Special Lecture Delivered by Dr. Kribanandan Gurusamy Naidu, MD of JTK Consult Sdn. Bhd, Malayasia on "Advances in Waterproofing Materials & Technology"

1.0 Introduction

Waterproofing is one of the most important parameters considered in the construction of building and structures to prevent leakages, dampness etc and making the structures durable. For waterproofing latest advanced technologies are being used worldwide. During his presentation, Dr. K. G. Naidu presented how this advanced waterproofing materials and technologies can help for making durable structures.

2.0 Concrete Volumetric Proportions and Design Aspects

Hydration is the major process in the concrete. On addition of water to cement, hydration process starts and during this period, two phases occur. In first phase gel formation of cement takes place which also includes solid hydrated products of cement. In second phase capillaries are formed which consists of water and pores. Besides these there is some cement which never takes part in the hydration process thus forming unhydrated cement. Covercrete is a cover provided to protect the heartcrete and zone of poor quality concrete. Covercrete protects the reinforcement and concrete from chloride attack and sulphate attack. In the design and construction stage of concrete, the specifications and details of concrete should be mentioned and in the construction stage, concrete must be good compacted, proper cover should be provided and proper curing of concrete has to be carried out as per the standards. The covercrete is to be provided to structure as per standards, to resist the environmental attack on buildings and structures. The durable concrete should be designed for low porosity, low permeability and low water absorptivity and penetration.

2.1 Approach to concrete placement

The concrete should have mix design with high workability and cohesive mixed design concrete texture. At the time of placing of concrete, concrete should properly compact with good practice of compaction. After placement of concrete, proper curing and protecting methods should be adopted. For waterproofing concrete, the water/cement ratio should be up to a maximum value of 0.4.

2.2 Low Permeability

For lower permeability concrete, silica fume which is a by-product of silicon metals or ferrosilicon alloys is used. On addition of silica fume at a dosage of 5 to 8% by weight of cement drastically reduces permeability by sealing voids and pores within a concrete mass.

2.3 Concrete Design for Reducing Water Absorptive and Penetration

To reduce water absorptive and penetration of concrete, a hydrophobic and pore blocking additives are used in concrete. The hydrophobic ingredients in the material creates a concrete surface which is repellant to water under static conditions and other inert component provides a pore blocking function by positioning themselves in the capillary pores and acting to block ingress of water under pressure (Figure 1).

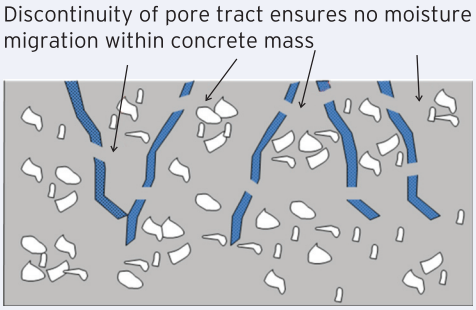

Fig. 1: Integral Water Proofers - Pore Blocking Effects

2.4 Concrete Design and Other Considerations

In concrete design, one of the major properties is workability of concrete. The workability of concrete should be designed for a minimum slump of 125 mm and preferably of 150 mm. The concrete having proper workability minimizes the risk of honeycombs and poor compaction practices during placement of concrete and it also reduces likelihood of any addition of water at site without authorization. The concrete should mix with proper proportion of materials which avoids excessive bleeding and possible segregation.

3.0 Waterproofing

Waterproofing is defined as a treatment of a surface or structure to prevent the passage of water under hydrostatic pressure as per ACI committee 515 where as damp proofing is defined as a treatment of a surface or structure to resist the passage of water in the absence of hydrostatic pressure. The damp proofing is rather to retard but not to stop the absorption of water or water vapor through concrete or masonry which results into the dampness on structure. To retard dampness or prevent dampness barrier system is to be used. The barrier systems are having two types of systems such as positive side and negative side.

