TECHNICAL BULLETIN
Expansive Soils Versus Soil Settlement

By Skip Walker

Few things are consistent across all the properties we will see as inspectors. However, every structure that we inspect rests on mother earth. Just like the people living in these homes, the soil that the dwelling rests upon will vary significantly from property to property.

Almost every dwelling we inspect will exhibit some degree of an out of level condition or displacement. Some of this may be the result of the dwelling being built a little out of whack. After all, people built them and as we know, people are not perfect. Most of what we see will be the result of some sort of soil related activity. When we inspect, we are not required to be geotechnical specialists. Nor should we try to pretend to be. What we should be able to do is look at a dwelling in a broader context and make appropriate recommendations to our clients.

Many soil related forces can act on a structure. This discussion will focus on two of the main forces; ***Expansive Soils*** and ***Soil Settlement***. The damage caused by these two issues may appear similar and can be easily mistaken for one another. These two issues behave very differently and the remediation required can be significantly different.

Expansive Soil

Expansive soils behave in a very predictable way. Expansive soils shrinks when it dries out and swells when wet. The amount of swelling varies significantly with the soil composition. In any case, the movement induced by expansive soils exerts significant pressure on foundation components, more than enough to damage sidewalks, driveways, basement floors, water, sewer and gas lines, and yes - even foundations. The pressures exerted by expansive soils can easily reach 5,000 pounds per square foot and in extreme cases as much as 10,000 to 15,000 pounds per square foot.

Expansive soils are found throughout the world. They are present in every state in the United States. Each year in the US, movement from expansive soils causes billions of dollars in property damage. Expansive soils are found throughout California. The American Society of Civil Engineers estimates that 1/4 of all dwellings in the United States have some type of damage caused by expansive soils. The annual property financial loss from the action of expansive soils in the US exceeds the loss from earthquakes, floods, hurricanes and tornadoes combined.

Not all expansive soils have the same swell potential. Soil surveys can provide general information about soils in an area. They are available from the California State Department of Natural Resources, U.S. Department of Agriculture, US Geologic Survey (USGS) and several other groups. These maps provide only generalized location and soil conditions. For site-specific information, the soil at the site must be tested.

Photo 1: Polygonal pattern of surface cracks in the dry season. These cracks are approximately one inch wide at the top.

Photo 2: This crack is at least 32 inches deep. The yardstick was easily inserted to this depth; narrower, less straight cracks may extend much deeper.

Even though expansive soils cause enormous amounts of damage, most of our clients have never heard of them and those that have do not fully understand the magnitude of the issue. This is because the damage from expansive soil occurs slowly over time and cannot be easily attributed to a specific event. The damage from expansive soils is often attributed to poor construction practices or the common misconception that all buildings experience this type of damage as they age.

Generally speaking, older construction techniques are inadequate to resist the forces imposed by expansive soils. That does not mean that nothing can be done. Properly engineered site drainage, vegetation management and foundation repairs can significantly improve the performance of older dwellings. Modern construction techniques used in foundations in expansive soil areas will generally perform far better than older systems. This is one situation where older is not better.

The building codes represent the minimum acceptable standard for construction. Unfortunately, most dwellings are built to these minimum code requirements. Expansive soils are a challenging environment. Dwellings constructed to minimum building code requirements will often have issues over time – it is only a matter of how long it may take them to manifest themselves. A more conservative design up front may cost slightly more, but can significantly enhance the performance of the structure over time.

With expansive soils, the swell/contract cycle can continue almost indefinitely. ***This means that damage from expansive soils will become progressively worse over time.*** As opposed to ***soil settlement***, where the displacement occurs mainly at the earlier stages of the dwellings life and diminishes over time. The failure modes vary by foundation type (slab on grade or raised perimeter) and site vegetation conditions.

Expansive Soil and Raised Perimeter Foundations

Generally speaking, most of the damage to a structure with a raised perimeter foundation occurs in the dry cycle – not the wet cycle, as you would assume. During the wet cycle, the soil expands but the dwelling load "pushes" down on it. This causes soils to essentially "squish" outward leaving voids that then collapse during the dry cycle. This cycle repeats, resulting in the perimeter foundation dropping and the adjacent grade rising. See the Figure below.

