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# BUYER'S GUIDE TO SLAB-ON-GROUND FOUNDATIONS

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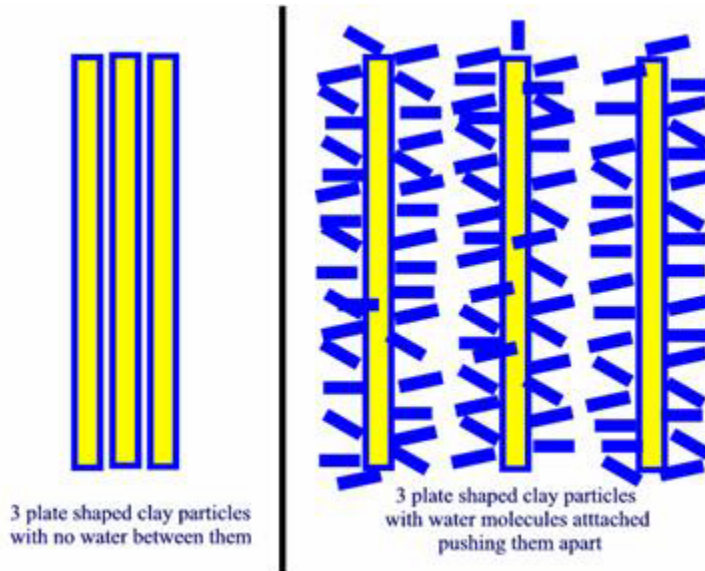
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## FREQUENTLY ASKED QUESTIONS ABOUT EXPANSIVE SOILS

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### What are expansive soils?

Expansive soils contain clay particles. Clay soil particles are very small and are shaped like very thin plates; due to the thin plate shape, clay particles have a lot of surface area for their size. The clay particles are electrically charged and bond to each other like small magnets. The electrical bonding force is relatively weak and can be easily broken by water molecules that become inserted between the clay particles. As the soil becomes wetter, more and more water molecules attach themselves to the plate-shaped clay particles and the water molecules push the clay particles further and further apart. (Think of the plate-shaped clay particles being like a deck of cards where the cards are being pushed apart making the card deck appear thicker.) This results in the apparent volume of the soil mass increasing so that we have soil heave or expansion. As the soil dries out, the process reverses; as the water molecules evaporate and become detached from the clay particles, the clay particles move closer and closer together. This results in soil shrinkage. In a sense, expansive soils act like a sponge; the apparent volume of the sponge increases as it takes on water and shrinks as the water evaporates.



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## **Why do so many houses in the Greater Houston Area show signs of damage due to foundation movement?**

There are several reasons why the Greater Houston Area includes lots of houses that show signs of damage due to foundation movement:

- **Expansive Soils:** The expansive soils found in the Greater Houston Area swell when they get wet and shrink when they become dry.
- **Climate:** The Houston climate is characterized by weather that alternates between very wet to very dry with occasional periods of little or no rain that may last as long as 2 years or more.
- **Flexible Slab-on-Ground Foundations:** The large majority of houses in the Greater Houston Area are founded on thin, flexible slab-on-ground foundations that are designed to distort as the supporting soils distort by shrinking and swelling.

When you put the above facts together, it is surprising that there are not even more residential foundation problems in the Greater Houston Area caused by expansive soils.

## **What parts of the Greater Houston Area are affected by expansive soils?**

Most of our soil consists of various types of clay with some sand mixed in. The South, Southwest, East and Central Areas of Houston are characterized by what is known as the Beaumont formation. This soil formation contains significant amounts of moderately to highly expansive clays. The north and some parts of west Houston are underlain by the Bentley and Lissie formations. The Bentley and Lissie formations consist of sands and sandy clays; these soils generally have a low to moderate shrink/swell potential.

Some of the sandy soils in the north and west parts of the Greater Houston Area also contain silt and can become very weak when they become wet. In many cases, the silty, sandy soils on the surface are underlain by an impermeable clay strata that can hold water, creating what engineers call a perched water table. Perched water tables can hold water, allowing the underlying clay soil to soften, which can result in the clay soil losing much of its bearing capacity resulting in foundation problems. In some situations, the underlying clays are expansive, making a bad situation even worse.

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The section of this book titled **Houston Areas and Soils** provides more specific information concerning the types of soils commonly found in the Greater Houston Area; associated risks of damage due to foundation movement are also discussed.

**The bottom line is this: although some areas may not be as bad as others, or may have a different mix of problems than other areas, there are very few subdivisions in the Greater Houston Area that do not have the potential for foundation movement that can cause damage to a conventionally constructed house.**

## FREQUENTLY ASKED QUESTIONS ABOUT SLAB-ON-GROUND FOUNDATIONS

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### What are post-tensioned slab-on-ground foundations?

A post-tensioned slab-on-ground foundation is simply a ground-supported concrete slab that is reinforced with flexible cables that are tensioned after the concrete hardens. When the cables are tensioned, the concrete is placed in compression. The cables are normally not tensioned until at least 7-days (and sometimes not until 30-days or longer) after concrete placement. Since the cables cannot provide any crack control until after the cables are tensioned, every post-tensioned slab experiences anywhere from 7 to 30-days during which there is no crack control at all. This allows for the development of large, visible curing cracks called restraint-to-shrinkage (RTS) cracks.

In spite of this, post-tensioning is generally considered to be a superior method of bending crack control as compared to conventional reinforcing.



this is a bundle of post-tensioning cables as they are delivered to the site



an overview of a post-tensioned slab-on-ground foundation ready for concrete



this is a close-up of the post-tensioned cables after installation – notice the conventional reinforcing steel at the left side; it is not unusual to mix post-tensioned and conventional reinforcing



close-up showing a live-end anchor; notice the use of duct tape – this shows poor workmanship

## What are conventionally reinforced slab-on-ground foundations?

A conventionally reinforced slab-on-ground foundation is simply a ground-supported concrete slab foundation that is reinforced with what are called “deformed steel bars.” Unlike post-tensioning cables in a post-tensioned slab, the concrete bonds to the conventional reinforcement as the concrete cures. The conventional reinforcement provides crack control almost immediately.



reinforcing steel in field area of a slab-on-ground foundation



reinforcing steel in field area of a slab-on-ground foundation

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reinforcing steel in a perimeter stiffening beam of a slab-on-ground foundation



reinforcing steel in a stiffening beam intersection of a slab-on-ground foundation

## What are the significant differences between conventionally reinforced and post-tensioned slab-on-ground foundations?

The most important differences between post-tensioned slabs-on-ground and conventionally reinforced slabs-on-ground are listed below:

- **Post-tensioned slabs-on-ground are usually thinner than conventionally reinforced slabs-on-ground.** This fact alone makes the post-tensioned slab potentially more flexible than a conventionally reinforced slab. There are other aspects, however, that in practice mitigate this difference.
- **Post-tensioned slabs are less likely to develop cracks due to bending.** Since the concrete in a post-tensioned slab is placed in compression, cracks due to bending are less likely than in conventionally reinforced slabs.
- **Post-tensioned slabs are more likely to develop cracks due to restraint-to-shrinkage (RTS).** Since the cables cannot be tensioned for at least 7-days after the concrete is placed, visible RTS cracks are almost inevitable in a post-tensioned slab. These cracks will tighten when the cables are tensioned. However, certain conditions, including debris lodging in the crack, may prevent an RTS crack from fully closing. These cracks are

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normally not structurally significant to the performance of the foundation, whether they close or remain open.

- **Post-tensioned slabs-on-ground can be less expensive.** If several foundations are to be constructed using the same design, a post-tension design will almost always be less costly to the builder. This situation is common with large builders; constructing post-tensioned slabs can bring significant cost savings for such builders.

## **Should it make any difference to me what kind of slab-on-ground foundation a house has?**

The reality is that the large majority of house foundations constructed in the Greater Houston Area in the last 25-years have been post-tensioned foundations. In addition, if you are looking for a house within a specific price range in a particular subdivision or area of town, every house that fits your criteria may be either post-tensioned or conventionally reinforced. From a practical perspective, what is important is how well or how poorly a specific foundation has performed in the past rather than how it is reinforced.

One of the authors grew up in a house founded on a conventionally reinforced foundation, and has lived in a house founded on a post-tensioned foundation for the almost 30-years. Neither house has ever shown any significant distress due to foundation movement with the exception of the house the author grew up in; that house displayed problems only after it was rented and the occupants did not water the soil adjacent to the foundation during dry periods.

The bottom line is that, in our opinion, whether a house has a conventionally reinforced foundation or a post-tensioned foundation should be a non-issue.

