POST FOUNDATION REPAIR PERFORMANCE OF RESIDENTIAL AND OTHER LOW-RISE BUILDINGS ON EXPANSIVE SOILS

by

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of

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PREFACE

This document has been developed by a group of foundation repair contractors and consultants in southeast Texas with the goal to educate and inform those involved in the repair of foundations.

The need for this document was prompted by the lack of satisfactory performance of some foundation repairs. As a result, this document has been prepared and made freely available to the public through the Foundation Performance Association at www.foundationperformance.org so that owners, tenants, realtors, builders, inspectors, engineers, architects, repair contractors, and others involved with residential and other low-rise building foundations may benefit from the information it contains.

This document was written specifically for use in the southeast region of the state of Texas and primarily within the City of Houston and the surrounding metropolitan area. Therefore, it should be used with caution if used elsewhere, or if adapted for foundations other than those supporting residential or low-rise structures. The Foundation Performance Association and its members make no warranty regarding the information contained herein and will not be liable for any damages, including consequential damages, resulting from the use of this document.

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1.0 INTRODUCTION

What is foundation repair?

Many methods are available to stabilize foundations from the effects of expansive soils, some which work better than others. The process of foundation repair usually includes foundation stabilization and the implementation of one of these methods. This may involve modification of the foundation support system itself, under pinning with deeper support, the construction of peripheral barriers that function to isolate the soils under the structure, or the installation of some type of system that attempts to control the moisture content of the soils or the molecular action of the clay when the moisture content is changed.

In addition to stabilizing a foundation from future movements, foundation repair may also include the process of restoring a foundation to its original constructed position by using some type of leveling procedure. This usually involves jacking the concrete grade beams at the lower portions of the foundation upward until they are level with the other areas, and then re-supporting the grade beams at the areas that have been raised. In limited circumstances, lowering high areas may be possible by supporting the foundation in the high area, excavating a void, and then lowering the foundation with the installed support. In some cases, it may be desirable to level and then raise the whole ground floor even higher than the original constructed position. The leveling procedure may also include the injection of grout or foam under the low areas of the slab-on-grade.

Generally, in the southeast Texas area, damage to residential and low-rise buildings as a result of foundation movements, is most often due to changes in moisture content of expansive soils. Damage may occur to components of the superstructure, the foundation, or both. In some cases, foundation repair can simply consist of only repairing damage that occurred to the foundation elements.

Why does foundation repair sometimes fail?

Aside from the possibility of a manufacturing defect, the success or failure of the product installed can be governed by the experience of the inspector, engineer, or contractor. A lack of good quality control by the contractor or improper foundation maintenance by the property owner can adversely affect the longevity of the foundation repair. These and many other things can go wrong when repairing a foundation.

Piers or pilings will not prevent foundation uplift unless they are designed to do so. The type of repair piers or pilings that are most commonly used for residential and low-rise building repairs in the Houston area are not tied to the grade beams, and thus cannot prevent foundation uplift due to heaving soils.

Heave or uplift is not generally considered to be a failure of the piers or pilings, but if it occurs, the piers or pilings could be perceived to have failed since they are part of the overall foundation system. If heaving is a concern, the entire ground floor system should be lifted above the maximum potential vertical rise of the soils. Leaving a void between the soils and the slab allows space, which can accommodate the heaving soil without causing the foundation to heave. In this case, the piers or pilings must have sufficient depth and tensile resistance to resist the uplift forces resulting from friction along the pile or pier surface from the upward moving soil.

Foundation uplift is an example of post-foundation-repair performance that may be incorrectly attributed to a defect in a particular foundation repair method. Included in this document is a partial list of systems used to help repair foundations and the ways they can fall short of acceptable performance. These lists are provided in order to assist building owners, and others who may not be familiar with foundation repair techniques, in identifying the cause of poor post-foundation-repair performance.

