Getting to the Bottom of Underpinning

By David B. Peraza, P.E.

The process of excavating for a new building foundation, especially in urban settings, can often result in damage to adjacent buildings, despite what may seem adequate bid documents and structural design. In some cases, the damage can be severe, resulting in the need to temporarily vacate a building and even resulting in a partial collapse. The consequences can include injuries and loss of life, extensive property damage, construction delays, and expensive litigation. Even in cases of minor damage, the resulting insurance and legal issues can be expensive and distracting. Therefore, it is advisable that the engineer of record (EOR) do all within his/her control to help prevent such accidents from occurring. Many of the failures that have occurred are preventable, at little or no added cost, with just the application of some common sense principles.

This article identifies problematic building types and soil conditions, provides preventative recommendations, suggests ways that the engineer of record can better protect his/her clients and himself/herself, and discusses strategies for dealing with buildings that are exhibiting distress. It also discusses the roles and responsibilities of the geotechnical engineer, the structural engineer, and the underpinning engineer.

Case Histories

A few examples illustrate the range of problems that can occur due to inadequate underpinning.

In the 1980s, three civil war vintage buildings in Lexington, KY collapsed dramatically while extensive renovations were underway. The buildings were part of the Victorian Square complex. The renovations included lowering the basement slabs. The contract documents required underpinning of the perimeter wall footings, and required leaving an earth berm in place until the underpinning was installed. Nevertheless, the contractor overexcavated and undermined the footings. Fortunately, the buildings gave warning, in the form of breaking glass and unusual sounds, which allowed time for the workers to evacuate and for the emergency personnel to cordon off the area. No one was hurt, and the news media was able to broadcast spectacular live footage of an uncontrolled collapse. The contractor took responsibility for the collapses and, as part of the restitution, he was required to rebuild the buildings using the same historic bricks that had collapsed.

In another case, a $200 million high-rise residential complex was built next to an old four story bearing-wall building (*Figure 1*) that was used as a temple by Buddhist nuns. The building was supported on rubble foundations. The underpinning was reasonably well planned and executed: the design documents recognized the need for underpinning, the foundation contractor hired a specialty engineer who prepared a detailed underpinning plan, and the work was executed by an experienced foundation contractor. However, the combination of the old rubble foundation, together with some inopportune rainy weather, resulted in significant settlement of the building. Wide cracks appeared along the inside of the settled wall. The construction was stopped, and the building was vacated by the building department while emergency measures were implemented. Needless to say, the local media latched onto this classic David and Goliath confrontation, and reported on it from every possible angle. The underpinning was quickly completed, and positive connections between the existing masonry wall and joists were added to prevent the wall from "peeling away." Within 2 or 3 days, the building had been stabilized and a crisis averted. The developer eventually bought the damaged building, thereby preventing the possibility of any lawsuits!

Figure 1: Excessive settlement of this building during underpinning prompted an order to vacate this building, and emergency stabilization measures.

A more typical type of failure is exemplified by the following case. A consultant prepared drawings identifying the areas of the adjoining residential buildings to be underpinned. The consultant, however, failed to call for underpinning of one particular basement wall, which was set back about 5 feet from the property line. When the excavator removed the soil in this area, the footing was undermined and the residence suffered settlement. Underpinning was added on an emergency basis over the Christmas holidays, which stabilized the building. The residence did not suffer structural damage, but it did suffer minor damage to finishes and racked door frames, all of which were readily repairable. Nevertheless, the owner initiated a law-suit, which continued for many years, seeking compensation for millions of dollars — many times the value of the actual damages.

Problematic Conditions

Underpinning of an existing foundation is typically required whenever a new excavation compromises the stability of the soils supporting that foundation. Underpinning involves extending a building's foundation downward, usually by adding concrete under the existing foundation wall. It is a specialty operation, which even under the very best conditions, has considerable risk associated with it. There are some conditions that make it even more difficult to perform without causing damage. These are as follows:

Rubble Foundations

Older buildings may use foundations composed of large stones, which may or may not be mortared together. These rubble foundations, while perfectly adequate for distributing gravity loads to the soil, are not well suited to bridging over underpinning pits. They lack the continuity that is inherent in reinforced concrete footings, or even unreinforced concrete footings. In some cases, it may not be feasible

