Often, concrete structures are designed for a very long service life but majority of the structures deteriorate very soon after construction due to various factors and reasons.

Waterproofing is an important but often neglected aspect of the construction process. It is important to get waterproofing right as leakages can be very damaging, to both structure and occupants. Waterproofing does not begin only when construction has started. Right from project initiation, effective waterproofing system has to be considered. Taking the full project life cycle approach requires consideration of the appropriate waterproofing system, from design to implementation, as well as remediation in the event of failure.

Waterproofing below-grade building elements is critical to keeping a facility watertight. While there are many excellent systems in the marketplace that can be specified and installed, the key point to success is understanding the benefits and limitations for any particular system. Proper design and inspection is well worth the effort, especially considering the cost of excavating and replacing a failed system.

Waterproofing is a system, not a product. As such, when designing and installing a waterproofing system for a structure, one must consider the performance and quality of the primary waterproofing membrane as well as of the accessory products that support it. Often, these attributes affect the most critical areas, such as penetrations, terminations and transitions. A system with accessories that are not only installer-friendly, thus increasing the likelihood for a successful installation, but that will also stand up to the test of time is most preferred choice.

Most of the below ground structures, whether tunnel or basement, generally require a tailor made solution to be designed on a project by project basis and the costs of producing such a system are relatively low in comparison with the overall construction costs. The benefits that can be achieved however are considerable.

The waterproofing system designed with membranes consists of various materials for sealing, draining and protecting whilst also facilitating inspection and repair possibilities both during and after construction. The correct laying or “installation” of the products by qualified agencies is essential and regular inspection and Quality Assurance is vital to ensure a fully functional system. Water and moisture penetration are a concern in any structure. The main problem is that almost all rock and soil contains water either draining from above (seepage) or penetrating from below. In some cases the water may be under considerable pressure. This water can come from a variety of sources: surface water will penetrate down into the ground, whilst broken pipes and sewers are an unexpected source of liquid. The watertable must be taken into account as should migrating water vapor. Underground streams and lakes often run below or past sites and Perched watertables can be a factor, whether naturally occurring or manmade. It must be assumed that all basements or tunnels will come into contact with water at some time during their life and therefore will all require an adequate waterproofing system.

While planning any underground structure it is necessary to design and keep the construction dry, not only for reliability...
and functionality of the building but also for safety reasons (speci-
cially for underground transport system and railway tunnel). It is imperative that water be kept away from the structure and the inner working area. This can only be achieved by incorporating an appropriate waterproofing system. The creation of an underground site should be undertaken with the appropriate involvement of experienced waterproofing companies and detailed engineering planning.

PVC Geo-membranes have proven track record in waterproofing of basements, tunnels, reservoirs and roof construction. PVC membranes are Heavy Duty, Long life cycle, Fire retardant, flexible systems. These are often loose laid systems but installed in such a way to restrict liquid migration from one area to another. PVC membranes are today widely used to prevent water ingress into below ground structures including being used as liners for tunnels and waterproofing for basements.

Advantages of PVC Geo-membranes (Chryso Armourflex) are:
- Long life expectancy
- Resistance to wash-out action
- High puncture resistance, elasticity, tensile strength, chemical resistance.
- PVC membranes can be welded to proprietary PVC surface water-stops.
- Loose laid to act independently of structural movement
- Resistance to root penetration
- Generally installed using automatic heat welding machines which ensures a perfect joint. Also, joints can be tested for any leakages during installation stage.

The main criteria for the correct design and execution of the flexible PVC sheet membrane waterproofing system against groundwater ingress in underground structures are:
- Type and purpose of the structure and its dimensions (length, width, depth, etc.)
- Condition of the substrate to be waterproofed
- Type and design of the retaining walls
- Piled foundations and the pile cap location
- Groundwater tables (max., min., average, immersion depth of structure) and condition of groundwater (aggressive water, salt water, polluted water)
- Requirements for single, or double-layer waterproofing system with vacuum control
- Level of waterproofing and its terminations
- Lowering of groundwater level during construction (sump pumping methods)

PVC membranes are installed using automatic heat welding machines which uses two pressure rolls which are independently motorized and advances the machines in determined speed along the lap. Temperature, pressure and speeds are adjusted before executing the final welding. The machines are completely electronically guided. The double welds created at each overlap, can be tested for any leakage by applying air pressure. Protection of geo-membrane against rough surfaces, sharp corners, debris is very important to avoid puncture and damages. The membrane is often protected by the installation of an additional protection membrane or second geo-textile.