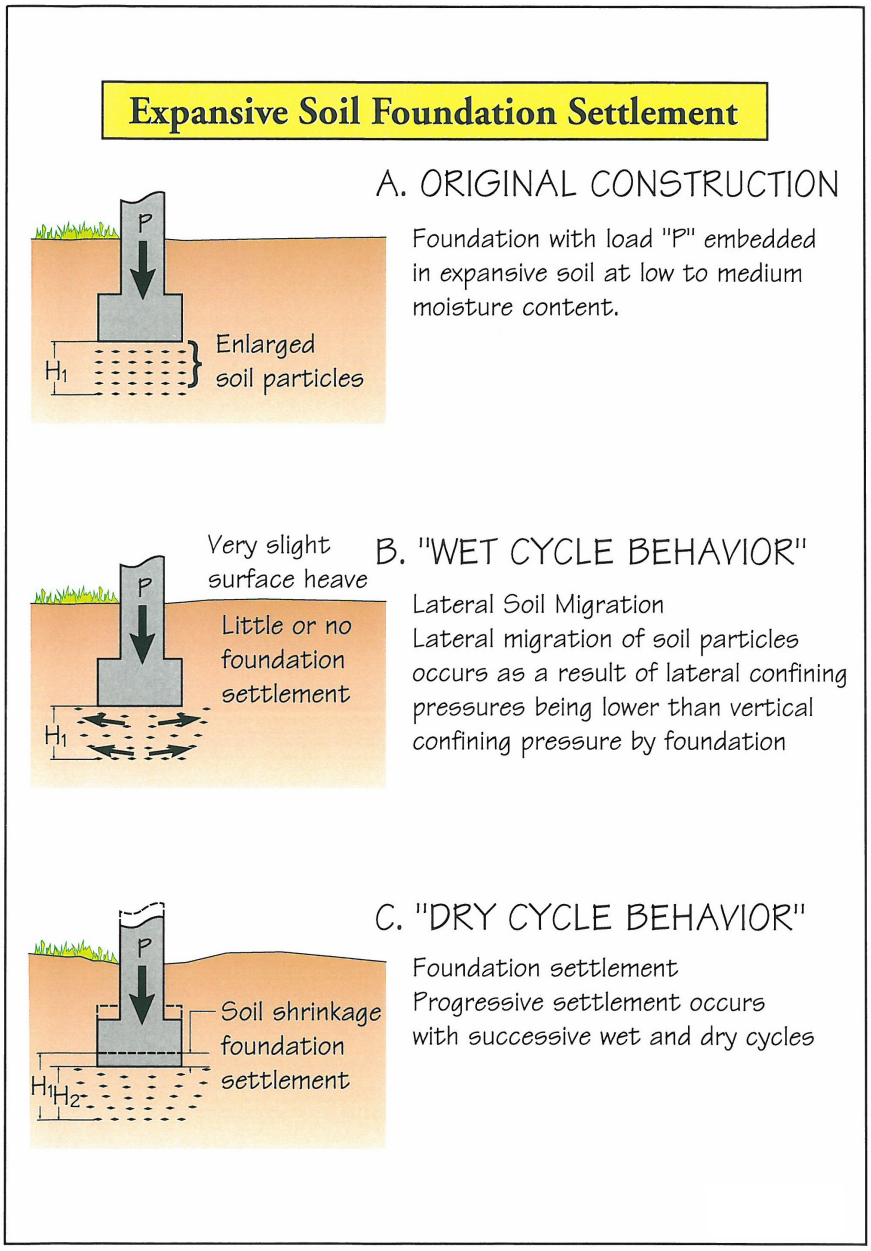

Figure 1: Wet/Dry Cycle on Raised Perimeter Foundations

Expansive Soil and Slab on Grade Foundations

The behavior of a slab on grade foundations in expansive soil conditions is significantly different from a raised perimeter foundation. In the earlier stages of the dwellings life, the edges of the slab a pushed upward due to the forces of the expansive soils. This is particularly true in older designs that may be of relatively uniform thickness with little or no perimeter footings. Older post-tensioned slabs may also exhibit significant edge lift due the combination of the upward push of the expansive soils combined with the pull on the edges from the tensioned cables.

Unrestrained slabs will “walk” or move on the soil. Movement can often be seen where the foundation abuts driveways, masonry/concrete stairs, etc. In areas, you may see gaps develop where the foundation and flatwork drift apart. In other areas the driveway may move vertically as the as they move together.

As the soil passes through repetitive wet/dry cycles, moisture tends to accumulate at the center of the slab causing the center of the slab to rise. The same wet/dry cycle action occurs at the edges as is found a raised perimeter foundation. That causes the slab perimeter to drop over time. The combination of forces causes the crowning we often see in failed slab foundations. See the figure below.