## **How do slab-on-ground foundations work?**

The structural function of a slab-on-ground foundation is to act as a buffer that mitigates the differential distortions between the supporting soil and the house supported on the foundation. Slab-on-ground foundations do this by resisting the moisture-induced distortion of the supporting soil and by spanning over small moisture-induced distortions in the supporting soil.

The foundation is intended to do this while maintaining the surface levelness within permissible levelness tolerances. The levelness tolerances are dependent on the as-constructed levelness of the foundation surface and the construction of the house. The

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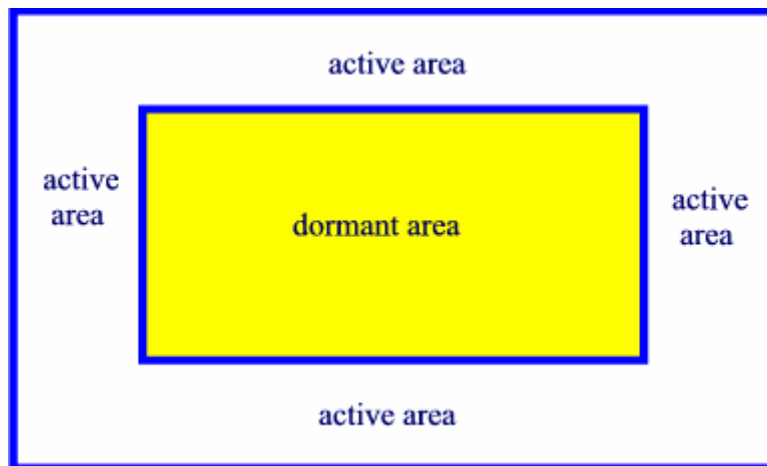
intent of the design protocol is for the foundation surface to distort within a range that:

- **Does not result in significant structural damage to the house frame.**
- **Does not distort the frame structure so that numerous doors and windows cannot function.**

It is important to understand that slab-on-ground foundations are not designed to eliminate the possibility of cosmetic damage or minor door problems.

### **What are active and dormant areas of slab-on-grade foundations?**

When a slab-on-ground foundation is placed in the ground, the presence of the slab inhibits the ground under the foundation from wetting up or drying out, due to wet and dry weather respectively. This is most pronounced in the central area of the foundation. Since this area is protected from seasonal weather-related changes in the soil moisture content, the ground supporting the central area of the foundation does not shrink and swell very much compared to the area near the perimeter or edge of the foundation. Most of the soil shrinkage and swelling occurs in the area of the foundation within 8 to 10-feet of the foundation edge. This area near the edge of the foundation is called the active area since this is where most of the soil distortion due seasonal weather changes occurs. The following sketch shows the relative locations of the active and dormant areas of a rectangular slab-on-ground foundation.



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## FREQUENTLY ASKED QUESTIONS ABOUT FOUNDATION PERFORMANCE EVALUATIONS

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### **How do engineers identify damage caused by foundation movement?**

Professional Engineers usually make judgments concerning whether cracks and other forms of damage or distress are due to foundation movement using their knowledge of structural mechanics, the engineering characteristics of building materials and their experience inspecting hundreds and sometimes tens of thousands of homes.

There are two points that should be recognized at the outset. If the damage is minor, such as a few hairline cracks, it is very difficult to say definitively what caused the damage. On the other hand, if the damage is severe, such as  $\frac{1}{4}$ <sup>th</sup> inch wide cracks in the drywall, the damage is almost certainly due to structural distortion. The problem is with the houses in between. The following are some rules of thumb published by the Institution of Civil Engineers and the Building Research Department in the United Kingdom.

- **Foundation movement usually tends to produce a few large cracks, usually at least  $\frac{1}{16}$ <sup>th</sup> inch wide, rather than a lot of small cracks.**
- **Cracks in brick veneer due to foundation movement will normally extend from the top of the wall to the bottom of the wall.**
- **Brick veneer cracking usually will be tapered if caused by foundation movement. By tapered, I mean that crack will be wider at the top or the bottom. If a crack is due to foundation movement, it will almost never be the same width at the top and bottom; such a crack is more likely to be due to thermal stresses than to foundation movement.**
- **Considered as a whole, the pattern (meaning the location and taper) of the cracking should be consistent with a possible known mode of foundation distortion. For instance, if a brick veneer wall shows cracks that were close to each other and one was wide at**

**the top while the other was narrow at the top, it would usually be unreasonable to consider both cracks to be due to foundation movement since they are not both consistent with a known mode of foundation distortion.**

- **Foundation movement usually results in cracks in drywall and brick veneer at weak points such as at the corners of windows and doors.**
- **Cracks that show up after a long period of dry weather and tend to close when the weather turns wetter are usually due to foundation movement from expansive soils.**
- **Foundation movement can distort door openings causing doors and windows to stick and bind. Wallpaper can exhibit rucking at the inside corners of walls and at the intersection of walls and ceilings.**
- **In some situations, finish floors can become perceptibly out-of-level. Unfortunately, floors are constructed out-of-level and foundations that undergo a normal range of movement can also become more or less out-of-level over time. Relating floor levelness to foundation movement is always based to a great degree on the engineering judgment of the inspecting engineer; that judgment is always subjective and interpretative.**
- **Brick courses, countertops and sills can become noticeably out-of-level due to foundation distortion. These items are normally constructed to a tighter level tolerance than are floors.**

## **What are foundation inspections and foundation performance evaluations?**

A foundation inspection consists of observing the interior and exterior of the house for signs of structural distortion that might be related to foundation movement. An engineering evaluation of the performance of a foundation consists of taking the data from the inspection and using it, in conjunction with the engineer's knowledge of structural mechanics, the structural behavior of houses (including the structural behavior of brick veneer walls, stucco walls, drywall walls and door frames) and the engineering

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properties of building materials to make engineering judgments about the performance of the foundation.

## **Are there different types of foundation engineering evaluations?**

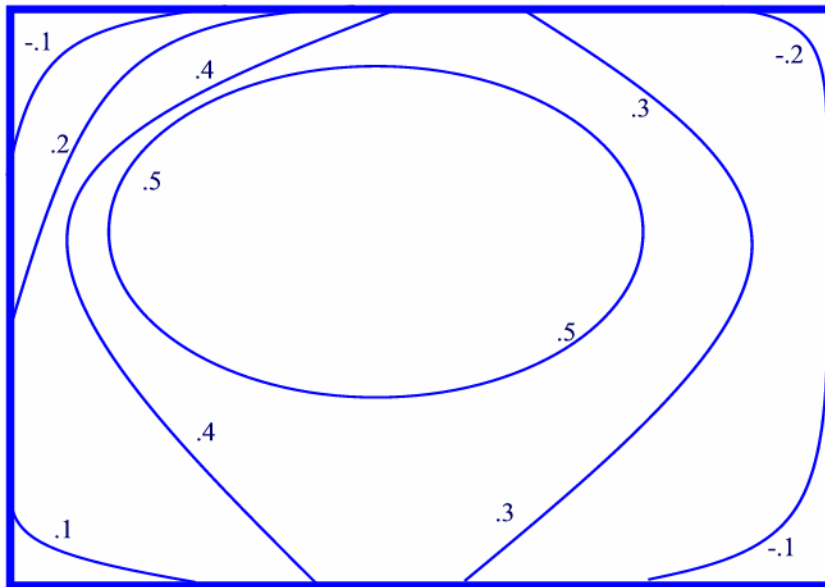
The Texas Section of the American Society of Civil Engineers (TSASCE) has recognized different levels of residential foundation evaluations including a Level A and a Level B evaluation. The Level A evaluation is usually referred to as a visual evaluation or a report of “first impressions.” We prefer to describe it as a visible damage evaluation. The Level B evaluation is built on a Level A evaluation but also includes some finish floor elevation measurements. Some engineers claim to be able to use elevation measurements to confirm or deny whether the observed damage from the Level A evaluation is due to foundation movement; but, recently published studies have concluded that this belief is founded more on faith than any verifiable empirical data.

## **What is a finish floor elevation survey?**

One way engineers use finish floor elevation measurements is to create a sketch of the foundation showing contour lines. Every point on a contour line has the same elevation. The contour lines show the approximate shape of the foundation surface. The foundation surface can be considered an approximation of what engineers call the deflected shape of the foundation. There are several important points about elevation surveys.

- **Elevation surveys are always approximations for a number of reasons, such as the fact that slab-on-ground foundations are not constructed flat and level.**
- **Elevation surveys can provide an engineer a valuable insight into the mode and degree of distortion a foundation exhibits at the time of the inspection if the assumption of an as-constructed foundation surface being flat and level can be verified.**
- **If the assumption of an as-constructed foundation surface being flat and level cannot be verified, then an elevation survey can be very misleading.**
- **Elevation surveys are often used to calculate maximum floor slopes. Unfortunately, foundation deflection is not related mathematically to slope. It is not mathematically possible to determine if a foundation has or has not distorted excessively on the basis of floor slope.**

The sketch below shows an example of an elevation survey with contour lines. The lines show points of equal elevation. The numbers shown on the survey indicate the elevation of each line in inches. This type of sketch can aid the engineer in understanding the shape of the foundation surface.



