APPENDIX ONE

Re-evaluation of Research, Demonstrations, Design Precepts, Constructions and Failures of MSE and GCS®/GeoMonliths

Al and I supervised about 25 million dollars of our own GCS® research and participated in many other programs over the past 40+ years. And all that time, we had a "feeling" that something was amiss with our conclusions. We repeated some projects that did not provide results compatible with our preconceived notions. We kept thinking, hoping, wishing that someone would create the magic mechanistic formulae explaining the counterintuitively stellar performance of GCS® constructions that would, at once, be easily understood, defensible, repeatable and infallible.

Well, if the answer was a snake, we would have been bit. When John Steward, John Mohney and Dick Bell built the first series of "fabric walls" in the great northwest, they were building Unique Composites, not quasi-tieback systems. John and John were leading edge researchers for the USFS and Dr. Bell of Oregon State was one of the premier geotech professors of his era. Dr. Bell once told Al and me that if he could magically replace the fabrics in his walls with paper towels post-construction, the wall would not fail. (He did insist on "wet strength" paper towels, if you remember those old commercials.)

Dr. J. T. H. Wu of the University of Colorado/Denver proposed that not only are post-construction working stresses in the inclusions in closely spaced composites very low, that these stresses reduce with time as a function of stress relaxation found in polypropylene chemistry.

Polypropylenes have a delayed stress/strain relationship even below the creep threshold where they will accept a load for days, weeks or months and will then strain to some extent to final equilibrium, perhaps zero if the system allows. In the case of confined granular soil, which will not creep at these low stresses, the end result is a lessening of load or stress in the polypropylene and without perceptible movement in the Unique Composite.

Mike Adams of the FHWA has shown repeatedly a zero volume change phenomenon in these composites were total lateral deformation equals total vertical deformation in load testing. I am still not sure what the significance is, but it is fascinating and probably is related to other counterintuitive phenomenon in these Unique Composites.

Dr. Bell understood intuitively that he had created a "Unique Composite", but like all of us, he kept reverting to element contribution to explain it. As described in the opening discussion, a Unique Composite, a GeoMonlith in this case, **cannot be accurately modeled using an additive representation of their constituent elements.** We should have seen this from the very first day.

What we should have done was call our first fabric wall a Unique Composite. These can only be quantified AFTER it was constructed and then set up a triaxial testing protocol to evaluate practical combinations. We would have seen **the immense importance of soil properties and the critical, non-linear relationship of spacing of the inclusion.** We would not have taken the wrong road of placing value on strength/stiffness/connection of the inclusion.

Simplified “equations” are as follows:

Bucket of Sand + Tensile Inclusion (tieback, soil nail) = Bucket of Sand + Tensile Inclusion (tieback, soil nail), A Simple Composite with equal properties.

Bucket of Sand + layers of geogrids on 24-36 inch spacing = Bucket of Sand + layers of geogrids on 24-36 inch spacing, A Simple Composite with equal properties

Bucket of Sand + Sack of Cement + Water = Unique Composite with properties superior to the constituents

Bucket of Sand+ jar of asphalt = Unique Composite with properties superior to the constituents

Bucket of Sand + sheets of geosynthetics on 8 inch spacing = Unique Composite with properties superior to the constituents

Unique Composites are described and tested after they are created. They cannot be easily described with mathematical models that are based on constituent properties.

Look at what a team of Japanese researchers demonstrated. They built a GeoMonolith with a 60 degree negative batter, removed the facing and added a brutal surcharge. That we did not revise our thinking about mechanistic design when we saw this is just shameful. How dense can Al and me and a group of pretty smart people behave? There are no Rankine or MSE or other tieback-based models that can capture this behavior. They built a Unique Composite. If this photo were on the cover of Engineering News Record for 52 weeks, I don’t expect anyone would still recognize that this bold demonstration refutes all our sacred tenets that everything is a tieback, that MSE and GRS/GCS®/GeoMonoliths are the same thing.

Another graphic demonstration of how our collective tieback paradigm blinded rational understanding can be found at the Federal Highway Administration's Turner Fairbark Highway Research Center. Mike Adams of the FHWA and with cooperation of our CDOT team and with participation of Dr. J. T. H. Wu of the University of Colorado/Denver constructed a 20 foot high GeoMonolith in the configuration of a bridge pier. He loaded this to 10 tons per square foot, which was the capacity of his frame, without reaching failure. Yet none of us could go beyond element contribution/tieback analogy in trying to describe this performance.

