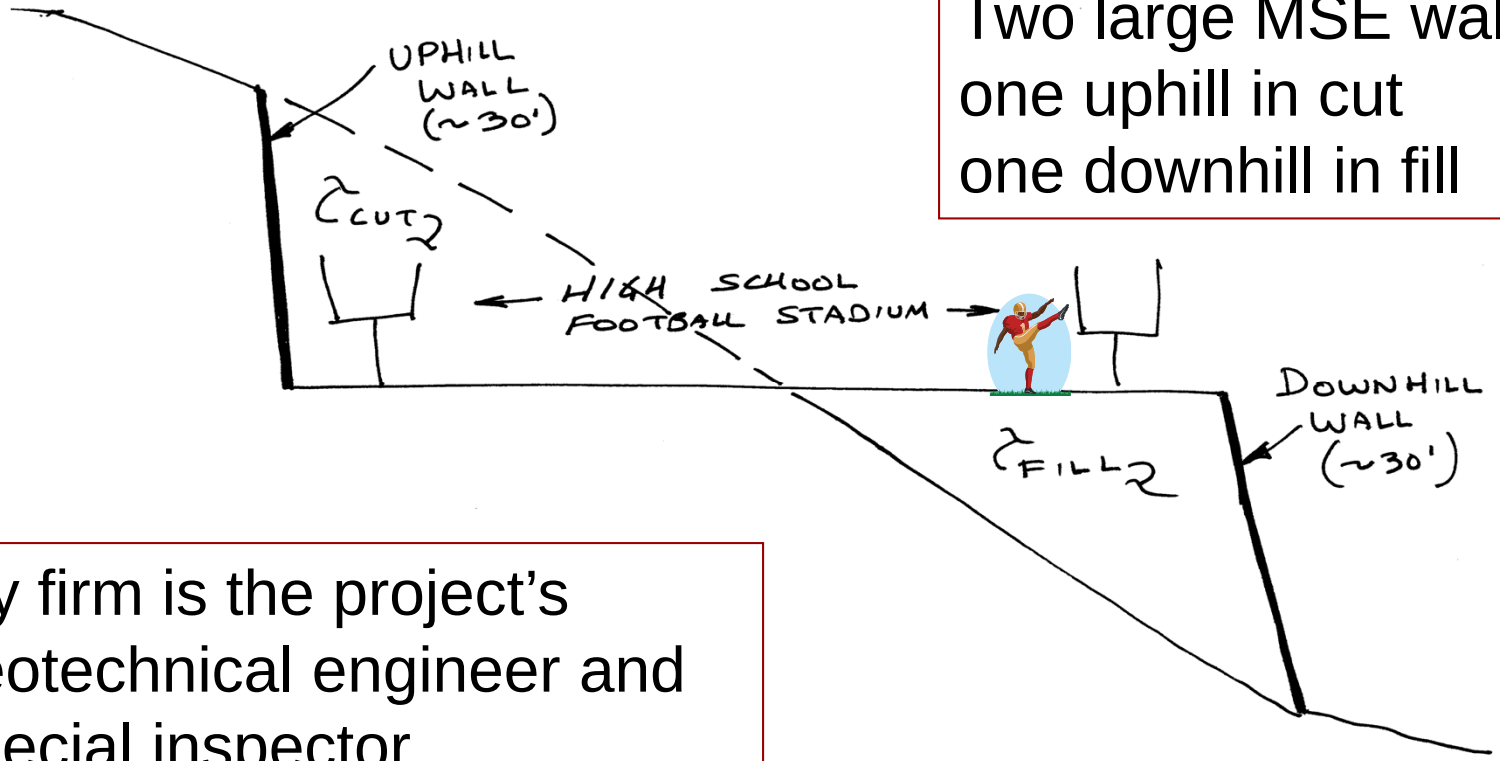
What is a “Failure”?

