SEGMENTAL BLOCK Retaining Walls

The keys to a rugged wall are a solid base, good drainage, granular backfill, and geogrid reinforcement

by Bruce Zaretsky

From time to time, most builders encounter the need to hold back soil. Whether you have to terrace a sloped yard, support a parking lot, or level an area for a pond and waterfall, a retaining wall is the tool for the job. Even to simply level a building site, you may have to cut fill out and support the slope that remains, or fill in an area and hold the fill in place.

In the past, the builder's choices were a timber wall, a dry-laid stone wall, or an engineered concrete retaining wall (see "Retaining Wall Choices," page 6). But these days, many contractors prefer to use segmental block retaining walls. Every material has its advantages and disadvantages, of course. But for many jobs, segmental block walls combine most of the advantages of a timber or stone retaining wall, without most of the drawbacks.

Sizing Up the Site

As with any retaining wall, geogrid and block systems have to be individually designed for every site. That means carefully assessing the ground the wall will rest on, the soil it has to hold back, the wall's necessary height, and any unusual loads before making any design decisions (see Figure 1). Once we know all these factors, we can make decisions about block type, base preparation, fill material, and reinforcement.

Soil conditions. Whether it's a new home or an existing house, I'm always careful to determine the site soil conditions in advance (Figure 2, next page). I visit the site several times before my crew starts work, and if it's a new building site, I ask the site contractor not to fill the area where we'll be putting our wall or steps. Taking control of that location, and responsibility for it, improves my odds of success.

When we build a wall on the site of an existing building, our first question is whether the spot we're building on was cut or filled when the structure was originally built. We must be absolutely sure to place the wall either on virgin ground or on properly compacted fill.

Building a wall on uncompacted fill is an invitation to disaster. I remember one job site where a deck contractor built his deck on posts bearing on pad footings set below our area's 42-inch-deep frost line, just as code requires. Imagine his surprise when the deck settled 10 inches! No one ever told him

Key Elements of a Geogrid-Reinforced Wall

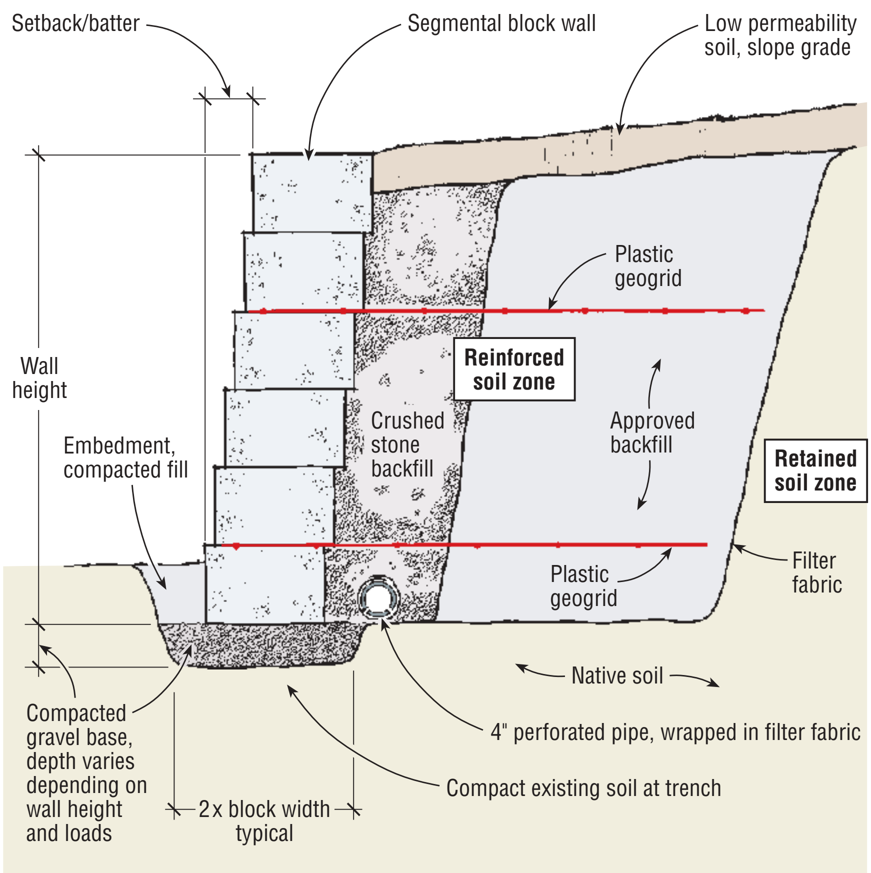

Figure 1. Block suppliers routinely provide engineering for large walls, but the engineering is only as good as the soil information. Critical factors include compaction (subsoils, gravel base, and reinforced fill must all be well compacted); geogrid choice and placement (grid of the specified strength and length must be placed at the specified locations); and drainage (surface runoff should be led away from the wall mass with an impermeable clay cap, and groundwater must be drained away with drain tile protected by filter fabric). If any doubt exists, the soils engineer responsible for the site should supervise the wall design.