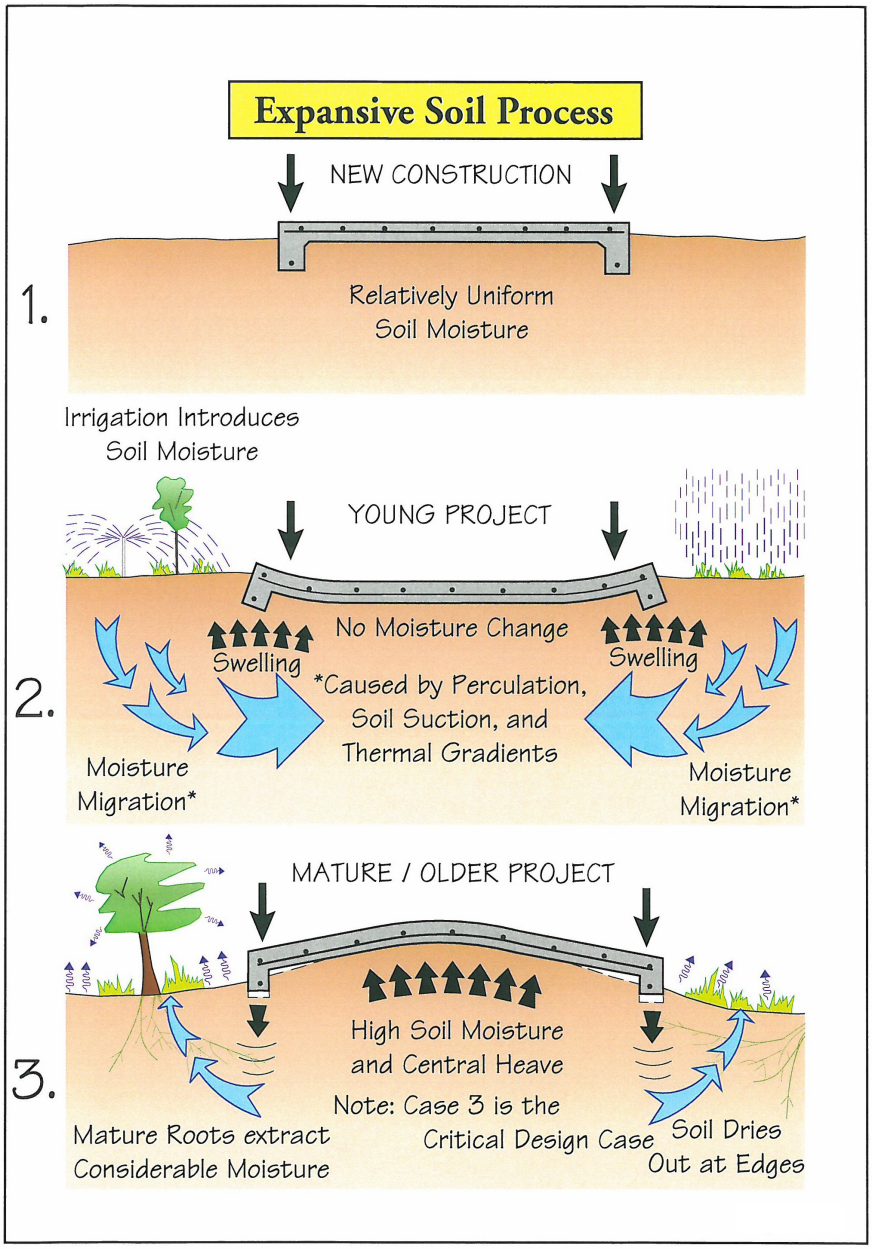

Figure 2: Slab On Grade Expansive Soil Cycle

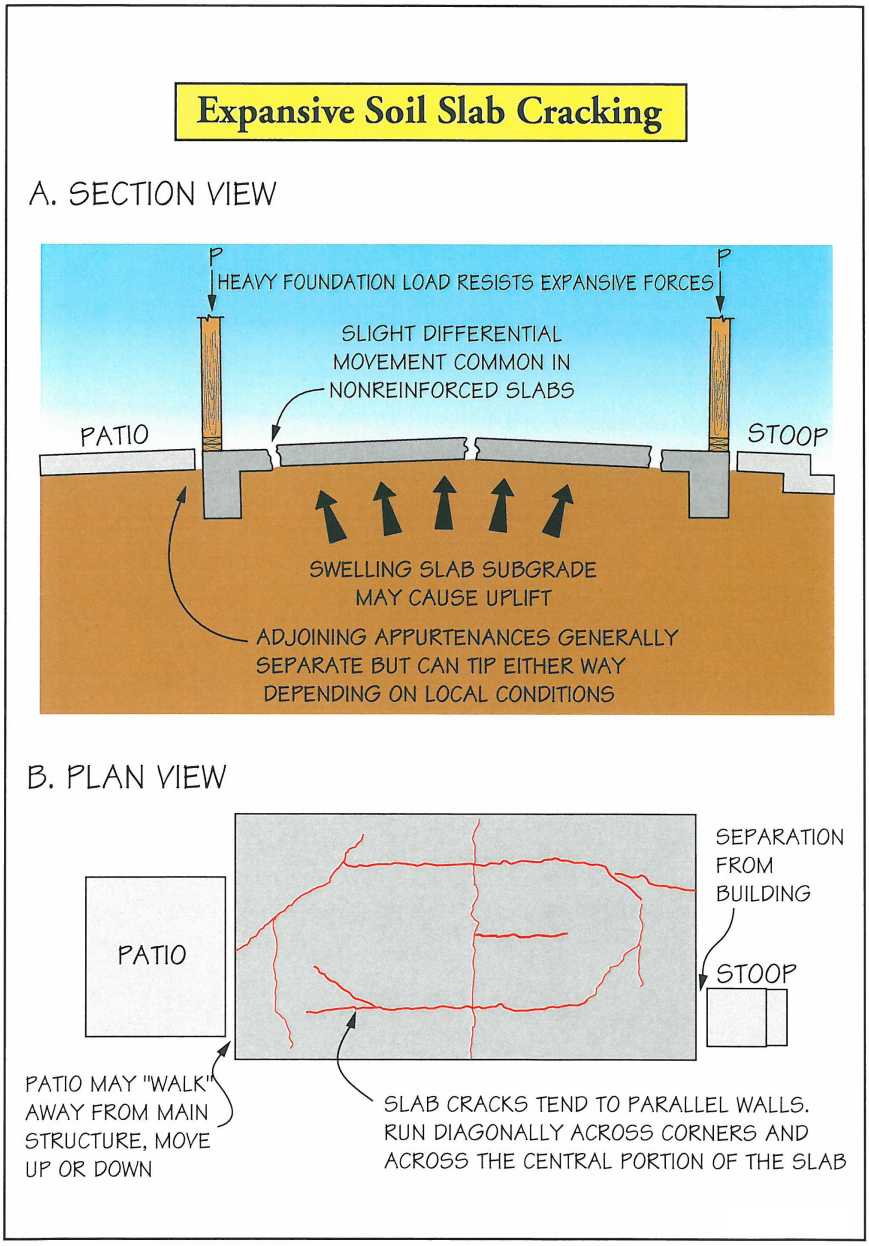

Figure 3: Slab On Grade Cracking

Site Vegetation and Expansive Soil

When inspectors see trees adjacent to a foundation, we automatically start looking for indications of distress from tree roots. In expansive soil conditions, there can be other issues caused by trees and site vegetation. All landscaping requires water to survive. The primary job of the root system is to find nutrients and water to feed the tree or shrub. During a wet cycle, there is enough water to both supply the tree and allow the soil to expand. What happens during a dry cycle? The tree roots extract as much water as is possible from the soil. This results in the area within the tree root zone being dried out more than areas where there are no trees or vegetation. This can result in uneven or

differential movement in the soil. The long-term impact on the structure is that the dwelling may "tip" or "lean" towards the trees or areas with heavy water requirement vegetation. In older dwellings, it would not be uncommon to find the low point in the dwelling being the area closest to the large yard tree. In general, to minimize the risk of root damage to the foundation, arborists would like the tree to be 8-10 times the potential maximum trunk diameter from the foundation. However, to avoid root water impact issues, the tree would need to be much further away. Significant water seeking roots may extend out a distance equal to the tree height. See the Figure 4 below.

