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Advance in water proofing materials and technology challenges for industrial buildings

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Abstract
Leakages in industrial building roofs is the common phenomenon on old and new buildings due to lack of quality of works done during execution phase, which not only affects normal use of house, and erodes the main structure of buildings, but brings about great challenge to infrastructure maintenance and seriously shortens service life of buildings. Starting with the common causes for roof leakage on large industrial buildings while combining with engineering practice, this paper discussed how to prevent and control of roof leakage on industrial buildings so as to reduce the significant harm brought with.

Keywords: industrial buildings, roof leakages, forms of leakages, causes of leakages, preventive measures, control measures, dampness, water proofing chemicals, leakages, moisture, damp proofing etc

1. Introduction

Now a day's Waterproofing is the process of making a structure waterproof or water resistant so that it stays unaffected to the exposure of water, wet environment and other similar conditions. There is a wide difference between waterproof and damp proof. Water proof is the resistance to the penetration of water in liquid state whereas damp proof is the resistance to moisture, humidity or dampness. For industrial constructions, especially construction of large buildings for commercial and industrial buildings, different forms of leakages will occurs on buildings due to variety of causes e.g.; design, materials, construction and external climate etc. For the past few years, although various new water proofing materials have appeared one after another they are not widely used in Indian country yet because of expensive cost, high construction requirements and their durability which needs to be further verified. Therefore, the problem of roof leakage has not been completely solved.

In water proofing process there are taking precautions and care for leakage proof buildings. Water proofing is a treatment on a surface or structure to resist the passage of water in the presence of hydrostatic pressure. Waterproof or water-resistant describes objects relatively unaffected by water or resisting the ingress of water under specified conditions such items may be used in wet environments or underwater depth to specified depths. One of basic requirements in case all the buildings are that the structure should remain dries as far as possible. If this condition is not satisfied, it is likely that the building may become inhabitable and unsafe from structural point of view.

The discussion in this papers is based on a large no's of industrial buildings like's Subs-stations, Main control rooms in Solar PV Power plant with including storage room, Conference rooms, Scada room, Battery room, panel rooms, office rooms, pantry room, Toilets and bathrooms etc. Now a day due to cost control everyone has been used the Bricks bats water – proofing system used to control the leakages on roofs of buildings. But the control of leakages depends upon the workmanship during construction stage, Quality of bricks bats used for water proofing and cement mortar ratio with water proofing chemical proportion etc. The leakages frequency occurs on roof in recent years and it is hard to repairs. Based on the common forms and causes of roof leakages on such industrial buildings, this paper proposed corresponding preventions and control measures to reduce the great harm of roof leakage for bricks bats water proofing system.

But now a days, brickbats water proofing system found outdated from market, because form last couple of years there are various advance materials and technology solution comes in markets for water-proofing solutions for roofs of industrial buildings. In this papers I have provide the ASTM standards list of various types of water proofing solutions. But due to cost limitations we are highlighted or compared or explain only two common method which we will used during my working experience in oil and gas project in Cairn India Limited, Barmer projects, Rajasthan, India.

There are following two types of important treatments to be given to any buildings to control dampness, water leakage and anti-termite treatments will be discuss:

- Damp: Proofing.
- Water: Proofing.
- Anti: Termite Treatment

1.1 Damp Proofing: One of the basic requirements of all the buildings is that the structures should remain dry as far as possible. If this condition is not satisfied, it is likely that the building may become inhabitable and unsafe from structural point of view. Hence to prevent the entry of Damp-ness inside of the buildings for damp-ness courses layers.

1.1.1 Cause of Damp – Proof: The dampness in a building is universal problem and the various causes which are responsible for the entry of dampness in a structure are as follows:

Condensation (most common) – Moisture in the air.
Penetrating dampness – Rain getting in through gaps in the brickwork, roof, window frames, and around doors.
Rising damp – Affects basements and ground floor rooms, the signs include decayed skirting boards and floors, stained

plaster and peeling paint and wallpaper.

1.1.2 Importance Sources of Dampness: Some important sources of dampness are listed as follows:

- Defective junctions between roof slab and parapet wall.
- Defective roof covering of pitched roofs.
- Faulty eaves and valley gutters.
- Improper rain water pipe connections.
- Inadequate roof slope.
- Moisture from wet ground below foundations.
- Splashing rain water.
- Unprotected tops of walls, parapets and compound walls etc.

