Research Article

Journal of Environmental Nanotechnology

Effect of Waterproofing Systems and Materials on the Environment

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Received: 10.08.2018 Accepted: 14.10.2018 Published: 30-12-2018
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ABSTRACT

The primary aim of concrete waterproofing is to prevent water from penetrating the concrete, thereby increasing its longevity. The use of waterproofing materials has a beneficial impact on the environment by preventing water and resource wastages, reducing health hazards and improving the internal air quality of concrete structures. There are several waterproofing materials and solutions available in the market. Modified cement mortars, membranes and coatings are the three types of waterproofing systems. Each of these categories, as well as its subclasses, has been thoroughly examined to determine their benefits and drawbacks. Finding the perfect waterproofing technique and material is still a pipe dream.

Keywords: Environmental effects; Waterproofing materials; Waterproofing systems.

1. INTRODUCTION

Waterproofing is a basic requirement for all types of structures like residential, commercial or industrial buildings. Waterproofing compounds are used primarily to stop the ingress of water into the concrete, but these directly or indirectly helps in nourishing the environment too.

Concrete waterproofing aids in preserving the environment by reducing the wastage of water. Waterproofing compounds like plasticizers, superplasticizers have been reported to reduce the consumption of water by 5 to 30% of the total water used at the time of mixing and reduce the water/ cement ratio (w/c ratio) without altering the workability of a particular concrete mix resulting in less permeable, denser concrete/masonry structures. The amount of water saved throughout the world in this era of large-scale constructions can be idealized. Waterproofing of concrete also prevents wastage of resources by reducing corrosion of steel and concrete spalling in RCC structures, caused due to moist environment of concrete, taking a toll on the overall durability of the structure and can be avoided by the use of some waterproofing compounds. It improves the pore structure and also provides a water-resistant environment for the steel. The increase in durability results in an increase in the overall life of the structure, which helps in the prevention of the wastage of resources used in construction. Waterproofing of concrete also minimizes health hazards mainly caused due to dampness of concrete. The dampness of concrete offers favorable conditions for the growth of mosquitoes and other infective microbes, which are the main causes of fatal diseases like Zika virus, Malaria, West Nile virus, Dengue fever, Yellow fever and Chikungunya. Many epidemiological studies have shown linkages between dampness and adverse health effects. Waterproofing helps in reducing the permeability of water and moisture transmission, thereby facilitating the concrete to be almost damp-free, which in turn helps to fight the adverse effects of dampness on human health. Waterproofing also improves the internal air quality of buildings.

The degraded quality of air caused by dampness and mould growth within the buildings has adverse effects on human health and manifests in various forms ranging from irritation of mucous membranes, respiratory symptoms and infections to chronic diseases like asthma and allergy. Etiopathogenesis of these diseased conditions predisposed by dampness is properly documented (Udofia *et al.* 2014). Waterproofing of concrete enhances internal air quality and eliminates repair and maintenance of buildings to a greater extent. The aesthetic look of the buildings could also be maintained for a much longer time by using waterproofing materials. Different types of waterproofing materials and systems are discussed below:

2. WATERPROOFING SYSTEMS AND MATERIALS

Numerous waterproofing systems and materials are available in the market. These waterproofing systems and materials have been classified as shown in Fig. 1.

2. 1 Modified Cement Mortars

Good compatibility of Modified cement mortars with cement makes them preferable over other waterproofing systems. Waterproofing chemicals (Modifiers) are added to cement mortars to upgrade their properties. This ensures no passage of water through the matrix. Such mortars are applied over rooftops, toilet floor, basement and wet areas to keep concrete dry. Materials used being economical makes it cost-effective, and surface preparation is not compulsory for its application. Modifiers are broadly classified as polymeric and non-polymeric materials. Non-polymeric materials are integral waterproofing materials in the form of dry powders or liquids such as plasticizer, mineral admixtures, pore blockers and repellents which function well when mixed with cement mortar.

Polymeric-based waterproofing materials offer low permeability, superior workability and strength and minimal shrinking, making those practical and long-lasting solutions. The most effective polymer-based modifiers include latex emulsions of styrene-butadiene rubber (SBR), acrylics, acrylonitrile rubber and styrene-acrylic ester.