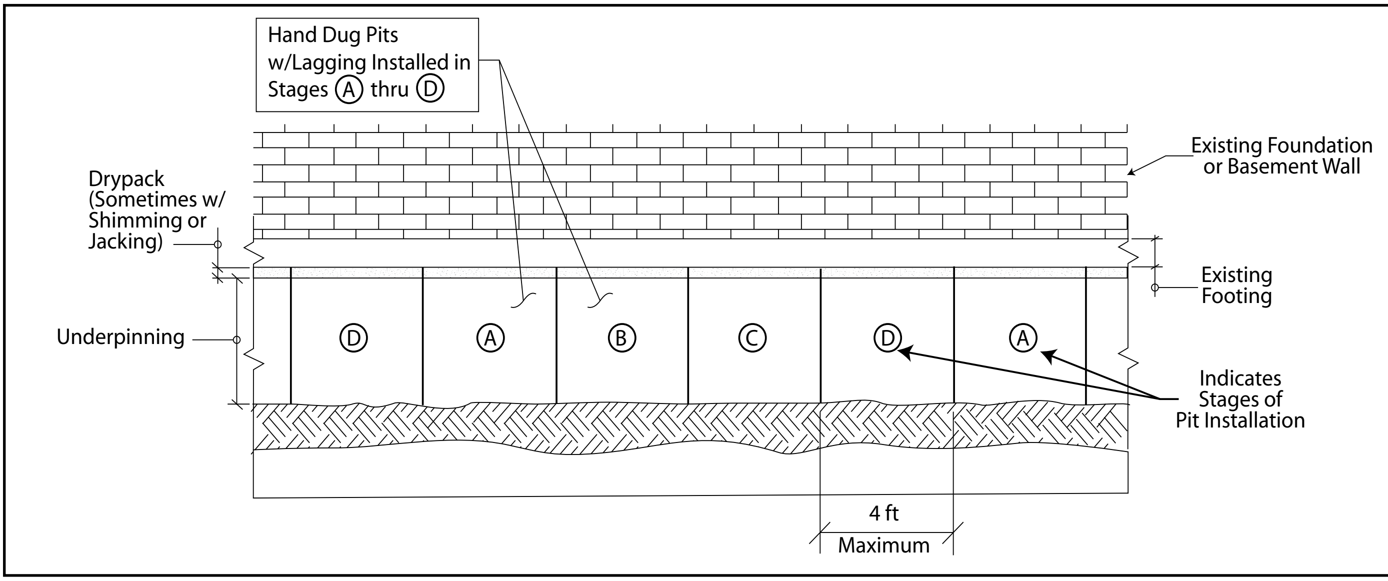

Figure 2: This figure shows, in elevation, a typical underpinning sequence that is often shown on drawings by the engineer of record. The letters indicates the stages of installation. Graphic courtesy of the Structural Engineers Association of New York

to underpin these foundations. Instead, it may be necessary to install a retaining wall next to the wall that is designed to withstand the lateral load due to the surcharge.

High Water Table with Silts and Clays

In one case that the author investigated, a high-rise building was constructed next to an abutting church. The basements of the high-rise building extended several levels below the church, which required underpinning the perimeter foundations of the church. In addition, the presence of a high water table meant the site would need to be dewatered. The underpinning operation for the perimeter footings was mostly successful. However, the church building had interior foundations for walls and columns that were not underpinned. The draw-down of the water table caused consolidation of the silty soils, which in turn caused settlement of these interior elements. The interior walls developed severe cracks and the slab-on-grade experienced extensive settlement. As a result, the building was vacated.

Sandy Soils

Sandy soils pose dual problems:

1) They settle when vibrated. Pile driving is one potential source of vibrations. Even if the permanent building does not use piles, the contractor may decide to use piles as part of the temporary soil retention systems. For example, soldier pile walls with wood lagging are commonly used. The settlement caused by vibration of cohesionless soils can affect not only the foundations immediately bordering the excavation, but can also cause settlement of interior foundations and slabs-on-grade.
2) They spill out. Cohesionless soils have no ability to stand vertically. So if sheeting or lagging is not installed as the excavation progresses, sandy soils will spill into the excavation, causing the building to lose foundation support.

Investigation

There are two inter-related investigations that need to be performed in order for the EOR to prepare adequate bid drawings: 1) A soils investigation for purposes of designing the foundations of the new building, and 2) An investigation of the existing adjacent buildings for purposes of determining whether underpinning or other stabilization methods will be required. For both of these, the geotechnical engineer normally leads this investigation, with input from the EOR. The deliverable for these investigations is normally a report by the geotechnical engineer.

The former is the more routine investigation. It is the same type of geotechnical investigation that is performed for any new construction. National and local building codes provide certain minimum requirements regarding the number of soil borings, and this is supplemented by the judgment of the geotechnical engineer.