1.2 Water Proofing

Over the past two decades, the construction industry has had technological advances in waterproofing materials, including integral waterproofing systems as well as more advanced membrane materials. Integral systems such as hycrete work within the matrix of concrete structure, giving the concrete itself a waterproof quality. There are two main types of integral waterproofing systems: the hydrophilic and the hydrophobic systems.

1.2.1 Hydrophilic System

In hydrophilic system typically uses a crystallization technology that replaces the water in the concrete with insoluble crystals. Various waterproofing agents available in the market claim similar properties, but not all can react with a wide range of cement hydration by product, and thus require caution.

1.2.2 Hydrophobic System

Hydrophobic systems use fatty acids to block pores within the concrete, preventing water passage. Sometimes the same materials to keep water out of buildings are used to keep water in such as for a pond linear or pool liner. Generally new technology in waterproof membranes relies on polymer based materials that are extremely adhesive a seamless barrier around the outside of a structure.

Comparison between above two methods of Waterproofing shown in Fig.1.

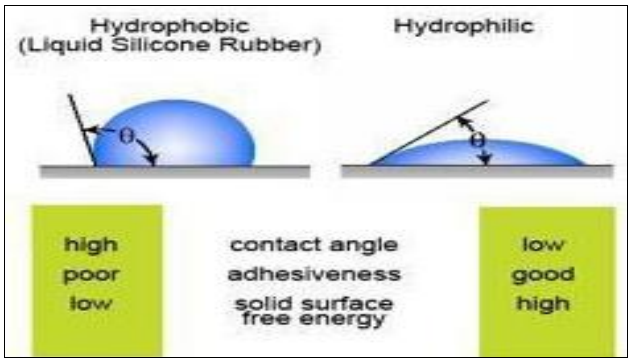

Fig 1: Hydrophilic System and Hydrophobic System (Sources from Google)

Reference Standards for various types of Roof Water – Proofing System

Table 1

List of ASTM (American Society for Testing and Materials International) for Roof water Proofing System	
ASTM Standards	Description of Standards
ASTM D1079	Definitions of Term Relating to Roofing and Waterproofing.
ASTM C836	Standard Specification for High Solids Content, Cold Liquid-Applied Elastomeric Waterproofing Membrane for Use with Separate Wearing Course
ASTM D412	Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers - Tension
ASTM D570	Standard Test Method for Water Absorption of Plastics
ASTM D903	Standard Test Method for Peel or Stripping Strength of Adhesive Bonds
ASTM D 1876	Standard Test Method for Peel Resistance of Adhesives (T-Peel Test)
ASTM D 1970	Standard Specification for Self-Adhering Polymer Modified Bituminous Sheet Materials Used as Steep Roofing Underlayment for Ice Dam Protection
ASTM D 3767	Standard Practice for Rubber - Measurement of Dimensions
ASTM D5385	Standard Test Method for Hydrostatic Pressure Resistance of Waterproofing Membranes
ASTM E96	Standard Test Method for Water vapour Transmission of Materials
ASTM E154	Standard Test Methods for Water vapour Retarders Used in Contact with Earth Under Concrete Slabs, on Walls, or as Ground Cover
ASTM D5601	Standard Test Method for Tearing Resistance of Roofing and Waterproofing Materials and Membranes
ASTM D1434	Standard Test Method for Methane Gas Permeability
ASTM D1894	Standard Test Method for Coefficient of Friction

2. Leakages

Leakage is said to be the accidental admission or escape of water through a hole or crack.

The water leakage term in buildings is used to mean the coming out of water from components like walls and floors of the buildings.

To prevent water leaks in the house, you need to address all the possible causes of this problem. Find the areas where water leakage is prominent and check these areas every once in a while, around every 6 months or so. This will help you also keep your home in good condition because you will be able to observe all of the parts of your home. In case water leaks in your house already, you need to be smart and solve the problem immediately, may it be through your own hard work or by hiring a professional repairman. Some signs of leakage are:

- Active water leakage, water ingress through any part of

the building, or from the pipe work / waste pipes.
- Dampness, moisture, wetness or signs of dampness on the floor, wall, ceiling or roof of the building. Some location where leakage is caused is: Underside of roofs, Ceiling with internal areas, Wall, Floor and Window, Basement, Drains or pipes.

