ReBuild

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A Quarterly Newsletter

WATERPROOFING

PART-1

BASEMENT WATERPROOFING OF NEW STRUCTURES

Dr. Fixit Institute
of Structural Protection & Rehabilitation

A Not-for-Profit Knowledge Centre

From the Editor's Desk

ReBuild

Ingress of water in any form is the major cause of structural deterioration. With the advance of technology, the innovation of new materials in waterproofing is taking place from time to time but the application in the practical field is very limited. The approximate waterproofing market in India is about Rs. 2000 crore while in our neighbouring country of China, the market is worth Rs 60,000 crore. This indicates that the usage of water proofing material is lagging far behind in India as compared to other developed countries. This is because awareness and knowledge in this specialised field is not disseminated to all practical engineers, architects and planners. The waterproofing codes in India have not been revised for the last four decades. The present codes available in India on waterproofing, based on bitumen and tarfelt based materials, are still being followed. There are no separate codes of practices in waterproofing for different components of buildings and other infrastructures. Keeping this in view, we have decided to bring out a series of publications in waterproofing materials and systems for wider knowledge dissemination among our readers. To start with, this issue of Rebuild is devoted to basement waterproofing of new structures.

Basements have become a part and parcel of any high rise building and commercial complex in metropolitan and other cities. But careful designs of basements along with proper systems of waterproofing can ensure better durability of structures. Though there are many different kinds of modern materials that are now available for basement waterproofing – which can provide a long service life – many builders and developers are still using the old traditional system of box type waterproofing of basements by lining them with lime stones etc. and grouting the joints which are not durable as compared to polymer-based coatings and membranes. Again, designers often do not have a proper study of existing site conditions related to the external environment, such as fluctuation of ground water table height in various seasons, aggressive chemicals/sulphates present in the soil etc. that may affect the basement and its waterproofing systems prior to the construction. Often damage to the basement can be seen in the form of water leakages, seepages, and damp patches on the vertical walls and the basement raft. Since the basement is a closed space without any ventilation, the moisture condenses inside the basement and structural members of the basement corrode.

It is important to design the walls and rafts of the RCC basement structures with pozzolanic materials and super plasticizers to reduce their permeability. The joints and pipe penetrations areas are more vulnerable for water leaking which can be taken care of by waterbars. The three different systems of basement waterproofing that are the tanking system, the structurally integral protection system and the drained cavity protection system - or a combination of these systems - may be adopted depending upon the location, type and importance of the structures. In the case of tanking protection, the basement is tanked from outside, inside or both with a liquid-applied coating or a preformed membrane, whereas in the case of the integral protection system, the structure itself is made watertight by selecting suitable materials and designs. In areas with a high water table and deep basements, drainage with a pumping arrangement should be provided.

It is indeed a difficult task for the designer to select a particular waterproofing material for the basement, since there are many types of materials available in the market. But all the materials do not provide a service life of 10-15 years. The waterproofing materials for shallow basements will be different from those for deep basements. So the designer has to match the performances of available waterproofing materials to the required performances of the materials by taking all factors into consideration, such as hydrostatic pressure to resist, required internal environment of the basement in terms of temperature and humidity and the prevailing external environment. The polymer-modified bituminous materials are most widely used in shallow basements. The materials may be cold applied or hot applied while cold application is preferred because of its ease of application. Self adhesive bituminous membranes can be easily installed by any unskilled labourer where film on the adhesive side needs to be peeled off and ticked to a properly prepared surface with a primer. The important factor for durability is surface preparation and application of a compatible primer before any coating application. In case of liquid application, the thickness of the coating is always erroneous by the owner which can be avoided by application of factory made preformed membrane. But the preformed membrane has certain disadvantages like the requirement of skilled manpower, more joint detailing and the cost of the material. But if applied correctly, it can give you a more durable service life. The commonly used preformed membrane materials are Polyvinyl chloride (PVC), polymer modified bituminous of APP (Atactic Poly Propylene) or SBS (Styrene Butadine Styrene) and EPDM (Ethylene propylene Diene Monomer), out of which the EPDM membrane is more suitable in deep basements and high water table areas. Post application, protection to the membrane with geotextile fabric and screed is also important to avoid any type of damage to the membrane.

All in all, basement waterproofing needs to be done more professionally with the latest materials and technology to avoid any remedial measures at a later stage. Keeping in view the problems in a large number of existing basements, the next issue of our Rebuild will be devoted on remedial waterproofing of basements. We hope this article will help in understanding the basic concepts of designing and waterproofing basements of new structures.

Basement Waterproofing of New Structures

[Excerpts from Dr. Fixit Healthy Construction Booklet "Construct Your Ideas", 2012, pp 9-12]

1.0 Introduction

A basement is one (shallow) or more floors (deep) of a building that are either completely or partially below the ground floor. Waterproofing is the formation of an impervious barrier that is designed to prevent water entering or escaping from various sections of building structures. The design and the construction procedures required to complete basement waterproofing are more important than waterproofing the basement itself. As the cost and availability of real estate increases in urban areas, basements are becoming more and more common in new structures such as high rise buildings, commercial complexes etc. Basements can provide space for most commercial activities, storage, archives, plant rooms or car parking. In residentials, they provide valuable additional space, which can be efficiently heated and is particularly useful for leisure activities with different games rooms, storage and parking without increasing the height of the building. Basements are required for under ground metro and railway stations apart from commercial activities. Basement waterproofing installers are highly specialized in new constructions and normally do not deal with landscape, demolition, excavation, underground utilities, backfill, compaction and a variety of other tasks which come into play during a basement waterproofing repair job. The term "basement waterproofing" is intended to encompass the topic of moisture protection and protection from all undesirable liquids and gases as applied to a variety of existing below-grade structures.

2.0 Influence of Environment in Designing the Basement

The environmental factor is important while designing any basement. Basement design involves the selection of combinations of construction and environment control systems that, together, provide the necessary control of the external environment to enable the required internal environment to be achieved. The basement designer should satisfy all the present and future needs of the client for the effectiveness of internal environmental control and at the same time it should also satisfy the prescribed building regulation norms of the local authority.

All liquids and gases that are present in the underlying and surrounding soil have the potential of penetrating the below-grade concrete and entering the structure. Groundwater and soil in developed areas are subject to contamination by toxic liquids and gases. Decomposing organic matter releases 'methane' as do leaks in sewer and septic systems.