### **What is a finish floor elevation profile?**

Finish floor elevation profiles are arguably a somewhat more sophisticated way to use finish floor elevation measurements. In this approach, a series of elevation measurements is made across the length or width of the foundation. Each series of measurements are then used to create a profile of the finish floor surface as shown below.

- **Elevation profiles, like elevation surveys, are always approximations due to the fact that slab-on-ground foundations are not constructed flat.**
- **Elevation profiles can provide an engineer insight into the distorted shape of a section of the foundation at the time of the inspection if the assumption of an as-constructed foundation**

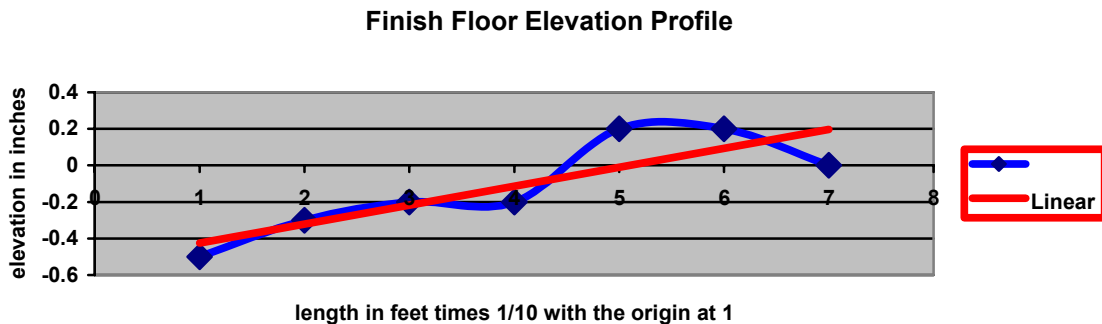
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surface being flat can be verified.

- If the assumption of an as-constructed foundation surface being flat cannot be verified, then an elevation profile can be misleading.
- Elevation profiles are very easy to interpret in terms of the structural engineering concept of “deflection ratio.” This is a very well accepted concept in the structural engineering profession.
- Normally, if a finish floor elevation profile can be interpreted as not indicating deflection in excess of the span of the profile (which would be the length or width of the foundation) divided by 360, then foundation repair would not be recommended unless the foundation-related damage is severe.

Elevation profiles can be made in different ways to show different aspect of the foundation surface geometry. An example of an elevation profile is shown below:

Finish Floor Elevation Profile Data (inches)						
-.5	-.3	-.2	-.2	.2	.2	0



In this finish floor elevation profile, the blue line is a curve drawn through the data points and is a graphical representation of the surface geometry of the finish floor at this location. The surface geometry of the finish floor is not structurally significant in itself, but it can be considered to be an approximation of what is called the deflection curve of the foundation. Structural engineers consider the deflection curve to be a very useful piece of information since it is a graphical representation of the distortion of the foundation. Thus, a finish floor elevation profile can also be very useful so long as it can be considered to be a reliable approximation to the deflection curve.

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The finish floor elevation profile shown above can be interpreted by a structural engineer to show several significant pieces of information. For instance, the red line is a linear trend line that can be interpreted as the showing the degree of tilt the foundation is exhibiting. In this case the tilt is approximately .6-inches over 60-feet or 720-inches. This is extremely small and could be due to an as-constructed condition. Also, note that the difference in elevation between the Finish Floor Elevation Profile and the trend line is approximately  $\pm .2$ -inches. This is well within the American Concrete Institute level alignment construction tolerance which is  $\pm .75$ -inches. Thus, in this example, the finish floor elevation profile does not indicate excessive distortion of the foundation.

### **Why do finish floor elevation surveys and profiles require engineering judgment?**

It has been pointed out above that both the finish floor elevation survey and the finish floor profile approach can be misleading if the slab surface was not constructed level and/or flat. Published construction tolerances for slab-on-ground foundations allow for two points on the surface of the slab 10-feet apart to have an elevation difference of as much as 1.25 inches. Some engineers who use finish floor elevation surveys will recommend foundation repair if the survey shows any portion of the floor surface with a slope in excessive of 1-inch in 10-feet. This can result in a foundation repair recommendation that is clearly unnecessary. Finish floor elevation profiles can also result in unreliable repair recommendations if the foundation surface was not constructed as flat as normal.

### **How can engineers judge how level a foundation was constructed?**

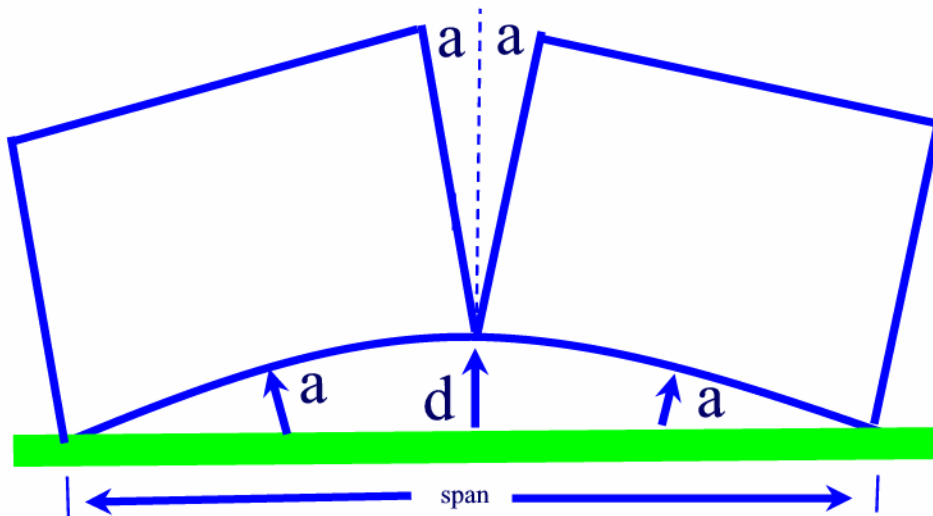
It has been pointed out above that the finish floor elevation survey approach can be misleading if the slab surface was not constructed level and flat. One way to verify if the foundation was constructed level is to use a four-foot level to check the levelness of countertops, window stools and other trim that is normally constructed to a much tighter levelness tolerance than slab-on-ground foundations. By using a four foot level in this way, an experienced engineer can usually make a reliable judgment as to how level the foundation was constructed.

For instance, if the floor shows an obvious slope but the window stool above the sloped floor is level, it is reasonable to conclude that the floor levelness was probably due to the original construction.

## Can engineers use crack width measurements to estimate foundation deflection?

Structural engineers can estimate how much deflection a brick veneer wall exhibits by measuring the maximum width of the visible cracks in the brick veneer and adding them together to obtain the single crack width equivalent to the cracks in the wall. This can then be used with a geometric model to estimate the amount of deflection the foundation is exhibiting. This type of approach takes into account the geometry of the foundation and the geometry and construction of the brick veneer wall. An example of a geometric model that can be used to relate crack widths in brick veneer walls to foundation deflection is shown below:

Geometric Model of Cracked Brick Veneer Wall  
Relating Crack Width to Foundation Deflection



## How reliable are foundation performance evaluations?

This is a very interesting question, but it is not clear what the answer is. In fact, it is not clear that it is even possible to answer the question. We really do not know how reliable foundation performance evaluations are and, we would argue, it is not *possible* to know how reliable they are in a quantitative sense. Foundation performance evaluations are always subjective opinions. The subjectivity makes many engineers and some real estate inspectors uncomfortable; but there is no way around the fact that these evaluations are full of subjective assessments and opinions. For instance, any recommendation to

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underpin or not to underpin a foundation rests, at least in part, on a subjective assessment of the likely effectiveness of underpinning and the associated risks for a specific foundation. For a specific foundation, there is simply no way to know how effective foundation underpinning will be and what the costs (in terms of damage to the foundation and the house) of the underpinning process are until after the foundation is underpinned. In fact, it will normally be some time after the repair work is completed before a reliable assessment can be made of how effective the foundation repair was. And, if the foundation is underpinned, we will never know how the foundation would have performed without the repair.

In a sense, deciding to repair or not to repair a foundation is like the fork in Robert Frost's road in his famous poem *The Road Not Taken*. There is simply no way to ever know for sure if you made the best decision or not. For precisely that reason it is important to gather as much information as possible and come to the best understanding you can before making a decision as to how to address expansive soil foundation problems. One essential element is to seek the council of an unbiased structural engineer who specializes in foundation performance evaluations.