There are various effects of leakage that can damage other building finishes and can also cause health problems due to growth of molds, mildew, dust mites, and other biological air contaminants.

2.1 Why Does Water Leak Though Joints?

The phenomenon of the leakage through the building joints is shown in Fig.2.

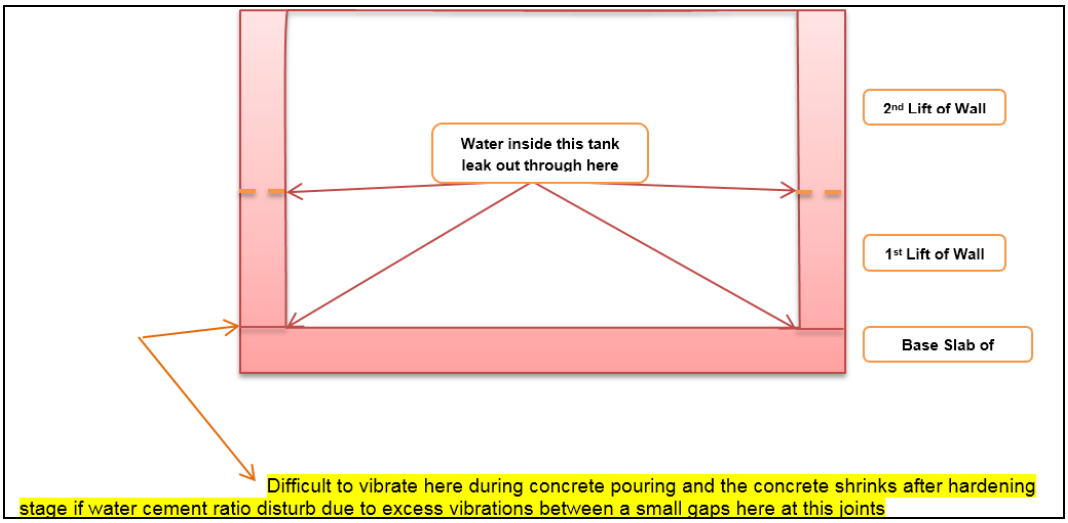

Fig 2: Schematic diagram of water leaks through joints

2.2 Why Leakage in Structural Components:

Following are some key reasons for the building leakages are:
- Poor ratio of concrete mix.
- No proper vibration while concreting.
- Concrete not being dense.
- Poor water curing.
- Poor selection of concrete raw materials.
- Bad workmanship.
- Damages caused to the building by various other agencies can also be a reason for building leakages.
- Construction, Expansion or Extension joints not joined as per specifications.

3. Objectives

The main object of the project is study of leakages and its causes and finding appropriate remedies. Some other objectives of the project are listed below.
- Study of leakage and their identification methods.
- Study of waterproofing and their methods.
- Visual Inspection of leakages, dampness & seepage.
- Determining the probable causes.
- Finding and finalizing effective remedies for the same.

4. Study of water leakage location and its causes

The study was conducted in new construction Residential site Vicenza high breeze: Tower A, B, C, D, E and F. The interested area for the study was taken as Wash, toilet, balcony, terrace, common toilet and garden area where the maximum chances of leakages.

The purpose of selecting an ongoing construction is to repair it at an early stage to improve its life period.

Once the survey work is completed, the next work is to find and suggest proper remedies for the same. The basic idea of this project is to ensure that the remedies suggested by us prove to be effective in curbing the menace of leakage and seepage problems. The remedial measure must not be only effective but also economic. It should be easily available. The implementation must be simple and not time consuming.

5. Method and Material

Initial inspection: This included identify the water leakage location and its causes by the physical verification.

Market Survey: It includes local market survey on waterproofing material available for waterproofing process.

Analysis of different Water proofing Materials: It involved estimation & costing of the waterproofing area based on the market survey.

Finally after above all steps we suggest the economical waterproofing material against conventional method used on site.

