A QUICK CURE FOR PROBLEM SOILS

This self-leveling, cement-based mix is cheaper and easier to use than compacted gravel fill

by Robert Hogrefe, P.E.

In the central New Mexico mountains where we build, clay and other problem soils can behave unpredictably, expanding and contracting excessively, or settling and shifting. Add in an ill-timed rain or snow storm during foundation prep work, and what appeared to be a suitable, compactable subsoil can suddenly become a wet, sticky, non-compactable mess.

Unfortunately, it's sometimes difficult to determine exactly what soil types exist below the footing trenches. Even proper soil investigations may not identify all problem areas, because the results are typically based on only a few borings that are taken to be representative of the site.

Lean Fill

When excavations reveal surprise soils with questionable loadbearing ability, we use a technique that protects against foundation settlement. Simply put, it involves over-excavating the footing trenches and replacing marginal soils with a cementitious self-compacting material known around here as "lean fill." The material is also commonly referred to as "flowable" or "unshrinkable" fill, or as "controlled-density" or "controlled low-strength" fill, depending on your locality.

Lean fill provides a cost-effective solution in any situation where uneven soil bearing capacity is a problem, including poorly compacted existing fill, clay soils that are susceptible to moisture, or deep foundations where moisture entry could cause settlement.

Here's how we used lean fill to handle a recent "headache" foundation where bedrock at varying depths would have made it nearly impossible to achieve uniform bearing.

Bedrock Problem

Because we would be pouring a slab on grade after the foundation was in place, we had soil samples tested for plasticity and swell potential. The slab subsoils tested out as "non-critical" for swell potential, with the typical recommendation for compaction (95% maximum density in the upper one foot, at or above optimum moisture content). The professional input from the soil tests was well worth the $300 fee. It allowed us to leave the native soils in place, which is less expensive than removal and replacement.

Figure 1. Lean fill was a simple way to consolidate the loose rock and span or fill the numerous fissures — some as wide as 2 inches — that crisscrossed the irregular bedrock.

Unequal bearing. However, we still had to deal with the footings. Trial excavations over a distance of about 50 feet had revealed bedrock that varied in depth from only a foot down to 7 feet below the surface. While it is possible to place part of a footing on bedrock and part on soil above bedrock, we worried that the unequal bearing strength of the two materials could result in differential settlement. But if we scraped the bedrock bare, it would be hard to maneuver the compaction equipment, not to mention the safety concerns of working in a 2-foot-wide, 7-foot-deep trench. Plus, if it rained or snowed before the foundation work was completed, conditions in the trench would go from bad to worse.