### **How much damage should a homebuyer be willing to tolerate?**

Structural safety problems that result from foundation movement are clearly intolerable. But beyond that, the correct answer is that there is no one answer that is correct for everyone. Different people have a different tolerance for cracks in wall coverings and sticking doors. It is important in searching for a home to purchase that you be realistic. Demanding a house that shows no signs of foundation movement, has never shown any sign of foundation movement and never will show damage that could be attributable to foundation movement is not realistic. You should not buy any home you are not comfortable with, especially without having a structural engineer make a damage evaluation. But the ultimate decision as to how much damage you are willing to tolerate is one only you can make.

### **How far out-of-level is acceptable?**

There is no answer to this question that is universally accepted. The Post-Tensioning Institute has published a peer-reviewed paper in which it is stated that a diagnosis of excessive expansive soil movement cannot be made unless the slab surface is out of level substantially in excess of published American Concrete Institute (ACI) standardized construction levelness tolerances for slab-on-ground foundation construction. The ACI publishes several different construction tolerances but recommends the use of what are called F-numbers. The F-number system allows the elevation of two points 10-feet apart to be different by as much as 1.25-inches. If a foundation were to deflect  $L/360$  in both directions (which most engineers would consider acceptable), the resulting slope (adding

an as-constructed slope to the slope caused by foundation distortion) could result in a foundation surface slope of 1.65-inches or more over 10-feet. A slope greater than 1% (1.2-inches over 10-feet) is noticeable by most people. Thus, a noticeable floor slope may or may not indicate excessive foundation movement. You should also understand that the as-constructed slope and the slope due to foundation movement may not add together; the foundation may distort in a way that makes the slab surface more level than it was constructed.

Some engineers prefer to judge the levelness of the foundation due to distortion by looking not at the levelness of the slab surface, but at the levelness of first floor countertops and sills since these elements are normally constructed to much tighter levelness tolerances than slab-on-ground foundation surface tolerances. If the countertops and sills are reasonably level within normal construction tolerances, then it is reasonable that any floor out-of-levelness is probably due to original construction.

### **Will my house fall down?**

It is important to understand that it is extremely unlikely for expansive soil foundation movement to cause a house to collapse. First, very few houses collapse for any reason. The most common reason for this type of failure is probably fire. It is conceivable for a house that has extremely severe moisture and termite damage to collapse, especially if it is abandoned. Houses under construction have been known to collapse when subjected to high winds. Houses under construction are subject to this risk because there are periods in the process in which key structural elements have not yet been installed. Of course, extreme weather events such as hurricanes and tornadoes can also cause a completed house structure to collapse. But I do not know of a single case in which expansive soil movement caused a house structure to collapse.

What seasonal weather-related expansive soil movement can do is cause cosmetic damage to the house in various forms, usually drywall cracking and brick veneer cracking. Door frames can become distorted so that doors no longer fit properly in their frame; also, doors may not latch and could stick and bind. It is also possible for foundation movement to cause framing members to pull apart to some degree. In most cases, the damage is restricted to cosmetic damage that can be repaired using normal decorative repair techniques or minor functional problems such as sticking doors that can be corrected by adjusting or reinstalling the door.

The fear of a house falling down due to expansive soil movement is not based on reality.

# FREQUENTLY ASKED QUESTIONS ABOUT FOUNDATION CRACKS

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## What is a cracked slab?

The term “cracked slab” is not a technical term. You will not find it in any engineering text we are familiar with. The term “cracked slab” is used by lay people and foundation repair contractors. We frankly do not like the term and believe it should not be used. Language can be used in a way that helps us understand and solve problems and language can be used to obscure and confuse. In our opinion, the term “cracked slab” serves no legitimate purpose.

The term “cracked slab” can be understood literally to mean a slab that exhibits cracks. But if this is what the term is taken to mean, then it conveys no useful information at all. All concrete exhibits cracking. It is a characteristic of concrete that it cracks. There is, in fact, no difference between a “cracked slab” and a “concrete slab” since all concrete slabs have cracks.

The other commonly intended meaning of the term “cracked slab” is a slab that has failed. But this usage, in our opinion, is illegitimate. Slab-on-ground foundations do not fail in any normal sense. These are ground-supported structures. They are not elevated structures that can collapse and fall down like, say, an elevated structure such as a bridge. Slab-on-ground foundations are most realistically understood and evaluated, not in terms of “failed” or “not failed,” but in terms of performance and specifically in terms of degrees of performance. To quote Donald P. Coduto, P.E.

**“A common misconception, even among some engineers, is that foundations are either perfectly rigid and unyielding, or they are completely incapable of supporting the necessary loads and fail catastrophically. This ‘it’s either black or white’ perspective is easy to comprehend, but it is not correct. All...foundations have varying degrees of performance that we might think of as various shades of gray.” (*Foundation Design - Principles and Practices*, by Donald P. Coduto, P.E., page 10).**

The term “cracked slab” presumes that slab-on-ground foundations are best understood and evaluated in terms of “failed” and “not failed.” We consider this perspective to be wrong and misleading.

### **If my floor tile is cracked, is my slab cracked?**

We take this question to mean that if there are cracks in the floor tile, are there corresponding cracks in the slab surface? The answer is that it depends. There are usually one of two situations that present themselves for evaluation. We discuss each of these below:

- **There are one or more individual tiles that are cracked but no cracks that run from tile to tile:** In this situation, the most reasonable explanation is that there is probably no crack in the slab surface under the cracked tile. If there is such a crack, it is almost certainly not an active crack.
- **There is at least one crack in the tile that runs from tile to tile:** When this is the case, there is almost always a crack in the slab surface that mirrors the crack or cracks in the floor tile. The cracks in the slab are usually restrain-to-shrinkage (RTS) cracks and are not considered a major structural defect.

### **What is a corner or wedge crack?**

The large majority of slab-on-ground foundations will develop what are called corner cracks or wedge cracks. The name comes from the fact that these cracks develop at or very close to the outside corners of the foundation and frequently form a wedge at the corner.

These cracks develop as a result of the expansion of the brick veneer when it is warmed by the sun. When the temperature of the brick veneer rises, the brick veneer wall expands in length and pushes or slides against the slab surface. At the end of a brick veneer wall at an outside corner of the slab, there is nothing to push back and the concrete cracks at each side of the corner, forming a wedge. Builders will usually place a piece of plastic between the bottom of the first course of brick and the slab; this reduces the friction force when the brick expands and slides against the slab. This has the practical

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effect of reducing the cracking on the slab at the corners but it by no means eliminates the corner cracking.

These cracks do not indicate anything unusual about the foundation. If the cracking at a corner becomes very bad, the concrete wedge may become loose and even fall off. In extreme cases, the wedge will no longer adequately support the brick veneer; when this happens, the corner will need to be repaired. This is a concrete repair and not a foundation repair.



corner or wedge crack

### **When does a crack become a problem?**

We can divide this question into two questions:

- **When does a foundation crack become a concern?** The Shallow Foundation Committee of the American Society of Civil Engineers has published some guidelines for evaluating cracks in slab-on-ground foundations based on the width of the crack. Their recommendation is that if a crack is  $1/16^{\text{th}}$  inch wide, it should probably be looked at by an engineer. They also state that cracks that are  $1/8^{\text{th}}$  inch or less do not typically indicate that the foundation is not capable of performing as intended. Also, the Shallow Foundation Committee points out that the presence of cracks in slab-on-ground foundations "does not indicate a life-threatening, dangerous condition."
- **When does a foundation crack become a serious problem?** Cracks due to foundation bending can result in significantly more flexibility in the slab. This means that the foundation will not do as good a job as it was intended to do to mitigate the amount of damage the soil distortion causes the

house. If the flexibility caused by foundation cracking results in structural damage to the house frame so that the frame structure can no longer carry normally imposed loads safely, then the foundation crack is a serious problem. Also, if a crack increases the flexibility of the house so that doors necessary for an emergency exit cannot be opened and closed by a small child, that too is a serious issue that must be resolved. Barring either of these two situations, a foundation crack may be a legitimate concern but it is not a serious problem from a structural engineering perspective.

A crack of any width should be monitored if it is active, meaning it is growing, especially in width. Unfortunately, no home inspector or engineer can determine if a crack is active based on observing it one time.



this is a very wide crack that has faulted severely; notice the business card

### **If my floor tile pops loose, do I have a foundation problem?**

Foundation movement, even foundation movement that is well within a normal, expected range, can crack floor tile. But it is virtually impossible for foundation movement to cause well-bonded floor tile to pop loose. Floor tile is bonded to the slab surface with what is called thin-set. This material does an excellent job of binding the tile to the slab surface if it is applied properly. The key is for the slab surface to be clean and free of any contaminants. The underside of the tile must also be clean but this is usually not hard to achieve. The slab surface is another matter. It is easy, during normal construction operations, for the slab surface to get material on it that prevents a good, permanent bond. When this is the case, the tile may eventually come loose.