For damp proofing the positive side system is used by introducing a barrier between surface and water, which results into less dampness. In negative side barrier

system the barrier is being introduced at the opposite end to prevent the water ingress in to surface of the structures.

4.0 Building Envelope

Building envelope consists of substructure and super structure with the combination of roofing, waterproofing, damp proofing and joint system and flashing system that act cohesively as a barrier, protecting interior areas from water and weather intrusion. A schematic diagram of building envelope is given in Figure 2.

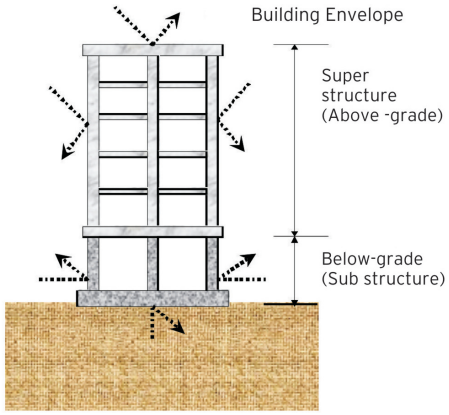

Fig. 2: Schematic diagram of building envelope

For the waterproofed concrete construction, the objective must be not only the individual components of the structure but also to waterproof of the whole structure. Here the stakeholders include the owner, architect, developer, main contractor, concrete producer, component system specialists such as concrete additive supplier, membrane supplier and installer and joint system supplier and installer and concreting sub-contractors.

5.0 Types of Modern Waterproofing Systems

The old traditional systems of waterproofing have certain limitations and being replaced by modern waterproofing systems. These are different types of waterproofing such as admixtures, impregnation, film forming membrane, surfacing, joint seal and grouting.

5.1 Admixtures

Admixtures are used in concrete during construction for different purposes. The various types of mineral admixtures such as lime, silica, fly-ash and chemical admixtures like plasticizers, super plasticizers, water reducers and high range water reducers, accelerators, retarders, viscosity modifying admixtures, air entraining admixtures and shrinkage reducing admixtures are widely used for specific purposes. But all these help to reduce the water content of the mix and make the concrete dense, compact, crack free and durable and thus able to make leakage free structure.

5.2 Impregnation

For waterproofing of old and new structures, impregna-tion type being used. In this method the solution is penetrated into the pore structure considering three different actions such as hydrophobic, partial filling, and filling. For the hydrophobic phase silane, siloxane, diffused quartz carbide solution are being used. For the partial filling phase silicone, sodium silicate (densifier/hardener) solutions are being used. For filling low viscosity epoxy and methacrylate solutions are being used.

5.3 Film Forming Membrane

This may be a liquid applied waterproofing coating or a preformed elastomeric membrane.

5.3.1 Liquid Applied Coating

Acrylic, bituminous, cementitious, coal tar, epoxy, silicone, urethane, polyurethane, polyurea materials are used as film forming membrane over concrete surface. These materials are applied either hot or cold over concrete by using brush, broom, roller, squeeze, spray etc. Acrylic and latexes are used in terraces, podiums, overhangs and roof gardens. A comparison of various properties of epoxy, polyurethane and polyurea materials is given in Table 1.

Table 1. Comparison of properties of different coatings

Properties	Epoxy	Polyurethane	Polyurea
Adhesion	Excellent	Very Good	Excellent
Abrasion Resistance	Good	Excellent	Excellent
Chemical Resistance	Excellent	Good	Good
Component Stress	Poor	Good	Good
Cost	Moderate	High	High
Coefficient Of Thermal Expansion	Low	Medium	Medium
Elongation	Low	High	Medium
Exotherm	Higher	Medium	Low
Handling	Straight Fwd	Straight Fwd	Req's Skilled
High Temp Opera-tion	Good	Poor	Very Good
Impact Resistance	Good	Excellent	Excellent
Low Temp Operation	Average	Good	Good
Moisture Sensitivity	Low	High	Excellent
Thin Film Cure	SLow	Variable	Very Fast
Tensile Strength	High	Medium	Very High
Tear Strength	N/A	Excellent	Excellent
Thermal Cycling Ability	Excellent	Very Good	Very Good

The polyurea material is used as a liquid applied coating to a concrete surface which gives better results than the polyurethane material. The polyurea membrane is used

in low movement structure, waste water treatment plants and substructures. Whereas, the polyurethane material is used in high movement structures, car parkings, roofs etc.

