CONCRETE PROBLEMS WITH DESERT SOILS

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Introduction

Increased population growth in the Las Vegas Valley over the last two decades has fueled large-scale residential construction. Almost all of these structures built during this time have concrete foundations. Although most of these concrete foundations will last for an indefinite period of time without major problems, others have already begun to show outward signs of deterioration in the form of cracked and heaved walls and footings, deterioration of sidewalks and driveways and foundations. Many of these problems could be minimized if adequate testing and proper precautions were taken during planning and development stages and if some alterations in the irrigated landscape were made.

Some of these problems are:

- Upheaval of structures and subsequent cracking of walls and foundations due to soils expanding and contracting from the wetting and drying cycles.
- Rapid deterioration of concrete and metals due to salts.
- Development of cracks in concrete structures due to the collapse or subsidence of soils high in gypsum (Figure 1).
- Deterioration of concrete and stucco walls from irrigation water containing salts.

In the Las Vegas Valley, an additional problem exists since there is a shallow, saline aquifer below much of the central and southeastern parts of the valley. This shallow aquifer has resulted from the over-irrigation of landscapes. Excessive irrigation leads to extremely wet soils. This combined with the possibility of increased water and salts moving to the surface from the shallow aquifer, all contribute to the damage of concrete foundations and floorings.

Engineering solutions are currently in practice which address this problem, including over-excavation of expansive clay soils and replacement with non-expansive fill and the use of deepened or stiffened foundations. Special consideration is also recommended for landscaping such as the use of desert landscaping, which limits the application of water and subsequent shrinking and swelling of these soils and minimizing damage. Where construction has already occurred, removal of irrigated landscaping in close proximity to the structure’s foundation is also recommended.
Damage From Salts

Because of the low amount of natural precipitation in arid regions, saline soils are typical of these regions. The salts in our soils come from the normal weathering of minerals, the upward movement of shallow groundwater containing soluble salts and from the water we use to irrigate. Some salts, such as those containing chlorides, sodium and sulfates, are more damaging to concrete structures than others. Although most soluble salts can be effectively removed or leached from the soil profile, other salts such as calcium carbonate are less soluble and not as easily removed. When these salts are present, it is best to leach these salts before construction or use soils for fill that are known to be low in salts (Figure 2).

Collapsing Soils

Collapsing soils damage structures through the removal of underlying support (Figure 1). This is due to the collapse of soils from the application of irrigation water. Collapsing soils can occur due to the presence of soil salts such as gypsum or poor strength when water is present (hydrocollapse).

Salts such as gypsum are extremely soluble in water and usually form in soils receiving very low precipitation. Prior to urbanization, the gypsiferous soils that formed in Las Vegas valley were safe from leaching due to our extremely low precipitation. Because turfgrass landscapes in the valley typically receive over 80 inches of irrigation per year, rapid solubilization of these crystals in the soil contribute to the eventual collapse of the soil’s structure. As these soils collapse, structures built on these soils lose their support and damage to walls, flooring and foundations appear as cracking.

Hydrocollapse is a phenomenon associated with some low density, fine textured soils located on the eastern edge of the valley. As these soil types become wet, they lose some of their binding properties and their structural strength. The best solution for both of these soils phenomena is to keep irrigations on these types of soils, particularly near structures, at a minimum. Desert-type landscaping with its typical low water application rates and frequencies can play a major role in slowing the collapse of these types of soils.

Gypsum Solubilization and Damage From Irrigation Water

In the majority of landscaping in the Las Vegas Valley, potable water is used for irrigation. This potable water originates primarily from the Colorado River. Colorado River water contains about a ton of salt per acre-foot of water (326,000 gallons). Tall fescue is typically irrigated in the 7 to 10-acre foot range. This means that 7 to 10 tons of salt are applied each year to one acre of tall fescue. In residential landscapes with a considerable amount of turfgrass this can translate to several hundred pounds of salt applied through the irrigation system per year. When water originating from the Colorado River is used in landscapes for irrigation, the salts contained in the water can cause damage to walls, sidewalks, driveways, streets, parking lot flooring and stucco exteriors on buildings (Figure 3).

Continued contact of this water on these surfaces can cause rapid deterioration. In addition, high water-use landscapes and over irrigation can cause soils containing salts in contact with the structural foundation to be continuously wet and potentially damaging. It is always best to limit the use of water and high water-use landscapes near foundations, walls, sidewalks, driveways, patios, parking areas and surface streets. In sandy soils, keep irrigation emitters and spray heads at least two feet away from these structures. In heavier soils like clays and silts, keep these emitters a minimum of five feet away. Keep spray heads directed away from block walls, stucco and foundations.
The Shallow, Saline Water Table

The floor of the Las Vegas valley slopes downward from the Northwest to the Southeast. This sloping drains the valley, both above and below ground, in the same direction. Subsurface water derived from over irrigation in the valley eventually drains into the Las Vegas Wash and ultimately Lake Mead.