5.1 Site Investigation for Water Leakage

Table 2: Water Leakage Location and Its Causes

Location of Leakage	Possible Causes
Underside of roofs (such as flat roof, podium roofs) and bottom of light wells	Damage or deterioration of waterproofing layer.
	Leakage at access doors or top hatch doors.
	Deterioration of corrugated steel roofing materials, joints and hook bolting locations.
	Defective enclosure for water tanks.

Ceiling with internal areas above	Leakage from bathroom or kitchen above usually caused by seepage from fitments, bathtubs, shower trays, buried pipes or drains due to improper construction of joints.
	Mal-function of waterproofing in nearby external features such as balconies or external walls above.
Wall	Water penetration through external wall defects such as cracks, joints, honeycombs, spalling, weak points, holes, punctures, leftovers of debris.
	Water penetration through defective external wall finishes such as loosened mosaic tiles, cracked ceramic tiles & paint surface.
	Water leakage through partition walls between units of pre-fabricated elements or between buildings.
Floor	Defective bathroom fitments such as bathtubs, shower trays or hand wash basins, or the improper installation of pipework or necessary sealants.
	Temporary floods and overview.
	Seepage from defective pipe-works or sanitary fitments.
Window	Improper fillings around frames.
	Deformation of frame, defective gasket, sealant or putty for window glass setting or frames.
	Air conditioning box or platform tilting inwards.
	Insufficient sealant around air conditioning units.
Basement	Inadequate or damaged waterproofing tanking.
	Deterioration of water stops at Construction/movement joints.
Buried or underground drains or pipes.	Seepage through defective joints or pipes caused by poor installation or differential movements / settlements, movement of building structures or ground or water table.
	Corrosion of pipes at junctions with floors or walls.
	Invasion of water into conduits and distribute throughout the network.
	Blockage leading to excessive pressure built up.
	Attack by rodents or roots of plants.

5.2 Conventional (Brick Bat Coba) Method used On Site Why Brick Bat Coba Not the Correct Method for Terrace Waterproofing?

All existing treatment, coatings on roof slab top is to be removed and surface cleaned by hard wire brush and washed with water. The surface should be free from any oil, grease, dust etc. Remedial measured by provided to all structural cracks. Expansions joints should be treated as per standard practice as shown in Fig. 3. This case study covered for First Solar PV Project at Pungunuru, Anantpur District, and The capacity of Solar PV Plant as 40MW.

Fig 3: Laying of brick bats

India is having more than 4000 Kms of coastal line. Generally, these coastal areas receive more than average rainfall in the rainy season. The homes in these coastal areas are, therefore, more prone to leakages from terrace and walls. This not only led to peeling of paints and ruining the interiors but also led to growth of fungus. Such unhygienic conditions can be detrimental to the health of families living in these houses. So, how can we tackle such severe leakage issues? In India, terrace waterproofing has always been done with very traditional materials. Typical conventional systems like brick bat coba, Lime terracing or the "Mud Fuska" technique are still very much prevalent. These systems are supposed to be offering terrace waterproofing solution with some insulation against heat. The brick bat coba is used particularly for waterproofing of flat roofs, primarily RCC with some thermal insulation (mud phuska) in the coastal region. It consists of putting brick bats on roofs, to give a slope and then grouting the same with mortar admixed with various proprietary chemicals most in the nature of waterproofing compounds. In the new construction house, it provides an excellent slope in a moderate cost, so that the water drains away. Though this conventional way of terrace waterproofing is prevalent, it is not a correct way of terrace waterproofing method, it just gives slope to terrace to drains away the water accumulated on terrace. Over the years, it has been followed and believed to be the most trusted waterproofing system which unfortunately is not true. Many times, it is said that it provides heat insulation which is also not true. This claim can't be quantified as it is not measurable. Moreover, it has been observed that the coba surface attains the same temperature as the bare cement slab during the peak hours in summer.

5.3 Procedure of Brick Coba Method

The following sequential methodology should be explain

On the above green mortar, a layer of brick bats, soaked overnight in water, is laid, having an average thickness of about 110 mm, about 70 mm near rain water pipe and 150 mm at ridge.

The gaps between the brick bats are generally kept between 15 and 20 mm. These gaps are filled with cement sand mortar, 1:4, admixed with water proofing compound.. In hot and dry weather, the surface should be covered with wet gunny bags immediately after finishing. Curing should start next day and continued for minimum of 7 days.