5.3.2 Preformed Elastomeric Membrane

The bituminous Butyl rubber, EPDM (Ethylene Polypropylene Diene Monomer), Hypalon, Neoprene, Polyethelene, HDPE, PVC (Poly Vinyl Chloride), materials are used as preformed elastomeric membrane applied by torch on, self adhesive, loose lay technique.

Crystallization and spray applications are other method of film forming membrane.

5.4 Surfacing

For waterproofing, asphalt, concrete, epoxy mortar, polymer concrete, polymer modified mortar etc. are used as an overlayment or cover over concrete.

5.5 Sealants

Joints are the necessary important part of the structures as it acts a link between various parts of structures such as column-beam joint, column-slab joint, slab-slab joint, beam-beam joint, floor-floor joint etc. all these joints should be sealed with proper sealants.

6.0 Construction Joint Detailing

6.1 Hydrophilic Water Stop Strip

These are made up of Butyl rubber having ability to expand in a controlled manner when in contact with water for a minimum volume expansion of 120%. These are used at construction joints. This is having an ability to shrink when water has dried out.

6.2 Injection Hose System

This is a multi injectable hose system. This is used in sealing and unsealing of structure, wherever necessary. For use of injection hose system the proper injection material should be selected. This is used where binding out exact location of joint is difficult; hose allows to complete the seal joint. The hose should be injected before installation of wall membrane to ensure all cracks on wall are sealed.

7.0 Treatment for Walls with Membrane system

If special care and attention is not paid to the construction sequence and post pour treatment are not given to concrete structure, then the cracks are visible on the walls. Therefore a membrane system is considered for cracked walls. For usage of membrane system, first inject the hoses laid at the construction joints before installing membranes. This help as all cracks to be sealed in the walls connected to construction joint. Elastomeric acrylic coating is generally used for external wall as an weather coating.

8.0 Method of Protection

For a durable construction, structure must be protected with frequent changing climatic conditions and other environmental factors. The structure shall be protected by using different methods of protection, such as:

- Altering service and exposure conditions
- Enhancing the physical properties of concrete
- Surface applied barriers considering service and exposure conditions
- Altering the electro-chemical behavior

While selecting the various protection methods one has to keep in mind the various services and exposure conditions. Among those entire methods one should choose the correct material or system with optimum cost and performance.

For durable as well as waterproofed concrete structure, the overall approach should be considered such as:

- High performance concrete designed for waterproofing with special admixtures and additives.
- Waterproofing membranes
- Construction joint detailing
- QA/QC Inspection and Supervision

Structure should be designed to resist the ingress of water into the concrete and for durability such as:

- The exclusion of moisture migration within the construction
- Low permeability achieved by introducing silica fume into concrete
- Low porosity is maintained by low water/cement ratio – water/cement ratio for waterproof concrete should have maximum value of 0.4
- Low water absorptivity and penetration be maintained by introducing special admixtures/additives called hydrophobic pore blockers.

9.0 Failure of Protection system

9.1 Surface Applied Protection Problems and Concerns

In liquid applied coating some of the pin holes had been left and through these pin holes, gas or vapour passes through the concrete and resulted into the cracking. Depending on wind and temperature conditions, moisture in concrete causes rapid evaporation during placement and results into the loss of protection surface. Due to poor surface cleaning, wet surface, contaminant, lack of proper priming, excessive shrinkage of surface applied material results into debonding between protective coating and the concrete surface. In case of improper time interval between the installation of layers and contamination or improper surface preparation of a layer results into the interlayer debonding. The bonding takes place between concrete and protective surface

layer by moisture trapping due to hydrostatic pressure, vapour pressure, ice crystal growth and salt crystal formation. Because of improper curing, improper surface preparation, improper jointing and improper usage of overlayment material causes shrinkage cracks and debonding which results into water trapping and water seepage through cracks.