that there was a 15-foot deposit of fill under his footings because the house was built on a steep slope. The soil under and around a retaining wall might experience forces greater than the weight of a deck footing. If that wall is placed on uncompacted fill, it's going to move.

Once we're sure the wall will rest on native soil, we still need to know the soil type, because that determines what kind of base preparation is required. For simplicity's sake, I'll talk here about the broadest soil categories: sand, gravel, and clay.

A well-drained gravel soil is ideal: It locks into place to provide good, stable bearing, and water percolates through it quickly. Clay, on the other hand, can seem firm and solid when you're digging in it, but if it absorbs water and expands, it can become a nightmare, making the wall shift up and down. Sand usually drains well, but it can be an unstable base.

Retained soil characteristics. The soil that the wall will be holding back also must be assessed to determine what engineers call its "angle of repose" — the angle at which materials are self-supporting.

Imagine three trucks dumping three different soils and making three cone-shaped piles of soil. The surface of each pile would naturally rest at a different angle with the horizontal — that particular soil's angle of repose. The steeper the soil's natural angle of repose, the less need there is to hold the soil back or to reinforce it behind the wall. And we always place the geogrid so that it extends past the line of that angle and embeds itself in soil that is self-supporting.

For strong soils like gravel, the angle of repose is about 45 degrees. But you can't assume that it's the same in every instance. In critical cases — walls that have to support loads imposed by decks, patios, driveways, or buildings — we remove all the natural material

Figure 2. The author always checks site soils carefully to identify uncompacted fill or problem soils. The upper left photo shows fill on the site of an existing 40-year-old home. The material is a silty sand that drains well. The author excavated down to original virgin soil for his wall base and placed filter fabric over the bank to keep fines out of the drain system (above). The photo at left shows a nearly vertical cut bank of native clay soils where contractor Jason Sweeney excavated the hillside to make room for a pool. Drainage is particularly important behind this wall, because the clay becomes soft and heavy when wet.

Figure 3. A base of "crusher run," ground stone and stone dust, is placed in the footing trench and tamped hard to support the base course of block. The taller the wall or the less firm the subgrade soils, the deeper and wider the base of crusher run should be.

from behind the wall until we are sure that the only thing the wall has to support is our imported granular backfill.

Consulting an engineer. We can usually assess the site soil conditions ourselves, but not always. If we are uncertain about anything, we bring in a soils engineer. Good soils engineers are worth their weight in gold — they can help you prevent a problem today from becoming a nightmare later on.

I generally call an engineer if the wall needs to support any unusual load, such as a parking lot or a building. I also bring in an engineer if I feel the need for a little extra peace of mind. For example, I consulted one recently when a customer called me to repair a failing wall that another contractor had built incorrectly. The engineer confirmed my assessment of the situation, and together he and I designed a replacement wall. I probably could have figured it out, but since the job was already problematic, I appreciated the additional security. (If the original builder of the wall had followed an engineer's advice, of course, I would not have had to be there in the first place.)

Base Preparation

Once you know your soil conditions, you can move forward with preparing the subgrade, placing a compacted gravel base, and beginning to place block.

Subgrade. We always compact the existing soil in the bottom of our trench. You may need an engineer to specify the compaction method and to verify that you've compacted sufficiently — or at least to check the results you're getting with your compacting equipment at the beginning,