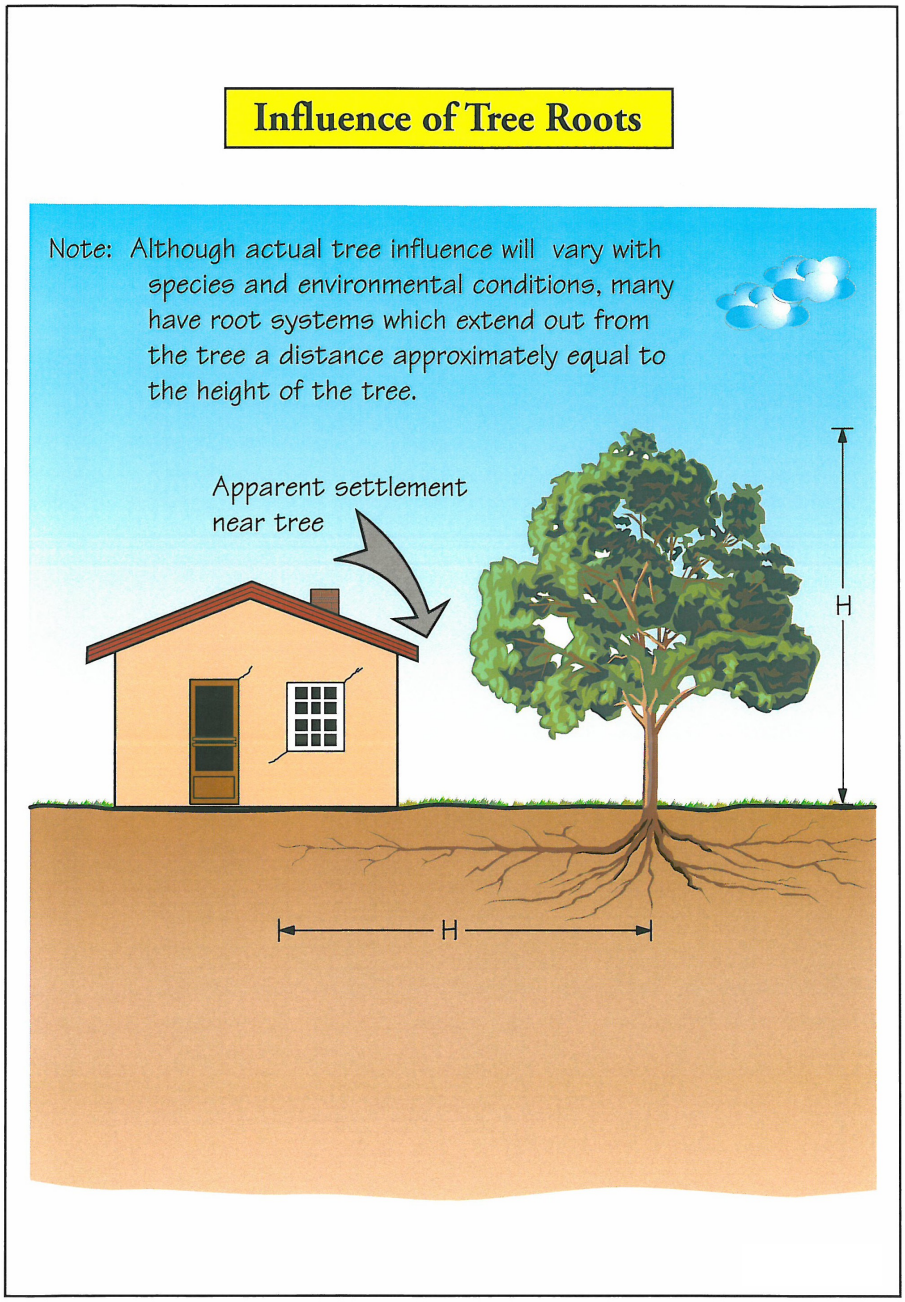

Figure 4: Tree Impact on Dwellings with Expansive Soils

Cracking in Exterior Stucco

In expansive soil areas, the exterior stucco walls can provide important clues as to the building performance. We see cracks in stucco everyday. In doing so, it is easy to assume that the cracks have little significance and essentially become blind to them. Certainly, some stucco cracking may be the result of seasonal/differential movement in the wood framing. Longer cracks, especially ones that are diagonal, may point to foundation movement and warrant further investigation. The size of the crack may not be an absolute indicator as to severity. If you have a dwelling with stucco facade that has a single 3/8" crack running at a 45 degree angle at one area and a series of 10 - 1/16" cracks elsewhere, which may have more significant issues? See Figure 5 below.

