Underpinning Basement Foundations

How to avoid a building collapse when digging down a basement

BY DOUG HORGAN

Photos by Doug Horgan/BOWA, except where noted

Basements, including basement apartments, are common in my area, and real estate is valuable. So, we often find that clients who live in older homes with short basements (5- to 7-foot ceiling heights), or even shallower crawlspaces, are interested in turning the spaces into full-height, usable rooms.

It's possible to dig down just the middle of a basement and "shelf" the perimeter so the dirt below the existing footings remains intact and has ample support, but we more often excavate the entire basement, wall to wall, which requires extending the existing foundation walls down to new footings, a process called "underpinning."

There's no question that this is a lot of work and even carries some unusual risks compared with other projects. In fact, there have been some disastrous failures in our area when contractors aggressively undermined too much of a foundation, and the building collapsed—or in some cases, the building and the connected building next door, too. One jurisdiction has twice modified the permitting and approvals process to include more stringent controls in an effort to avoid problems.

We've done several of these projects and have more on the boards. Here's how we do them, along with some lessons we've learned.

Complete collapse. These photos posted by the D.C. Fire and EMS Department show the tragic consequences of undermining the foundation when digging down a basement.

PRE-WORK INSPECTIONS

There's a strong possibility of foundation movement when you dig down a few feet and replace the entire supporting structure of a building. It hasn't happened to us, but everyone involved is thinking about it.

Before we begin, and usually with the clients and a camera, we thoroughly inspect the upstairs of any house we underpin. Any gaps or cracks are noted and photographed. We also check for moisture that might be transmitting through foundation walls.

When we underpin masonry row houses, and some of the walls we're reworking are party walls supporting adjacent houses, we typically inspect the neighbors' houses, as well. This is a normal process in Washington, D.C. On each of these inspections, we are accompanied by the neighbor, and we create a report for them noting any cracks or other issues. On a recent project, we found some water leaking into the neighbor's basement and were able to provide them with some free diagnostic information while we were there.

WHAT'S SUPPORTING THE HOUSE?

Before the job starts, we must dig down in several places to inspect how far the existing walls extend and determine what's under them. Around here, houses often don't have a concrete footing right below the slab, as you'd find in modern construction. On many of the houses we work on, the original builders put bricks on the dirt and started stacking upward.

Occasionally, the walls run a foot or two below the existing basement floor level and, in these cases, we may be able to drop the floor level far enough without needing to underpin the walls.

Within D.C. limits, we are required to have the dirt tested by geotechnical engineers to verify it can hold the building. In other jurisdictions, we may need soil tests if the engineer we're working with recommends it. Most of the time, we're digging down to more stable dirt and installing a stronger, wider foundation with more bearing area. Unless we find something unusual, the dirt is generally fine.

DIGGING DOWN BUT NOT TOO FAR

In cases where the walls extend far below the existing surface, we sometimes remove a foot or two of dirt before we start the underpinning. The less dirt in the space, the easier the work. However, we leave dirt near the footings for temporary bearing under the footing. Bearing stresses from the footing are distributed into the dirt at a "distribution angle," which varies by soil type; 45 degrees is typical, but engineers sometimes direct us otherwise. We make sure to never dig inside it.

FOLLOW THE PLAN

The general idea of underpinning work is to excavate and pour a series of small foundation and footing sections in a staggered

Pre-inspection. Before an engineering plan can be devised, the author's company digs several inspection holes like this one (above left) to document how far the foundation extends and what the footing's condition is. In addition, the company inspects all adjoining homes, in this case (above right) using a moisture meter to monitor moisture levels in a party wall.

Photos top and above left: District of Columbia Fire and Emergency Medical Services Department

pattern so you aren't undermining a large section of structural support all at once. For each small section, we typically dig a 3- to 4-foot-wide pit under the existing foundation, form and pour a new foundation in that area, and then repeat by digging out another small section and so forth.

All our underpinning projects have a work plan defined by the engineer. This plan includes the section sizes and the order to dig them in. We mark the sizes out on the walls and number them with spray paint. Typically, there will be two to five "number one" sections we dig and pour at the same time, then a bunch of "number two" sections, and so on.

Corners are tricky. It's difficult to dig one side of a corner without significantly undermining the adjacent wall as well. We have started asking engineers to plan for digging the whole corner at once and usually not in the first two sets of holes.

INSPECTIONS AND TESTING

Local building inspectors (or sometimes engineers or third-party geotech firms) do test the soil at the bottom of the holes—at least the first few. This can range from simple hand-held rod testing (by pushing a piece of rebar into the soil, an inspector can evaluate the bearing based on resistance to driving the rod) to elaborate testing apparatus like a Dynamic Cone Penetration test, which uses multiple blows of a calibrated weight to precisely measure how easily a conical-pointed rod is driven into the dirt.