2.1.1 Non-Polymeric Modifiers

2.1.1.1. Plasticizers

Plasticizers that allow a reduction in water content for the given workability or give higher workability at the same water content are called plasticizing admixtures. The advantages are considerable in both cases: in the former, concretes are stronger, and in the latter, they are more workable. Plasticizers based on lignosulphonates improve the flowability or workability of cement mortar by releasing water trapped between cement particles as a result of deflocculating the cement particles through electrostatic repulsion (Jayashree *et al.* 2011). Lignosulphonate-modified cement mortar has mechanical characteristics almost identical to that of unmodified cement mortar. When used solely inside, where there is no exposure to UV light or wetting-drying cycles, integral waterproofing modified cement mortars may be the most cost-effective modification of cement mortar.

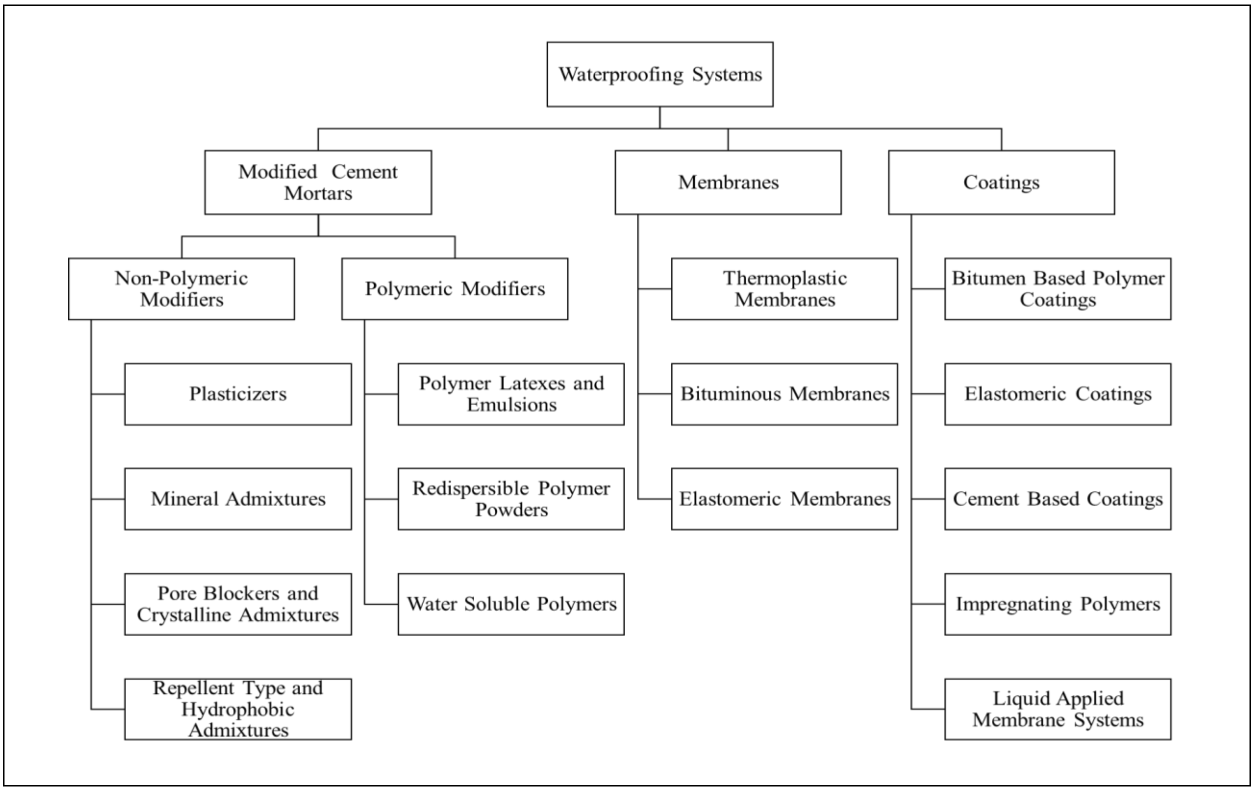

Fig. 1: Different types of waterproofing systems and materials

2.1.1.2 Mineral Admixtures

Mineral admixtures help in improving the quality of concrete. Use of mineral admixture decreases the permeability, retards or accelerates the initial setting time, prevents shrinkage, reduces segregation and increases the overall strength of concrete. Some of the commonly used mineral admixtures are silica fume, fly ash, rice husk ash, ground and granulated blast furnace slag. The dosage of each mineral admixture varies.

