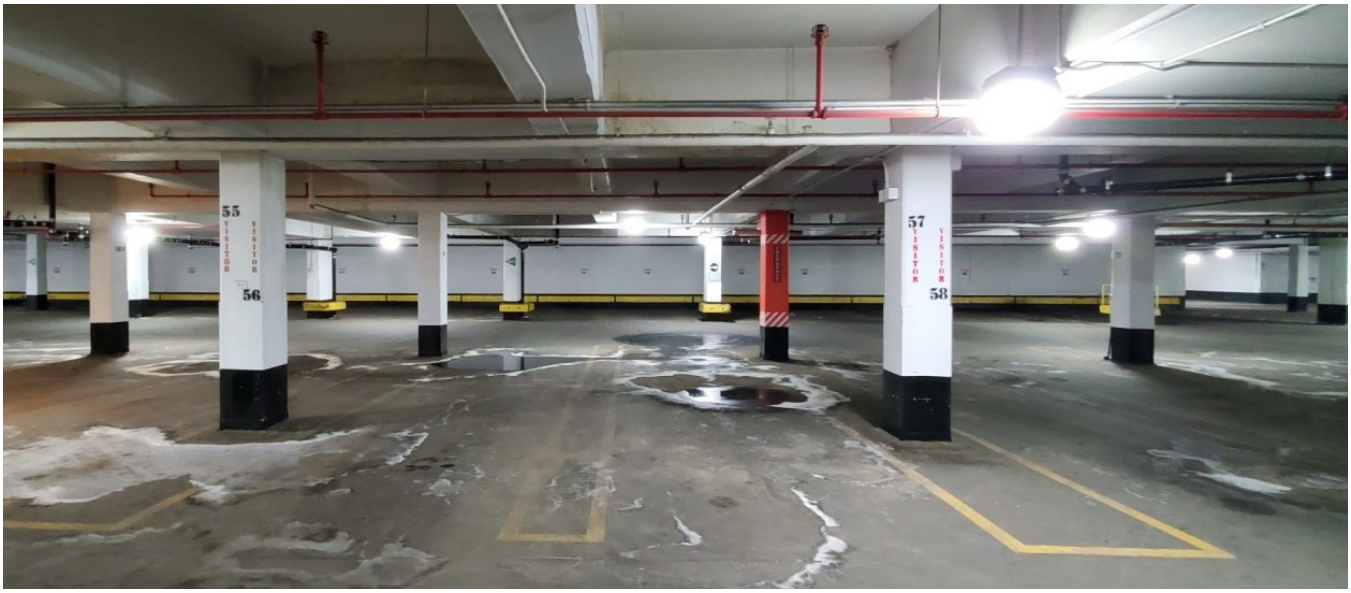
Reconstruction of an Underground Parking Garage Concrete Slab on Grade



The parking garage before the weeping tile system was replaced. Photos in this spread courtesy of Emma Ruixian Qian.

By Emma Ruixian Qian, Architectural Technologist, WZMH Architects

A great deal of research has been done to analyze the age-old problem of deterioration of underground parking garage concrete slabs on grade. The symptoms of a weeping tile drainage problem can often be elusive and difficult to uncover, as they are located underneath the concrete slab and buried in soil. Many issues go undetected for years, only becoming obvious when the concrete slab develops efflorescence or when mould and other microbial contamination problems appear. By knowing and understanding the source of water and its movement mechanism, effective solutions can be developed to eliminate or slow down moisture movement.

In this case study, we were called to address the issues in an old underground parking garage. The old, clay weeping tile drainage system had stopped working and caused water problems. The blocked drainage system was a major concern that had to be addressed immediately. Once weeping pipes were blocked, the water table rose; the sand layer beneath the concrete slab became a reservoir for water, which created hydrostatic pressure. As a result, there was no way for the water to drain or evaporate properly. It is well-known that moisture will always move from a high relative humidity environment to a space of low relative humidity. So, the only direction the moisture could move from below the concrete slab was up onto the surface, which inevitably led to water damage and deterioration of the slab.

ISSUES AND PROBLEMS

Water moisture can cause a variety of problems, like efflorescence, the white, crystalline substance that can occur on the surfaces of unsealed concrete. These deposits often contain compounds such as calcium, sodium, and potassium hydroxides or carbonates, bicarbonates, chlorides, and sulfates of calcium and magnesium. These substances typically originate as soluble compounds within the concrete that are transported and deposited on the surface by upward moisture migration and evaporation. Water is the solvent and vehicle for transporting the soluble salts to the surface. Efflorescence can form a thick layer on the surface that can completely hide the concrete's colour, create unsightly white patches, and degrade the slab strength.