Toe Embedment Anchors the Wall Base

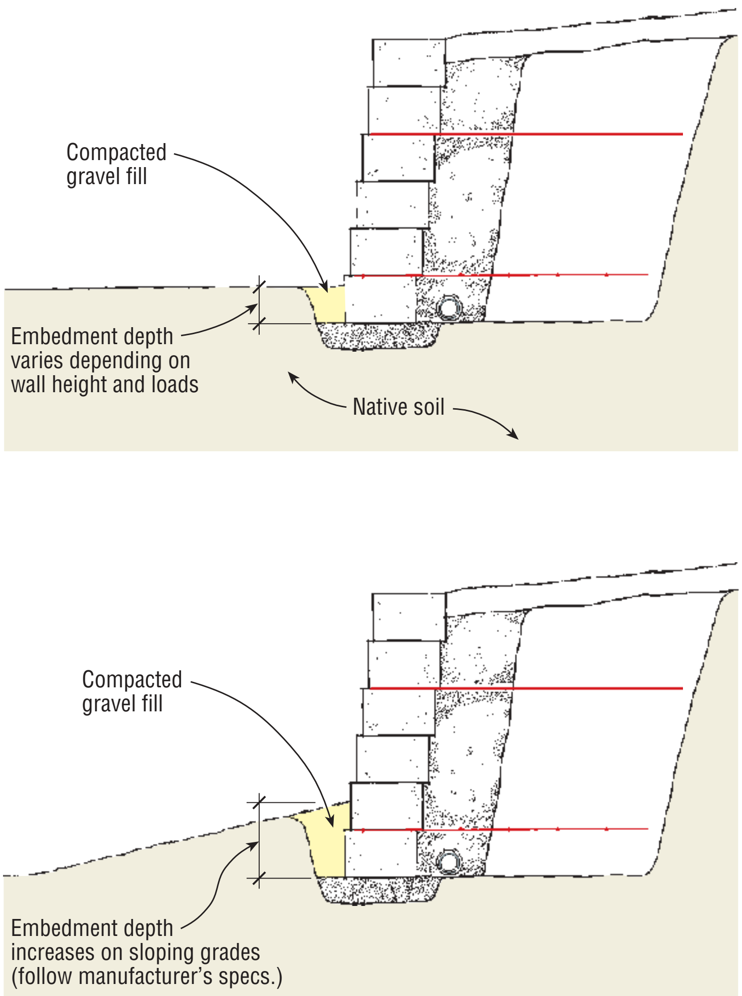

Figure 4. The author likes to firmly bed his base course of block into the granular base by beating the block with the top of the pick handle (right). He prefers to use the heavy Versa-Lok units shown here because in his experience they stand up to this treatment better. The depth of the first course of block ("toe embedment") varies depending on site characteristics (above). If the ground slopes downhill from the wall base, manufacturer specs call for a deeper embedment to hold the base in place.

until you're comfortable that your methods are working.

How we treat native soil depends on the soil type. Firm gravel is fine; we put our base stone right on top of it. If the soil is clay, we dig down at least double the recommended depth before placing our base material (if the manufacturer's literature calls for a 6-inch compacted stone base for a 4-foot wall, for instance, we'll dig a foot before placing the stone). Loose sand should be completely removed. But if it's too deep to practically remove, we dig extra deep and lay a soil-separating fabric, then place our stone on top of that.

Base material. Next we place the base material (Figure 3, page 3). In New York, we use "crusher run," a crushed stone mixed with stone dust to lock it solidly into place. We can tamp that nearly as solid as concrete with a walk-behind plate compactor.

The base is always at least twice as wide as the wall blocks; the planned height of the wall determines the base material's depth. For low walls (less than 2 feet tall), we use about 3 to 6 inches of base thickness. Larger walls can have as much as 2 feet of base below them. We place the material in 3-inch lifts and tamp it down with walk-behind plate tampers to ensure proper compaction. Once the base is placed and compacted, you can begin to build.

We generally bury at least half of the base course of block below the original grade to restrain the toe of the wall from kicking forward under the pressure of retained earth. For taller walls subject to higher soil pressures, it may be necessary to bury one or two full courses of block or more. The engineering documents required for walls higher than 4 feet should specify the embedment depth of the wall's base. In the case where the downhill slope continues at the base of the wall, the calculations are more complicated and the required depth of the wall foot is typically greater (Figure 4, page 4).

I like to pound my base course blocks into the layer of crusher run to make sure they're firmly seated. We smack them with the end of the wooden pick handle. That's one reason I personally prefer solid block units like Versa-Lok to hollow block systems — occasionally, I've broken hollow units by hammering on them.

Some companies make oversized base units for extra stability on very large walls. And if we're working with wall systems that use pins to hold segmental units together in the wall, we sometimes pin the base course blocks to the ground using 3/8-inch rebar, to help anchor the wall base to the earth.