- My definition: When a retaining wall does not perform as expected.
- Not just when a wall collapses
- Who’s expectations?
- What if your expectations are different than your client’s?

KLEINFELDER
Bright People. Right Solutions.

Failure #1
High School Football Stadium
A Simple Cut and Fill

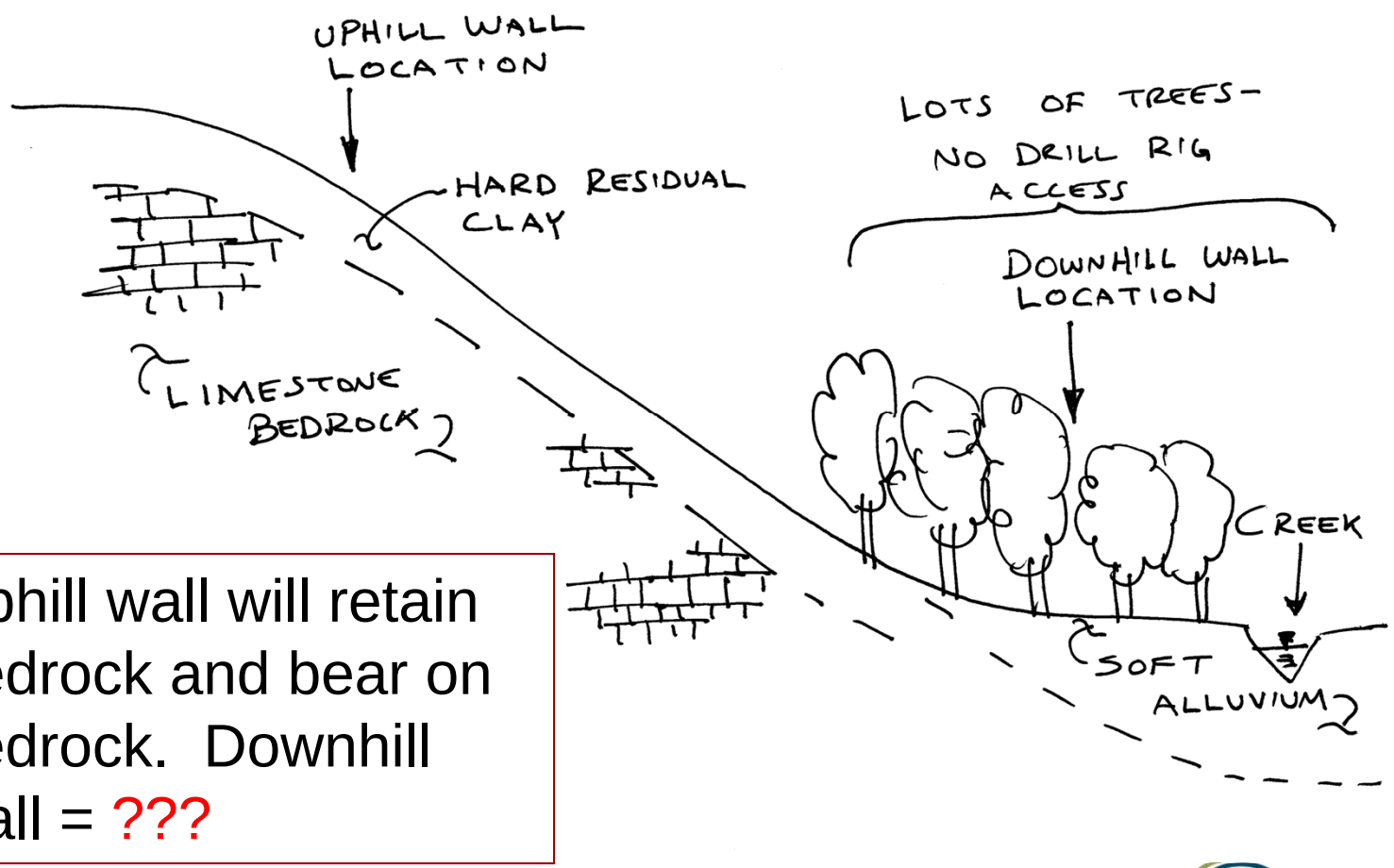
Two large MSE walls:
one uphill in cut
one downhill in fill



My firm is the project's geotechnical engineer and special inspector.