FHWA-TFHRC
GRS BRIDGE
PIER LOADED
TO 10 TSF
M. Adams

Deep Patch – A Good Bad Example of Mixing Paradigms

In the 1980's the USFS developed an empirical technique for slide repair they called the "Deep Patch". Let me digress to compliment those folks for real field engineering leadership – hard to find anywhere these days. The deep patch was used on roads in mountainous terrain where cut/cast construction resulted in sliding in the cast material. Those innovators would excavate vertically 6-10 feet and laterally to behind the failure scarp in the road, and replace that excavation with granular fill and sheets of non-woven geotextiles on close spacing. It seemed to work most every time.

During my tenure with Colorado DOT, I became enamored with this simple solution for that class of slides. That was before we had the Soil Nail Launcher. I obtained funding and partnered with Dr. J. T. H. Wu at CU/Denver to build a huge steel frame, inside of which we could build a full-scale embankment prototype. (Dr. Wu borrowed Japanese techniques to lubricate the sides of the test fills to negate edge effects and allow plane/strain behavior.) We discovered or demonstrated that this "Deep Patch" concept significantly unloaded the driving forces to the extent we were almost "cantilevering" dirt. What I now realize that we did create a form of cantilever. Model this as a GeoMonolithic beam, and the results are closer to what we observed.

Paradoxically, and in staying on the fundamentally wrong track from the getgo, the engineering mindsets had to describe the successful Deep Patch in terms of element contribution. In writing design guidelines for the Deep Patch, they deduced that the only explanation for this behavior was due to the added tensile capacity of the inclusion, and therefore concluded that the same results could be elicited with one sheet of stiff, high strength inclusion. It became economical on paper to use just one layer of high strength grid, which meant the excavation could be much shallower. It then looked like a simple tieback, not a unique composite to them. Engineers live in the paradigm of tie back behavior and did not question that their model was diametrically opposed to that demonstrated technique.

CDOT DEEP PATCH
TEST FRAME

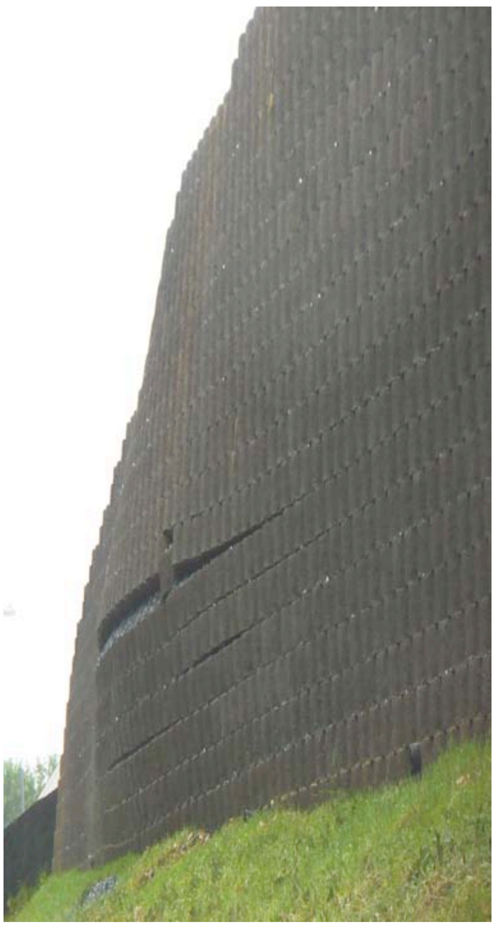
Even to this day, and after an impassioned request on my part for reconsideration, the USFS design manual for their Deep Patch does not follow my demonstrated successful research project nor USFS field experiments that led to the research. Most engineers and professors cannot yet separate the concepts of tieback and GeoMonolithic Composite behavior of GRS….and they have yet to see all the warts on the quasi-tieback MSE concepts. MSE has a failure rate! So will this misguided version of the Deep Patch