Besides gravity, ground water is influenced by its close interaction with earth materials. For example, ground water can move laterally or upward by "capillary action" or "wicking". Ground water will move in the direction of the most permeable soil. Ground water saturating the backfill will exert "hydrostatic pressure" against the floor and walls of the structure with the maximum pressure being at the greatest depth. Water seeping through basement walls may pond on the floors and even lead to flooding after a heavy rainstorm. More often, the moisture enters the building as vapour that circulates in the air of the interior spaces. The moisture may condense on cool surfaces or behind wall coverings that are in contact with the surrounding earth. The moist microenvironments provide a habitat for unwanted indoor 'microorganisms' such as spores, molds, fungi, and bacteria. In addition to the 'chemical hazards' already discussed, these 'biological hazards' add to the mix of indoor pollutants that must be excluded by a proper basement waterproofing program. The 'sulphates' in the soil may damage the reinforced concrete structures. The other minerals dissolved in ground water, aided by the presence of oxygen from the atmosphere, will react with the concrete and the reinforcing steel that has been embedded in the concrete. The result is corrosion and ultimately destruction of the structural integrity of the concrete. The basement showing positive and negative sides with hydrostatic water pressure and all other forces acting on it is shown in Fig.1

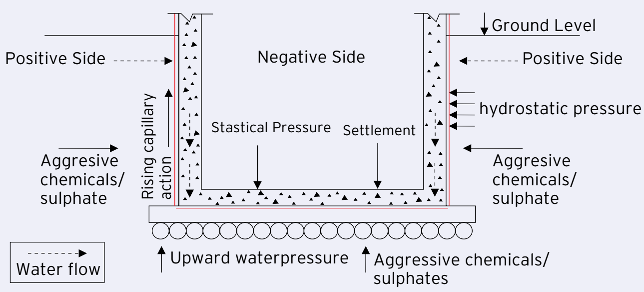

Fig. 1: Basement showing positive and negative side with all type of forces acting on it

3.0 Design of New Basements

In designing reinforced concrete in the basements, the following features should be taken into account: permissible crack widths, internal facings, and changes in section, columns and other point loads etc. The basement should be designed to ensure the prevention of differential settlement, the control of cracking and the provision of a dense impervious concrete structure. They should be designed to act monolithically with floors and walls continuously, and sharp changes in cross section of the floors and walls should be avoided.

Special consideration should be given to the provision of reinforcement at the junction of walls and slabs due to the bending stress which would occur at such positions. The wall and floor thickness should generally not be less than 250 mm with reinforcement percentages assessed on a serviceability crack width limit state. The minimum floor and wall thickness should consider the depth of basement measured from ground floor level as well as the water table. Cover to reinforcement on the external face should be determined in accordance with severe conditions of exposure as defined in IS 456:2000.

Service entries are particularly vulnerable to water penetration and their design and installation should be given careful consideration. The construction joints in the floor and the walls as well as the movement joints, if provided should be laid watertight, preferably with the provision of PVC water bars (Fig. 2). For the joints in the raft slab, surface type of water bar may be provided and for the walls water bar may be provided at the centre of the section. A waterbar looks like a rope which may be swellable or non-swellable. They are made of different materials like hydrocarbon based polymers, hydrophilic rubber, bentonite based butyl rubber and other materials such as pigments and fillers, adhesion promoters and many additives. Strip waterbar of the non swellable type may be of sizes 20 mm X 20 mm and 25 mm x 25 mm which are compressible and can be used to stop water leakages having a maximum of hydrostatic pressure head of 15-20 m. The swellable type of waterbars are smaller, in sizes of 5 mm x 10 mm or 10 mm x 10 mm which can be used for higher hydrostatic pressure heads of 50-100 m.

Fig. 2: Typical waterbar used in construction joints in basement

The lowest level of basement floor slabs should be cast in bays or a series of continuous strips with transverse induced contraction joints provided to ensure that cracking occurs in predetermined and protected positions. Closing pours should be of limited size with reinforcement lapped and coinciding with similar closing pours in the walls wherever possible. Longitudinal joints between the strips should form complete contraction joints. Pipes and penetrations through the walls and slabs should be minimised. Wherever a construction joint is required, the detailing should be made as per Fig. 3. The internal and external faces of the joint should also be sealed with sealant. The construction joints should invariably be chased open and regrouted in cement grout with additives. Injection grouting at 1 m centre to centre with cement slurry by the gravitational method should be carried out to render the joint watertight.

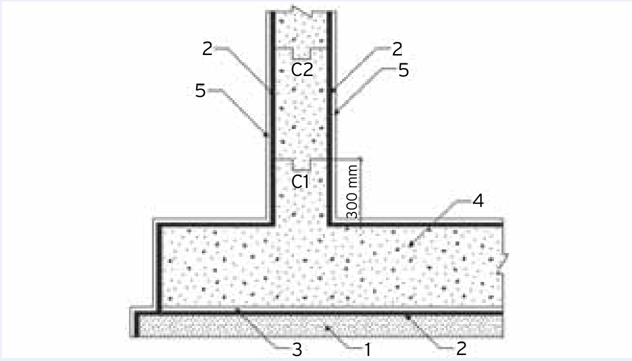

Fig. 3: Details of construction joints in basement

1. Plain cement concrete
2. Flexible waterproofing coating/membrane
3. Protective screed
4. RCC raft
5. Protective method on vertical surface

C1. First construction joint minimum at 300mm above raft top

C2. Subsequent construction joint (As minimum as possible)

In case of high watertable areas, the watertable can be lowered by providing a perforated drainage pipe system at the foot of the wall (Fig. 4) to reduce the uplift pressure of sub-soil water, only when the pipes can be connected to a nearby storm water drain. If this is not feasible and economical, the structure should be fully designed for the uplift and during the initial construction period, pressure pipes with filler chambers may be suitably provided to release

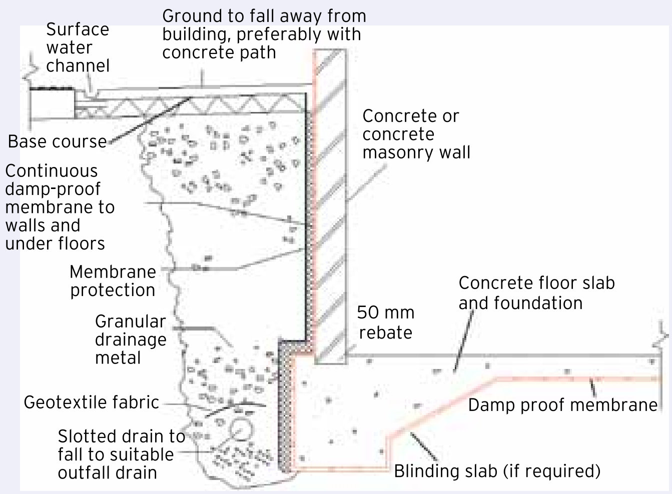

Fig. 4: Cross sectional details showing typical waterproofing by membrane and perforated pipe arrangement to lower ground water table to relieve raft of hydrostatic pressure head

the pressure of sub-soil water till the required designed dead load is taken by the structure. At least 35 mm thick concrete of M 20 screed and 25 mm thick plaster rendering in cement mortar (1:3) with latex additives should be provided to the floor and walls respectively to form an internal box.