KLEINFELDER
Bright People. Right Solutions.

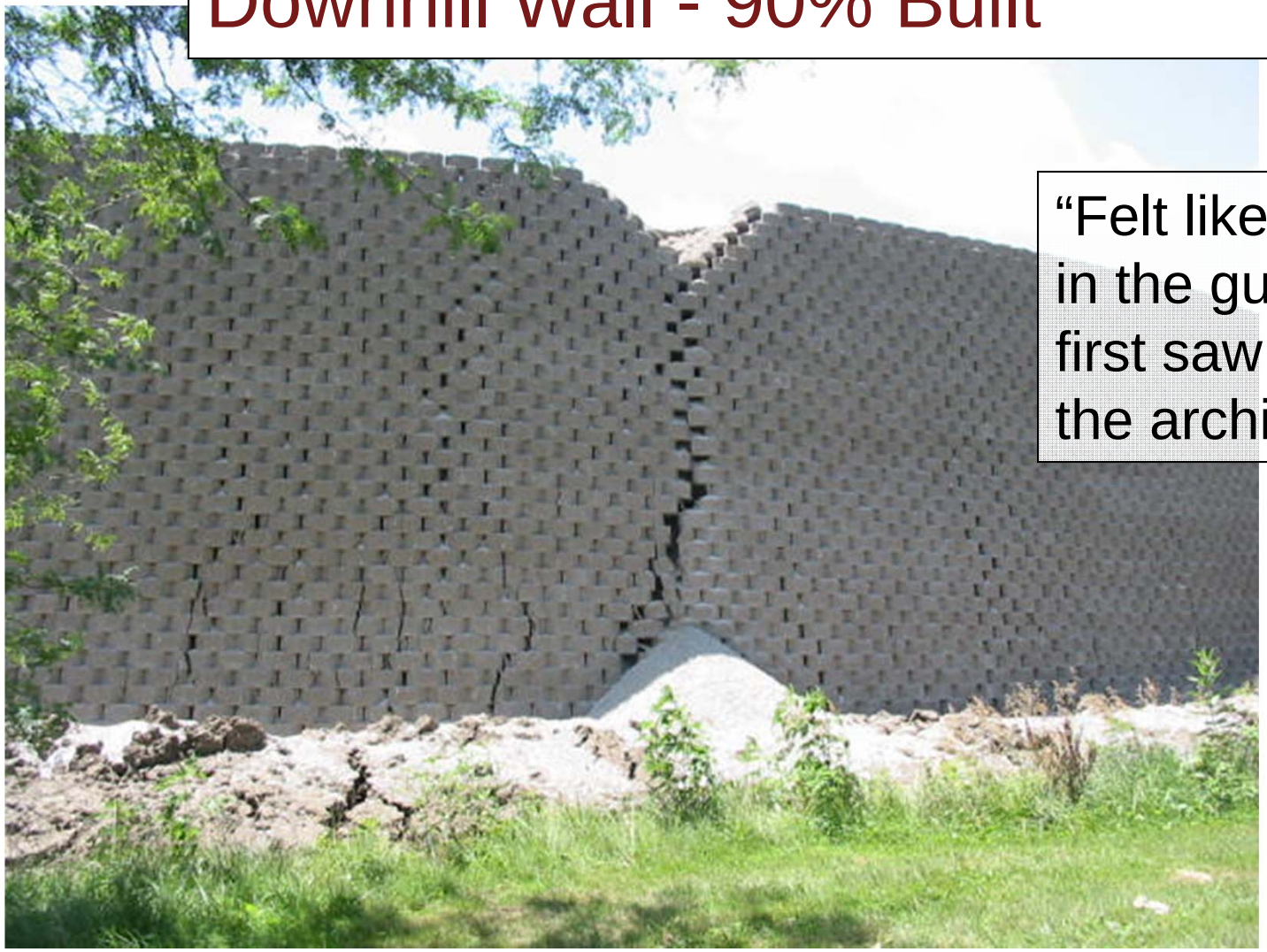
Site and Subsurface Conditions



Uphill wall will retain bedrock and bear on bedrock. Downhill wall = ???

KLEINFELDER
Bright People. Right Solutions.

Downhill Wall - 90% Built



"Felt like a punch in the gut when I first saw it" says the architect

KLEINFELDER
Bright People. Right Solutions.

Tension cracks behind top of wall

Don’t fall in!

Bulging ground at toe of wall

Communication Failures

The wall experienced a **global stability failure**.

- Wall design engineer blundered. He used the recommendations for the uphill wall (on bedrock) to design the downhill wall (on soft soils).
- Architect did not distribute shop drawings and design calculations. Why didn't we ask for them? So, no one discovered the design errors until after the failure.
- Our field staff did not speak with our design geotechnical engineers. How did we inspect the downhill wall subgrade if we didn't have drawings?
- We did not ensure that the global stability analysis was completed prior to construction.

Miraculously, there was no litigation.

KLEINFELDER
Bright People. Right Solutions.

Lessons Learned

This should be common sense or standard practice:

- Always have the design geotechnical engineer **review the wall design**.
- Inspector should **confirm** that the design geotech has reviewed the wall design.
- P.M. should make sure a **global stability analysis** has been completed by geotech or wall designer
- Put **everything in writing**. "If it isn't written, it didn't happen".

KLEINFELDER
Bright People. Right Solutions.

Failure #2 - High Rise Office Building

"Can you really build a wall there?"

The slope is naturally at 1.2H:1.0V and approximately 150 feet tall.

During heavy rains, it has frequent shallow slope failures.

It is covered with dense vegetation.

The developer wants to put a high rise office building on the slope with the edge of the building 150 feet over the edge.

So, we'll need a big retaining wall on the slope to hold up the building pad.

KLEINFELDER
Bright People. Right Solutions.

The Constructed Wall

KLEINFELDER
Bright People. Right Solutions.