In summary, this problem is almost always a bonding issue and not a foundation movement issue.

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## FREQUENTLY ASKED QUESTIONS ABOUT BUILDING CODES

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### What does the code say about foundation performance?

The Texas State Legislature recently adopted the *International Residential Code for One and Two Family Dwellings* as a state building code. The following is a summary of some key issues from this code:

- There is no stated requirement that foundation deflection not be allowed to exceed some specified amount such as  $L/360$ .
- The Building Official has the discretion to permit the construction of a slab-on-ground foundation without an engineered design if past experience has shown that the proposed slab-on-ground foundation design has performed adequately.
- For a non-engineered slab-on-ground foundation to be judged to be performing adequately, it must meet three stated criteria.

**1. The foundation must be able to resist differential volume changes:** While this would eliminate some minimal foundation designs, almost all foundation designs typically used in the metropolitan areas of Texas could be said to provide some degree of resistance to differential soil volume changes.

**2. The foundation must be able to prevent structural damage to the supported structure.** In this context, it is clear that structural damage means damage to the supported structure that reduces the ability of the supported structure to carry the imposed loads in a safe manner. Most foundations would be able to pass this test.

**3. Deflection and racking of the supported structure shall be limited to that which will not interfere with the usability and serviceability of the structure.** This would imply that the foundation deflection should not result in functional problems such as doors or windows

that bind and stick. This is clearly a problem with some homes.

## **What do the code-approved design protocols say about foundation performance?**

For engineered slab-on-ground foundations on expansive soils, there are two code-approved design protocols that may be used, one published by the Post-Tensioning Institute (PTI) and the other published by the Wire Reinforcement Institute (WRI). The 1996 edition of the PTI book *Design and Construction of Post-Tensioned Slabs-On-Ground* includes the following wording:

*Application of these recommendations results in slab designs similar to those that have exhibited satisfactory performance.*

The WRI publication, *Design of Slab-on-Ground Foundations – An Update*, includes similar wording. Neither code-approved design protocol promises that the actual deflection of engineered slab-on-ground foundations will be less than some stated amount. They do promise that actual foundation performance in terms of superstructure distress will be “satisfactory” and the distress “minimal.” I think it is fair to say that slab-on-ground foundations designed and constructed in accordance with either design protocol will not deflect enough to cause structural (load-bearing) damage to the superstructure. There is likely to be some degree of cosmetic distress and some minor door problems. The levelness of the slab surface is not addressed by either design protocol.

## FREQUENTLY ASKED QUESTIONS ABOUT MITIGATION AND REPAIR

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### What options are available for addressing foundation performance issues?

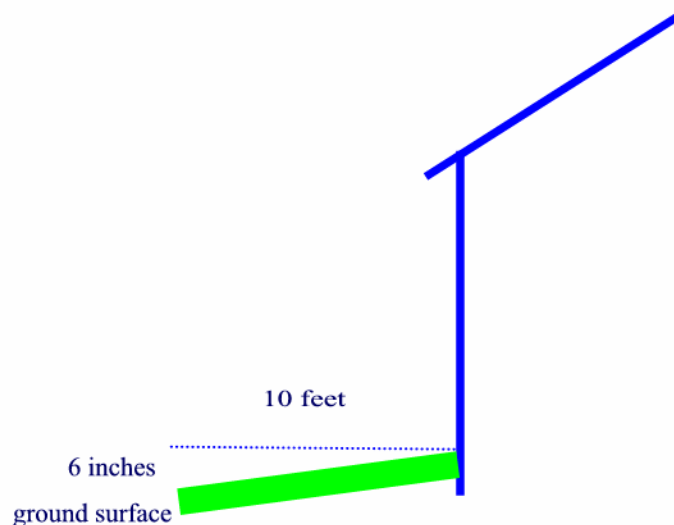
Many houses in the Greater Houston Area will experience foundation performance issues during their useful life. The foundation performance issues experienced can range from hairline cracking that is difficult, if not impossible, to reliably attribute to foundation movement (or any other specific cause) to severe cracking in drywall and brick veneer accompanied by wood framing members being pulled apart. Such a wide range of performance problems dictate a wide range of options to address the issue. The options available include the following:

- **Taking no action at all.** This is a perfectly acceptable option so long as there is no structural damage. In our experience, this is also the most common response when the damage due to foundation movement is minor.
- **Non-structural remediation measures.** Non-structural remediation measures include vigilantly watering the foundation during dry periods, making occasional cosmetic repairs, improving and maintaining drainage around the foundation, removing trees and/or large shrubs and making changes in the finishing of the house such as changes in wall coverings. Many homeowners do this to some degree.
- **Structural remediation measures.** Structural remediation measures applicable to slab-on-ground foundations usually include what engineers refer to as structural underpinning, grouting and mudjacking, crack injection and tendon stressing. According to the Shallow Foundation Committee of the American Society of Civil Engineers, underpinning the foundation and other structural remedial measures should be considered if the house exhibits *severe* distortion.

## What options are available for mitigating moisture changes in the soil supporting the foundation?

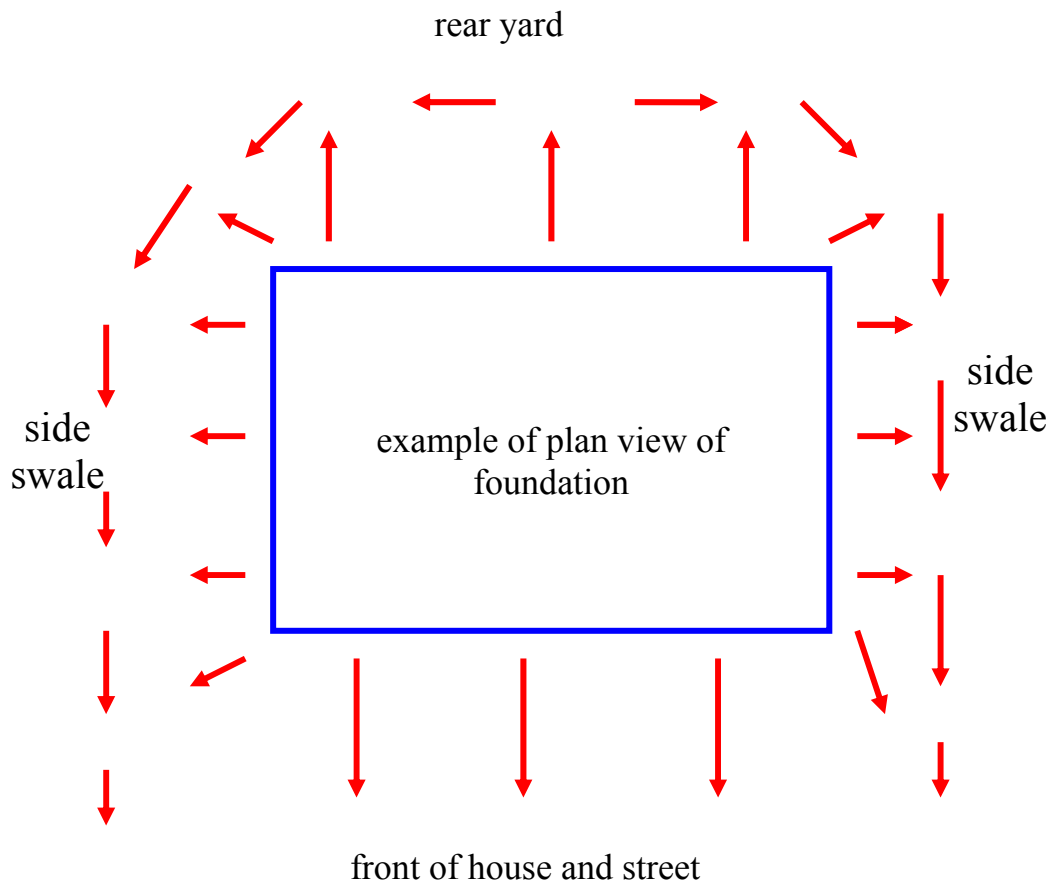
There are a number of potentially applicable options for mitigating changes in the moisture in the soil supporting the foundation. These options include soil surface grading, subsurface drains, watering the foundation, removing and pruning trees, controlling roof water, maintaining ground covers, and controlling lawn irrigation. Each of these is briefly discussed below:

- **Soil Surface Grading:** This is your first line of defense against excessive moisture in the supporting soils. It is very important that the ground adjacent to the foundation be graded so it falls 6-inches in 10-feet or to the property line.