2.1.1.3 Pore Blockers and Crystalline Admixtures

The addition of admixtures such as finely split inert fillers and wax or bitumen emulsions, which cover the tiny holes in the hardened cement paste, can limit water permeability through mortars. When exposed to water under pressure, the wax and bitumen emulsions fill the capillaries and function as plugs to prevent additional water penetration (Chan *et al.*1999*)*. The interaction of crystalline admixtures with calcium hydroxide in the presence of water is predicted to increase the impermeability of concrete by producing water-insoluble crystals that fill and plug holes and micro-cracks in the concrete.

2.1.1.4 Repellent Type or Hydrophobic Admixtures

Hydrophobic admixtures reduce permeability, of soaps based on calcium, potassium, ammonium and butyl salts of long-chain fatty acid derivatives, such as stearates, oleates and caprylates and petroleum-derived materials. Water-repellent salts are formed by the reaction of calcium hydroxide in the inside the pores; moistened cement paste acts as a barrier. Water is prevented from infiltrating the concrete structure by the application of such materials, which cause water to bead on the surface.

2.1.2 Polymeric Modifiers

General Mechanisms

Glass transition temperature, minimum film-forming temperature, viscoelastic behavior, the minimum dosage in the mix, its compatibility with cement mortar and cost-effectiveness are the important considerations for a polymer to be used as a modifier of cement mortar (Manjrekar, 1995). Both cement hydration and polymer film formation should occur together to yield an interpenetrating network of both phases when the polymer is incorporated in the cementitious matrix of the mortar and concrete (Ohama *et al.* 1998). The mechanism of polymer modification of the cement mortar can be described in three steps and the co-matrix phase formation has been illustrated by a simplified model shown schematically shown in Fig. 2.

Immediately after mixing with water, a mixture of cement and polymer particles gets dispersed in water around the aggregates. The steps involved are:

a) The deposition of polymer particles begins on the surfaces of the un-hydrated cement particles and the hydration products.
b) A dense layer of polymer particles is then coated on the mixture of hydration products and un-hydrated cement particles.
c) The hydration products are enveloped by polymer films in the third step.

The minimum film-forming temperature of the polymer and the relative humidity of the surrounding atmosphere are the chief factors on which the film formation of a polymer depends (Beeldens *et al.* 2005).

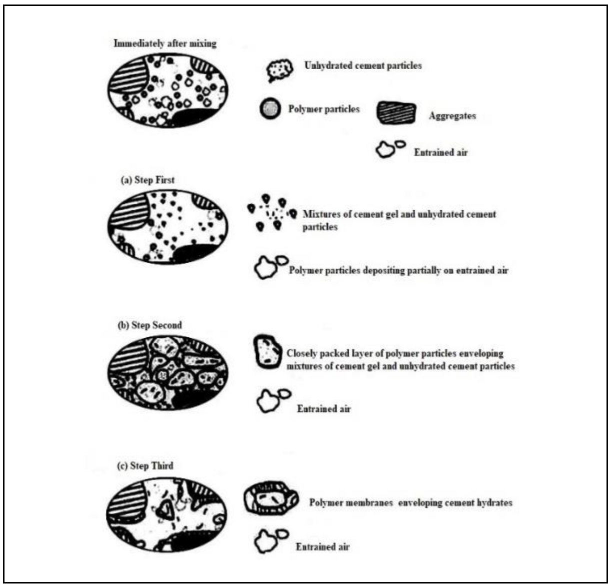

Fig. 2: Typical model of formation of Polymer cement co-matrix

2.1.2.1 Polymer Latexes and Emulsions

These are prepared by emulsion polymerization of polymer particles dispersed in an aqueous medium. Elastomeric latexes, thermo-plastic latexes, thermosetting latexes and bituminous latexes are the polymers incorporated as latexes in cement mortars. The workability of the cement mortar can be increased or the w/c ratio for the same workability can be decreased by the incorporation of the latex (Mirza *et al.* 2002). Latexes have been used to improve the adherence of cement mortar and concrete to the foundation concrete and to inhibit the absorption of water and external contaminants into the cement matrix (Afridi *et al.* 1995).