Leveling the Grade with Lean Fill

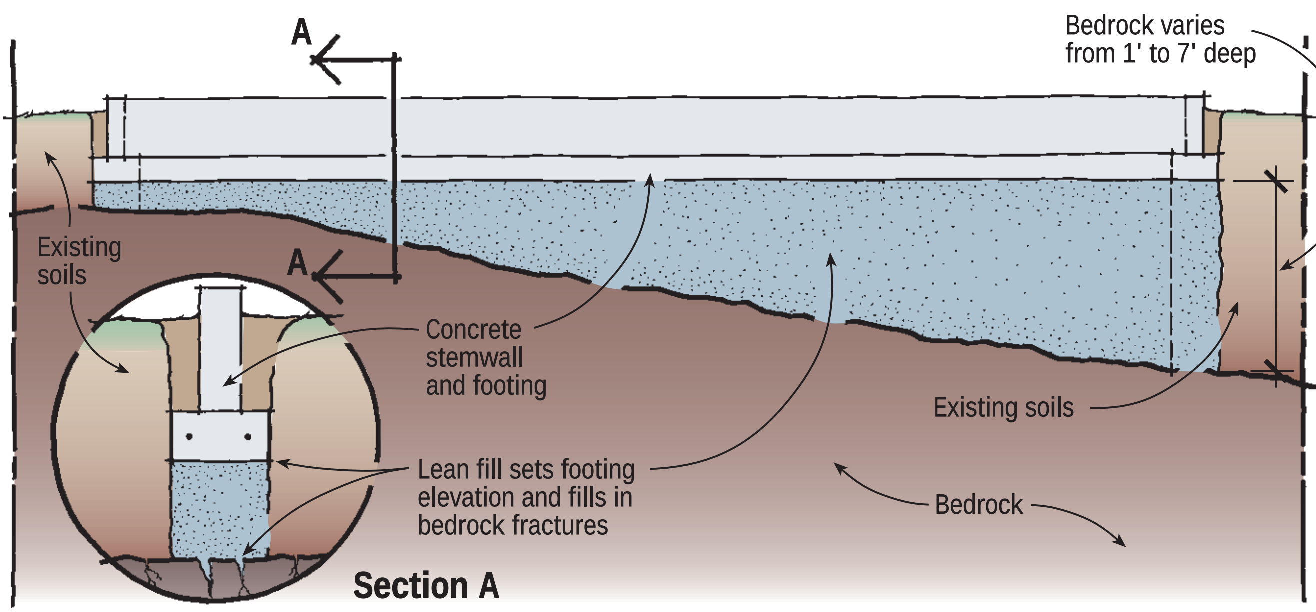

Figure 2. Over the length of the excavation, the bedrock dropped from a depth of 1 foot to about 7 feet at the lowest point. The top of the lean fill set the elevation of the structural footings, which were calculated to ensure that stemwall forms would not have to be stacked.

Lean Fill vs. Soil Bearing Pressures

Material	Lean fill @ 50 psi	Lean fill @ 300 psi	Massive Crystalline Bedrock	Sedimentary Rock	Sandy Gravel types	Sand/Silt types	Clay types
Allowable Bearing Pressure (psf)	7,200	43,200	4,000	2,000	2,000	1,500	1,000

Source: *Uniform Building Code* (1994) Table 18-1-A Allowable Foundation and Lateral Pressure

(*UBC* values based on 12x12-inch footing. Values are higher for deeper or wider dimensions.)

Figure 3. The bearing capacity of lean fill exceeds that of many types of rock and compacted soils.

To complicate matters, the underlying bedrock was pitched and broken, with fractures that varied in size from just a crack to an inch wide or more (see Figure 1). This could further jeopardize the ability to achieve uniform bearing for the footings, so any solution would have to include filling or bridging the bedrock fractures.

We decided to over-excavate to bedrock and re-establish the desired footing grade with lean fill (Figure 2). The lean fill would, by virtue of its mortar-like flowability, fill in some of the bedrock fractures and bridge the other irregularities in the bedrock.

What Is Lean Fill?

Although the American Concrete Institute (ACI) refers to lean fill as a "controlled low-strength material" (Report 229R-94, Code LT 203W, $5 from Portland Cement Association; 800/868-6733), I think the term "low strength" is somewhat of a misnomer. It's true that lean fill is not a classic concrete mix, which typically reaches 2,500 psi or more for structural applications. By contrast, lean fill strength typically ranges from 50 psi to 300 psi, up to a maximum of about 1,200 psi. But lean fill is not used like structural concrete — it is primarily a substitute for compacted fill. In this application, the comparatively low strength of lean fill is equivalent to soil of relatively high bearing strength. In fact, even at a design mix of 50 psi, lean fill will handle bearing pressures of 7,200 psf, which is far more than what is normally required (Figure 3).

Lean fill can be poured or pumped into shallow or deep trenches that have been excavated to remove low-strength, soft, wet, or otherwise questionable or undesirable subsoils. The lean fill mix can be adjusted so that the self-leveling material can easily fill a void and self-compact without the need for conventional placing and compacting equipment. This can be a huge cost and time savings to the builder, who also avoids the potential danger of putting workers in deep trenches.

Prep Work

The backhoe started working from the shallow bedrock corner of the house and carefully scraped out a 2-foot-wide trench following the bedrock as it dipped deeper (Figure 4). The operator was careful not to get the teeth of the bucket engaged in any bedrock fractures, since we wanted to avoid pulling bedrock pieces out. Fortunately, the bedrock was in large sections with horizontal fracture lines. We stockpiled the soil for use later as infill, saving substantially on the cost of import material.