The ground should be graded so that water clearly flows away from the foundation. At the front the water should flow directly away from the foundation and to the street. Alternatively the water can flow to a swale that is at least 10-feet from the foundation and is shaped to direct the water to a

side swale. The ground between the house and the adjacent house should be shaped so that the water flows into a swale that is shaped to direct water to the street. The ground in the rear should fall at least 6-inches in 10-feet as you move away from the foundation. The ground should be shaped so as to direct the water to the side and into a side swale. The following sketch gives a general idea of how water should flow away from the foundation to promote better slab-on-ground foundation performance. The arrows show the desired direction of the water flow away from the foundation and off the site.



- **Subsurface Drains:** Underground drains are appropriate for playing a supplemental role in preventing the supporting soils from absorbing too much water. I say supplemental because it is usually a mistake to rely on an

underground drain system when the ground adjacent to the foundation is not properly graded. Grading the soil properly to an underground drain around 10-feet away from the foundation is acceptable. Leaving the ground surface flat and placing the subsurface drain close to the foundation is asking for trouble. Underground drains can clog and they can develop leaks.

- **Managing Trees and Large Shrubs:** Trees and large shrubs extract large amounts of water from the soil every day. When they are close to the foundation, they can significantly exacerbate the shrinkage of soil when there is a drought. It is during extended dry periods that we see most of the damage due to foundation movement; the houses that exhibit damage during a drought almost always have trees close to the foundation that are clearly making the situation much worse than it would be otherwise. Trees and large shrubs can be managed for improved moisture control and foundation performance. Large shrubs can be removed. Trees can also be removed. In many cases, the roots of trees can be pruned between the tree and the foundation.
- **Controlling Roof Water:** Large quantities of water come off the roof of a house. The best way to control water flow off a roof is with a roof gutter system. It is important that all eave areas be guttered. Guttering some of the eaves while leaving other eaves without gutters may make the problem worse, not better. It is also important that the water not be discharged onto the ground within 5-feet of the foundation. Discharging roof water close to the foundation has the potential of causing significant foundation movement. Water discharged close to the foundation can easily percolate through the backfill to the supporting soil under the perimeter of the foundation if the backfill is not properly compacted. Unfortunately the backfill is usually clay that is not compacted.
- **Maintaining Ground Covers:** There are many homes that have areas around the foundation where it is difficult for grass to grow. The grass simply cannot compete with the trees for moisture and soil nutrients. The best thing to do, in many cases, is to turn these areas into gardens and mulch them heavily. Mulch can be very effective in preventing the soil from losing excessive moisture. What happens in many cases is that the area is not turned into a garden, but is left as an area that is bare and exposed. During a dry period, these areas can easily become desiccated, resulting in more settlement and damage than would otherwise be the case.
- **Maintaining Lawn Sprinkler Systems:** There is nothing wrong with having a lawn sprinkler system. Having stated that point, I must also point out that most of them are installed in a way that presents a (potential) problem to

the future performance of the foundation. The two most important problems with these systems are the following:

- **The supply lines are usually placed too close to the foundation.** These lines are prone to leakage which can cause swelling of the soil near the areas that are leaking.
- **The control valves are prone to leakage.** Since these valves are usually very close to the foundation, they should be checked frequently for leakage. Ideally, they should also be located at least 5-feet from the foundation.

One point that should be kept in mind is that lawn sprinkler systems are not normally designed or operated with the foundation in mind. For instance, landscape experts normally recommend that vegetation be watered deeply only once twice or at most 3-times a week. This type of schedule will encourage the plants to develop deep root systems. During dry periods, slab-on-ground foundations need to be lightly watered 3-times a day.

### **Are there any practical limitations on our ability to mitigate moisture changes in the soil?**

It should be understood that, from a practical perspective, there are several fundamental reasons why a homeowner, or an engineer for that matter, has only a limited ability to mitigate moisture changes in the soil supporting the foundation. One problem is clearly the weather. Houston weather varies from very wet to extended periods of dry weather and even drought. While this can be compensated for by watering the ground adjacent to the foundation, the reality is that it is difficult to assure uniform wetting of the soil to a sufficient depth to be effective.

Also, there is virtually nothing a homeowner can do about the movement of moisture from lower soil stratum to the soil near the surface supporting the foundation. The fact is that engineers have a limited, even inadequate understanding, of how moisture moves through the soil.

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From our experience, most engineers practicing in this area believe that aggressive moisture stabilization measures can cut foundation movement by around 50%. That is a significant reduction, but it may take 6-months to 3-years to obtain that result. It is important to realize that aggressive moisture stabilization results in a wide range of foundation movement reduction. Some houses may get a much greater reduction and some may get a much lower reduction.

### **How is the need for structural foundation repair established?**

Unless foundation movement results in a structural safety issue that can only be corrected by underpinning the foundation, repairing the foundation structurally should be viewed as an option, not a need. In the large majority of situations where there is impaired foundation performance, structural foundation repair should be viewed as an option that may or may not be appropriate for a given situation. Deciding to make structural repairs to a foundation should be made with a clear understanding of the likely benefits and risks of the proposed repair.

For instance, there is a series of questions that should be asked and answered before deciding to underpin a foundation.

- **What improvement in foundation performance can realistically be expected from underpinning?** If the damage is not severe, it may be better to make cosmetic repairs to the house and take other appropriate non-structural remediation measures. Underpinning is not normally effective or cost efficient unless the foundation related damage to the house is severe. No honest foundation repair contractor will guarantee that underpinning will result in a level foundation. In fact, studies have shown that the typical foundation repair job, where the perimeter of the foundation is underpinned, can become less level over time as the central non-underpinned area settles during dry periods while the perimeter is not allowed to settle due to the presence of piers or pilings. Foundation repair contractors also cannot guarantee that the underpinning will prevent future damage to the house. There is always some residual risk of damage due to foundation movement after the foundation is underpinned.
- **What means are available to mitigate soil moisture changes?** Foundation movement in expansive soil areas is normally driven by changes in the moisture in the supporting soil. Even if the foundation-related damage to the house is severe, underpinning is not likely to be effective in the long run unless the causes of the moisture change in the soil are removed. There are several ways homeowners can mitigate the changes in the soil moisture. They

include maintaining positive drainage away from the foundation. The normal recommendation is to shape the surface of the ground adjacent to the foundation so that it falls 6-inches in 10-feet as you move away from the foundation. No water should be allowed to discharge within 5-feet of the foundation. This includes plumbing leaks, air conditioning condensate discharges, and discharges of water from roof gutters. Trees, especially hardwoods such as oaks, and large shrubs can remove large amounts of water from the soil leading to excessive foundation settlement, especially at the outside corners of the foundation. All ground within 5-feet of the foundation should have some sort of ground cover to prevent excessive drying. Last, but not least, the ground adjacent to the foundation should be watered when the weather is dry.

Unfortunately, the migration of moisture through the soil is one of the least understood aspects of expansive soils. We know that, in at least some situations, soil moisture migrates from lower soil strata to the soils supporting the foundation. This moisture can become trapped under the slab-on-ground foundation resulting in a center lift distortion mode.

- **What damage to the house is the repair process likely to cause?**  
Underpinning and grouting and mudjacking can result in unintended damage to the foundation and the house. The damage is usually minor, but it can be significant. One of the authors has personally seen drywall cracks as wide as 1.25-inches that were *caused* by underpinning. Underpinning can result in portions of the foundation being forced to act as an elevated structure instead of a ground-supported structure. This can result in significantly higher stresses in the slab structure than it was intended to experience. True structural failure can result.
- **Is the foundation movement excessive and progressive?**  
Foundation movement is usually considered excessive if the foundation is deflecting more than an inch for every 360 inches of span. Thus, a 60-foot (720-inches) wall could deflect 2-inches at each end; a 30-foot (360-inches) wall could deflect 1-inch at each end. Foundation movement is considered progressive if it is clearly growing over time. This can be determined only by monitoring foundation movement over a period of time, usually at least 6-months but possibly lasting as long as 2-years.

**In summary, the decision to underpin or not to underpin a foundation is a judgment based on an understanding of the type and extent of damage**

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**judged to be caused by foundation movement, the probable benefits and risks of foundation repair and the costs involved.**

### **How are foundations structurally repaired?**

In most cases, foundations that are structurally repaired are underpinned. This is an engineering term that, in this context, refers to the process of providing structural support under the existing slab-on-ground foundation. Underpinning a slab-on-ground foundation is usually done with the intent to lift some foundation areas to attempt to bring the slab surface to a closer approximation to the as-constructed condition. The underpinning is also intended to make the foundation perimeter less susceptible to future settlement. The traditional way to underpin a slab-on-ground foundation is to place reinforced concrete piers under the perimeter of the foundation. The bottoms of the piers are belled out. This spreads the load transferred to the soil and prevents the pier from being pushed up when the soil swells.