2.0 FOUNDATION REPAIR SYSTEMS

Below is a description of some foundation repair systems and typical problems that cause poor performance. Please note that in order for most of these systems to perform properly, the moisture content of the soils under and around the perimeter of the foundation must be maintained a constant, and stormwater drainage must be directed away from the foundation. Improper drainage can cause continued movement to the repaired slab because of the resulting fluctuations in moisture content of the expansive soils that may occur. Continuously saturated soil is detrimental to the foundation and the repair piers. In some instances, void boxes under the slab or grade beams can fill with water due to improper drainage and are believed to be the cause of differential movement.

2.1 Mud Jacking

Mud jacking is a procedure whereby a foundation is lifted by pressure injecting a slurry composed of sand, fly ash, or topsoil and cement between the slab and the soil. Some reasons why this type of repair might fail are:

A. If the soil moisture content changes, the slab can move.
B. This is a shallow repair system effected by active moving soil
C. Moisture changes from broken sewer or water pipes under the slab
D. Trees allowed to grow within close proximity of the slab
E. Extreme seasonal moisture changes
F. Poor drainage
G. Mud can become entrapped by tree roots, pipes, or unknown objects and cause an uneven lift
H. Failure to control the amount of mud injected can cause upward bulging or cracking of the concrete slab
I. Excessively high pressures from injected mud can cause damage due to blowouts
J. If underground utility lines have holes or cracks, the grout may possibly enter the holes and fully or partially plug the lines

2.2 Foam Injection

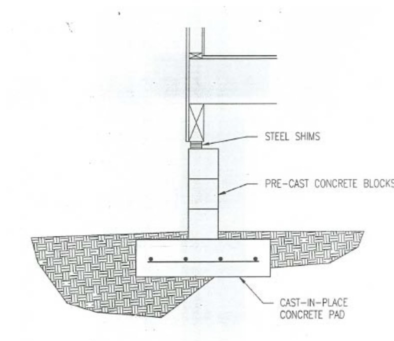
Generally foam injection is used to lift low areas of a slab by injecting a urethane based foam material under the slab area. The foam expands creating pressure to raise the slab. After the injections, the lifted area of the slab will sit on the foam.

A. If the soil moisture content changes, the slab can move
B. This is a shallow repair system effected by active moving soil
C. Moisture changes from broken sewer or water pipes under the slab
D. Trees allowed to grow within close proximity of the slab
E. Poor drainage
F. Extreme seasonal moisture changes
G. Improper mixture of chemicals used to create expanding foam
H. Failure to control the amount of foam injected can cause upward bulging or cracking of the concrete slab
I. Prior to hardening, excessive water from an overly wet foam mix can seep into expansive soils, increase the moisture content, and cause local heave and out-of-levelness
J. Excessively high pressures from injected foam can cause damage due to blowouts
K. If underground utility lines have holes or cracks, the foam may possibly enter the holes and fully or partially plug the lines, particularly if the foam is pressurized

2.3 Spread Footings / Block and Base

Spread footings are most often wide, cast in place concrete pads, placed under a footing to spread the load and reduce pressure on the soil. On expansive soils, the bottom of a spread footing may be several feet below the surface. Block and base structures will typically have the floor held above the ground on wood or concrete supports placed on a wider base of precast concrete. There is usually an air space to allow ventilation for the wood components and access for maintenance.

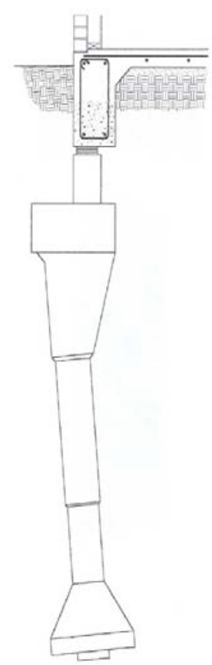
A. Foundation sagging may occur from blocks placed too far apart under the wood beams
B. Improper drainage or ponding of water under the house can allow the blocks to move, settle, or tilt
C. Incorrect material can be overloaded, overstressed, and break allowing sag of the supporting beam
D. Seasonal moisture changes
E. Improper depth and placement of base, supporting blocks, and shims
F. Improper size of base blocks