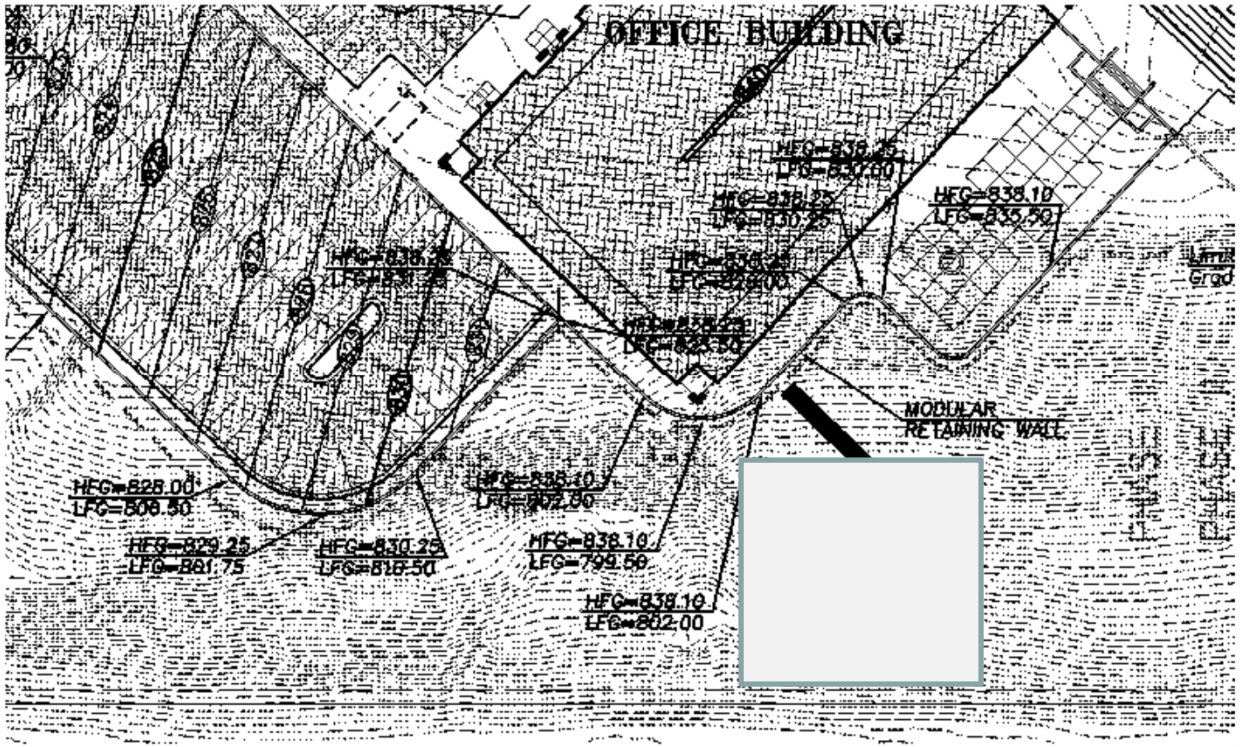
Immediate Concern – Global Stability

Global stability on steep, unstable hill is a major concern. The earthwork and wall construction contractors are nervous about the site. Bearing on massive limestone bedrock at the toe of the wall takes care of this concern. Also, 9 large drilled piers with grade beams, permanent casing, and structural floor slab are within the wall backfill helping support the wall.

KLEINFELDER
Bright People. Right Solutions.

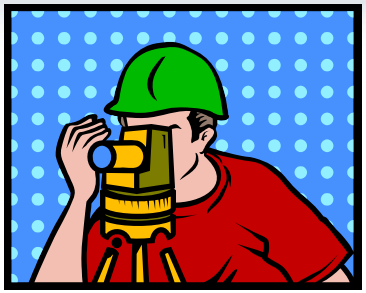
Second Concern – Communication

I make sure there are meetings and e-mails between all involved discussing the risks, design, and construction of these retaining walls. I take the lead to make sure all necessary communication occurs. I am the champion of this wall!!!



KLEINFELDER
Bright People. Right Solutions.

And Yet, the Wall Fails



- The wall was built in the wrong location! It was off about 5 feet horizontally and 2 feet vertically.
- How did this happen? Inaccurate surveying, the grade staker did not understand the drawings.
- Is this really a failure? If the owner thinks it is, then it is. They had to change the design of the patio around the edge of the building.

KLEINFELDER
Bright People. Right Solutions.

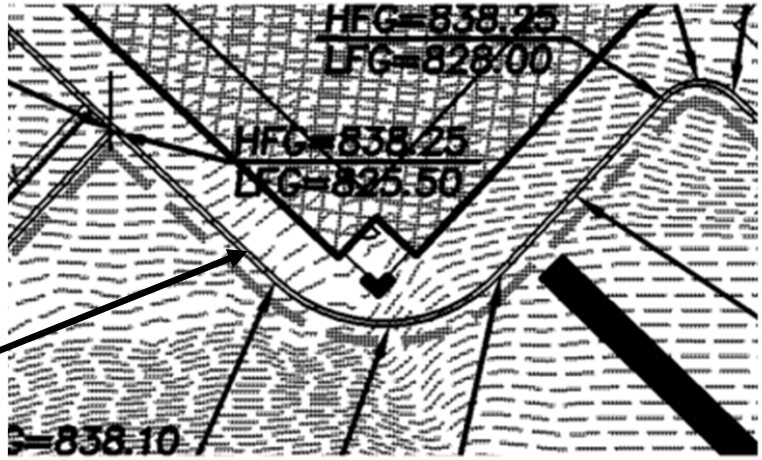
The Undersized Patio

KLEINFELDER
Bright People. Right Solutions.