4.0 Waterproofing Materials

4.1 Selection of Materials

While selecting any waterproofing material for a basement, one has to check the major functional properties required such as hydrostatic pressure head to resist, presence of aggressive chemicals if any, required internal dryness and service life of the waterproofing system. The thickness of the coating/membrane and other properties need to be selected based upon their required performances of the waterproofing systems.

The thickness of polymer modified bitumen membrane or self adhesive SBS (Styrene Butadine Styrene) modified bitumen membrane and EPDM (Ethylene propylene Diene Monomer) membrane varies from 1.2 to 2 mm where as torch applied membrane thickness varies from 3 - 4 mm. Whenever the membrane is used in deep basements it should resist the minimum hydrostatic water pressure head of 50 m (5 Bar). In general the various properties of the membrane such as water absorption should be 0.14 g/m^2/24 h, and water vapour transmission rate should be less than 0.1 g/m^2/24h. The membrane should have better chemical resistance properties, crack bridging ability of 1.5–2 mm, elongation from 100-200%, puncture resistance of more than 900 N and adhesion strength from 1.5 to 2 N/mm while being used in basement.

4.2 Types of Waterproofing Materials

4.2.1 Lining Forming Materials

In this system a lining masks the surface with cementious bonded materials also known as box type waterproofing. The claddings take place on cement mortar bedding with rough Shahabad Kota (Lime stone), Red Agra (Cuddappa) and slate stone slabs. Latex modified cement matrix, polymer cement concrete/ mortar lining to the floor and walls surfaces are applied after surface preparation. Stones are first laid over blinding concrete in a staggered joint fashion to avoid the continuity of the mortar joints. The joints are effectively filled with rich cement, sand mortar admixed with integral waterproofing compound and cured. Over this, the raft is laid and shear/brick walls constructed. The limestone slabs are erected around the walls in a similar fashion leaving a gap of 25-50 mm between the external surface of the wall and the inner face of the stone surface. The joints are again effectively sealed with rich admixed mortar and the same mortar is filled in the gap between the wall and the stones. By this method an external tanking is provided to the raft and the sidewalls to protect from direct exposure to sub soil water. Polymer ferrocement lining can be used to provide waterproofing structural lining. A typical waterproofing by lining system is shown in Fig. 5.

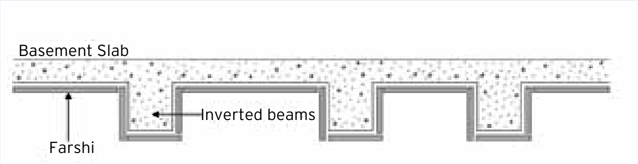

Fig. 5: Typical waterproofing detail of a basement by lining system (Box type waterproofing)

There are many instances of leakages in such systems because the joints of these stones need to be grouted properly otherwise leakage occurs through these joints. Also this system is labour intensive which requires more time for installation. But unfortunately the same traditional system is still followed by many builders despite the availability of more durable waterproofing material systems.

4.2.2 Membrane Forming Materials

It masks the surface with an in-situ self bonding monolithic liquid applied membrane of either bitumen or polymer based materials. The advantage of a liquid applied membrane is their ease of seamless application over any curvature without any lapping and joints. They should be breathable in nature to avoid blisters and craters, which affect the performance of coating systems, should have crack bridging ability, and should be elastomeric and resistant to aggressive chemicals in water. Liquid applied membranes are more economical as compared to preformed membranes. These are mostly used for shallow basements.

a. Bitumen/tar based Materials

- Cold-applied asphalt/coal tar, a common below-grade waterproofing for the residential market, is good only for damp proofing, not for waterproofing. It has poor elastic and crack-bridging properties, and not being UV stable, the membrane becomes very brittle at low temperatures. The presence of a solvent makes these coatings toxic. But cost wise it is very cheap. Bitumen based membranes are not breathable.

b. Polymer based Materials

These are applied after surface preparation. They are natural asphalt-modified bitumen under tar-based coatings-epoxy, polyurethane, acrylic and natural rubber. Synthetic rubbers are grouped under polymer based coating systems.

- Hot-applied polymer-modified asphalt membranes exhibit excellent waterproofing characteristics, as well as elasticity, flexibility, good adhesion to concrete, overall resistance to cracking, and provide seamless application. The necessity of having heating equipment at the job site, accidental burn injuries, thermal degradation of polymer due to prolonged heating, and the emission of hazardous hydrocarbons has reduced the overall effectiveness of this technology.

- Cold-applied bitumen-modified polyurethane cured membranes show very good elastic and hardness properties. They have excellent adhesion and crack bridging properties. The excellent chemical resistance of these coatings makes them particularly suitable for basement waterproofing in areas where chemical contaminants and aggressive ground water conditions prevail. These membranes have good resistance to hydrostatic pressure but poor water vapor permeability (0.2 perms). Overnight curing time is required (longer at lower temperatures and humidity). The presence of a solvent makes them unsafe and unpleasant to work with. As these membranes are moisture sensitive, they are susceptible to pinholes, wrinkles, and blistering. Due to the presence of the solvent, these membranes are not suitable for insulated concrete forms.
- The cured membranes of polymer-modified asphalt emulsion exhibit excellent waterproofing/ vapour-proofing properties as well as elasticity, flexibility, good adhesion to concrete, and resistance to cracking and failure. There is no need to have heating equipment at the job site. These are one-component water-based waterproofing membranes with excellent resistance to hydrostatic pressure and water vapour permeability (0.02 perms). Typically, these materials cure within 2 h (compared to 24 h for other cold-applied urethane systems). As these are solvent-free, they are ideal for insulated concrete forms. It can be applied immediately to newly stripped below-grade green concrete walls as well as masonry blocks. They are easy to install with a sprayer, heavy mop, roller, or soft bristle brush.

c. Cementitious Material

It can be used against both positive and negative water pressure resistance but they are not truly elastomeric. They form better bonding with the substrate but have no crack bridging ability. But polymer modified cementious coating exhibits excellent bonding to concrete surfaces, high elasticity and builds a tough film that provides excellent waterproofing properties. Integral crystalline, which is a cementitious-based system, can be admixed with concrete during construction and the crystalline coating can also be applied on the negative side to prevent dampness. Whenever these crystalline products come in contact with water they create crystals and seal the capillary pores, thus helping in waterproofing.

d. Preformed Membrane

Preformed membrane type materials mask the surface with in-situ membranes with bonding adhesives. There are many advantages with preformed membranes. Since membranes are factory made, quality control for thickness is possible, and they are suitable for high water table, deep and large basements. But they require highly skilled manpower for installation. The other disadvantages of preformed membranes are overlapping joints and the difficulty of application across a change in the geometry of the structure. The labour cost increases because of cutting, handling, reinforcing, and the detailing one has to go through during the installation.