2.1.2.2 Re-dispersible Polymer Powders

The polymer latexes are spray-dried to obtain powders with particle size in the order of 1-10 μm. Before mixing with water, these are dry blended with cement. Some of the polymers included in this category are poly (ethylene-vinyl- acetate) (EVA), poly (styrene-acrylic ester) (SAE), poly (acrylic ester) (PAE), polyvinyl acetate (PVA) and vinyl acetate and versatate copolymer

(VA/VeoVa). Though they are employed in similar applications as latex-modified cement mortars, they are more popular in cementitious tile adhesives.

2.1.2.3 Water-soluble Polymers

Cellulose derivatives, polyvinyl alcohol (PVA) and polyacrylamide (PAN) are commonly used water-soluble polymers. During mixing, they are added to the cement mortar or concrete as powdered or aqueous solutions. More hydration is observed after 90 days for 1% polyvinyl alcohol-acetate, methylcellulose and hydroxyl ethyl cellulose modified mortars, in spite of initial retardation of hydration (Knapen *et al.* 2009). This attributes to a better dispersion of the cement particles in the mixing water on the addition of these polymers. Between the stacked calcium hydroxide crystals polymer bridges are formed, binding the layers together and reinforcing the microstructure. Intensive storage at high relative humidity or underwater, on the other hand, results in a significant reduction in flexural and cracking tensile strength.

2.2 Waterproofing Membranes

The sheets applied or pasted over concrete surfaces to act as a covering to protect a concrete structure from moisture are known as membranes. Seamless and essentially watertight, non-slip and durable surface is provided by the ideal membrane-based waterproofing system (Caputo *et al.* 1987).

Flexible membranes, completely bonded or membranes that adhere to joints of concrete structures, are bonded membranes. In case of a possibility of penetration or damage and to prevent lateral water migration or leakage fully bonded system is employed. At the joints, the membranes are adhered to by self-adhesive strips present longitudinally on the membranes. An embossed membrane, such as flexible polyolefin, is bonded with a specific sealant grid and reinforced with a non-woven fleece to create a waterproof membrane system. For damp-proofing, these fully bonded systems are applied to protect a structure from rising humidity, protecting concrete against the aggressive environment in the ground and waterproofing against hydrostatic pressure. Installation is easy and safe, as no welding or primer are used. The corners are initially sealed or formed with suitable adhesive waterproofing tapes and then bonded to membranes during the installation of a bonded membrane.

Almost complete durability and reliability requirements of deep foundations like basements for high-rise buildings, cut and cover tunnels and metro-stations are provided by partially bonded membrane systems, such as loosely laid PVC or FPO membrane system with compartments and injection back-up. The possibility of water migrating below the whole raft, between the whole retaining wall and the waterproofing membrane, leading to a complete failure and leakages everywhere from the raft and walls at the weak points of the concrete, are checked by employing this backup system. Complete backup mechanisms to prevent leakages, versatility and earthquake resistance are some properties of partially bonded membrane systems. These could be used for green roof installation and fasteners are employed to fix the membrane on the concrete slabs. The main types of commercially available membranes are discussed below:

2.2.1 Thermoplastic Membranes

This category comprises loosely laid or self-adhering waterproofing membranes attached to a surface using adhesives, mortar, tape, straps, anchors, plastic welding or fasteners. Sheets or panels are overlapped and fused together by heating and subsequently converted to solid upon cooling. Thermoplastic membranes change from solid-state to semi-solid state on heating. Thus, a monolithic, continuous sheet membrane is formed. The polyvinyl chloride (PVC) or vinyl membrane system is the most well-known of the available thermoplastic roof membranes. PVC membrane systems may be non-reinforced or reinforced with glass fiber or polyester fiber.

2.2.2 Bituminous Membrane

In waterproofing, styrene-butadiene-styrene copolymer (SBS) and atactic polypropylene (APP) polymer-modified bituminous membranes are commonly used. To obtain high tensile strength, tear and puncture resistance, polymerized bitumen is coated with a dimensionally stable non-woven polyester/fiberglass carrier. These are employed as flexible sheets for waterproofing of concrete bridge decks and to prevent water infiltration through the pavements and basements. These membranes are located on the positive side of the structure to prevent the ingress of water to the surface from the ground while waterproofing basements.