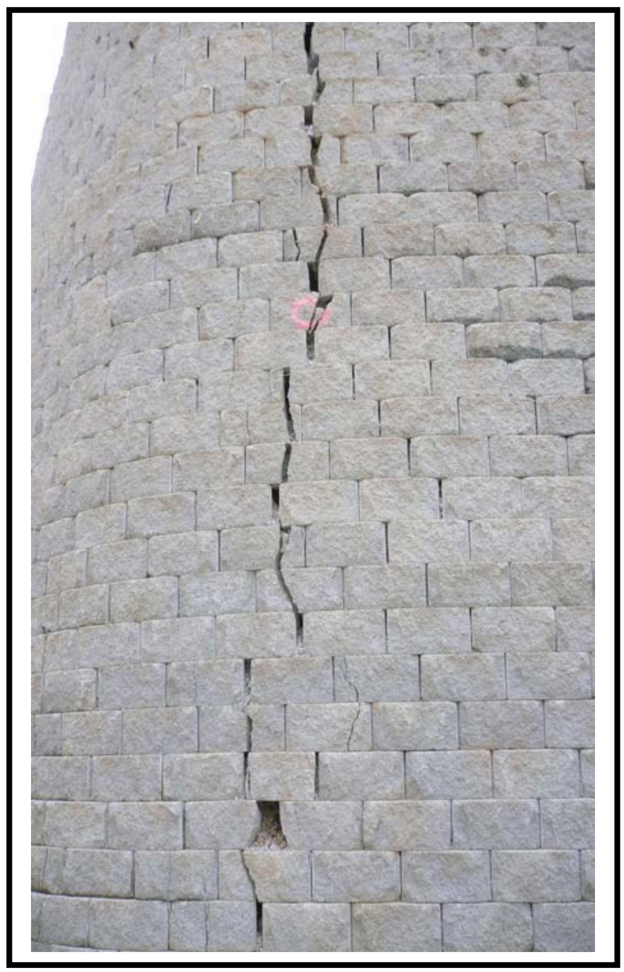
MSE FAILURES

A scenario we see playing out all over the world….an MSE wall fails and we send the Swat Team in to find fault. The "designer" says he followed AASHTO/FHWA/NCMA to the letter. He multiplied reduction factors, checked overturning, installed a drainage layer at the face, embedded it, specified a .7 base to height ratio, used a concrete leveling pad, specified big blocks with pins to connect with the stiff grids. Couldn't be anything he did wrong. (What he did not say is that he had no idea what he was really doing or where any of that nonsense came from, but that is not the point here.)

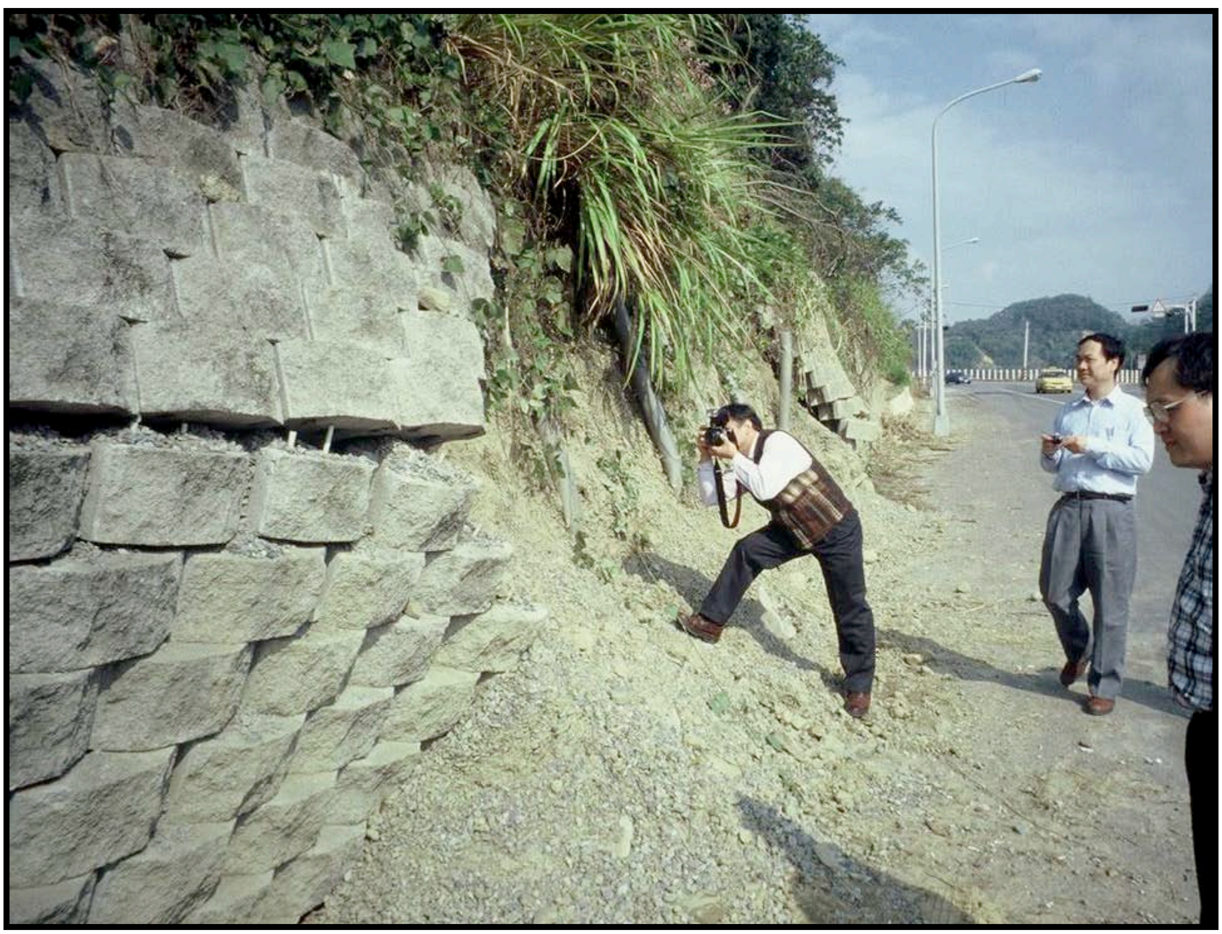
Mr. Contractor says he followed the plans to the letter and provided specified materials, and has the inspector's reports to prove this. (What is not said is that the inspector had not a clue about what this feature is about or what he was supposed to look for, but that is not the point here.) The Owner says, yes, he took low bid, but the plans were sealed with a P. E. stamp and the contractor was reputable and bonded.