9.2 Joint Sealant Protection and Problems & Concerns

In case of sealant failure, water seepage takes place through the joints which results in dampness, leakages etc. water seepage takes place through joints because of different types of failures such as sealant failure, failure of concrete and failure of waterstop.

Failure of sealant takes place due to adhesion failure or cohesion failure. Due to honeycomb, spalling at concrete, concrete failure takes place. Failure of waterstop takes place due to overextended split break at connection, contamination of surface-debond misalignment.

10.0 Integral Water Proofers for Concrete

There are different types of materials used as an integral water proofers for concrete such as water repellants (hydrophobic pore liners), pore blockers (ex. bituminous emulsion, crystal growth) and combined water repellants and pore blockers.

- Permeability reducing waterproofers and hydrophobic waterproofers reduces the surface layer chloride concentrations as a result of the lower sorptivity. In Portland cement concretes, waterproofers reduced the chloride diffusion coefficient, particularly with lower water/cement ratios.
- Integrated water repellants reduces chloride ingress and surface chloride levels, ineffective under an externally applied water pressure and did not reduced carbonation. Pore blocking admixtures expected to reduce penetration of chlorides in solution under pressure and most effective in lower grade concrete.
- Calcite limits the ingress of deleterious agents into the concrete making the system effective in providing protection against corrosion.
- Calcium nitrite provides superior corrosion resistance to both cracked and uncracked concrete specimens.
- Corrosion inhibitor should be use in steel reinforced cast-in-place, precast, post tension, GFRC, prestressed or other steel reinforced concrete.
- Crystalline based products prevent the intrusion of water, salt water, sewage and most chemicals. It helps protect reinforcing steel against oxidation and deterioration.

11.0 Standards for Performance Tests for Waterproof Concrete

The various standards for performance tests for waterproof concrete are:

- BS 1881 : Part 122 : 1983 – water absorption
- DIN 1048 : Part 5 : 1991 – water penetration
- ASTM C 642 – permeable voids and water absorption
- AASHTO – T 277/ASTM C-1202 – Rapid chloride permeability

11.1 Performance Tests for Waterproof Concrete Specifications

The structural designer and architect has to specify the requirements depending on the exposure conditions. DIN 1048 recognizes that a water penetration of 50 mm or less represents a concrete that is waterproof and water penetration of 30 mm or less is usually specified for severe exposure conditions.

11.2 Additional Performance Tests for Durable Concrete

For a durable concrete structure the concrete should have following specifications such as:

- The design of concrete mix should be considered for a design life of 120 years.
- As per ASTM C642 specifications – the absorption of concrete should not exceed 4 % and the permeable voids should not exceed 10%.
- As per AASHTO T 277 and ASTM C1202, the chloride permeability of concrete should not exceed 1000 coulombs.

12.0 Quality Assurance and Quality Control

The waterproofing system should become a part of designing and detailing for ensuring the proper installation of each component. Quality control to be taken such as to check prepour preparations for slab castings, to supervise at the batch plant, to supervise at the concrete placement, to check prepour installation for seals and hoses prior to casting of wall elements, to ensure proper compaction and placement of concrete during casting, to ensure proper and sufficient curing of concrete after casting, to inspect construction joints for defects prior to installation of membranes, to ensure proper records were kept for all activities etc.

(Lectures were delivered on Healthy Construction Lecture Series organised by Dr. Fixit Institute of Structural Protection & Rehabilitation, Mumbai by Dr. Kribanandan Gurusamy Naidu, Managing Director of JTK Consult Sdn. Bhd a Design and Technology Consultant Group from Malaysia (www.jtkconsult.com.my) on 17th and 18th February 2011 at Hyderabada and Mumbai respectively)