Drainage. Without question, the most critical factor in retaining wall construction is drainage (Figure 5). Without it, walls will be exposed to hydrostatic pressure (which can double the load on the wall). In the North, poorly drained soils will expose the walls to frost action. If you see a wall that's bulging in the center, chances are that it's not properly drained; it's only a matter of time before it fails.

We always bury at least a 4-inch perforated pipe behind the wall. The pipe should be wrapped in a landscaping filter fabric and run to daylight out of the wall and away from the base.

Backfill and geogrid. We backfill all walls with a #2 crushed stone, placed and compacted in lifts of 6 inches or less, and layered with reinforcing geogrid (Figure 6, page 7). It's important to lay landscape fabric on the slope behind the wall, so that dirt does not wash into the stone — silt material impedes drainage and can clog the drainpipe or its filter fabric wrap.

The geogrid spacing and the distance it runs back from the wall into the slope are important factors in the wall's strength. The geogrid requirements are usually determined by the height of the wall, the soil type, and

Figure 5. A drain tile in the granular backfill, sloped and run to daylight, is critical for retaining wall performance. It helps keep frost problems to a minimum and maintains soil behind the wall in a drained condition to reduce lateral pressure of soil against the wall.

Retaining Wall Choices

Dry-laid stone will always be my favorite material for retaining walls. I love the beauty of it, and you can't beat it for durability: Properly built, stone walls can last forever. We build our stone walls 18 to 24 inches thick with hand-cut stone, and stack them carefully to be self-supporting. Stone is very heavy, which helps it hold back the weight of soil. But it does have structural limitations; I've built a few stone walls 8 feet high, but we typically don't go higher than 4 feet.

And stone's cost is a drawback. The stone itself is quite economical: Anywhere in the country you can find a stone yard or quarry that has native stone for a few dollars per ton. I pay $10 a ton in my area for local native limestone; special stone that we truck in from Pennsylvania runs us about $100 a ton. A ton gives us 20 face square feet, so stone walls cost 50¢ to $5 per face square foot just for the material. But the hand labor of cutting and stacking the heavy stone pushes the cost up to $40 a square foot and higher.

Preservative-treated timber walls are much more economical. And wood is much lighter than stone or block, which is especially helpful on sites with difficult access. If you have to walk up a backyard slope to your wall location, you can carry timbers in on your shoulder: An 8-foot pressure-treated 6x6 weighs less than one concrete retaining wall block.

Timber walls are also good if you want a certain look. On houses with vertical cedar siding, we sometimes build vertical timber retaining walls and face them with vertical cedar for a matching architectural appearance.

The problem with timbers is durability. I've built literally miles of timber retaining walls. Some have lasted 20 years or more; others have begun to rot after 3 or 4 years. For whatever reason, the treatment effectiveness seems to vary. It's a good product for a customer who wants something economical and doesn't necessarily want a lifetime solution.

Timber walls also have some structural limits. I've built them up to 10 feet high, but that was back in the days before segmental block. For slopes that high, you really have to ask whether you want to use a material you can't be sure will last five years. These days, I put in only a couple of timber jobs a year, typically for a low wall or planter box.

Segmental block wall systems are quite durable, and they definitely take the prize for structural capability. They're designed to automatically "batter" back into the hillside as we stack them up, and successive courses either get pinned together or have shapes that interlock. Backed up by loads of compacted granular fill layered with reinforcing geogrid, these systems can do the work of a concrete and rebar structure at lower cost. Engineers are speccing segmental wall systems for bridge abutments, highway overpasses, and slopes 40 feet high and higher. It's hard to imagine a residential requirement that these systems couldn't satisfy. And while concrete walls need footings that rest below the frost line, segmental walls can flex to handle moderate amounts of freeze-thaw soil movement without damage, so we can set them in just a 1-foot or 2-foot trench.

Cost for segmental block varies depending on location and manufacturer. When all the backfill, geogrid, and labor are included, a segmental block wall typically costs a little less than stone but quite a bit more than timber.

Appearance can be a limitation — block walls aren't suited to every architectural need. But as new tumbled, profiled blocks are coming out every year, our ability to be creative continues to expand, and segmental systems have become quite popular with customers. The systems are versatile and allow a lot of flexibility in structural design. For the money, you don't get the natural beauty of stone, but you do get a variety of choices in style along with reliable engineered strength.