The various types of preformed membrane with chemical adhesives used for lining are: bitumen felts, plastic or Butyl rubber sheets, Chlorosulphanated rubber (Hypalon), Neoprene rubber, Asbestos glass fibre aluminium foil based felts, low density polyethylene (LPDE), high density polyethylene (HDPE), Polypropylene (PP); Polyvinyl chloride (PVC) sheets, polymer modified bituminous of APP (Atactic Poly Propylene) or SBS (Styrene Butadine Styrene), TPO (Thermo-plastic Polyolefin) and EPDM (Ethylene propylene Diene Monomer).

- APP membrane is torch applied and requires more skilled labour and a protective screed to avoid any damages to the membrane. APP modified bitumen has superior puncture resistance, high tensile strength and can withstand structural stresses. Sometimes an APP membrane is reinforced with a fiberglass mat that is completely impregnated and coated with an elastomeric modified bitumen compound. It helps to achieve high performance waterproofing properties with greater elasticity and flexibility at low temperatures, making them suitable in deep basements.
- SBS is a self adhesive membrane, applied by simply pressing with a roller after peeling off the release film. The membrane is protected on the self adhesive side usually with a silicone coated release film. SBS modified bitumen is having superior low temperature application and good flexibility. Due to its flexibility and presence of a tough and durable top surface, this membrane can be used as a direct substitute for protection boards where soft backfill is used. But it is not suitable for high water table. It also requires a screed for protection.
- HDPE is the best material for waterproofing in high water table, which is applied as loose lay. HDPE is also used on blind face of retaining walls.
- Rubberized asphalt sheet membranes show good waterproofing and vapour proofing, as well as factory-controlled thickness, excellent resilience, and self-healing properties. These sheet membrane waterproofing systems provide a cost-effective way to waterproof foundations, vertical walls, and below-grade floors in residential and commercial

constructions. These membranes are equally effective for use as a between-the-slab waterproofing on plaza decks, parking decks, and structural slabs.

- EPDM based waterproofing preformed membrane exhibits a high degree of resistance to water, weathering and abrasion. It has high tensile and tear resistance. It retains its elasticity at low temperatures and has high chemical resistance, making it most suitable for basement waterproofing in aggressive soil conditions. It withstands the movement of the structure due to its higher elongation property. It has a long durable life and is most suitable for deep basement waterproofing.
- Comparing all polymer based waterproofing products, naturally occurring sodium bentonite is eco-friendly and has exceptional waterproofing qualities because of its ability to swell up to 18 times its dry state when in contact with water and converting the dry clay to an impervious gel. In bentonite waterproofing system a uniform layer of sodium bentonite clay is sandwiched between a durable puncture resistant nonwoven polypropylene fabric and then needle punched together with thousands of high strength denier yarns. Some geotextile products interlock the fabrics together through a special needle-punching process. Bentonite waterproofing membranes have the ability to heal themselves if ripped and punctured. In a hydrated state, the bentonite clay has tremendous impermeability and excellent resistance to chemicals. Bentonite waterproofing systems are available in a variety of forms to suit various applications. For instance, a biodegradable corrugated panel with flutes completely filled with bentonite. Special panels are available that feature a temporary, water-resistant coating to inhibit hydration prior to backfilling. Another form integrally bonds bentonite to one side of a heavy PVC or HDPE membrane. These products are positioned with the bentonite directly against the concrete to be waterproofed.

5.0 Waterproofing Methods

There are three types of basement waterproofing usually adopted; A) tanked protection where the basement is tanked from outside, inside or both with a liquid applied coating or a membrane, B) structurally integral system; where the structure itself is made watertight by selecting suitable materials and designs, and C) drained cavity protection system where drainage with a pumping arrangement is provided. Based on the importance of usable area and internal dryness required, the basement can be designed as per any one of the above methods or a combination of any two or all the systems.

5.1 Tanked Protection

The tanked protection system comprises of a waterproofing system that the system should surround the structure on all sides. Protection is totally dependent on a continuous barrier system applied to the structure. The waterproofing should preferably be placed on the positive side of the basement. The membrane should also preferably be bonded to the basement structure to avoid the problems associated with differential settlement as leaks may occur where an unbonded membrane is no longer supported against the structure.

For non-cohesive soil, the waterproofing should extend by at least 300 mm above the maximum ground water level. For cohesive soil, the waterproofing should extend at least 600 mm above the ground level. In cases where there are slabs abutting the basement, the waterproofing should turn below the soffit of the ground slabs for a minimum distance of 600 mm. The waterproofing should not suffer any impairment of its protective action as a result of the anticipated movements of the building's components due to shrinkage, temperature fluctuation or soil settlement.

They are not generally applied to exposed floor surfaces because they lack the necessary wearing properties and are unable to resist external hydrostatic pressure. A tanked structure is generally required to be monolithic, with minimum movement at the joints. The tanking system should be selected to accommodate the movements that are likely to occur. For large deep basements (with a permanent hydrostatic head) tanking is only practicable with reinforced box construction, except where walls are cast onto steel piling. This should be designed properly to avoid any damage in the waterproofing system if the basement exists on a sloped surface.

5.1.1 Types of Tanked Protection

There are four types of tanking systems based on the surfaces on which tanking protection are installed and a comparison among those systems is given in Table 1.

5.1.2 Practical Site Conditions

Site access is an important issue for positive waterproofing. Open cut excavations allow easy access to basement walls to enable correct placement of the waterproofing system where as confined sites, which use soil retaining systems such as sheet and contiguous pile system, make installation of the waterproofing system very difficult. Special considerations should be made to ensure that the waterproofing system can be installed within confined sites and the installation work procedure should take this into consideration.

5.1.3 Precautionary Measures

A sound leveled surface, which is the first protection layer, must be provided for the installation of the waterproofing membrane. Projections or recesses

Table 1: Comparison of different tanking systems

Functions	External Tanking	Reversed Tanking	Sandwiched tanking	Internal tanking
Material application surfaces	On the exterior face of walls and floors	Onto some external source of support where membrane is fastened/ bonded	Within the two leaves of structural wall	On the interior face of walls
Application sides	Positive	Positive	Sandwitch	Negative
Water pressure head	Permanent hydrostatic pressure head	Pressure head minimizes by sheet piling/ cofferdam	Medium hydrostatic pressure head	Nil
Condition of application	Possible if sufficient offset is available in between property boundary line and the structure	Used when tanking is applied to a surface prior to construction of structural elements	Used only when external tanking is impracticable for construction procedure, access or ground conditions	Used as additional protection
Types of materials preferred	Hydrophilic membranes or bonded sheet membrane	Liquid applied /Bonded sheet Membrane	Water /vapour resistant membrane	Membrane or water resistant rendering with mechanical anchorage
Protection to membrane	Provided if required with geotextile membrane and 50 mm screeding	Protection required to the membrane applied on blinding concrete of basement floor	Not required	Protection required with geotextile membrane and 50 mm screeding
Manpower	Skilled manpower required	Skilled manpower	Skilled manpower	Semi-skilled manpower
Cost	High	Medium	Medium	Medium

should be minimized. The base must be able to withstand construction load so that the membrane will not be subjected to excessive stresses while installing. Care must be taken to ensure that the waterproofing membrane is not damaged during and after installation.