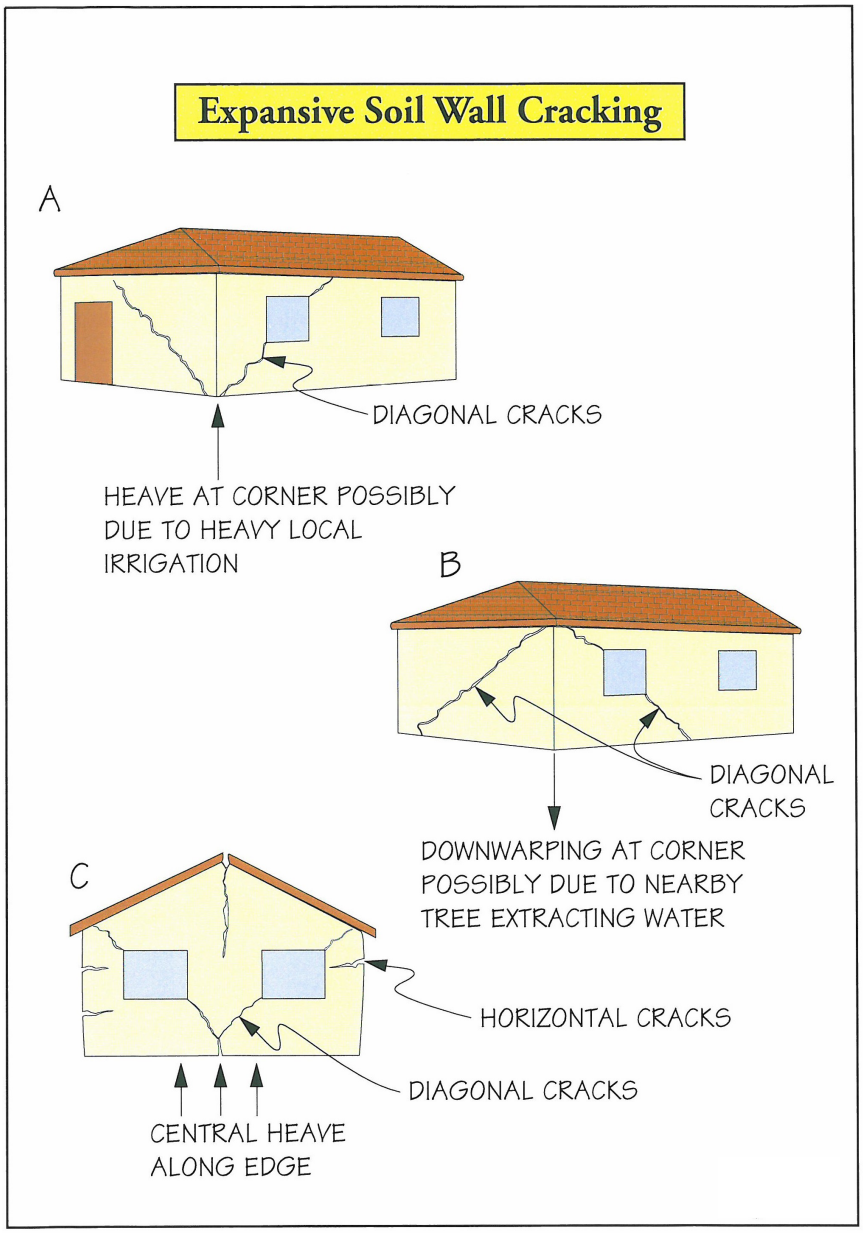

Figure 5: Stucco Cracks and Soil Movement

Soil Settlement

Other types of soil related damage can also occur and should not be confused with the damage from expansive soil. Damage due to soil settlement is a very different issue from that of expansive soil. All types of soil are compressible to one extent or another. Settlement is most pronounced in soil that is inadequately consolidated. Load placed on the soil, such as the weight of the soil itself, a structure, etc. can cause unconsolidated soils to compress. Compression can be exacerbated by water, which can cause the soil particles to loose their bond and consolidate further

Settlement in a dwelling often occurs when the foundation is constructed on unconsolidated soils. Essentially, the soil has "holes" in it. As time passes, the soil particles work closer together. As the soil particles force themselves closer together, the soil becomes more and more dense. As this soil compaction occurs, the foundation will settle with it. Soil compaction results in downward displacement of the dwelling. Settlement is often seen in areas constructed on unconsolidated fill as well as areas with significant amounts of organic debris intermingled with the soil. As long as the settlement is relatively uniform, the structure may actually perform quite well. Settlement can become an issue when the soil is not uniform, such as in cut and fill sites. Any dwelling that straddles an undisturbed soil zone and fill area may see dramatic differential movement.