If you visit the [www.dawsonfoundationrepair.com](http://www.dawsonfoundationrepair.com) website, you will find an excellent discussion of the foundation repair process.

## **How much improvement in performance can reasonably be expected from foundation repair?**

This is a question that is difficult answer. Most people are surprised that no foundation repair contractor actually promises to make their foundation work better than it did prior to the repair work. All they warrant is that after the foundation repair work is completed is that the piers or piles they install will not settle more than 1-inch for every 30-feet of underpinned span. The repair work is almost always done without any definitive evidence that the foundation has settled more than an inch for every 30-feet of span. Most homeowners who underpin their foundation have no way of knowing if their foundation has settled more than an inch for every 30-feet of span. Nor do they normally have a rational basis for believing that the foundation will or will not settle more than the warranted amount in the future absent any underpinning.

In our experience, foundation underpinning will usually reduce future foundation settlement by about half. In terms that the lay person can relate to, that generally means that the number of drywall and stucco cracks will be cut in about half. The number of brick veneer cracks will usually not change but the average width of the brick veneer crack will usually be cut in half. The number of sticking doors may also be cut in half.

## **If I buy a house that shows signs of foundation-movement-related damage, will I be able to sell the house?**

Engineers and real estate inspectors are in the business of informing potential buyers as to the condition of the house, not its marketability. However, there are a couple of points that bear on this question that can best be made by an engineer or inspector:

- **It is unreasonable to not expect some degree of damage due to foundation movement in resale houses in the Greater Houston Area.** The combination of expansive soils, thin flexible slab-on-ground foundations and wooded lots virtually guarantees that many houses will experience some damage due to seasonal foundation movement. This type of movement rarely affects the structural stability of the frame structure of the house.
- **There is a wide range of opinions concerning how much cosmetic damage is acceptable or not acceptable.** Some people find even hairline cracks unacceptable; others find almost any crack width acceptable so long as there are no structural safety or stability issues. If the degree-of-damage shown by a house you are considering buying makes you

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uncomfortable, you should probably not buy the house.

## What are some examples of foundations in need of concrete repair?

The following are two examples of concrete repair that are sometimes required:

- **Wedge or Corner Cracks:** These are cracks that are frequently formed within 12-inches of the outside corners of the foundation. They result when the brick veneer expands when it is heated by the sun. As the brick veneer expands it pushes outward on the foundation. The frictional forces on the concrete surface cause the foundation to crack at the corner. Wedge cracks or corner cracks are not indicative of a structural performance issue. They may, however, require concrete repair if the cracking is so bad that the brick veneer begins to fail.



- **Exposed Cable Ends:** In post-tensioned slabs-on-ground, the ends of the post-tensioning cables may become exposed. When this happens, the anchors that hold the cables in place can become damaged due to corrosion. To prevent the damaging corrosion, a concrete repair should be made that will protect the anchors.



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## What is your philosophy of foundation mitigation and repair?

Our philosophy of foundation evaluation can be summed in the following statements:

- **Most houses that show distress due to foundation movement do not warrant foundation repair.** The reason is that most damage due to foundation movement is cosmetic. Making cosmetic repair is more economical than underpinning the foundation and underpinning the foundation is not likely to be effective in preventing future cosmetic damage. In our opinion, foundation repair should be reserved for houses that show true structural damage or severe cosmetic and/or functional damage.
- **The cause of the soil moisture changes causing the damaging foundation movement should be isolated.** This is the key to mitigating the damage to the house caused by the moisture changes in the soil. The US Army Corps of Engineers recommends that no underpinning be done until the causes of the soil moisture changes have been corrected and some period of time allowed to pass so the effect of the corrections can be evaluated.
- **The work may have to be repeated because of a failure to isolate the cause of the moisture changes in the foundation soil.** It is not always obvious what the source of the moisture changes in the supporting soil is. Any homeowner should be prepared for the possibility that the search for the source or sources of the moisture changes may take awhile.
- **Only one remedial measure at a time should be attempted at a time so that its effect on the structure can be evaluated.** The best approach is usually to attempt one remedial measure at a time. It is important to allow some time to pass before attempting another remedial measure so the effect of the first remedial measure can be evaluated.
- **The structure is seldom rebuilt to its original condition.** It is unrealistic to expect that non-structural remedial measures or foundation underpinning can make the house like new. Once a house is damaged by foundation movement, it will always show some distortion.
- **Remedial measures may not be successful.** Many people naively believe that foundation underpinning will "fix" the foundation. Nothing could be further from the truth. The fact is that some houses cannot be "fixed" regardless of any structural repairs or non-structural remedial measures that are taken.

- **Be prepared to live with what you are buying.** Since it is possible that remedial measures may not be successful, understand that if you buy the house, it will be yours and you will have to live with it. Do not purchase a house that shows a level of foundation performance that you are not comfortable with or are not willing to tolerate.

We believe the above approach is consistent with the Texas Section ASCE publication *Guidelines for the Evaluation and Repair of Residential Foundations* and with US Army Corps of Engineers publication *Foundations in Expansive Soils*.

## FREQUENTLY ASKED QUESTIONS ABOUT RETAINING ENGINEERS

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### What is the difference between a real estate inspection report and an engineering performance evaluation?

From a practical perspective, the difference between a real estate inspection report and an engineering evaluation comes down to what they report if the foundation performance is judged to be inadequate.

- **The Real Estate Inspection Approach:** Under the rules licensed real estate inspectors are required to follow, if they judge the performance of the foundation to be inadequate, the inspector is required to report the foundation as in need of repair.
- **The Engineering Approach:** An example of an engineering approach can be found in a publication of Texas Section of the American Society of Civil Engineers titled *Guidelines for the Evaluation and Repair of Residential Foundations*. The guidelines state that if the foundation performance is judged to be inadequate, the engineer should report to his client the options that are available to improve the performance. Those options do include structural foundation repair but also can include non-structural options such as landscaping changes, more or less aggressive watering of the foundation, making cosmetic repairs and/or changes to the house and, if appropriate, doing nothing.
- **Why the Engineering Approach is a More Comprehensive Approach:** According to the US Army Corps of Engineers publication *Foundations in Expansive Soils*, the fact that a foundation is not performing "adequately" does not mean that foundation repair is either necessary or desirable. Nor does it mean that foundation repair will actually improve the performance of the foundation. An engineer has both the training and duty to exercise his engineering and analytical judgment in judging both the adequacy of the performance of the foundation and in reporting what options are applicable for improving inadequate foundation performance. The real estate inspection approach frequently results in a repair recommendation that is both unnecessary and counterproductive. Many real estate inspectors know this. They usually follow the rules by reporting a house that shows signs of damage due to foundation movement as in need of foundation repair, but then also

recommend a second opinion from a structural engineer.

## **What should a homebuyer look for when retaining a Professional Engineer?**

When engaging an engineer, your first choice should be an engineer who specializes in foundation performance evaluations for purposes of a real estate transaction. These engineers will usually have an advertisement in the Greater Houston Area Yellow pages under “real estate inspectors.” There are a very limited number of engineers who specialize in this area of practice.

- **Select an engineer who uses an engineering approach that you can understand and are comfortable with.** Some engineers use a damage evaluation approach based mainly on visible cracks, especially on how many there are and how wide they are. Another approach is what I call a levelness evaluation which focuses on how level the finish floor surface is. Either approach, if done by a skilled and experienced engineer who exercises good engineering judgment, is acceptable. But the approach should make sense to you.
- **Obtain a sample report.** Most engineers will provide you a sample report if you ask. It can be E-mailed to you in a few hours. Most engineers do not maintain websites but that is likely to change soon. If an engineer has a website, visit it and you may find you can download a sample report.
- **Select an engineer who has no relation to any foundation repair company.** Do not assume that an engineer has no relation to a foundation repair company. If you want an unbiased report, make sure the engineer you retain is not related in any way to a foundation repair contractor. Be especially wary of any engineer who has a relation to CableLock.

## **What is the most important criteria for selecting a Professional Engineer?**

When you retain an engineer, you are paying for his judgment. That is true of any professional you retain whether it is an engineer, a doctor or an accountant. When you talk to the engineer on the phone ask yourself the following questions:

- **Does the engineer sound as if he or she knows what they are talking about?**
- **Does the engineer answer your questions in a manner that you find understandable?**
- **Does the engineer sound as if they are a reasonable person?**

## HOUSTON AREAS AND SOILS

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Below we have provided a list of many subdivisions, developments and areas in the Greater Houston Area with descriptions of the types of soils and foundation problems found in each. Unfortunately, we cannot list every subdivision, but we have listed representative subdivisions in every area of the Greater Houston Area.