The top surface is then finished smooth with 20 mm thick cement sand mortar, 1:4, admixed with water proofing compound. All liquid admixtures should be mixed with the mixing water. The surface when green is marked with the squares boxes sizes of 300X300mm to prevent the cracks occurs due to poor workmanship or temperature cracks.

Curing should be done by pounding methods.
The procedure also describes by the Figs. 4 and 5.

Fig 4: Cementing after brick bats lying

Fig 5: Bricks lying and mortar filling for each layer

Fig 6: Final layer finishing surface of bricks bats water proofing

5.4 Why is brickbats COBA (BBC) not the correct method for terrace water proofing?

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This conventional method has serve following limitations, hence it can't be called as a waterproofing method

5.4.1 Imposes unnecessary load

This system has the disadvantage of imposing an unnecessary load on the system. The thickness of the Bricks bats coba is maintained at about 125mm to 150mm which adds unnecessary dead load on the slab. Once cracks appears they are almost impossible to repairs and water as in the case of the tar felting travels below the coba and exits wherever it finds a path. It is impossible to trace the inlet point let alone repairs it.

5.4.2 Cracks reappeared due to temperature variations

The bricks bats coba system is a rigid one and cannot accommodate the movements due to thermal stresses. This leads to developments of cracks. The bricks bats coba treatments, though successful in the damp heat of coastal regions, Cracks up completely on contact with the variations of temperature faced in North India between day and night temperatures.

5.4.3 Damages Mother Slab

Some parts of the coba sticks so well to the concrete that even if an attempt is made to dismantle the system the mother slab get damaged.

5.4.4 Bricks acts as water reservoir

The bricks used in the system are porous and when water enters, these bricks readily absorb and hold large amount of water creating a sort of reservoir above the slab. The quality of bricks used in BBC is usually of not a good quality hence over a period of time they absorb water and become loose and give way to more leakages.

5.4.5 Creates Noise, Debris

The coba adheres firmly to the slab and the usage of chisels

and hammers can create cracks on the slab, aggravating the problems rather than resolving the same. The disposal of the debris from the dismantled system is yet again a cumber – some issue. Re-laying of the similar bricks bats coba again is certainly not answer to this problem.

5.4.6 Lack of skilled manpower

These days due to lack of skilled manpower and lack of attention to details, rainwater seeps through the cracks in the brickbat tiling and collects under the mud phuska causing seepage into the RCC roof. In order to repairs this all layers of the roof have to be opened up and waterproofing layer done. This causes hardship to the apart from cost related issues. The expert in the field of construction Industry validates these points.

Bricks bats coba will have lot of surface cracks and hence it is not a water-proofing system. The quality of bricks used in BBC is usually of not a good quality, hence over a period of time they absorb water and becomes loose and give way to more leakages. Bricks bats coba should not be confused for waterproofing. It is a good weather proof layer

This process works well when the quality of workmanship is high and the masons are well experienced in taking care of the details and jointing etc. But there is lack of skilled labours and lack of attention to detail. So the system gets failed miserably". He further confirms that hardly anybody uses such method of brickbat coba for terrace waterproofing internationally. The best practice used internationally is to coat the terrace with elastomeric coatings. These coatings have certain define advantages over conventional brickbat coba method.

- It does not impose any unnecessary load on mother slab, as it just a coating of 300-400 microns.
- These coatings have high crack bridging ability. As it is elastic in nature, it can accommodate the movements due to thermal stresses.
- It can be easily applied by brush or roller, so it does not damage mother slab while application.
- It does not create any noise, debris while application. It can be applied over existing brickbat coba, without dismantling the same.
- If any of the patches is damaged by some reason, it can be coated with ease again.
- This method ensures the waterproofing of terrace in much less time as compared to brickbat coba.
- It lasts long for 5 years without any hassles.

These initiatives have been taken solely to spread awareness of good and healthy construction practices.

5.4.7 Market Survey

There are umpteen companies available and wide material available for different waterproofing materials of different level and different problems.

