APPENDIX FOUR

GRS/GCS®/GeoMonolith Construction and Inspection – How Easy Is This!

Construction of a GeoMonolith has evolved to become "disappointingly simple". One, two, three. A row of concrete blocks, a lift of compacted, granular backfill and a sheet of woven polypropylene. Inspectors already know the basics. Checking manufacturers certs on materials, verifying gradation and compaction, confirming survey location and batter. These steps provide a Unique Composite structure with a factor of safety of perhaps 20, based on research and demonstration by Barrett, Ruckman, CDOT, UC/D, USFS, FHWA, NCHRP and many others.

Prologue

Bear with me while I explain how this became so easy….and why the current MSE paradigm is so dangerous.

Al Ruckman and I first partnered with the pioneers of confined soil, John Steward, John Mohney of the USFS and their professor at Oregon State, Dick Bell, to build the largest wall dedicated to confined soil research. Planning began in 1979 and the wall was built in 1982. This wrapped face fabric wall was 300 feet long, 15 feet high and had 10 different fabric schedules, each for 30 feet of the wall length.

At the urging of Bill Hilfiker, we added a 30 foot long segment of their new wire wall to provide a side by side comparison. Our contractor had not built one of these, and made the rookie mistake of allowing the face to bulge. Bill blamed this on Al and me, thinking I suppose we had engaged in subversion to make our wall look better than his. I think he still holds a grudge. But I digress.

This wall was included in a major Glenwood Canyon I-70 construction and the successful contractor was Peter Kiewit and Sons. It was a first for all of us at Colorado DOT. Spacing of the non woven fabrics was 12 inches and we used the USFS forming system as shown in their 1976 design manual. Backfill was pit run gravel screened to 6 inch maximum and compacted with a 50 ton roller. We hand compacted near the face.

Some of those fabrics – none of which are made today – were relatively weak…perhaps only 50 pounds per inch. Of course, we have no good way to compare them to today's application-specific testing. We had tests developed for the clothing industry such as the Mullen Burst for elbows punching through your sleeve. And we had grab tensile tests, perhaps used by football teams to select tear-away jerseys. These did provide comparisons of sort between fabrics, but were of little value in design. Those first editions of non-woven polypropylenes were inconsistent in quality and most did not contain Ultraviolet inhibitors.

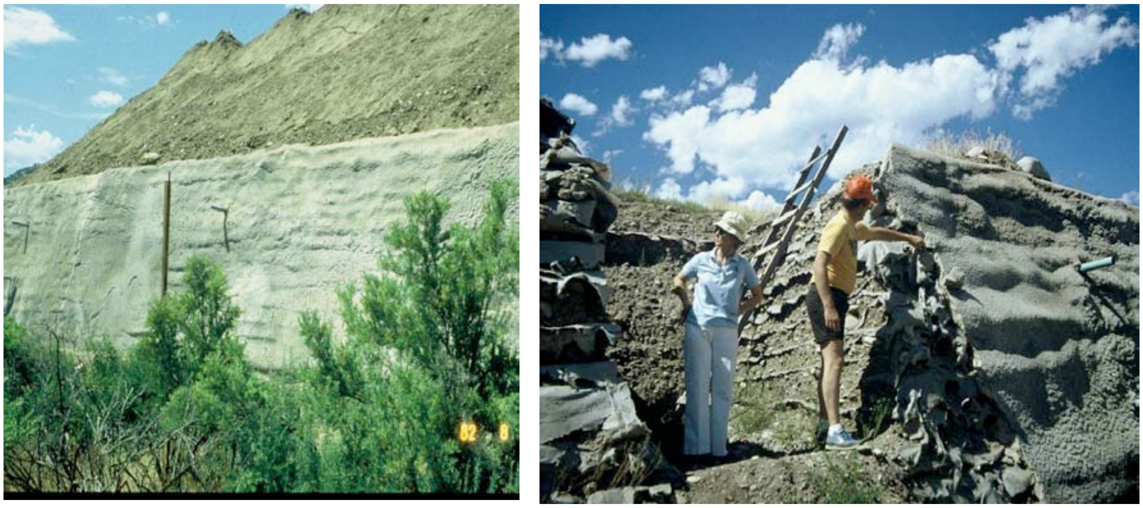
We roughly calculated factors of safety for each segment, using now to my great embarrassment, Rankine equations with element contribution. Two segments were “designed” (I use the term loosely, and you will soon see why) to fail before full height of 15 feet. About halfway up, the contractor’s superintendent discovered our plot and refused to put his men on those areas. The compromise was to set up warning lights on posts installed adjacent to those segments which would be triggered by the expected outward deflection.

