The annual World of Concrete Expo that will be held in Las Vegas, Nevada in early February provides us with an opportunity to re-examine the relationship between waterproofing and concrete and provide further explanation of why waterproofing is required for concrete.

Waterproofing is required at below-grade concrete surfaces for several reasons. The primary reason is to keep moisture from intruding into the facility. However, it is also required to protect the structural contents from water infiltration that can cause structural damage to the concrete or corrosion to the imbedded steel. Concrete is by design a porous material and water can pass through it by hydrostatic pressure, water vapor gradient or capillary action. Water can also enter at cracks, structural defects or at improperly designed or installed joints. Waterproofing is also required to eliminate deterioration to the concrete that can occur from exterior and interior chemicals that are present at the building site.

**Susceptibility of Concrete to Chemicals**

Concrete is vulnerable to chemicals due to three of its primary composition characteristics: permeability, alkalinity, and reactivity. Permeability to liquids and gasses varies considerably with different concretes. Even the best concrete has some small degree of permeability. Permeability increases rapidly with increasing water-cement ratio and with decreasing moisture-curing time. Penetration of fluids into the concrete is sometimes accompanied by chemical reactions with cement, aggregates, and/or embedded steel if it is present. Leaching of cement hydration compounds, or deposition of extraneous crystals or crystalline reaction products can also degrade the system.

The alkaline, hydrated Portland cement binder reacts with acidic substances. This reaction is usually accompanied by the formation and removal of soluble reaction products, resulting in disintegration of the concrete. When the reaction products are insoluble, deposits are formed on the concrete surface or in the concrete causing a considerably reduced reaction rate. Usually the rate of attack will be increased by an increase in the concentration of aggressive agents in the solution.

The solutions can be alkaline, neutral, or acidic based on the pH factor of the solution. Neutral solutions have a pH of 7. Acid solutions have pH values less than 7 and alkaline ones have values over 7. When the pH factor decreases from 7, the solution becomes more acidic and it will become more aggressive in its attack on concrete.
The chemical agents physical state is also important. Dry solids do not attack dry concrete, however, it may attack a moist concrete. A moist, reactive solid can attack concrete in a similar fashion to an aggressive liquid or solution. Dry gases, if they are aggressive, may come into contact with sufficient moisture within the concrete to make the attack possible. Moist, aggressive gases tend to be more destructive.

Alternate wetting and drying can be harmful to the concrete structure and can result in destruction due to alkali – aggressive reaction. This occurs when the dissolved substances migrate through the concrete and deposit at or near a surface where evaporation occurs. The deposit that results may be the original substance or it may be some reaction that is formed in the concrete. The effected result is efflorescence that is seen on the concrete walls, brick or stone.

Salt solutions can be more destructive to concrete through freeze and thaw cycles than water alone. Damage from water or salt solutions can be minimized by an adequate amount of intentionally entrained air in the concrete. This will allow high quality concrete to produce air bubbles of the correct size, spacing, and distribution.

There are several chemicals that are destructive to concrete. These types of chemicals are often located in the soil or surrounding areas of a below grade structure. It is the designer’s responsibility to have a proper chemical analysis of the soil conducted prior to design of the waterproofing system. The chemicals present may also be harmful to the waterproofing barrier. Some of the more destructive chemicals to concrete are acid waters, aluminum chloride, aluminum sulfate, ammonia vapors, ammonium sulfate, ammonium chloride, ferric sulfide and ferrous sulfate, which all can disintegrate concrete and attack the steel.

In addition to chemical attacks from organic and mineral acids, certain acid containing or acid producing substances such as acidic industrial wastes, silage, fruit juices, sour milk, weak based salts and some untreated waters may also cause deterioration of concrete. Ammonium salts and animal wastes can also oxidize and attack the concrete producing some deterioration. Many agents attack concrete and destructively alter its chemical composition by means of reaction mechanisms that are only partially or incompletely understood. Seawater, perhaps largely because of its sulfate content, may be destructive to permeable concretes or those made with cement having a high tricalcium aluminate content. The deterioration typically occurs from leaching of dissolving calcium from the concrete.
Not all chemicals are harmful to concrete. Among the common neutral salts that do not attack concrete are most carbonates and nitrates, some chlorides, fluorides, and silicates. Limewater is usually beneficial to concrete because it promotes hydration without removal of lime from the concrete. Other weak alkaline solutions are not usually harmful. Products derived from petroleum, when free of fatty oil additives or other potentially acidic materials are normally harmless to mature concrete. Some of these materials can cause undesirable discoloration.

**Cracks, Openings and Points of Infiltration**

Waterproofing is required at concrete structures to keep moisture out of the facility and to protect the structural components of concrete and imbedded reinforcing steel. If the integrity of the concrete is maintained it can remain waterproof. However, concrete can crack before and after hardening and all of these cracks become openings that are susceptible to moisture infiltration. Prior to hardening concrete can crack from construction movement, plastic or drying shrinkage or from early frost damage. Concrete can crack after hardening from settlement, seismic forces, vibration, creep, excessive loading or deflection from soil movement.