Elevation control. One of the many advantages of the lean fill pourback technique is the ability to set the footing elevation virtually anywhere you want it. We knew we could save money on the structural foundation if we didn't have to stack stemwall forms, so we made sure to set the elevation of the lean fill so that we could use single 4-foot-tall forms all the way around. With two step-downs, the depth of the lean fill varied from 8 inches to just over 4 feet at the deep end. We set the "pourback" elevations using a transit, and marked the locations with flagged nails poked into the sides of the trench every few feet.

Figure 4. Trenches for the footings were dug with a backhoe, following lines marked on the ground. To avoid loosening the fractured bedrock, the operator was careful to keep the bucket teeth from snagging.

Placing the Lean Fill

No steel was needed in the lean fill, so after the elevations were set we were ready for lean fill the next day. Regular concrete batch trucks hauled the mix to the site, where a concrete pumper was already in position to place the material (photo, page 1). We placed 50 cubic yards within a few hours' time, including filling in the isolated spot footings we had also dug out to bedrock. Lean fill flows easily and is almost self-leveling, so it didn't take much effort to smooth off the top of the pour at the elevation settings.

Bad weather, no problem. Lean fill sets up enough in just a few hours to support foot traffic, so by the next day we could have started placing the steel for the footings. As luck would have it, however, an 8-inch snowfall delayed the work. But because the bottom of the trench was now effectively sealed off, there was no moisture damage and we were able to work on the footings the next day (Figure 5). Had we not been working with lean fill, we would have had to either anticipate the storm and cover the trenches, or shovel out the snow before it had a chance to melt and freeze the subgrade. The lean fill also kept the trenches from becoming mud holes.

Pouring the Footings

A typical lean fill mix should be ready for structural loading within about a week. This is similar to the rule of thumb for structural concrete footings and walls, which should be allowed to gain at least seven-day strength (about 67%) before loading is applied. Of course, if you have questions about how soon you can apply loads, have an engineer check the job's structural conditions.

In our case, we placed concrete the same week. We again used flagged nails in the trench sidewalls to set the footing elevations, but now we were working at a comfortable depth of about 3 feet at the most (Figure 6). As is common in our area, the sides of the excavation formed the footings, so no additional footing forms were required.

Figure 5. A sudden snow storm the day after the pour delayed foundation work, but workers were back in the trench 24 hours later. The lean fill kept melting snow from turning the trench into a mud hole.

Figure 6. Structural footing concrete was placed on top of the lean fill within a week. For heavy structural loads, check with an engineer to see if the lean fill will have to cure longer than seven days.

By the following week, the stemwall forms were set. As planned, the lean fill elevations enabled us to use a single run of 48-inch-high forms, which resulted in substantial savings. The stemwall pour went smoothly, in spite of another snow storm that came and went. Again, there were no worries about moisture adversely affecting the exposed foundation, because we were protected all the way to bedrock. I can tell you that using the lean fill pourback technique allowed me to sleep more soundly than I ever had before when hit with bad weather in the middle of foundation work.

Lean fill is not waterproof, however; it takes on moisture the same way compacted granular fill does. Its permeability varies depending on the mix design — greater cement content decreases permeability, for example, and higher aggregate content increases permeability. Always provide perimeter and surface drainage just as you would for a foundation built on natural soil, especially if the structure calls for in-slab radiant heating, tile, or other moisture-sensitive details.

Availability and Cost

Lean fill has the advantage of being readily available from concrete suppliers, who can deliver it in ready-mix trucks and place it via chutes or a pump. Cost depends on mix design, transportation, and other standard factors, but we pay in the range of $35 to $50 per cubic yard, delivered. This makes lean fill about 20% to 30% less expensive than structural concrete.

But any cost comparison should also account for costs that are avoided by using lean fill. The biggest savings comes from not having to supply equipment and labor to compact fill in 6-inch lifts. By using lean fill, we were also able to eliminate any shoring, since nobody needed to work in a deep, narrow trench. These savings more than made up for the cost of over-excavation, which in this case was only about four extra hours of machine time.

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