Over the course of thousands of years, the Las Vegas Valley has gradually filled with soil derived from alluvium eroded from the adjacent mountain ranges. Clay and caliche layers have developed over time in most of the central and southeastern portions of the valley. These clay and caliche layers impede the natural downward movement of water resulting from over-irrigation. This has resulted in a perched shallow aquifer in the central and southeastern part of the valley. This perched shallow aquifer can cause serious problems to the stability and soundness of large structures that require deep footings to support their weight or are designed to have part of their structure located underground. Local hotels situated on top of this shallow aquifer are actively pumping subsurface water into the municipal sewer system in an attempt to keep this nuisance water from damaging or creating a hazard at their facility. At UNLV, the shallow aquifer beneath the swimming pool must be pumped continuously so that the pressure exerted by the rising water table would not force the pool out of the ground.

Not only has this water been a nuisance in the past but it also carries dissolved salts, potentially damaging to concrete and steel. These salts originate from irrigation water derived from the Colorado River and build to higher levels as the water is extracted by plant roots, water draining below the root zone is often ten times higher in salt concentration before entering the shallow aquifer.

Capillary rise from water tables, (water “wicking” upward), can be significant if the soil is high in silts and clays, if water evaporation at the soil surface is high and if the depth to the water table is less than 5 feet. If the water table is greater than ten feet and the soil is sandy in nature, it is doubtful that much water could move to the surface. Water “wicking” to the surface could carry significant amounts of salt that could potentially damage concrete and unprotected metals.

More recently as the price of potable water has risen dramatically, this nuisance water has actually become valuable. Research at the University of Nevada has demonstrated the usefulness of this water for irrigating plants, including turfgrass, that exhibit tolerance to this moderate level of salt.

Causes of Damage

Many factors are involved in the permeability of concrete to water. Although concrete appears to be solid, it is in fact a porous material. Outside of the movement of liquid water through large cracks, water can move through very small micro pores as a vapor. Vapor movement of water is driven by a vapor pressure gradient, a difference in water content between materials. Since an arid atmosphere typically has very low water vapor content, while irrigated soil typically has a saturated water vapor content, a steep vapor pressure gradient exists, and subsequent movement of water vapor can occur, bringing moisture into contact with foundations.

Water vapor in the soil always moves from warmer regions to colder regions. Thus it would move downward during the day and upward during the night and it would tend to move into the cooler soil under foundations. Although salts are not transported in the vapor state, capillary rise of water from the shallow aquifer and applied irrigation water could transport significant amounts of salt to the vicinity of concrete structures. If there were no significant leaching then this salt transported upward via capillary action would build up in the soil profile increasing salt related problems.
Although it is relatively resistant to most types of corrosion, concrete and reinforced concrete and uncoated steel are susceptible to relatively rapid deterioration under certain conditions. Chemical attack on concrete in desert soils is likely to occur because of the presence of high sulfates or, in some cases, high chlorides. This is even true of concrete made of sulfate resistant cements such as Type V. Sulfate resistant cements give the concrete a greater longevity but under extremely high soil sulfate levels, as we have in parts of our valley, even concrete made with resistant cement will corrode with time. Sulfate damage occurs most often to concrete structures partially buried. Capillary action and surface evaporation work together to buildup sulfate levels in contact with the concrete. This does not generally occur on concrete structures buried fully underground.

The movement of salts into and through the concrete foundation can damage flooring placed on top of concrete foundations. Typically the water and salts damage the flooring by attacking the adhesives that connect the flooring to the concrete. New adhesives are being developed but even the best on the market are still susceptible to damage from water and salt accumulation. Using a sealant on the concrete to reduce vapor contact with the adhesive may be beneficial. Care should also be taken in deciding what type of metal to use in the concrete for reinforcement and what types of metal framing should come into contact with the concrete foundation in damp, wet locations (Figure 4) Zinc, galvanized iron and aluminum have all been demonstrated to be much more prone to corrosion than copper and stainless steel.

**Recommendations**

- Site selection should include a complete evaluation of the soil for the presence of high levels of salts, presence of gypsum, caliche, depth to water table, chemical composition of groundwater and the presence of expansive clays.
- If soils are high in sulfates, a sulfate-resistant cement should be selected. Sulfate resistance does not guarantee that damage will not eventually occur. The concrete should have the proper cement to water ratio and the concrete should be densely packed.
- Gravel layers and drain systems below foundations should be considered if water tables are shallow and significant vapor movement is possible.
- If water and vapor movement to the foundation are likely to occur, the use of a vapor barrier below the concrete foundation, and/or a sealant on top of the foundation, should be considered to help protect the flooring.
- All metal reinforcement and metal framing in contact with the concrete should be resistant to corrosion caused by high salts.
- All irrigations should be applied in parallel to the environmental demand. Contact your local *Extension Office for irrigation advice*.
- The installation of low water use landscapes is highly recommended in those areas subject to subsidence due to high sulfates or expansion due to high shrink-swell clays.

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