Most soil in our region is well over 2,500-psf bearing strength and, for the houses we underpin, the soil is rarely a concern. One project we did was clearly on two different types of dirt—we had to use a chipping hammer to dig out a third of the house, while the rest of it was easy to shovel. Both soil types were sufficient to support the standard 24-inch-wide footing called out on the initial plans. In fact, the 24-inch footing was 150% of the size of the original foundation bearing, which was just two bricks laid on the dirt. Some other regions have more complex soils and need other tests, including testing rigs that penetrate down through multiple layers of earth.

We've also had engineers epoxy precision targets to spots on the wall so they can check with a leveling instrument in the future to see if the elevation has changed. Our permit plans sometimes are required to state how much movement is acceptable and what will be done if there's more than that.

Many of our underpinning projects have included significant additional work, such as removing center bearing walls, changing entire framed floors, and the like. We often have engineered temporary support plans that need to be integrated with the underpinning work. The value of these engineered support walls was shown to us when an earthquake hit our area while we had a five-story masonry building on temporary supports. The design must have been effective because nothing bad happened.

A SERIES OF MINI-FOUNDATIONS

There's usually a rebar schedule for the new foundation. Since we're pouring a series of small foundations, we extend the rebar into the dirt next to the section we've dug, so it will connect to the future concrete when we dig that section.

Soil bearing is evaluated at the bottom of one pit by conducting a Dynamic Cone Penetration test.

Some engineers call out keyways in the sides of each pour, which we create by placing a wood strip next to the dirt before we pour. This strip is pulled out when we dig out the next section, leaving a vertical channel for the next pour to key into. We've also been asked to install water management gaskets between pours. Since the existing solid masonry walls are usually quite leaky, I don't think these add much value, but it's easy enough to do. We normally install an interior water management system at the end of the underpinning work.

The engineers or local inspectors come to check each pour once it's formed up. They verify the size of the footing and wall and check that the rebar is installed per the design.

Our foundation subcontractors often build formwork that allows them to pour both the footing and the wall at the same time. Dirt serves as a form on the sides and back, while a custom wood form is used on the inside. The height of the pours varies, and the form usually stops a few inches below the bottom of the old wall or has a special removable panel near the top. This allows room to get the concrete in over top of the form and under the old wall.

Once the concrete is poured, the gap left between the new concrete and the old foundation is filled with "dry-packed" non-shrink grout. A very dry mix is made and compacted into place with wood blocks and sledges. The idea is to fully support the old walls; trying to pour concrete up under them would be unlikely to provide solid bearing over the entire area.

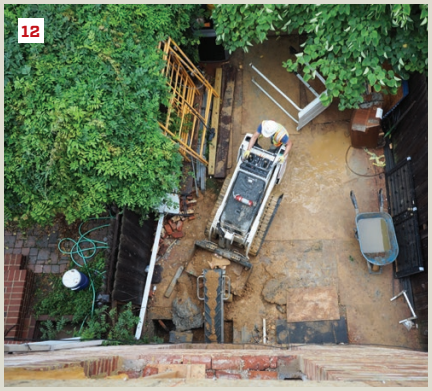
Once all the "number one" sections have been poured and dry-packed, we can move on to the "number two" sections, where we repeat the same steps. The third sections are often adjacent to the first pours, and we clean the rebar that was stuck into the dirt earlier, then tie new pieces to it so it acts continuously across all the sections. The overlap is called out on the plans.

PROGRESSION OF AN UNDERPINNING JOB

Before the job begins **(1)**, the basement must be cleared out, including removing duct work, framing—even the stairs leading to the first floor. Exploratory holes are dug to evaluate the footing and water table **(2)**, and a new sump pit roughed in **(3)**.

With the basement cleared, work begins on demolishing the slab **(4)**, while the order of excavation of small sections is defined with spray paint on the walls. All the “ones” are dug and rebar cages tied in place **(5, 6)**.

Inner-city access is often tight so concrete must be “walked” in through alleys and backyards **(7)** and delivered via chute to the basement **(8)**. Corners are tricky; it helps to pour both sides at once **(9)**. Note the dry pack above the initial pour.



After the “ones” are dug, poured, and dry-packed, work starts in on the “twos” **(10)**. As work proceeds, the basement fills up with dirt **(11)**; to remove it, the crew uses a conveyor belt that dumps into a stand-on skid steer **(12)**.

Once the crew has worked through the series of footing/foundation sections, the extended foundation is complete **(13)** and excavation continues. With the basement dug out, drainage lines and an ejector pump for a new bathroom are installed **(14)**. In addition, a new sump pit is installed and the subslab stone is placed **(15)**.