Accessories: Geo-membranes are the most important part of a waterproofing system. To make it function in a correct way different accessories complete the whole system. All accessories have to be compatible with the used geo-membrane. Following accessories are part of such a system:
- Protection layer (geo-textile, plastic sheeting, ...)
- Fixation elements (laminated metal sheet, water stop, stainless metal plates, anchorage amongst others)
- Compartment and injection devices to be able to control and repair the waterproofing after pouring concrete (water stops, injection pipes, ...)

Compartmentalization

The waterproofing of tunnels or underground structures using PVC membranes is a loosely laid system. In case of leakage, water is able to enter between the membrane and concrete shell and will look for the weakest point of the concrete structure. Therefore, creating compartments become necessary in tunnels & underground structures with water pressure using suitable Water stops. The water stop divides the lining system into compartments which limits the spreading of the infiltrating water; in case of leakage. To limit the flow of water in case of leakage, the waterproofing membrane is divided into sections. Water stoppers are welded onto the membrane to compartmentalize the system at the location of the construction joints before the concrete is cast. In this way it is possible to prevent
water tracking from one compartment to the next. These water stops can also be placed at additional locations if so desired, to reduce the size of the compartments.

Construction Joints

Due to limitations of concrete placement and shrinkage of concrete during hardening process, construction joints can’t be avoided or eliminated. In all below grade constructions, effective treatment of construction joints is very essential and it becomes even more critical under high water table areas or areas where water table is likely to increase in coming future.

Use of cement injection grouting was very common for last few decades but now a days use of PVC water stoppers at construction joints has become very common. PVC Waterstops are used in concrete joints subjected to hydrostatic pressure. Embedded in concrete, PVC Waterstops span the joint to form a continuous, watertight diaphragm that prevents the passage of liquid through the joint.

Although, PVC Water stoppers elongate the length of water path and greatly reduces the water head pressure before it reaches the other end but it is not 100% foolproof system because during the hardening process, concrete shrinks and PVC never bonds with concrete, thereby a gap is created which may lead to water leakages through the construction joints.

Recently some new products and technologies have been introduced to effectively treat the construction joints which include use of Swellable water bars and Re-injectable grouting hose system.

Swellable Water Bar (Chryso Swellseal) is an easy to use, pre-formed, hydrophilic water bar that swells upon contact with water to forms a long lasting compression seal in concrete joints and doesn’t allow water to pass through the joint.

Following the complex work of waterproofing, leakages can’t be excluded in general. Therefore, it makes sense to plan the waterproofing in such a way that a repair is possible after finishing the construction without damaging the waterproofing system.

In combination with an injection system a repair of a leaking compartment can be done without damaging the geo-membrane, and at a reasonable cost. Suitable injection spouts needs to be installed for each compartment so that grouting material can be injected to treat the damage or leakages as and when required at a later stage.

Sometimes, long after construction has been completed, and sometimes during construction, one may also have to think about waterproofing repairs. In underground structures, there are many critical locations where it is not possible in future to get accessibility in case of leakages through construction joints or many times it is not advisable to drill holes in reinforced concrete to fix injection nozzles, so it is always better to install re-injectable hose system (Chryso Reinjecto) along the construction joints at the time of casting the concrete slabs.

Chryso Re-injecto is an advanced injection hose system that is tough, flexible and resilient, made of chemically inert polymer for installation in construction joints. It enables treatment of construction joints for water-tightness, any number of times during the life of structure. Special type of acrylate gels are used with Chryso Reinjecto system for grouting to prevent leakages. After each use, the hose can be cleaned and it becomes ready for future use.

Summary

Use of PVC geo-membrane waterproofing systems for foundations, basements & tunnels is a safe technology to protect the construction against destructive influences of water. This system provides a complete protection and incorporates inbuilt repair system. Depending on the severity of the water (humidity, temporary water pressure, permanent water pressure, condition of water) the lining system has to be adapted. This is expressed in the thickness of geo-membrane and a system of control and repair. Under the influence of permanent water pressure a minimum thickness of 2 mm of the geo-membrane has to be used. A lot of attention needs to be paid for all details such as treatment of pile heads, pressure release pipes, cables, tunnel eyes, etc. Therefore, it is always advised to engage a specialized & experience application agency. A thorough site inspection, detailed methodology and checklist to be prepared before execution of the system.