Deterioration can be found anywhere on the concrete slab, especially around cracks. Cracks at concrete joints are easily caused by higher water pressure, sealant, and vapour barrier damaging. Once cracked, the concrete can be separated at the joints and water or moisture may enter. A hairline crack can grow into a bigger problem, resulting in floor slab failures, mould growth, efflorescence, and other microbial contamination problems.

Due to concrete's porosity and permeability, water can migrate through the material as a result of hydrostatic pressure, capillary action, and the water vapour pressure gradient. The penetration or water can be accompanied by the leaching of chemicals from the underside footing soil or the

The previous metal drain here is corroded, which left standing water on the surface.

Another sign of water damage and deterioration is efflorescence, an often-white powdery substance that appears on the slab's surface.

materials used in the concrete mix. As the water and chemicals permeate the concrete, it can begin to disintegrate, and the rebar within the slab or steel core column within concrete cladding can start to corrode. As this happens, the steel expands and creates tensile stresses that can cause internal cracking, spalling, or delamination of concrete. One problem may be caused by numerous factors.

RECONSTRUCTING CONCRETE SLAB AND WEEPING TILES

After a site inspection, it became clear the existing clay weeping tile drainage system was unsuitable for the existing building system. We selected a polyvinyl chloride (PVC) tile to replace the existing clay weeping tile, and kept as many of the existing weeping holes as possible within the concrete foundation wall to maintain the structure's strength and reduce reconstruction labour. We used high-performance, galvanized steel in the trench system to allow for easy draining, should the system become clogged, and we installed drains throughout the slab to allow water to drain more easily.

NEW PVC WEEPING TILE

Many of the earliest plumbing systems were comprised of clay sewer pipes, which still hold up against the test of time—if they remain unplugged and uncracked. While they are made of green materials, these pipes can have serious drawbacks that make them inappropriate for many applications. Modern PVC pipe, on the other hand, has many advantages, including the following:

- It is much easier to make holes in and is also quite malleable. The pipes also connect easily and securely to one another;
- It is lightweight, making it easy to transport; and
- It has high tensile strength and high compressive strength, allowing the pipes to endure abuse from extreme environments.

CONCRETE SLABS

Concrete slabs can crack due to many factors, including construction movement, shrinkage before and / or after hardening, excessive loading, settlement, freeze / thaw cycles, structural defects, fluctuations in temperature, earthquakes, and more. Some cracks are preventable; others aren't. But

all cracks can become problems. To prevent initial cracks, the concrete itself must be mixed properly. If the water-to-cement ratio is too high, the slab will be too porous, leading to issues with bleed water, plastic shrinkage cracking, and primary efflorescence, increasing the chance cracks may occur. Once a slab has cracked, moisture may enter and cause corrosion along the concrete reinforcement, so, in this case, we used an epoxy-coated rebar to protect against corroding. Additionally, if a concrete slab is properly waterproofed, it will better maintain its integrity.

HIGH-PERFORMANCE VAPOUR BARRIER

If a concrete slab is properly waterproofed, it will reduce the occurrence of water-related problems. The longer it remains properly waterproofed, the longer the slab will maintain its integrity, and the longer you will go without water damage, which is why installing proper vapour barriers is essential.

Once a good vapour barrier is installed beneath the concrete slab, it will help stop water from rising and will prevent any other volatile organic compound contaminated gas from rising into the building. This will then contribute to an energy-efficient build; it will mean less work for your ventilation system and a better moisture-protected and thermal-protected building overall—a reason most green building codes include high-performance vapour barriers in their specifications. Presently, there is no cost-effective way to protect the building from encroaching moisture; however, over time, if you do the job properly the first time, it will save you money over the long-term.

The installation detail at the joint is also very important for proper protection, as these gaps allow moisture to seep in more readily than the solid slab. The vapour barrier must be looped at the joint to allow for the movement of concrete, while still sealing the gap *at the bottom of the joint,* ensuring no moisture gets into it. This typical detail also is applied around the re-finishing concrete-steel column and at other construction joints.

SAND MAT AND CRUSHED STONE

A sand mat layer must be installed below the vapour barrier to prevent the sand from becoming a water reservoir. This also provides a smooth surface, upon which the concrete slab and vapour barrier can be installed. Water drains faster through gravel than it does through most types of soil, so if you have a layer of gravel atop the earth, with the weeping tile installed within this layer, it will provide a pathway for water to flow easily away from underneath the slab.

With this new drainage system and slab assembly, the risk of creating a water reservoir was eliminated, even if the groundwater table rises at any time during reconstruction. If any problems do occur, like cracks in the slab, or tears in the vapour barrier, there won't be a water reservoir present to cause water damage. Even so, don't ignore these issues if they arise!

The new, dependable drainage system will provide long-lasting control of the ground water and water table, relief on the hydrostatic pressure, and retarding water moisture transmission, which will go a long way toward preventing moisture problems in the parking garage. ■

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