This wall was instrumented to the hilt. We had a full time crew dedicated to monitoring. Nothing happened. We kept blaming the instruments and the crew. It did not deflect, creep, nothing. Well, it did settle. We built it over an old lake deposit with zero blow count mud and observed differential settlements of 8 to 24 inches along the length. The huge, flexible, geomonolithic beam conformed with ease.

It is most disappointing to not be able to fail a wall when that is your goal. So we added a 17 foot high earth surcharge, a brutal addition to a 15 foot high wall. Nothing happened….well, we did get more global settlement of course. The “factor of safety” was reduced to about .33. We still did not get it. The concept of a “Unique Composite” was still decades in the future. We still thought we could refine or discover mechanistic computations based on element contribution to reflect this behavior and predict outcomes of variations in the two components.

We were confounded. We extended the project for 11 more years and began an annual schedule of exhuming fabrics. Coupons were carefully removed with summer college kids using archeological techniques with trowels and brushes. Those were sent to Oregon State University, where Dr. Bell and his graduate students including Tony Allen at some point had performed a battery of tests on the original roll samples. We were then doubly confounded. Those 50 ton rollers kneaded the fabrics with coarse gravels and inflicted construction damage to the tune of 45 to 60% loss of strength. This was consistent and flat lined – we did not see any changes in the sample properties over the years. (An FHWA study sometime later concluded that the half life of polypropylene fabrics in these benign environments could be 500 years or more, which exceeds the service life of about any construction material used in our transportation facilities.)

What did this do to our “factor of safety”? We were bordering on the surreal. Reducing the strength of the fabric element by 50% brought the factor of safety to .11. Now, in retrospect, someone should have seen we did not know what we were doing. See how powerful paradigms can be?



1982 Glenwood Canyon Fabric Wall Research

Wrapped faces are great in terms of economy and efficiency but are lacking in esthetics. We moved on to using timbers and experimented with tires. We developed a design manual that used charts for fabric schedules and our own system for installing and attaching the facing timbers. Al and I called this a "Geosystem" and promoted it for international use as a generic option. We expected this design would be quickly adopted at CDOT. Note that we focused on the quality of the "connection", another paradigm artifact that impeded our intuitive talents. The Unique Composite theory was far away in the future. We built four of these Geosystems, one for the Town of Aspen, one for a private development in Glenwood Springs and two for CDOT at Wray and Colorado Springs.

Then came the spotted owl with the attendant escalation in the cost of wood products. We began working with concrete blocks, i.e., the ordinary Concrete Masonry Unit or CMU or "cinder block". These became cost effective in that they were easier to use and now less expensive than timber. We had great trepidations with connection and with compaction near the face. We were firmly embedded in the tieback paradigm.

(For a discussion on CMU durability see http://www.gcswall.com/pdf/DURABILITY-.pdf)

It was during this era that I chaired the Transportation Research Board Committee on Geosynthetics, described in Appendix One. Our group there was on a mission to develop a set of design guidelines for walls with geosynthetic inclusions. The momentum shifted from the "fabric wall" with its inexpensive generic components and limited applications to larger blocks with positive connections and inclusions that exhibited in-air stiffness on wider spacing. We aimed at getting closer to tieback analogies in design, which is more palatable to bridge engineers. We limited compaction at the face. We added a host of what we thought to be safety (i.e. reduction) factors in order to avoid early failures that could kill the technology. We multiplied reduction factors, added a two part backfill with gravel at the face, used cantilever wall rules to bury blocks in the ground (or was that to go below frost? either way, it was wrong), placed the blocks on a concrete footer, included overturning as a possible failure mode…I cringe to think of my ignorance at those meetings and I can see this paradigm blindness in every MSE wall failure today.