Figure 6. Space behind the wall is backfilled with 1-inch and 2-inch gravel, placed in 3- to 6-inch lifts and compacted in layers (above left). Geogrid at specified intervals (above right) locks the compacted fill into a single mass, which holds back the natural soil or fill behind it. The grid also holds the face block in place, either by interlocking with gravel placed into the block cores, or by engaging locking pins as in the Versa-Lok system shown at left.

any additional load on the earth above the wall. Most walls get geogrid at least every 2 vertical feet in the wall and extending into the slope twice the height of the wall at the point where the geogrid lies. But the geogrid length varies in different soil conditions — the material needs to extend well past the line of the soil's angle of repose, so that it will stay firmly embedded.

Geogrid is locked into the wall face by pins, by friction between the block units, or by stone fill placed inside hollow block units, depending on the manufacturer. That's to hold the face block in place. But geogrid also separates the backfill into different layers, working to prevent the soil from slumping and increasing the stability of the wall. The grid effectively locks the backfill soil into a solid mass that acts as a heavy, bulky gravity wall.

Terraced walls. If you're building a terraced wall, where the upper wall will be built on the backfill of the lower wall, the geogrid becomes especially significant. You may need engineering in those cases. In general, terracing should be designed so that the lower wall does not have to support the upper wall. A rule of thumb is to set the upper wall back a horizontal distance at least one and a half times the height of the lower wall.

A Wall That Failed

Two of my favorite books are a matched pair by Mario Salvadori, the late Columbia University professor, titled *Why Buildings Stand Up* and *Why Buildings Fall Down*. Both are interesting, but I've always thought the second one teaches more. When it comes to retaining walls, I personally have learned more from structural failures than from structural successes. Here's one of our stories:

We were called in to propose a wall for a client. This wall was to be a terraced system of two walls, each to be about 4 feet of exposed wall. In addition to holding back soil, it would support the back of the home and a deck, which would be cantilevered over a 9-foot-tall stretch of the wall system.

After receiving three proposals from three different contractors, the client decided to go with the lowest price (which wasn't us). I cautioned the client to make sure he had structural diagrams and plenty of references from the chosen contractor. He said he did.

The construction started in November 1995 and was finished one month later. In January 1996, the client called me in to evaluate the wall, which had already started to fail (sections had started to fall over). I took a look at it and told him to call an engineer. After many long meetings with the client and the engineer, we decided to dismantle the wall and rebuild it. Here's what we found when we tore into it:

First, instead of digging down deep enough to install a 12-inch base of crusher run and two courses of 8-inch block (a total of 28 inches), the wall builders had set their base course of block on 4 inches of crushed stone and explained that they would fill in in front of the wall with 8 inches of topsoil. They did not understand that the base needs to be buried in the "inactive zone" of consolidated subsoil so as to create a "passive wedge" strong enough to keep the base course from sliding forward.

Second, along the 9-foot-tall section of wall supporting the house and deck, the builders had rolled up the geogrid behind the wall so they would not have to remove the existing railroad tie wall. They just built the new wall in front of the old wall, which had also been failing in the first place (that's why a new wall was needed). There was no locked-together soil mass to support the retained soil and the superimposed loads.

But here's what really made me scratch my head: Instead of running the downspouts from the back of the house into solid pipe directed away from the wall, the builders had tied them into the drainage pipe behind the wall! Five downspouts deposited most of the home's roof runoff into the wall. And they could hardly have made a worse choice for backfill: They used blowsand, a cheap, poorly draining material that holds about 19% moisture. In effect, they designed this wall to have continuously saturated fill behind it.

The three most important things that make a wall strong and durable are base preparation, drainage, and reinforcement. In this case, all three were accomplished either shoddily or not at all. With any of these items poorly done, the wall would fail eventually; doing all three of them wrong was a recipe for immediate failure.

We had quoted a price of $38,000 to build the wall originally. When all was said and done, it wound up costing the client $64,000. The moral of the story: Build it right the first time.

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Sources of Supply

Allan Block Corporation
800/899-5309
www.allanblock.com

Anchor Wall Systems, Inc.
877/295-5415
www.anchorwall.com

ICD Corp.
800/394-4066
www.selecticd.com

Keystone Retaining Wall Systems, Inc.
800/891-9791
www.keystonewalls.com

Risi Stone Systems
800/626-9255
www.risistone.com

Rockwood Retaining Walls, Inc.
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www.retainingwall.com

Shaw Technologies, Inc.
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www.shawtechnologies.com

Tensar Earth Technologies, Inc.
800/292-4459
www.tensarcorp.com

Versa-Lok Retaining Wall Systems
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www.versa-lok.com