5.1.4 Surface Preparation

The surface should be cleaned or repaired of surface contaminants or defects. The surface should be cleaned by water or mechanical methods. Better surface preparation will result in better adhesion, which can be tested by a Pull-off test. Oil, wax, grease and formwork releasing agents should be thoroughly cleaned by chemical cleaning following by flushing with sufficient water to avoid any residue of chemical and contaminants on the surface. Mechanical cleaning is the most suitable method for increasing adhesion of the surface which can be done by high pressure water jetting, sand blasting, grinding or rubbing the surface with a mechanical scarifier by removing laitance, dirt and weak unsound surface materials. For membranes applied on negative side, any wall in contact with the waterproofing should be free of voids.

Protective measures should be taken to prevent the waterproofing membrane from damage by construction activities. Unless the waterproofing membrane is robust, it should be provided with protective layers. Special considerations and precautions should be taken for waterproofing deep basements. Surface preparation is an important preliminary activity for the success of the treatment. Chemical treatments have failed or give unsatisfactory service due to inadequate surface preparation.

5.1.5 Method of Application

The application process depends upon the type of materials used for waterproofing. The detail of application is given below:

i. Application of Primer

Polymer modified elastomeric bituminous coating diluted with water in 1:1 proportion or a solvent based bitumen primer can be applied as primer on clean, smooth and dry surfaces by brush or roller depending on the type of waterproofing material. The primer should be dry for 8 to 10 h prior to the application of the coating. The primer helps in filling pores in the concrete and better adhesion of the coating material. The synthetic rubber based solvent containing contact adhesive specially designed is used for fixing EPDM, TPO membranes. The primer should be compatible with the waterproofing material. The primer or the special formulated bonding adhesive should be in tacky condition during application of the liquid applied coating or the membrane. For cementious coating the surface should be in SSD (surface saturated dry) condition before application of the coating.

ii. Application of Membrane on PCC (Plain Cement Concrete) below the Raft slab

- Polymer modified elastomeric bituminous coating should be applied in two coats without any dilution with a roller or rubber squeegee over the primed surface.
- Self adhesive bituminous membranes should be applied over the solvent based bituminous primers. The self-adhesive side off the release film should be peeled off and the unrolling of the membrane should be done by pressing it to the surface. The membrane should be smoothened from the center to the edges with a roller in order to remove entrapped air. Furthermore, an iron roller should be used for rolling on top of the applied membrane to ensure a proper and strong adhesion of the bitumen compound with the base.

The typical detailing of a shallow basement with polymer modified bituminous coating is shown in Fig. 6 and with self adhesive membrane is shown in Fig. 7.

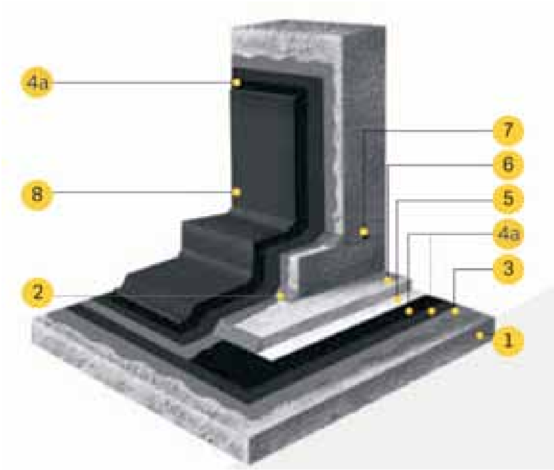

Fig. 6: Polymer modified bituminous system waterproofing

Fig.7: Self adhesive membrane system waterproofing

1 PCC 2 Angle fillet 3 Primer
4a Polymer modified elastomeric bituminous coating (2 coats)
4b Self adhesive bituminous membrane 5Geotextile fabric
6 Screed 7 Waterbar 8Protection board

iii. Application on Vertical Surfaces

- While applying on vertical faces, angle fillets should be made all around the corners of the raft and the retaining wall. The fillets can be made with polymer modified mortar. One should take care to chamfer all the edges of screed and raft slab to facilitate the membrane to move over it.
- Polymer modified elastomeric bituminous coating should be applied in two coats over the fully dried primer on all vertical surfaces. Application of polymer-modified bituminous coating in a shallow basement is shown in Fig. 8.
- While using self adhesive bituminous SBS membrane (Fig. 9), it should be applied starting with the sides of the raft and will go right up to the top of the external wall face and terminate there appropriately with a C-Shaped aluminum flashing strip or by tucking it into the concrete wall groove of 12 mm X 12 mm. In case of the groove, the aluminium flashing can be fitted to press the membrane into the groove and then filled with single component non-sag polyurethane sealant.

Fig. 8: Application of polymer-modified bituminous coating in a shallow basement

Fig. 9: SBS sheet membrane applied in double layer to concrete foundation wall in a basement

iv. Protection to Membrane on PCC below the Raft slab

- Geotextile membrane of 120 gsm as a protection layer should be applied over the coating/ membrane.
- A 50 mm thick leveled screed must be overlaid in M 20 concrete grade, which will facilitate the reinforcement cage to be assembled, for the RCC raft to be cast over it.
- A swellable, adhesive strip waterbar of 20 mm X 20 mm should be provided in the construction joints, which is placed on the inside of the reinforcement, in both the raft concrete floor and the side retaining concrete walls.

v. Protection to Membrane on Vertical Surfaces

- Geotextile membrane of 250 gsm/bituminous protection boards should be applied over the coating/membrane before the back filling.
- A 4 mm thick bituminous protection board or a HDPE dimpled drain board (12 mm thick) shall be placed, vertically over the preformed membrane, allowing the soil backfill.
- The back filling should start simultaneously as one moves upward. Before back filling begins, the membrane must be protected either with plaster or with a protection board.
- For plaster, sand should be sprinkled over the membranes as soon as it is fixed after torching. The plastering shall be done in a 1:3 sand cement mortar at 15 mm thickness. Thermocol of 20 mm thickness can be used as a protection board. The cold bitumen (mastic) can be used for fixing the Thermocol over the preformed. Once the Thermocol is fixed, back filling can start in layers. This will allow people to work comfortably as it will create the platform to work as one move upwards.
- Aluminum flashings should be used for mechanical fastening, sealed with acetic cure silicone sealant at the upper end. In case of full bonding the membrane to vertical surfaces, these must be clean and dry. The bonding adhesive is applied both to the membrane and to the substrate in uniform and smooth films - so that a continuous coverage of both surfaces can be obtained (membrane and substrate). The adhesive is left to cure, and then the membrane with the applied adhesive is rolled onto the adhesive covered substrate, avoiding the formation of folds and creases. The adjoining membrane sheets must overlap by approximately 150 mm.
- The underground waterproofing system is finished at 500 mm above the level of the high soil water.

vi. Waterproofing of Deep Basements

The surface preparation, application of primer, coating/ membrane, protection measures are similar to the shallow basement. The application process depends upon type of waterproofing system. The typical detailing of a deep basement with APP/SBS modified bitumen based membrane is shown in Fig. 10.