The latter is a special investigation, which is a combination of evaluating the soil conditions, the existing foundations and the existing building itself. Codes do not specify minimums for this type of investigation. However, a reasonable effort should be made to investigate the foundations of the adjoining buildings. The nature, depth, and condition of the adjacent foundations will determine whether underpinning will be needed and whether it is feasible. It will also help determine the type of underpinning or stabilization needed. Components of this special investigation often include:

Drawing Review

Drawings of the adjacent buildings can provide invaluable information, which might not otherwise be obtainable or may only be obtainable after a costly and time-consuming field exploration. It is therefore worthwhile to make a diligent search to locate the original drawings.

Site Inspection

Regardless of whether or not drawings are available, it is advisable that the consultant request entry into the adjacent buildings to make visual observations. There are many reasons why this should be done. It is important to know the elevation of the lowest basement or cellar level(s), since this will likely affect whether underpinning is needed. Another purpose is to attempt to determine the nature of the foundation system and of the building's structural system. This will be important for estimating the loads that the underpinning will have to be designed for. The condition of the building, including evident foundation related problems, may also affect the feasibility of underpinning.

Test Pits

If drawings are not available, as is often the case with older buildings, consideration should be given to making test pits. This will provide definitive information regarding the type, depth and condition of the foundation.

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Test pits can sometimes show that underpinning is not needed. The author has been involved with cases where the foundations of adjacent existing buildings were found to extend a considerable distance below their basements. In one case, the existing building was supported on wood piles and the existing load-bearing masonry wall extended about 15 feet below the basement floor. This apparently was done to ensure that the piles would stay completely submerged below the water table. In another case, the load bearing walls of an existing building were extended about 10 feet below the basement, apparently to reach bedrock. In both cases, the foundations of the new buildings did not extend below the adjacent existing foundations, so underpinning was not required. The test pits also alerted the engineer that it would be necessary to tie back the existing walls because the excavation removed the balancing earth pressure.

Test pits can also provide information about the foundation condition. Wood pile foundations are particularly vulnerable to deterioration. On a case investigated by the author, the tops of the wood piles and the wood cap plate along one side of an early 1900s building were completely disintegrated, causing the building to tilt in that direction. What caused this disintegration? In the 1960s, construction of a depressed railway at this side of the building had drawn down the groundwater table locally. The tops of the piles were no longer submerged, allowing them to disintegrate.

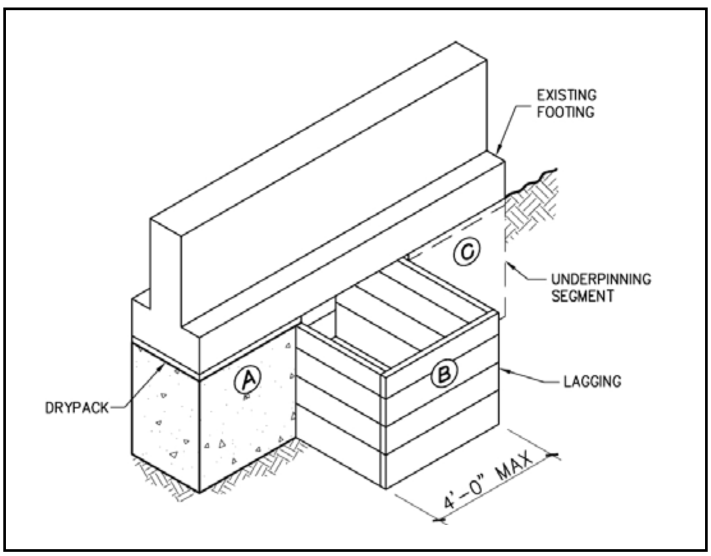

Figure 3: An isometric view of the typical underpinning process. Graphic courtesy of the Structural Engineers Association of New York

Design Documents

The design documents prepared by the EOR should incorporate all of the information discovered in the investigation phase.

It is important that the design documents prepared by the EOR identify those portions of the adjacent buildings that will need underpinning. Without this information, the foundations of the neighboring building could become accidentally undermined, or at best, the contractor's bids will underestimate the cost of the work.