Communication Failures

- There were 4 civil engineering / surveying firms working on the project. “A” did the grading plan. “B” designed the wall. “C” did grade staking for the retaining wall contractor. “D” did grade staking for the general contractor.
- They had different interpretations of the narrow, solid line on the grading plan that represented the wall’s location. Top of wall? Toe of wall?
- Topographic lines on grading plan were not accurate, no surprise on steep slope with dense vegetation. Various drawings have multiple disclaimers regarding who is responsible for accuracy of topography.

What does this line represent?
Top of wall?
Bottom of wall?
Wall at ground surface?



KLEINFELDER
Bright People. Right Solutions.

Failure #3
Big Box Retail Store

"Why did you ignore the manufacturer's recommendations?"

16.5 ft tall, 800 ft long

My firm did the wall design.

5-inch rain fall a few weeks after completion of construction.

KLEINFELDER
Bright People. Right Solutions.

24 inches of “clay” on top to limit infiltration of surface water.

Fill for reinforced zone behind the wall is “clean” sand

We used sand instead of clean gravel for drainage fill at contractor’s request to save $$

KLEINFELDER
Bright People. Right Solutions.

Why Did it Fail?

Heavy rain caused hydrostatic pressure which blew out the front face of the wall.

- We failed to take and distribute minutes of the conference call when the decision was made to use sand as the drainage fill. After the failure, some people had different memories of what we discussed.
- Manufacturer's written guidance on the use of sand fill immediately behind the wall was inconsistent.
- "Clay" cap was really silty loam, allowing water to soak in. Who gave the landscape architect authority to reject higher plasticity clays?

KLEINFELDER
Bright People. Right Solutions.

Lessons Learned

- Take the minutes for the project meetings and conference calls. If you write the history, you control the history.
- If the project deviates from the wall manufacturer's guidelines, get your client's and the contractor's acceptance in writing.
- Get to the job site as soon as you can after a failure so you see, hear, and participate in everything.

KLEINFELDER
Bright People. Right Solutions.

Failure #4

It Popped Like a Water Balloon

43 feet tall “big block” wall.

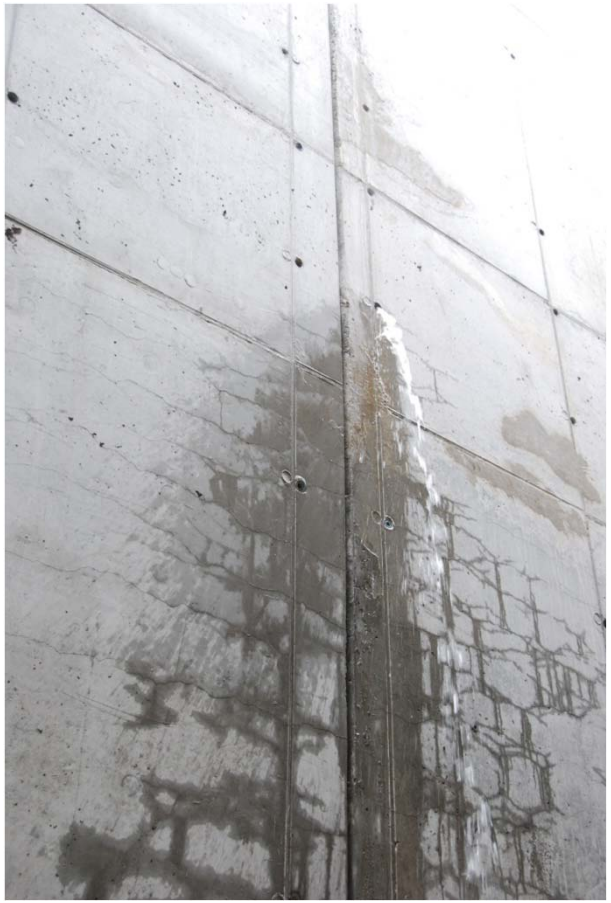
It failed during a heavy rain 8 months after it was built.