It was at this time that the National Concrete Masonry Association (NCMA) paid my way to several presentations around the country on their behalf and published articles in their trade magazine. One I remember was "What can you do with a Concrete Block?" which was also the theme of the presentations where I described the economy and versatility of the One, Two, Three wall design and construction process. Another article I wrote featured a GCS® wall with a CMU face designed by Al Ruckman for a CDOT project using asphalt millings as backfill.

Just when Al and I thought we had turned the corner away from vendor dependence – RECO and VSL were about the only game in town – our TRB enclave along with NCMA and FHWA embraced a tieback system of large concrete blocks with pin connections and a heavy plastic grid on wide spacing. NCMA even cancelled a scheduled presentation - I had to send back their plane ticket. They formed a sub group within NCMA to deal with Segmental Retaining Walls (SRWs). Several members developed and patented special molds for SRW blocks.

CMU's and woven polypropylene fabrics (silt fence/paving fabrics) are commodity products without much marketing support. No one makes much money with these items. The grids are basically the same chemistry, but in these peculiar biaxial and uniaxial drawn shapes, command 3 or 4 times price increase for marketing costs. The heavy SRW blocks require special molds and handling and cost 3 times more than CMU's. NCMA wrote a design procedure that mandated these expensive, proprietary elements.

I had ferverently hoped that our geotech and structural engineering communities would see that they were losing control of this powerful technology. It continues to disappoint to watch how easily we let others do our work for us, with no one at the helm except the exploiters. This sloth is at the taxpayers' loss. Our transportation users remain with only a few champions.**

I was a party to this as well. Even with expending perhaps 25 million tax dollars and collaborating with the world's smartest people over 40+ years, I could not find a mechanistic model that predicted the behavior of granular soil with closely spaced tensile inclusions…..wait, these are not tiebacks, they are now confining elements. I built extreme demonstrations to verify the counterintuitive behavior of GCS® structures and in hopes that the light of understanding would magically pierce the night. One was the cotton bed sheet pier described in Appendix Two.

Another was the awesome bridge abutment and pier demonstration at a CDOT yard in Denver. The photo below shows that bridge abutment and two piers, each built with the One, Two, Three design concept. The pier is 26 feet high and only 3 feet across. The middle pier was never loaded. Look how close the girders are to the edge of the abutment. One would think that looking at this and comparing this performance to MSE, which not even come close to this capacity, that our engineers and professors would take another look at their marriage to the MSE tieback paradigm.

Alas, the folks from around the world who visited this demonstration were as clueless as the folks looking at the amazing Japanese demonstration shown in Appendix Two. We have even had a DOT bridge engineer send out memos to disregard any findings from these GCS demonstrations because they did not conform to AASHTO, that they were an "AASHTO" state.

Construction

Back to guidelines for field construction and for field inspection. The astute student understands there will be site specific considerations and constraints that will take precedent over what I present from an overview from my experiences. Also bear in mind that I welcome inquiries to asktheexperts@gcswall.com

Before you break ground, consider the larger picture of need. What is the intended use for the GCS®/GeoMonolith? Retaining wall, abutment, pier, rockfall barrier, avalanche deflector, mudflow deflector or other? Each of these have special constraints for settlement, footprint size, batter, scour protection and more, and it would be prudent to look at the physical site just to make sure the design intent can be field fit.

Second, review the geologic regime. Perhaps the designers missed something important like a swamp or something. Well, even swamps can be accommodated. Al and I built a huge abutment in Jamaica on 90 feet of zero blow count soils. I built a bridge pier for BLM in California and placed the fabric over cattails rather than sub-excavate. Keep in mind that the GeoMonolith is the most accommodating of all the possible choices for a structure, but it does have limits.