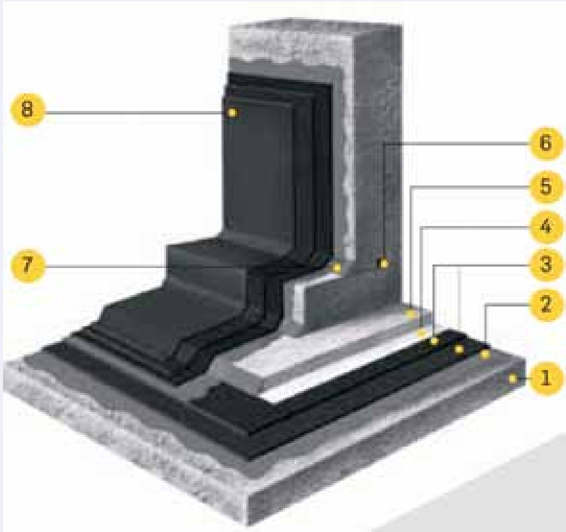

Fig. 10: APP/SBS modified bitumen based membrane system waterproofing for deep basements

1 PCC
2 Primer
3 Torch applied membrane (2 layers)
4 Geotextile
5 Screed
6 Waterbar
7 Angle Filet
8 Protection board

- SBS based polyester reinforced membrane should be laid by providing an overlap of at least 100 mm. A second layer of SBS based membrane should be laid with an overlap of 50 % above the 1st layer.
- The torch applied membrane roll should be unrolled from one end, once the priming coat is dried. It should be aligned correctly & re-rolled by half in alignment before torching. Avoid shifting of the membrane while torching. A gas burner can be used to heat the substrate and the underside to softening points. When the embossing disappears, roll forward & press firmly against the substrate. Ensure sufficient bleed on side and end overlaps. Once half of the roll is torched properly to the substrate, unroll the balance roll and repeat the process. An overlap of 100 mm should be maintained for all the continuing sides. Heating should be done on both the membranes to be overlapped and pressed firmly with the help of a round shape trowel. Care should be taken to leave no gap at any point in the overlapped area. If noticed, reheating must be done to seal it. The membrane must be laid over the entire PCC area with a minimum of 150 mm overhang from the size of raft on all sides. The step by step method

for installation of the torch applied membrane is given in Fig. 11.

a. Clean & remove dust, dirt, loose particles and unsound substrate

b. Apply primer coat with solvent based bitumen primer

c. Unroll the membrane

d. Align the membrane Roll

e. Use gas burner to heat substrate & underside to softening points

f. Keep overlap margin for minimum 100 mm

g. Heat both the overlaps & use round tipped trowel to seal overlap

h. Seal the edges well and protect with a Polysulphide sealant

Fig. 11: Step by step method of application of torch applied membrane

Fig. 11 i. Protective screed applied all over the membrane

- EPDM based membrane can be installed in all deep basements and high water table areas. The membrane usually comes in a roll of 20/25 m long and 1.2/3 m wide. An overlap of 50-70 mm is usually provided. On the horizontal surfaces, the EPDM membrane is loose laid between two layers of 120 gsm geotextile. The adjoining membrane sheets must use a splice tape, as the overlapping must be at least 150 mm wide. In case of deep basements, the membrane may be fully adhered or loose laid using mechanical fastening at the upper end. The walls must be dry and smooth, without any lumps, sharp edges and protruding reinforcement.The protective layer of geotextile should be 500 gsm, for vertical membrane, which is spot-adhered using bonding adhesive. The installation of EPDM membrane is shown in Fig. 12 & 13 respectively.

Fig. 12: Installation of EPDM based membrane system

Fig. 13: View of EPDM based waterproofing membrane system

- Hybrid Rubber Neoprene system (Fig. 14) is spray applied which gives a seamless waterproof membrane without any joint and fully bonded to the substrate in few seconds having high elasticity and crack bridging properties. It is the fastest method for installation. It can be bonded to any kind of surfaces. Basement area can be backfilled immediately after the application but requires specialised applicators for installation. This system is very much suitable for large and deep basement.

Fig. 14: Spraying **of** Hybrid Rubber Neoprene system

5.1.6 Performance Tests for Waterproofing System

Testing of waterproofing such as ponding tests and spray tests should be conducted prior to covering with screeding. Some tests like resistance to chemical attack, tensile strength, flexibility, fatigue fracture and water vapour transmission may be conducted before installation of the protection system. Other important tests such as the joint movement accommodation test should be conducted for checking the movements caused by thermal or moisture content changes in the surfacing or substrate materials. Wherever the high water table exists, the waterproofing material should be checked through the hydrostatic pressure test. Materials used must be waterproofed or water resistant for their intended life and must maintain their integrity in their intended use.

5.2 Structurally Integral Protection System

The structurally integral protection system (Fig. 15) comprises of only the reinforced or prestressed concrete structure that is designed to minimize water penetration by the structure itself. The permeability of the concrete is reduced by introducing water-reducing agents, high performance PCE (Polycarboxylate ether) superplasticizers, and pozzolanic products such as Silica-fume or Aluminosilicate, organic binders or pore blocking additives. Provisions have to be made to make all the joints watertight with hydrophillic waterbar and hydroreactive expansive sealant. Protection against water penetration relies on the design and construction of high quality concrete, with cracking controlled to prevent the penetration of moisture to an unacceptable degree. The design of a concrete mix is important, and whether the concrete is site-mixed or ready-mixed it should be produced in accordance with IS 10262:2009.

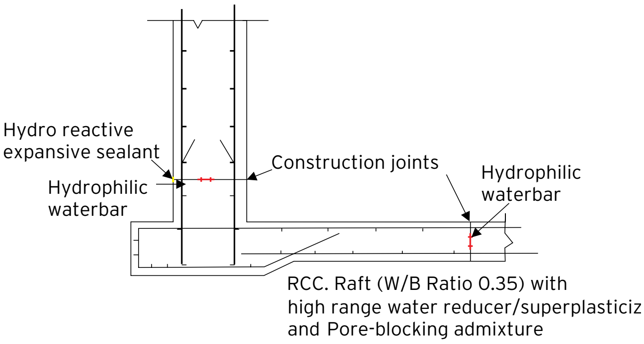

Fig. 15: Details of integral protection system

The degree of success in achieving a watertight structure depends on the quality of workmanship in making and placing concrete, good site organisation, clean and dry excavation, careful storage of materials, close fitting formwork, correctly fixed reinforcement, clean and properly prepared joints and adequate curing. The degree of water and vapour resistance achievable generally increases with construction costs; however, complete environmental control, by integral protection alone, cannot be guaranteed in practice for any construction method. This should be provided along with tanked protection for all habitable and storage areas.