Atascocita Area      This area contains mostly loose sandy soils and sandy clays on the surface. The surface soils are usually underlain by impermeable clays with low to high shrink/swell potential. Perched water tables can cause upper soils to loose bearing capacity resulting in foundation distress. There are pockets of the Atascocita Area that have experienced severe problems with foundation movement.

Bellaire      The Bellaire area is underlain with clay soils that are highly expansive. Houses in this area are at a high risk that slab-on-grade foundations will be underpinned at some point in the life of the structure. The City of Bellaire no longer permits the use of slab-on-ground foundations.

Brightwater      Highly expansive clays and sandy clays are typical. The shrink/swell potential is high with high risk of foundation distress.

Bunker Hill      Sandy clays, sands and clay soils are the most common soils. The clays are generally moderately expansive. This area contains some faults; houses constructed adjacent to ravines in this area can pose special foundation problems.

Champions Forest      This area is characterized by a number of different soil formations. The soils are generally sandy clays ranging from low to moderate shrink/swell potential. The soils are poorly drained and some formations have perched water tables after heavy rains, especially during the cool months of the year.

Cinco Ranch	Parts of Cinco Ranch have surficial soils that are clay and some parts have surficial soils that are sand. The clays are highly expansive with a high shrink/swell potential. The areas with surficial sand soils may suffer loss of bearing capacity with a perched water table condition.
Clear Lake Area	Highly expansive clays and sandy clays are typical. The shrink/swell potential is high with high risk of foundation distress.
Copperfield	Loose sandy soils and sandy clays on the surface underlain by impermeable clays with low to high shrink/swell potential. Perched water tables can cause upper soils to lose some bearing capacity resulting in foundation distress.
Cypresswood	Loose sandy soils and sandy clays on the surface underlain by impermeable clays with low to high shrink/swell potential. Perched water tables can cause upper soils to lose some bearing capacity resulting in foundation distress.
Fairfield	Loose sandy soils and sandy clays on the surface underlain by impermeable clays with low to high shrink/swell potential. Perched water tables can cause upper soils to lose some bearing capacity resulting in foundation distress.
First Colony	Highly expansive clays and sandy clays are typical. The shrink/swell potential is high with high risk of foundation distress.
Greatwood	Highly expansive clays and sandy clays are typical. The shrink/swell potential is high with high risk of foundation distress.
Hedwig Village	Sandy clays, sands and clay soils. The clays are generally moderately expansive. Some faults. Ravines can pose special foundation problems.
Heights	Sandy clays, sands and clay soils. The clays are generally stable to moderately expansive.
Hunter's Creek	Sandy clays, sands and clay soils. The clays are generally

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moderately expansive. There are some faults in the Hunter's Creek area. Ravines can pose special foundation problems.

Kelliwood  
Gardens

Highly expansive clays and sandy clays are typical. The shrink/swell potential is high with high risk of foundation distress.

Kingwood

Generally, the soils in Kingwood are loose sandy soils and sandy clays on the surface underlain by impermeable clays with low to high shrink/swell potential. Perched water tables can cause upper soils to lose some bearing capacity resulting in foundation distress. Some areas of Kingwood, such as the Kings Point area, are underlain with very expansive soils overlain with silty sands interacting with perched water tables.

Kirbywoods

Highly expansive clays and sandy clays are typical. The shrink/swell potential is high with high risk of foundation distress.

Lake Olympia

Highly expansive clays and sandy clays are typical. The shrink/swell potential is high with high risk of foundation distress.

Lakewood Forest

This area is characterized by a number of different soil formations. The soils are generally sandy clays that ranging from low to moderate shrink/swell potential. The soils are poorly drained and some formations have perched water tables after heavy rains and during the cool months of the year.

Memorial

Sandy clays, sands and clay soils. The clays are generally moderately expansive. There are some faults in Memorial. Ravines can pose special foundation problems.

Memorial  
Northwest

This area is characterized by a number of different soil formations. The soils are generally sandy clays that ranging from low to moderate shrink/swell potential. The soils are poorly drained and some formations have perched water tables after heavy rains and during the cool months of the year.

Meyerland

Highly expansive clays and sandy clays are typical. The shrink/swell potential is high with high risk of foundation distress.

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Montrose	The Montrose area contains clays that with shrink/swell potentials that range from high to severely high. Most homes in this area are shallow pier and beam construction that will require periodic releveling.
New Territory	Highly expansive clays and sandy clays are typical. The shrink/swell potential is high with high risk of foundation distress.
Northgate Forest	This area is characterized by a number of different soil formations. The soils are generally sandy clays that ranging from low to moderate shrink/swell potential. The soils are poorly drained and some formations have perched water tables after heavy rains and during the cool months of the year.
Oaks of Devonshire	Loose sandy soils and sandy clays on the surface underlain by impermeable clays with low to high shrink/swell potential. Perched water tables can cause upper soils to lose some bearing capacity resulting in foundation distress.
Oyster Creek	Sandy soils in some areas. Soil conditions are variable with a shallow water table.
Pecan Grove	Highly expansive clays and sandy clays are typical. The shrink/swell potential is high with high risk of foundation distress.
Piney Point	Sandy clays, sands and clay soils. The clays are generally moderately expansive. There are some faults in Piney Point. Ravines can pose special foundation problems.
Plantation Colony/Quail Valley	Highly expansive clays overlaying loose silts and sands are typical. The shrink/swell potential is high with high risk of foundation distress.
River Oaks	Moderately expansive to highly expansive clays with a high potential for excessive foundation movement.
Sharpstown	Moderately expansive to severely expansive clays with a high

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potential for excessive foundation movement.

South Shore Harbour	Highly expansive clays and sandy clays are typical. The shrink/swell potential is high with high risk of foundation distress.
Spring Branch	The Spring Branch Area is characterized by moderately expansive soils that are poorly drained.
Sugar Mill and Sweetwater	The surficial soils consist of highly expansive clays. Below are loose silts and sands. Typically a floating slab foundation is used. Piers can be used on some lots if the underlying soil is suitable.
Tanglewood	Clay soils that are highly expansive. High risk that slab-on-grade foundation will need underpinning.
Twin Lakes	Many of the lots in this area contain fill material necessitating pier-supported slab-on-ground foundations.
Vicksburg	Highly expansive clays and sandy clays are typical. The shrink/swell potential is high with high risk of foundation distress.
West University	Clay soils that are highly expansive. High risk that slab-on-grade foundations will need underpinning.
Westbury	Westbury is underlain by clays that range from moderately expansive to highly expansive. There has been a lot of foundation repair work done in the Westbury area; many houses have been underpinned more than once.
Weston Lakes	Variable soil conditions with highly expansive soils in some locations.
The Woodlands	Loose sandy soils and sandy clays on the surface underlain by impermeable clays with low to high shrink/swell potential. Perched water tables can cause upper soils to lose some bearing capacity resulting in foundation distress.

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Worthom

Loose sandy soils and sandy clays on the surface underlain by impermeable clays with low to high shrink/swell potential. Perched water tables can cause upper soils to lose some bearing capacity resulting in foundation distress.

## OTHER SOURCES OF INFORMATION

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Below are several sources of additional information concerning slab-on-ground foundation performance and repair.

### Websites

[www.houston-slab-foundations.info](http://www.houston-slab-foundations.info): This website is the best single source of information for Greater Houston Area home buyers and sellers concerning foundation performance evaluation and repair. The book you are now reading is an abbreviated version of this website.

[www.dawsonfoundationrepair.com](http://www.dawsonfoundationrepair.com): Easily the most informative foundation repair website that we know of.

### Books for Homeowners

*So Your Home is Built on Expansive Soils: A Discussion of How Expansive Soils Affect Buildings*; This small book is a gem. The book was written by the Shallow Foundation Committee of the American Society of Civil Engineers. It is written for homeowners in language that is easy for the non-expert to understand. There are only two drawbacks to this book. It does not specifically address the issues commonly seen in real estate transactions and it does not address issues specific to the Greater Houston Area. The book can be ordered online from the American Society of Civil Engineers at [www.pubs.asce.org](http://www.pubs.asce.org)

*Has Your House Got Cracks?, 2<sup>nd</sup> edition*; The small book is another gem. It is also written for homeowners in language that is easy for the non-expert to understand. There are, however, three drawbacks to this book. In addition to the same drawbacks applicable to the ASCE book, *So Your Home is Built on Expansive Soils: A Discussion of How Expansive Soils Affect Buildings*, it also suffers the drawback that it was written and published for a British audience. In the United Kingdom, house damage due to foundation movement is normally covered by homeowner's insurance; this is not the case in the United States. The book can also be ordered online from the American Society of Civil Engineers at [www.pubs.asce.org](http://www.pubs.asce.org)

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