2.4 Drilled Piers

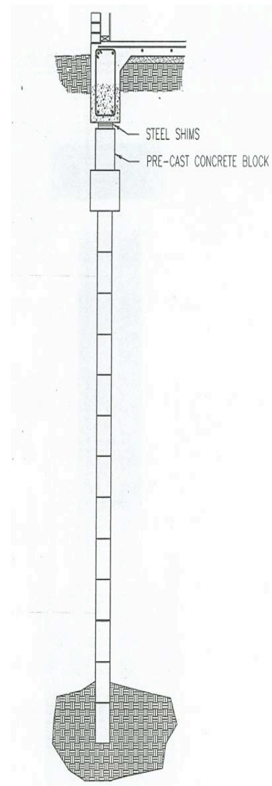
Drilled piers are a cast in place foundation support system. This system can be a drilled straight shaft, or a drilled straight shaft with an under ream at the base commonly referred to as a bell. A hole is excavated in the soil. Steel reinforcement is placed in the shaft. Redimix is placed in the hole and vibrated. The main support on this system comes from the bottom of the pier with some additional support obtained through skin friction on the sides of the shaft. The concept is to achieve support below the active zone of the soil to minimize future movement.

A. Improper depth of pier may allow pier to move
B. The soil condition is not conducive to construction of drilled piers
C. If required, improper bell at bottom of pier
D. Improper drainage may cause piers to move
E. Too much load on pier
F. The soil packs or shears at bottom of the pier
G. The cap or head of the pier is not thick enough and can allow the head to crack
H. Improper reinforcing steel placement may allow the pier to crack
I. Improperly shimmed
J. Seasonal moisture changes on shallow drilled piers may allow the pier to settle
K. Shaft installed at too steep of an angle can allow the pier to lay over or become overstressed when weight is applied
L. Failure to vibrate or low slump concrete may allow the concrete to honeycomb
M. Collapsing of the soils within the bell or sloughing of the soils along the shaft can result in the accumulation of loose fallen materials at the base of the pier, which could lead to settlement of the pier when these loose materials are compacted under the applied bearing pressures.
N. Any gaps that occur around the shaft of the pier (e.g. from drying action of the soil) can later serve as a free path for infiltrating water to reach the lower inactive zone of the soil and cause detrimental heaving of the pier
O. Sometimes the pier is installed properly, but blocks, pads, cylinders, or a rock on the beam bottom may shatter, allowing the beam to resettle.



2.5 Pressed Piles

Pressed piles are precast concrete sections pressed into the ground using the weight of the structure being supported as ballast for resistance. Concrete sections are stacked one on top of the other and pressed into the ground until the pile stops going down and the structure begins rising. The main support in this system is the skin friction generated up the side of the pile as it is pressed into un-dug soil. Some support is also gained by the soil compressed under the base of the pile. The concept of this system is to achieve support below the active zone of the soil to minimize future movement.