The job has progressed from a state of chaos to order. Drainage mat is secured to the walls, and the floor is prepped for a slab with a vapor barrier and welded wire **(16)**. The new slab is poured **(17)**, followed by interior framing and mechanicals **(18)**.




Each section of the underpinning is both footing and foundation. Typically, the rebar cages are wired up with extensions driven into the dirt on each side so they overlap and are wired to rebar in the adjacent sections (top). A variety of forms are used, depending on the depth of the foundation extension and width of the footing, as specified by the engineer (above).

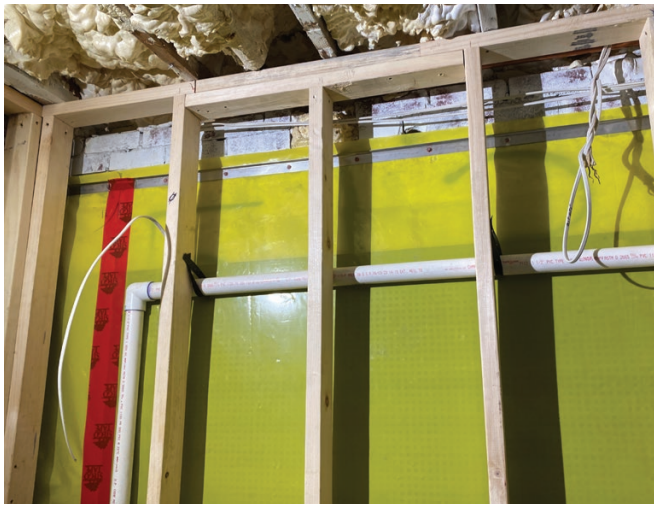
MANAGING GROUNDWATER

In addition to managing the structural work, we need a plan to manage groundwater during an underpinning project. It's not rocket science: We dig a deep sump pit and pump water out. If we play our cards right with the location and depth, the sump we use during construction can be left in place for future use as a permanent dewatering system for the home.

Most of these foundations also get an interior water management system. This entails a heavy plastic sheet (6- to 20-mil poly or a dimpled mat product) that catches water coming through the wall and directs it downward to flow below the new slab floor into a perimeter drain that flows to a sump. On solid masonry buildings, I believe this type of water management is superior to exterior waterproofing because it collects not only groundwater within the perimeter of building but also any rainwater that's running through the above-grade masonry walls. We have seen heavy rains soak upper-level masonry walls, causing water to seep through the masonry and run down to the basement level. Interior drainage solutions manage this water and are usually less expensive than exterior systems on existing buildings, especially when done during a complete basement underpinning project.

WORKAROUNDS AND EFFICIENCIES

Zoning rules are sometimes a challenge. On one project, the existing old brick foundation walls couldn't be replaced because of historical zone rules, but our engineer didn't think the walls were strong enough to resist soil pressure (there was abundant evidence that the foundations were pushing inward before we underpinned). The solution was to add vertical steel anchored to the wood floor system above and the footings/slab below to prevent the old and new foundations from hinging at the joint and pushing in. We're still puzzling out how to manage water on a



Water management typically includes both protection from groundwater seeping through the foundation (in this case, 15-mil Stego Wrap secured by a termination bar, as shown at top) and interior drains running to a sump pump (above).

system like that going forward. On this one, we installed an interior drainage system around the inside of the steel, which will work but is inelegant at the least.

The sequence and the work are not complicated, but it's a huge amount of labor to dig down 3 to 5 feet, tie the rebar cages, mix and pour the concrete (or wheel it in from a mix truck, as we do on larger projects), and remove all the dirt. Some of our contractors use micro-excavators that can drive through the basement doorways, or small conveyor belt machines to move the dirt up and out into the yard. We even had two excavators and a conveyor in one basement! On some sites, the yard is only part of the journey; we've had to drive skid-steer loaders 150 feet along alleyways to get to and from dump trucks and concrete deliveries.

The smoothest jobs are done by companies that specialize in this work. They have experienced people and a good set of machines that accelerate the work. But we have also worked with masonry or excavating generalists; the work is essentially just a lot of little foundations, and they've been successful executing this work too, if a little slower.

One common mistake I've seen is rushing to dig more sections than what is shown on the work plan. The engineers want all the "one" sections done before the "two" sections are started, minimizing the areas that are unsupported, but some contractors want to dig more at the same time. It's all in the name of being quick and efficient, but it's risky and we don't permit it. The stakes are just too high.

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Vertical steel was added prevent the old brick and new concrete walls from hinging (top). The steel precluded the addition of a robust drainage matrix to the walls. Above, the perimeter is prepped for interior perimeter drains.