Once you have the survey complete and an understanding of what you mean to do, it is time to lay some block. The first row needs embedded only to the extent that you anticipate future erosion. The first row needs to be uniformly level or, the other choice, uniformly on grade. Sand is a good material to work with. For heaven's sake don't make the MSE error of a concrete footer. The inspector may want to assist with checking survey, grade and leveling just to avoid future problems.

Then bring on the backfill. These lifts are nominally 8 inches (7 5/8 inches actually). First you will need to bring a lift of about 4 inches to the blocks. This windrow is foot tamped. This locks the block in place. Look at the photo below from a Mexican project where I am demonstrating this neat trick. Can't explain why, but you can then complete the lift and run the vibratory compactor beside and even on the blocks. Counterintuitive, I agree.

The Mexicans went on to build their first GeoMonolith. Its 55 feet high with a 20 foot high earth surcharge and a two story warehouse on top. The fabrics in the first 35 feet are Amoco 2006/Mirafi 600x and the top 20 feet has the more economical 500x, all of course, at each row of blocks. What is the wide strip tensile strength of 500x? It is less than 100 pounds per inch, but the manufacturer has quit providing that information, hoping you will use grid and they can make some money. Run that spacing and strengths through your MSE equations if you think GeoMonoliths are a subset of MSE.

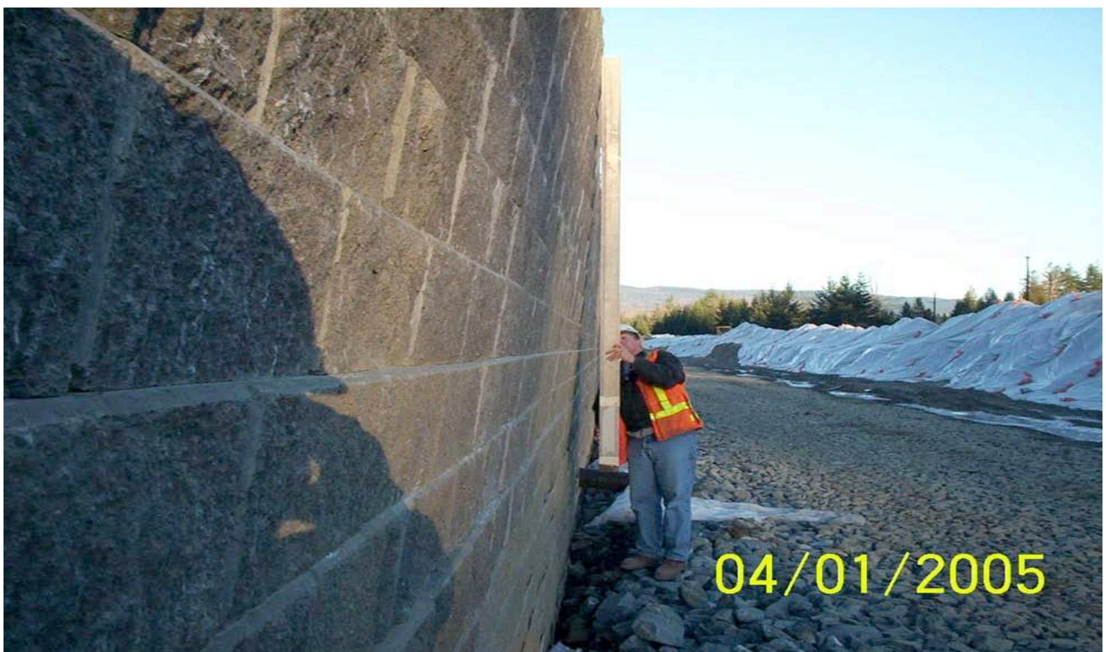
The inspector needs to verify backfill gradation. This would be predetermined by the large scale triaxial test designed specifically for GeoMonoliths. As explained in other parts of this essay, a GeoMonolith is a Unique Composite, much as is concrete, and, like concrete, is tested after the components are selected and mixed. MSE on the other hand, is a tieback and can be predicted sorta by adding the properties of the inclusions and backfills. That this sometimes does not add up and walls fall down is not important to folks in the GeoMonolith paradigm.