The design documents will usually show a general scheme for the underpinning work, such as the concrete underpinning method shown in *Figures 2* and *3*. The sequence for this classic construction technique is as follows:

1. An approach pit is dug next to the foundation, and the sides of the pit are stabilized with wood lagging. The minimum pit width is about 4 feet, measured parallel to the foundation, and is set by the need to accommodate a worker. Wider pit widths can be used if the existing foundation is capable of spanning larger distances and if the lagging can support it without excessive deflection.
2. The underpinning pit is excavated beneath the foundation, and the sides are stabilized with lagging.
3. Specified reinforcement is positioned, the outboard face of the underpinning pit is formed with lagging, and the concrete is placed. The upper several inches cannot be concreted, resulting in a gap.
4. After the concrete has gained sufficient strength, the gap between the original foundation and the underpinning concrete is drypacked. This moistened mixture of cement and sand is pounded into the gap to help ensure uniform bearing of the original foundation onto the underpinning concrete. Sometimes wedges or shims are installed in the gap prior to drypacking.
5. This process, which is initially done for the "A" series of pits, is then repeated for the "B" series, and so on until the entire wall is underpinned. Depending on the depth, the underpinning may need to be done in several "lifts."

Figure 4: Completed concrete underpinning.

Figure 4 shows a photograph of a completed underpinning installation.

The EOR drawings typically do not show the details of the underpinning. It is common for the EOR to require that the underpinning and sheeting be designed by a specialty underpinning engineer, who is often retained by the foundation contractor. The specialty engineer will typically decide the width of the pits, the reinforcement, the details of the load transfer, and, if needed, the design of tiebacks to stabilize the underpinning piers. It is prudent to require that the underpinning drawings and specifications be submitted to the EOR for record purposes.

It is important that the EOR identify on his drawings the need for special inspections of underpinning and sheeting operations.

The EOR can also recommend that monitoring be performed during construction. The monitoring may take several forms. Prior to construction, professional surveyors can establish benchmarks on the adjacent buildings that can be surveyed as needed during construction to determine the amount of movement. Vibration sensors can be mounted on the adjacent buildings to monitor the peak particle velocity generated by construction activities. If there are pre-existing cracks, crack monitors can be mounted in them to determine whether the cracks are widening. Although this monitoring is not required by code, it is a prudent measure that can help protect the owner and the EOR against frivolous lawsuits. Normally, the monitoring firm is retained by the owner. Some of these monitoring firms also provide visual pre-construction surveys. The quality, cost, and thoroughness of these surveys can vary dramatically.

Construction Phase

Even with a diligent investigation and the best design documents, the success of the project ultimately depends on proper execution of the work. Although this is an aspect that is often not within the direct control of the EOR, the EOR can influence the process in several ways.

The EOR should follow up and make sure that the detailed design of the underpinning, as required by the contract documents, is being performed by a qualified specialty engineer. This specialty engineer is typically retained by the foundation contractor.

It is important to realize that the vast majority of problems are not caused by inadequate underpinning — they are caused by undermining. All too frequently, the excavation advances more quickly than the underpinning, and the inspecting engineer may not even be aware that excavation work has begun. An overzealous excavator can cause a tremendous amount of damage in a very short time. For this reason, it is crucial that the excavation work, the inspection work, and the underpinning work be closely coordinated. The excavator needs to be aware of the potential consequences of over excavation; the engineer responsible for inspection of the underpinning and sheeting work needs to be notified before excavation work begins; the underpinning contractor must either be able to keep pace with the excavator or be able to control the excavator; and, the monitoring firm needs to know when critical activities are taking place. There should be a single firm responsible for this coordination. It is usually coordinated by the general contractor or the construction manager. The EOR can help by advising the owner and/or the contractor regarding the importance of this coordination. A useful technique for doing this is to require a "Pre-Excavation Conference" where these parties participate to discuss responsibilities and the lines of communication.

In some jurisdictions, the EOR has the authority to approve the proposed inspecting engineer. The EOR can seize this opportunity to discuss with the proposed inspector on how he or she intends to carry out the inspection.

*The Structural Engineers Association of New York (SEAoNY) is tackling this problem head on. At the request of the New York City Department of Buildings, it has formed a committee to develop a series of informational pamphlets and booklets, targeted at builders, design professionals and building owners. For more information about these efforts, and to download a pamphlet that has already been completed, visit **www.seaony.org**.*

Conclusions

Much of the damage to existing buildings resulting from new construction could be avoided if the parties involved in the construction process had a better understanding of underpinning and of the possible consequences of not performing it in a timely or proper manner. The EOR can help minimize these problems by making sure that an appropriate pre-design investigation is conducted, by showing the extent of needed stabilization on the design drawings, by clearly delineating roles and responsibilities of various parties, and by encouraging communication during the construction phase.▪

*David Peraza, P.E. is a structural engineer in the New York office of Exponent (Failure Analysis Associates). He specializes in structural failure investigations, condition assessments, and the development of remedial measures for distressed structures. Dave can be reached at **dperaza@exponent.com**.*