In addition to being a porous material, concrete is susceptible to moisture infiltration at a number of locations. Points of moisture infiltration include all concrete joints; control joints or expansion joints. Openings can also occur at tie rod holes, penetrations and structural connections. Internal drains are also entry points for moisture intrusion.

There is always a debate regarding positive side versus negative side waterproofing. When considering this decision one should always remember that it is the responsibility of waterproofing to protect the structure. This cannot be accomplished with negative side waterproofing. To be effective, waterproofing should always be applied to the positive hydrostatic pressure side of the structure. The installation of any system on the negative hydrostatic pressure side is to take the risk of the waterproofing system being pushed off or disbanded by moisture infiltrating the concrete in either vapor or liquid form. Waterproofing of the negative side of the structure also tends to bring any contaminants present in the ground moisture into the concrete mass.
**Treatment of Concrete Surface Defects**

An important factor affecting the performance of waterproofing systems is the quality of the concrete surface. A smooth surface essentially free of honeycombs, depressions, fins, holes, humps, dust, dirt, oils, and other surface contaminants is necessary to provide continuous support to the waterproofing material and good adhesion between the membrane and the substrate. Water pressure acting on unsupported material may cause it to extrude, deform and eventually rupture. Good adhesion between the concrete surface and the waterproofing membrane is also essential to prevent water migration and leakage if there are any openings or imperfections in the membrane or concrete surface. Form coatings or release agents and concrete curing membranes could interfere with the development of good adhesion and should be removed prior to the waterproofing application.

The designer should specify proper substrate preparation in the concrete division of the specifications. Separate trades typically complete concrete placement and waterproofing application and this can create confusion and problems. Particularly in what is considered proper concrete preparation and whose responsibility it is to perform the repairs required for the waterproofing application.

The designer can eliminate these issues by providing language stating that concrete placement and repair be completed in accordance with ASTM D 5925. This is an excellent reference guide that contains a list of remediation measures for identifying and repairing fins, bug holes, form kick-outs and similar surfaces that are unsuitable for the application of waterproofing. Reference to this standard in the Concrete Section and Waterproofing Section will eliminate potential problems during the project. The designer should also require that the waterproofing contractor approve the surface in writing prior to installation.

Specific issues that must be addressed in the design specifications include concrete repair after form removal and removal and repair of any surface defects that occur during construction. Precast concrete is normally produced in a shop operation. Sharp offsets between precast sections should be corrected as indicated for new cast-in-place concrete. Surface defects, including tie holes should be repaired immediately after the forms have been removed.
All honeycombed and defective concrete areas should be removed down to sound concrete. If chipping is necessary, the edges should be perpendicular to the surface or slightly undercut. No featheredges should be permitted. The area to be patched and a surrounding band of approximately six (6) inches should be dampened to prevent absorption of water from the patching mortar. A bonding grout or bond coat should be prepared using a mix of approximately one part cement to one part fine sand that is mixed to a consistency of a thick cream. The mix should be evenly brushed into the surface.

Fins, protrusions or similar irregularities projecting from the concrete surface should be removed back to the surface by chipping, hammering or wire brushing. Care should be exercised to obtain a reasonably planar surface for application of the waterproofing membrane system. Sharp offsets in the surface, such as those caused by formwork misalignment, should be mechanically abraded to provide gradual and smooth transitions between the offset surfaces. Some waterproofing systems do not require all concrete surfaces to be within the same plane as long as the transitions are gradual and smooth. The waterproofing manufacturer should be contacted for specific requirements in these cases.

Tie rod holes should be thoroughly cleaned out and dampened prior to complete fill with a proper patching material.

**Concrete Surface Preparation**

An important step toward achieving adequate bond strength is to pay careful attention to the preparation of the surfaces that are to receive the waterproofing materials. Proper waterproofing performance depends on good surface preparation. The concrete surface must not be contaminated by chemicals that can have an adverse effect on the adhesion properties of the waterproofing membrane to the concrete surface. The surfaces must be newly exposed concrete that is free of loose, weak or unsound materials. Concrete surfaces should be generally dry, however, some waterproofing membrane manufacturers allow the placement of their materials over damp concrete surfaces. The waterproofing manufacturer should be contacted for specific requirements in these cases. Care must be taken to prevent moisture from collecting at the interface between the concrete and the waterproofing membrane during curing.
Prior to the application of the waterproofing membrane, testing should be completed to determine the adequacy of the surface preparation. The strength of the prepared concrete, as well as the ability of the membrane to adhere to the concrete, are two major items that must be checked prior to the project inception. The waterproofing manufacturers requirements and requirements of the American Concrete Institute and ASTM should be reviewed for recommended practices in these cases.

**Conclusion**

Concrete is susceptible to moisture infiltration and waterproofing is required in sensitive and occupied areas. This can be attested by the condition of concrete roads or driveways. The success of the waterproofing system will rely on proper concrete surface preparation. All concrete surface defects must be addressed in an acceptable manner prior to waterproofing application. As an architect, it is best to provide proper concrete surface guidelines in the initial design. This will eliminate conflict that can arise between the different trades that are typically involved in waterproofing applications. This will lead to success in one of the most difficult to design and highly litigated components of the building.