Compaction is paramount. Confined Soil is not confined soil until it is compacted. This is a joint goal of the builder and inspector.

Then comes the fabric. Well, first, take a moment and make sure the tops of the CMUs are clean, using a brush or broom as required. Place the fabric to design depth and out to the face of the CMU. Don't blast out bedrock to place the inclusion as is sometimes done with MSE. Avoid wrinkles on the facing block, but don't stress too much on tensioning elsewhere. I don't pay much attention to warp or machine directions. Field people don't either, even when directed. This not nearly as critical as is placing uniaxial grid the right way, which does not always happen. Joints do not need to be overlapped. Keep it simple and easy.

Some convicts and I built a GCS wall® for North Carolina DOT and there was a huge stockpile of geogrids left over from some other misguided project. They offered it to us and we gave it a try. It was hard to cut and both sides aimed at our eyes when it released. Then the stuff would not lay out flat. It was uniaxial and had to be placed in short strips. We wrestled with it till noon and then went and got some real wall building fabrics. So I guess I have built a little MSE, come to think of it. That is more than the folks who say GRS/GCS®/GeoMonoliths are "expensive". None of them have participated in a field construction. In the first place, the cost to construct is about a dead heat. Differences are we can build a lot more things in more places and we don't ever have to go back and redo GeoMonoliths

Tony Allen sent the photo of a failed WashDot wall (below) that I think was a demonstration of the K something concept that there is too much geogrid in today's MSE walls. The contractor did not follow the design, as I understand it, and it moved out of plumb. The contractor was deemed liable and had to rebuild it. Reminded me of NCHRP Project 24-12 led by Dr. Marr where they experimented with lower quality backfills. Dr. Marr told us at the Bob Holtz symposium in Mexico (2008) that their first one got rained on during construction and failed. We just don't have any stories like these to share for GeoMonoliths.



8" of negative batter along a 10' straightedge.

Washington State Department of Transportation

Now you can continue the One, Two, Three process. A row of blocks, a lift of compacted, granular backfill and a sheet of fabric. After about 300 feet high, the blocks could begin to crush, otherwise, not to worry. The blocks are persnickety and will tend to rotate out with height. You can use sand or roofing shingles or strips of fabric placed at the front edge to counter this tendency. Don't wait too long to begin shimming. Watch the batter. You can build negative, none or positive, but be consistent. Soon this becomes an enjoyable, repetitive process for all involved. You will see why you chose GCS® with light blocks and easily handled fabric and assurance you got compaction every 8 inches.

Closure

I will close with a photo of an MSE disaster in the making. This wall over-wintered and construction picked up in the spring right where they left off. I often see several blocks stacked above the platform with the grids rolled up. I wonder what the designer, the person of record endorsing this, could be thinking. Where there can be errors, there will be errors. Wide spacing invites them.

Robert K. Barrett, July 2010

**Now there is one explanation (excuse) that I am really reluctant to present. When a new paradigm is presented, it is a universal human trait to resist and cling to the status quo. There are multitudes of examples in history that seem humorous in retrospect. An easy one is flat earth vs. round earth. You may recall some of the conflicts and controversies with these two paradigms. It delayed global exploration for centuries.

I can't help but laugh thinking about the bridge engineers sitting in AASHTO committees over the years "voting" on what should be adopted in the way of MSE protocols. None, at least to my knowledge, has any real experience with research, development or construction of reinforced soils and few had even cursory experience with soil mechanics. Is it illegal to practice outside one's expertise or is it just unethical? Are they ever present or accountable at the revisiting failures in MSE walls? Are they concerned that this continued arrogant pretense has practically killed FHWA/NCHRP's GRS/GCS® abutment development, and at the cost of billions to our transportation communities? Have they even looked at what Al and I have created and constructed? The horse's teeth are counted by debate at that table with those groups.

MSE is embedded in our culture, so there will be people who keep on using it. I just hope that folks will now see the profound differences between MSE and GeoMonliths and go forth accordingly. Now there is a choice. RKB