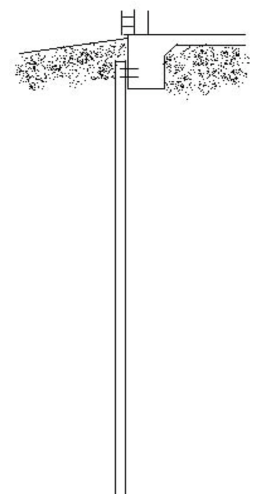


A. The structural problems are not conducive to pressed pile, for example, insufficient steel in the beam/slab or not enough weight to allow driving pile to the proper depth
B. Pile caps or cylinders can break during installation. If not corrected further settling may occur
C. If the contractor did not shim immediately after driving pilings, the piling will spring back if bulb of pressure at the base of the pile is not maintained
D. Shallow piling not driven sufficiently below the moisture active zone can continue to settle as seasonal moisture changes occur
E. Drought can cause skin friction to release at shallow depths
F. Sometimes the piling will hold, but blocks, pads, cylinders, or a rock on the beam bottom may shatter, allowing the beam to settle
G. Improper moisture close to the pile from poor drainage or from leaking sewer or water lines can cause the pier to move
H. Water jetting may be used to install the piles through stiff sandy soils, which can locally introduce large amounts of water, increase the moisture content of expansive soils, and cause heave of the pile
I. The cylindrical segments may not be driven vertically due to misalignment when starting the first cylinder, or by being deflected laterally by tree roots, rocks, or calcareous nodules in the clay soils, which in turn could lead to a reduction in the vertical load capacity of the pile, or stress concentrations due to uneven load bearing that could result in crushing the concrete
J. Unreinforced pressed piles that do not have a central steel bar or cable running along the center of the pile are subject to potential differential lateral movements between the upper most concrete segments

2.6 Steel Pipe Piles

Steel pipe piles are pressed in the ground using the weight of the structure to be supported as resistance. Steel sections are pressed into the ground one on top of the other until the needed resistance is met or onto rock or other load capable strata. The main support with this system is skin friction generated up the side of the pipe sections unless pressed down onto rock or other load capable strata. This system attempts to gain support for the foundation down past the active moisture zone of the soil to minimize future movement.

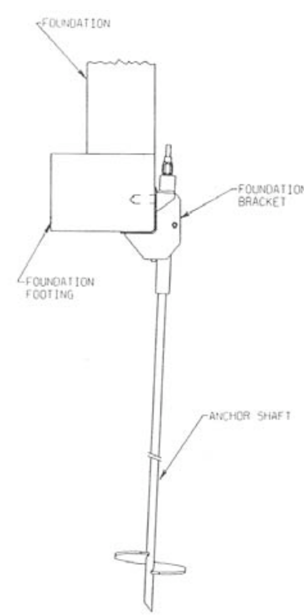
A. If not pushed to refusal, the shallow pipe pile may move as seasonal moisture changes occur
B. If not pushed at the correct angle, the pipe pile may lay over or bend when the full load is applied
C. The pipe pile can be overloaded, causing the shaft to bend
D. Improper moisture close to the pile such as poor drainage or a leaking sewer or water line can cause the pier to move
E. The structural problems are not conducive to steel pipe pile - for example, insufficient steel in the beam/slab or not enough weight to allow driving pile to the proper depth
F. If the contractor did not clamp bracket immediately after driving pilings, the piling will spring back and loose some bearing pressure.
G. Drought can cause skin friction to release at shallow depths allowing the pipe pile to move



2.7 Helical Piers

The helical pier foundation system is an end-bearing anchor screwed into the soil by hydraulic drive equipment. Helical piers are steel pipe or solid square stock with helix plates attached at intervals. As the shaft is rotated, it screws into the soil. Anchors are driven to the required torque to obtain the needed capacity. Once installed, the bracket is used to transfer the weight of the structure from the foundation to the pier permanently.

A. Improper spacing may cause overload of the pier.
B. Piers not installed at the correct angle may allow the shaft to lay over when weight is applied.
C. Not installing the pier to the proper torque and depth below the active zone may allow the pier to move with seasonal moisture changes
D. Improper anchorage of the steel brackets that are used to support the foundation grade beams to the top of the helical piers can result in connection slippage and settlement of the grade beam



3.0 MAINTENANCE SYSTEMS

Maintenance systems should not be considered a repair; although they will enhance the performance of the foundation. Below is a description of some foundation maintenance systems and typical problems that may cause poor performance.

3.1 Root Barriers

Root barriers are designed to stop the growth and moisture draw of roots under and in the proximity of the foundation. A trench is dug in the intended area and a barrier of concrete, polyethylene, biocide treated mesh, or other material is placed to block the future growth of roots. Most barriers are 48" or less.