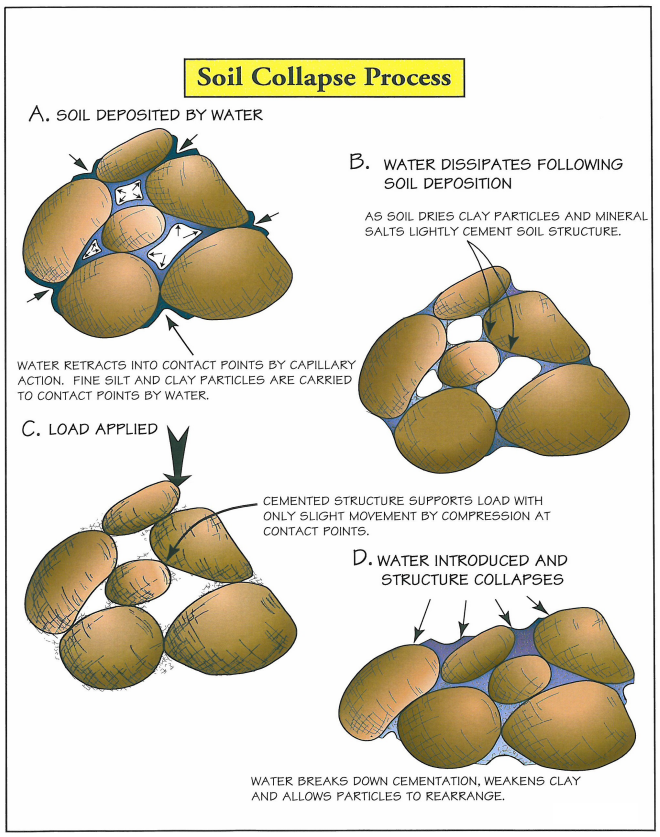

Figure 4: Soil Collapse Process

Soil damage from settlement occurs very differently from that of expansive soils. In improperly compacted soil, we would expect to see ***most*** of the settlement occur early in the building lifecycle. As time progresses, the soil becomes more and more dense. ***The building displacement will in fact decrease over time as the soils become moreand more dense. Finally, the soil will reach a point where it is sufficiently consolidated and then displacement stops.***

There are several basic forms of soil settlement; differential, uniform and transitional.

With differential settlement, the soil is all inadequately consolidated, but in a non-uniform fashion. We may see a dwelling that appears tipped out of level or where the displacement is uneven. This may be the result of the soils compacting at different rates or to different degrees. The damage potential in differential settlement areas would be classified as Intermediate. ***See Case 1 below***.

Where the soils are inadequately but uniformly unconsolidated, we may see the whole dwelling sink with little to no evidence of displacement. If a dwelling sinks uniformly, it may be displaced 6", 12" or more and still have no cracks in the foundation, doors and windows open and close properly. The occupants may be unaware of the displacement and may have no real complaints. There are some properties in my area with bay-fill. The dwellings are built on piers that were engineered for the soil conditions. However, the exterior flatwork, stairs, sewer/water pipe connections were not. In some cases, we see 6"-12" displacement at the exterior stairs. Sewer and water pipes can break due to the stress imposed at the joint between the dwelling and the settled perimeter soil. However, the damage potential to the structure itself in areas with uniformly unconsolidated soils would be classified as Low. ***See Case 2 below***.

In areas where the dwelling bridges a consolidated and unconsolidated soil zone the damage potential is generally highest. In transition zones, a portion of the dwelling does not want to move; the other areas show downward displacement. An example of this might be a cut and fill lot. In a transition zone, even relatively small amounts of displacement can create significant cracks in the foundation; doors and windows operation may be noticeably impacted. This can result in the occupants being very aware of even smaller displacement issues. The damage potential to the structure in a transition zone would be classified as High. ***See Case 3 below***.