5.3 Drained Cavity Protection System

The drained cavity protection system (Fig. 16) comprises of cavity floors and walls with drainage channels leading to sumps, from which any water penetrating into the basement can be pumped away. This system is usually adopted where an external tanking system cannot be provided due to the construction system e.g. cofferdams comprising diaphragm walls or secant piles. It is therefore more practical to accept some water penetration and design for positive removal of water. This should also be provided as additional protection for all important structures.

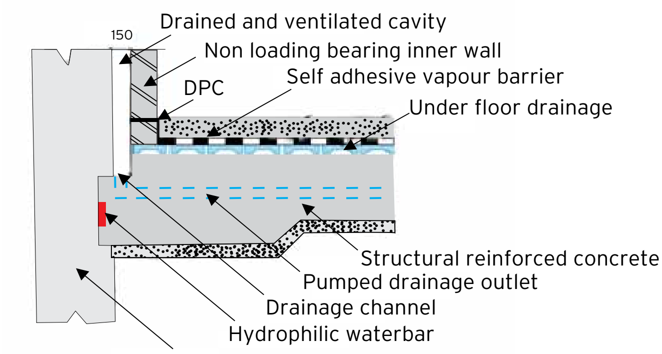

Fig. 16: Drained cavity protection system

In this system the basement structure should be designed to minimise the ingress of water. Any moisture which does find its way into the basement is channeled, collected and discharged within the cavity created through the addition of an inner skin to the walls and/or floor. Vapour transmission may be prevented by ventilation of the cavity and by providing an effective damp-proofing membrane over the under drained floors and walls. The cavity should not be used to conceal large leaks. Cavities should be provided to allow the free flow of any water penetrations, which should be directed to water collecting points. The water collecting points, either channels or scupper drains, should be provided within the structure to discharge into sumps. The collected water should then be pumped or connected to a drainage system. Wall cavities should be adequately ventilated to prevent any build up of a saturated atmosphere inside the cavities.

Care should be taken during the construction of the cavities to keep them clear and free from debris and mortar droppings. Any ties used to stabilize the inner skin should be made of non-ferrous materials twisted to shed any water that may collect on them.

6.0 Conclusions

In urban areas and particularly in metropolitan cities, availability of land for housing and commercial activities is limited for which the designers and developers keep a provision for basements for various purposes. But the most critical issue in basement design is the waterproofing of the structure. The design of the basement and the waterproofing material is more important for providing the serviceability of the basement towards the intended usage. Waterproofing failure is a common problem in most of the basements because of improper design, improper study of existing environmental parameters affecting the basement and traditional ways of waterproofing without using any polymer modified bituminous coating or different preformed membranes. Again choosing the waterproofing material for shallow and deep basements is also important. Positive side waterproofing with external tanking is always more suitable. Based on the required internal environment and importance of the structure, additional water proofing should be done on the negative side. If the structure is in high water table or in deep basements, drainage with an automatic pumping facility should be provided. So it can be concluded that the waterproofing of basements of new structures with advanced materials and systems is an art while understanding some basic principles of hydrodynamics rather than a science itself.

Codes of Practices for Reference

•BS8102:1990, Code of Practice for Protection of Structures against Water from the Ground, British Standards Institution.
•CIRIA Report 139: Water-Resisting Basement Construction - A Guide, Construction Industry Research and Information Association (CIRIA)
•Singapore Standard-CP 82:1999, Code of practice for Waterproofing of Reinforced Concrete Buildings

Case Studies of Basement Waterproofing of New Structures

1.0 Watertight Concrete Basement of a Car Park

This case study discusses waterproofing systems adopted in a basement at a new underground car park in London. The construction of this basement consisted of a car park serving five adjacent blocks of between 3 and 19 storeys which were multiple-usage developments comprising luxury hotels, residentials and retail/ commercial buildings located in the vicinity of London's Wembley Stadium. It mainly addressed the material requirements for the construction of a watertight concrete basement. After listing the waterproofing membranes and systems, including admixtures, the emphasis was laid upon providing increased resistance to water and water vapour.

All the concrete requirements were met including the minimum cement content and maximum water/ cement ratio for the inclusion of the admixture. Based on the cement content (350kg/m^3), the recommended dosage rate for the admixture was 4.1kg/m^3. An integral crystalline admixture was used as special chemical treatment, formulated to waterproof and protect concrete and was designed to be added at the time of batching. In this system, the active chemicals react with fresh concrete to generate a non-soluble crystalline formation. This seals the concrete itself against the penetration of water or liquid, inhibiting the ingress of water through small cracks or shrinkage and protecting it from the deteriorating effect of harsh environmental conditions. However, the most vulnerable parts in a basement are the joints. Those joints were provided with preformed waterbar in a ready-to-use roll which could swell up to 350% when in contact with water. When fully encapsulated by poured concrete, the expansive forces form a seal against concrete surfaces to resist hydrostatic pressure and to stop water from entering the substructures. It then returns to its original size if the concrete and substrate is completely dry but re-expands to seal the potential leaking joints when water or moisture is reintroduced. It withstands up to a 40 meter-head of water pressure. All the critical applications like rebated construction joints, service pipe penetrations etc. were taken care of by a gun-applied, one-component, hydro-reactive, expansion sealant that could swell up to 100 % when in contact with water to create durable waterproofing. It was observed that the minor and typical thermal/shrinkage cracks originally noted had actively self-healed. This active nature of water tight concrete admixture system used has more benefit than dormant pore-blocking systems.

[Source: Concrete, Concrete Society, UK, August, 2012, pp.36-37]

2.0 Twin Waterproofing System Ensures Dry Basements

This case study discusses a twin waterproofing system which was adopted in the construction of the basement at the new DMC Building at Goldsmiths, University of London. The basement was 4.5 m deep and extended to complete a 1800 m^2 footprint of the new two storey building above it.

In the first approach integral crystalline system was used to make watertight concrete. The blended cement used was 20% flyash with Portland cement of 350kg/m^3 admixed with integral crystalline admixture dosed @ 4.1 kg/m^3 (1.17% by weight of cement) with a water cement ratio of 0.45 to produce watertight concrete. All the construction joints to the capping beam, wall capping beam, wall-floor and floor-floor joints were waterproofed with a gun-applied one-component hydro-reactive expansion sealant and preformed waterbar forming a completely watertight concrete system. Where shrinkage cracks occured, the in-depth crystallization process of the admixture enabled those cracks to self-heal over a period of time, minimising the need for repair to non-structural cracks in the concrete. It also protected the steel reinforcement within the structure against harsh/ aggressive ground chemicals and enhanced the workability of the concrete.