2,400 pound blocks flew over 50 feet when the wall popped.

KLEINFELDER
Bright People. Right Solutions.

How Much Water is Too Much?

- Can a wall's drain system be overwhelmed?
- How much water can seep through the front face of an MSE wall?



KLEINFELDER
Bright People. Right Solutions.

Failure #5

Three-year Old Wall Starts Moving

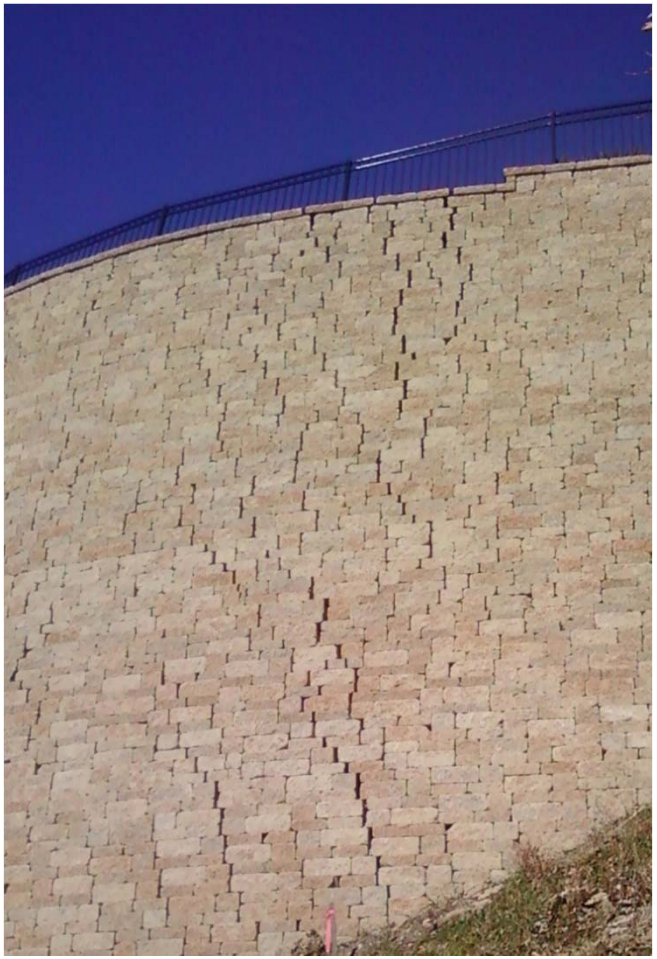
Completely stable for 3 years.

Starts sliding horizontally at about 1 inch per month, cracks are visible.

No apparent groundwater issues

<u>Can't figure out cause</u>

Fixed with rock anchors, and without attorneys



KLEINFELDER
Bright People. Right Solutions.

Summary – Water Control

- "90% of soils problems are really water problems."
- Where is the water coming from? How much will there be? Mother Nature will surprise you.
- How is it going to drain? Where is it going to go?
- How will the foundation and retained soils be impacted by water?
- Are there any water lines, sewers, or detention basins nearby? What if they leak?
- How will that change day to day and over the years?

KLEINFELDER
Bright People. Right Solutions.

Summary - Communications

- Communicate with everyone involved during design and construction. Be proactive – don't wait for others to do it.
- Document it all in writing.
- Take prudent risks only if the project team understands and accepts it

Any Questions?

swendland@kleinfelder.com

KLEINFELDER
Bright People. Right Solutions.