So, there is no fault here. No one is to blame. Win some lose some. Some walls fall down, some don't.





What amazes me is that it seems no one in the world except me seems to understand that an untenable number of MSE walls are on the brink of failure. MSE walls designed with AASHTO/FHWA/NCMA protocols, according to an NCMA official, have a failure rate of 2 to 8%. But no one is to blame, since they followed those guidelines. When we have a failure rate in “structures” that are supposed to have a factor of safety of 1.5, it is a mathematical certainty that a huge body of them exist at factors of safety well below 1.5. Another rational extension is that a statistically significant suite of MSE walls will not survive heavy loads, floods, quakes and will likely experience shortened service lives.



Failure Rate

There is an emerging trend even more damning than our system where technically unqualified engineers in our associations control the guidelines, thus don't and can't react to deal with a failure rate. (They don't even know this is happening let alone why it is happening.)

And that is the unscrupulous engineers and contractors who keep using ever lower quality backfill, and without requisite verification. These folks keep trying to beat the competition with compromised quality, no matter the risk and sacrifice on the part of un-adviseded owners and end users. There must be full scale testing to verify limits of behavior of any wall system, yet the scary trend is to build them and if they don't fall down immediately, they have met the criteria: not a 1.3 or 1.5 factor of safety, but it did not fall down. No one, not anyone, knows how close to the brink these obviously compromised walls really are. That no one sees this, that no one or no committees are demanding performance verification is even more amazing than the national remiss in failing to see the significance of a failure rate.

Conclusion

MSE technologies are deeply embedded in our collective paradigm and will continue to play a major role in our transportation systems, but perhaps now you can see why I suggest that **generic** GRS/GCS®/GeoMonoliths are superior in terms of safety, economy, versatility and longevity. Now I can celebrate my own philosophical and theoretical breakthroughs on why these structures legitimately refuse to be modeled in terms of element contribution as we do with tiebacks and MSE. We can now focus on developing proof/performance tests as we do with concrete.

I also celebrate that now we can extend this enlightenment to those embedded in the paradigm fixity of tiebacks. Our engineering instructors and our engineers have a responsibility to society to provide ever safer, more economical transportation facilities, and generic GeoMonoliths facilitate that mandate. Now we can initiate a whole new round of research at our universities to develop design and testing protocols to provide quality assurance to support worldwide implementation.

I can finally absolve my sin of not recognizing the obvious when I first observed a fabric wall.

Robert K. Barrett July, 2010