A. Soil expansion and contraction will occur with seasonal weather changes. The mesh root barrier will allow moisture to penetrate. The impervious barriers will not allow moisture to penetrate.
B. Caution should be utilized when water leaks occur between the impervious root barrier and the slab. The source of moisture may be from the plumbing lines, sprinkler systems, watering systems, downspouts, or poor drainage. The entrapped moisture can allow soil expansion and contraction to occur, allowing nearby foundations to move.
C. The root barrier may not be deep enough or may have soil above it thereby allowing roots to grow below or above it.
D. Property owner should remove wayward roots if they grow past the barrier
E. Root barriers that use chemicals to prevent root growth have a limited life and will eventually become ineffective after ten years.
F. Root barriers that consist of thin membranes such as polyethylene sheeting can be punctured during installation, allowing small root fibers to penetrate that can eventually grow into large roots
G. The root barrier installation may sever existing tree roots that already extend under the foundation, and as they wither and die, the surrounding soil could slowly regain its original moisture content, possibly causing local heave of the soil near the severed roots.
H. If the existing tree roots that already extend under the foundation are large in diameter, the decay of the severed roots caused by the root barrier installation could potentially lead to local settlement of the foundation.

3.2 Moisture Barriers

Moisture barriers can be either vertical or horizontal. Both types are designed to minimize changes in moisture content under the foundation. There are many different materials used in the construction of moisture barriers. A vertical moisture barrier is installed by excavating into the soil near the foundation and installing a waterproof barrier. The depth of the vertical moisture barrier would be determined by the soil type and site condition. A horizontal barrier is a waterproof barrier, which extends horizontally from the foundation and may be above or below grade, as site conditions require.

A. A water leak occurring between the barrier and the foundation beam may cause the slab to move The source of water may be plumbing lines, sprinkler systems, watering system downspouts, or poor drainage.
B. Property owner should visually monitor moisture or ponding water adjacent to the foundation.
C. The depth of a vertical moisture barrier may not be adequate, i.e., at or below the depth to constant suction.
D. The width of a horizontal moisture barrier may not be adequate
E. The barrier may not be properly sealed to prevent moisture penetration
F. The barrier may not have been properly designed
G. Thin membranes used for horizontal or vertical moisture barriers may be punctured or torn during installation and subsequently allow the transmission of water.

H. Horizontal moisture barriers such as polyethylene sheeting may be subject to degradation from ultraviolet radiation from sunlight if left uncovered.
I. Thin membrane vertical moisture barriers may be punctured by the growth of tree roots.
J. Horizontal moisture barrier systems can sometimes result in increasing the amount of moisture in the soil below the barrier through the process known as hydrogenesis (i.e. cooling of the ground during the night that causes water condensation of moisture-laden air in the soil on the underside of the barrier due to the temperature change), which in turn can cause heave.
K. Horizontal moisture barriers consisting of concrete pavement may be compromised by water that infiltrates through joints that are not properly sealed.
L. Horizontal moisture barriers may eventually "walk away" from the foundation as a result of cyclic movements due to alternate periods of shrinking and swelling of the supporting soils.
M. The installation of vertical moisture barriers can also cause severing of existing tree roots, which can lead to the same problems as described above for root barriers.
N. A vertical moisture barrier, which is normally designed to keep water from penetrating under the building, can also prevent water from migrating outward from underneath the building, which can amplify heaving action due to a leaking water line underneath the building.

3.3 Perimeter Watering Systems

Perimeter watering systems are used, particularly in expansive soils, to hydrate soils around a foundation to avoid drying and shrinking of the soils. Most systems emit a small amount of water on a regular basis to keep the moisture content even in the soils through nature's cyclic weather changes. Systems range from very simple manually operated, to highly complex automated systems.

A. Electric sensors may malfunction and cease to operate.
B. The system may allow water to run continuously, or not at all.
C. Over watering can cause adverse movement.
D. The soil type may not be conducive to a watering system.
E. Watering around the foundation tends to attract tree roots near the foundation so that cyclical soil movement is exasperated during periods of high and low moisture.
F. Lack of maintenance by the homeowner can make the system ineffective.
G. For automated systems, loss of power due to severed wires can cause failure of the system.
H. Dramatic foundation settlements could occur if the system is disabled.