2.2.3 Elastomeric Membrane

Preparation of these membranes is done by modifying thermoplastic polymers with a suitable elastomer to enhance the movement and flexure of the resulting membrane. Being ready to use, good adhesion onto the base concrete in both vertical and horizontal applications are advantages of elastomeric membrane systems, thus preventing water penetration and attack when exposed to chemicals and moisture. Styrene-butadiene styrene and rubber-modified self-adhesive membranes are commercially available with an adhesive on one side for the membrane to bond to the concrete surface.

2.3 Waterproofing Coatings

Waterproofing coating methods are commonly used to prevent water and any soluble salts from permeating the concrete, preventing reinforcing steel corrosion and contact with the cement particles. Concrete constructions subjected to unfavourable topographic circumstances, severe ground and ambient salinity and a high temperature-humidity system are protected against early degradation. Waterproofing coatings have several advantages, including good adherence to the substrate, vapour permeability and fracture bridging capabilities without lowering the substrate's alkali resistance. Waterproofing swimming pools and terraces are examples of situations where waterproof-coatings can be used. Depending on the circumstances which the coating may be subjected to, most coating systems are based on epoxy, silicone, urethane, acrylic rubber, acrylic resin, polyester and polymer-modified cement and mortar.

2.3.1 Bitumen-based Polymer Coatings

These are a mixture of bitumen, mineral fillers and polymers. Either elastomeric polymers, as in the case of styrene-butadiene-styrene copolymer or elastomeric polymers, as in atactic polypropylene and acrylics, are commonly used polymers. Even at low temperatures, addition of polymer to bitumen improves the flexibility and provides an almost impermeable barrier against ingress of water, especially in the pavement in bridges, industrial washrooms, refurbishing of old bituminous roofs and tunnels. This system is employed on structures in underwater conditions, like pipelines, foundations, tanks, sewage works, effluent plants, docks and harbor installations.

2.3.2 Elastomeric Coating

A shield preventing the permeation of chloride ions into the substrate is formed by coatings such as acrylic resin solutions, water-repellent silicone resins, certain types of silane resins, acrylics and polyurethanes. Coatings based on silicone can be applied with a roller, power roller, brush or spray as they are water-based. Minimum two coats are recommended to be applied for lasting weatherproofing. Stability during weathering conditions, resistance to sunlight, ozone, rain, snow, temperature extremes, protection against cracking, chalking, peeling and blistering are some of the advantages of elastomeric coatings. To prevent leaching of chemicals from concrete before the application of silicate-based coatings to precast concrete slabs, the basic precaution to be taken is pre-treatment of the substrate.

2.3.3 Cement-based Coatings

A blend of cement, fine graded sand, polymer-based waterproofing additives and sometimes fibers based on polyethylene, polypropylene, alkali-resistant glass and acrylates will constitute cement-based coatings; they are used to control cracking due to shrinkage. The regulation of water added to apply the coating on the defective surface is the main precaution while using this system.

2.3.4 Impregnating Polymers

Low viscosity monomer-activator systems can be impregnated into precast concrete and the monomer polymerized by means of microwaves or high temperature. A protective coating on the concrete surface is formed, which improves the mechanical properties of the concrete and also durability during freezing and thaw and on exposure to a severe environment (Nair *et al.* 2010). Though the chief drawbacks include a long reaction period to form a silicone resin network, still silicon resin-based water repellent systems are also impregnated into the concrete.

2.3.5 Liquid Applied Membrane Systems

Polymer coatings of acrylics or unsaturated polyesters that are reinforced with glass, polyester or fiberglass make up liquid applied waterproofing membrane systems. The thickness of liquid membranes varies from 0.7 to 1 mm and are applied on-site by brush or spray application of liquid polymers/acrylics/ polyurethanes. These membranes are generally reinforced with glass fibers for increased durability. For polyurethane-modified acrylic dispersion-based liquid membranes, to improve the performance against carbonation, it is essential to control the thickness of the waterproofing membrane and maintain the waterproofing topcoat (Tsukagoshi *et al.* 2012).

3. CONCLUSION

Waterproofing is mandatory for all concrete structures to increase their life, conserve resources, preserve the environment and safeguard human beings as well as animal health. A critical review of all the available waterproofing systems and materials has led to the conclusion that an ideal system and material for waterproofing is yet to come into existence. An ideal waterproofing system/material having the properties of high efficacy, ready availability, easy applicability, cost-effectiveness and long durability needs to be developed on a high-priority basis, for which concrete and collective efforts are to be initiated.

FUNDING

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

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