Additionally a heavy duty, deep studded HDPE cavity drained membrane system was also used as a secondary waterproofing system to provide extra security. It involved the installation of a cavity drained membrane - 5mm thick for the walls and 20 mm thick for the floors - a liquid rubber membrane applied to external surfaces as primary external waterproofer and a double drain tough geo-membrane applied as a drainage/protection layer. Application of the 20 mm membrane to the floors was used so that a grater capacity of water could pass beneath the floor to reach the drainage sumps and could reduce the blocking effects of any free lime that would have leached from fresh concrete. Over the floor membrane reinforced screed of 150 mm thick was provided. To complete the cavity drained membrane system, 300 linear meters of Aqua channel (drainage conduit) were laid around the basement perimeter to direct any water to the sumps. Pre-formed inspection ports were installed at approximately every 12m of conduit to meet the requirement for a sustainable drainage system.

(Source: Concrete, Concrete Society, UK, February, 2010, pp.32-33)

3.0 Watertight Concrete Solutions Below Ground

This case study highlights the benefits of the integral protection system of waterproofing. The Millennium Mile project consisted of 219 luxury apartments built over a large underground car park very close to the River Welland in UK. Because of the close proximity to the river and its high water table, an integral system was adopted to make the basement slab watertight for keeping the car park dry.

The watertight ready-mixed concrete with liquid admixture was pumped directly through a batching plant's standard admixture dispenser. The specification used was a minimum cement content of 350 kg/m^3, and a maximum water cement ratio of 0.45 with liquid admixture of 1.5% by the weight of cement. The capillary pores were reduced by reducing the water:cement ratio of the concrete which was achieved by adding a high range water reducing admixture of @0.5-1.0% by the weight of cement. The remaining capillary pores were blocked by using a liquid admixture @1.5% by the weight of cement. The slump with the same mix was 130mm which was enough for achieving a self compacting concrete.

The basement was cast directly up to the sacrificial, welded sheet pile walls and was waterproofed at the interface with hydrophilic strips. Due to the available concrete cover, two strips were run parallel along this joint for additional security. The strips were glued in place using a single component hydrophilic polyurethane sealant that swells in contact with water. This gave a secure fixing to the substrate and, being hydrophilic, an extra level of protection at the joint. It saved significant time and money due to its simple detailing of the concrete in comparison to traditional systems such as membranes and cavity drainage.

(Source: Concrete, Concrete Society, UK, July, 2009, pp.33-34)

4.0 Watertight Concrete Solutions for Basements

The highlight in this case study was that the membrane prevented the natural autogenous healing of early-age cracks in concrete. It is therefore better to avoid external membranes and rely on a correctly reinforced, quality watertight concrete system. Cavity drainage systems have their own problems. There can be a tendency for silt to build up in the drainage system, and pumps need to be maintained at regular intervals to ensure the system works correctly.

A high range water reducer/superplasticizer was used to reduce the water:cement ratio along with a second admixture as a pore-blocking admixture. The second one reacts with the calcium ions in the cement paste to produce a hydrophobic layer within the capillary pores and to block the pores to provide an effective protection even at 10 bar (100m head of water). The admixture used was easily dosed liquid that was added during the batching process at the plant. The ready-mixed concrete obtained was a minimum cementious content of 350kg/m^3 and maximum water cement ratio of 0.45. Self compacting watertight concrete was used in this case. The pour sequences and bay sizes were planned properly in order to reduce the risk of shrinkage cracking.

Non-movement joints were sealed using hydrophilic strips, which swell on contact with water and come in various shapes and sizes. The strips often have a protective surface coating to reduce the risk of premature swelling if for instance it rains prior to casting the concrete. To effectively place and keep its profile in position, it is advisable to use a hydrophilic adhesive that also enhances the performance of the joint. The profile needs a minimum of 75mm concrete cover. Where a structure requires a higher level of protection, more advanced joint systems are available, like a combination of hydrophilic elements built into a resin injectionable hose. This provides an excellent secondary line of defence. Where movement joints are necessary, these can be sealed using Hypalon strips secured internally or externally using specialist epoxy adhesives, or traditional PVC waterbars.

(Source: Concrete, Concrete Society, UK, July, 2008, pp.40-41)

5.0 An Innovative and Engineered Solution for Basement Waterproofing

The present case study is of BVR Mall at Vijayawada in Andhra Pradesh, India. It was designed for 3 basements where the basement floor was –12 m below ground level, water table was very high and the sandy soil substrate of the coastal belt posed a problem for differential settlement of raft foundation. The retaining wall flushed with the secant piling was creating problems for the installation of waterproofing systems in the absence of working spaces.

A special design-engineered membrane was used in this case. The membrane comprised of a complex cell mesh bonded to a polyethylene membrane, which allows poured concrete to interlock with the membrane, forming a tenacious mechanical bond preventing water migration in case accidental damage occurs. These membranes were loose laid over compacted soil and secured vertically against formwork before the concrete was poured. The thickness of membrane was 4mm and reinforcement was placed directly over the membrane. The membrane roll was 1.27 m x 30 m and unrolled directly on the reinforcement and overlapped using selvedge inbuilt with the membrane. Pre-applied systems enabled installation with minimum surface preparation even in wet conditions without any protection screed, saving time and cost of the protection screed. The simple and effective joint detailing for pressure releasing valves piercing through the membrane made using standard accessories easy.

In the absence of working spaces, a membrane was fixed to the sacrificial shuttering provided on the secant pile for achieving positive side waterproofing.

(Source: Civil Engineering and Construction Review, Vol.25, No.3, March 2012, pp.136-137).

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Date : 20th June 2012
Venue : National Institute of Technical Teachers' Training Institute and Research (NITTTR), Bhopal

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Venue : Veermata Jijabai Technological Institute (VJTI), Mumbai

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• Structural & Repair Consultants Meet

Topic : Advanced Non-Destructive Diagnostic Techniques
Date : 20th June 2012
Participants : ONGC, BMC and Repair consultants
Venue : SFI-SPR, Mumbai

• Paper Presentation/Publication

- Paper presented by Mr. T.P. Banerjee on "Improving life of Structures by Quality Waterproofing" at 2nd Annual Conference on "Metamorphosis in Construction & Building Industry 2012" organized by Braj Binani Group and Asian Industry & Information Services Pvt. Ltd. held at Hotel Hilton, Mumbai on 15th June 2012.

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2	7 March 2013	DFI - SPR, Andheri (E), Mumbai	Corrosion in Concrete and Protection Measures	₹ 2000	• Principles of corrosion and consequent damages in concrete • Diagnosis and evaluation of corrosion distresses • Protection measures – techniques and materials

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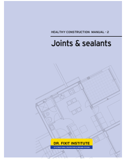

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Errata: Rebuild, Vol. 6, No. 1, page 3, 1.0 Introduction, 2nd line, Read 500000 crore billion as 5000 crore

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