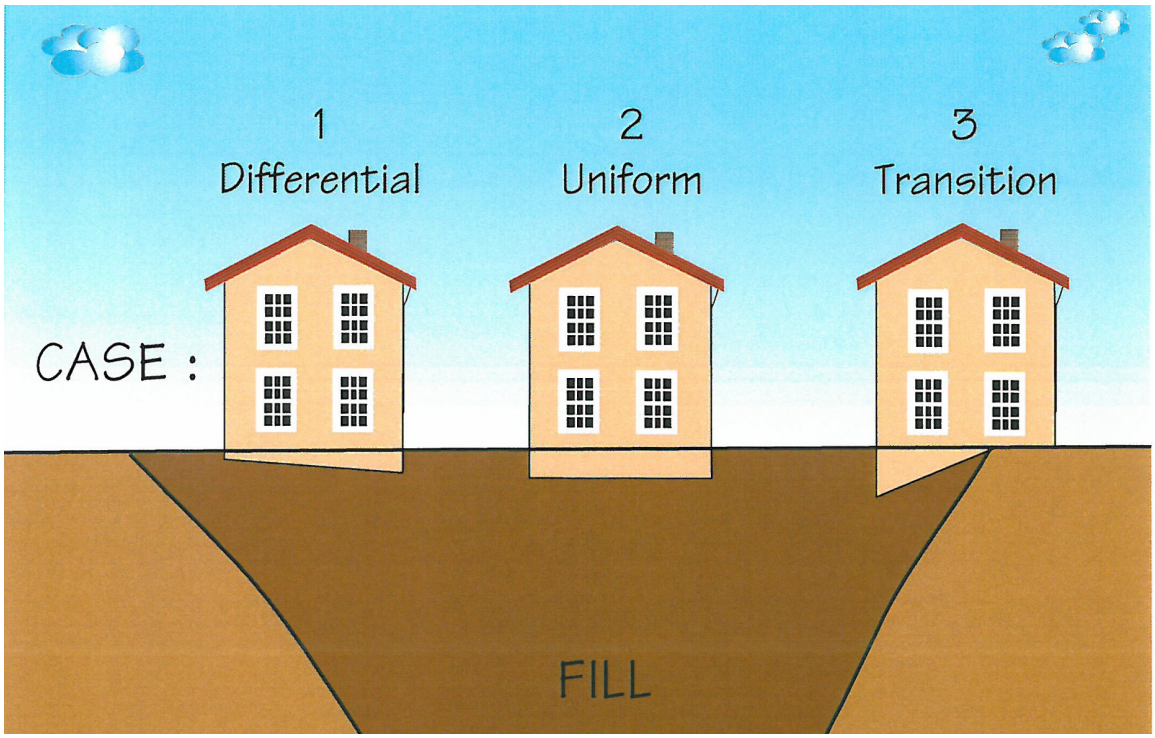

Figure 5: Settlement Examples: Differential/Uniform/Transition

The World Isn't Black and White

Unfortunately, the world we inspect in is far from uniform. There are few dwellings built on sites that are completely one type or the other. Rather, the conditions we observe will most likely be the result of different soil types, conditions all interacting in various ways. It is a virtual tug-of-war on the dwelling, if you will.

What Does This All Mean?

I am always trying to learn as much possible about a given area of our profession. The more I learn, the more I realize how little I actually know. As general property inspectors operating within the context of the Standards of Practice, we are generalists. There are a very few of us that are qualified on one specialty or another. Most of us, me included, are not.

CREIA is fortunate to have people like Abe Simantob, PE, GE, CCI as members. Abe is a frequent contributor on the CREIA Technical Information Exchange and a great resource to all CREIA members. CREIA is also lucky to have inspectors such as Gary Sniffin, CCI with his civil/structural background.

If we listen carefully, the dwelling will tell us its story. We need only be diligent observers. If we pay attention to the signs, the dwelling will make the call for us.

Special Thanks:

I am appreciative of the assistance **Greg Axton** from **American Geotechnical, Inc** gave in the researching this article. The figures used were reproduced with permission from "***The Plain English Guide to Soil Problems***", an American Geotechnical, Inc publication. Contact information for American Geotechnical and Greg can be found at www.amgt.com. A copy of this document is available for free download online at my website, www.PropertyEvaluation.net under the *Reference Information* tab.

To **Abe Simantob** at **L.A. Private Eyes Engineers/Prestige Engineering Inc** for always being there to answer and educate his fellow CREIA inspectors on the TIE.

Photo/Figure Credits:

Expansive Soils Photos 1 & 2 from "*DAMAGE TO FOUNDATIONS FROM EXPANSIVE SOILS*" by J. David Rogers, Robert Olshansky, and Robert B. Rogers
Figures Courtesy American Geotechnical, Yorba Linda, CA

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Skip Walker lives in the SF Bay Area and has performed over 2,200 paid inspections since becoming a CREIA member in 2003. Skip is both a CREIA Master Inspector and an ASHI Certified Inspector. Skip is an ICC Certified Residential Combination Building Inspector and an F.I.R.E. Certified Inspector. Skip is the education chair for the Silicon Valley ASHI/CREIA Chapter and the CREIA Region 3 Director. He also holds a California Real Estate Appraisal Trainee License. Skip may be reached at HomeInspection@sanbrunocable.com.