Few companies are:

Dr. FIXIT

BASF

FOSROC

SIKA

Membrane Water-proofing System

6. Advances in waterproofing and materials technology

"Water leakage is a serious recurring problem and the traditional approach from the negative side is, at best, a short term solution. Performance of most waterproofing technologies today falls short of expectations, often resulting in continuing damage and economic loss. The key to perfect waterproofing is to solve these existing problems with the positive approach."

> "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."

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. Leaks and dampness in walls, ceilings, roofs, etc. can certainly be prevented. It is important to appreciate that in a country like India with its seasonal heavy rainfall, efficient waterproofing of structures should receive the utmost attention right at the time of construction itself. Many builders tend to neglect this primary precaution, not with-standing the fact that the pre-monsoon repairs soon turn out to be more expensive than pre-planned preventive measures during construction.

7. Commonly used waterproofing systems till date

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.

7.1 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.

7.2 Impregnation: For waterproofing of old and new structures, impregnation 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.

7.3 Film Forming Membrane: This may be a liquid applied waterproofing coating or a preformed elastomeric membrane.

7.4 Surfacing: For waterproofing, asphalt, concrete, epoxy mortar, polymer concrete, polymer modified mortar etc. are used as an over-layment or cover over concrete.

7.5 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.

The conventional methods of lime concrete, brick bat cob a though are still in use as waterproofing system but these methods are slowly becoming obsolete due to their short life

and complexity of their application. In between polymeric membrane as a waterproofing coating gained popularity because of its abundant availability as a by-product from petroleum at a cheaper price.

6. About polymeric membranes

Polymeric materials – acrylics, epoxy resins, polysulphides, polyurethanes and silicones – have been employed in many forms for waterproofing applications in building and construction. Elastomeric sheeting materials – such as neoprene, butyl, hypaion, PVC, rubberized asphalt – have been used for waterproofing of roofs in several countries. Their high cost and unknown performance in tropical climates have, however, been reasons for non-acceptance of these materials so far in India.

Polymeric membranes represent a transformation to a superior, factory made component that reduces field work, where quality control is most difficult. Considered the next stage in the evolution of traditional built-up membrane, modified polymeric membranes reduce the2 or 3-ply, field-fabricated membrane to a more flexible, ductile sheet of 1 or 2 plies. The slightly higher material cost is generally offset by its cost effectiveness in the long run.

Two types of polymers dominate the modified membrane with their outstanding performance.

1. Atactic polypropylene (APP)
2. Styrene Butadiene styrene (SBS)

The two major polymers APP & SBS differ fundamentally in the chemical nature. APP is aplastomer whereas SBS is an elastomer. This chemical difference manifests itself physically in much greater elasticity for SBS- based modified bitumen, with more nearly uniform properties through wider temperature range e.g. greater flexibility at low temperature. APP modified bitumen are generally stronger and stiffer than SBS modified. They also greater resistance to high temperatures.

9. Latest addition to water proofing technology

Though all the polymeric membranes are widely used yet their performance today falls short of expectations, often resulting in continuing damage and economic loss. Figure 3 depicts the shortfalls of these technology and expectations from an ideal waterproofing material.

Some of the latest additions to the waterproofing technology are being discussed below which tries to overcome the above mentioned shortfalls.

a. Thermoplastic & Thermo set Membranes-Single ply synthetic roofing membrane based on thermoplastic & thermo set technology are the latest addition to the waterproofing membrane family besides polymeric modified bituminous membrane.
b. Thermo set membranes are those whose principle polymers are chemically cross linked. This chemical cross-linkage is commonly referred as vulcanization. Main characteristic of thermo set polymers is once they are fully cured they can be bonded to like material with an adhesive. The four common sub-categories of thermo set roof membranes are

- Neoprene (CR)
- Chlorosulfonated Polyethylene (CPSE)
- Epichlorohydrine (ECH)
- Ethylene Propylene Diene Monomer (EPDM)

Unlike thermo set membranes, thermoplastic membrane is different because there is no chemical cross linking. Thermoplastic membranes are single ply flexible sheet materials that are divided into seven general sub categories.

- Polyvinyl Chloride (PVC)
- Copolymer Alloy (CPA)
- Ethylene Interpolymer (EIP)
- Nitrile Alloys (TPA)
- Tripolymer Alloy (TPA)
- Chlorinated Polyethylene (CPE)
- Thermoplastic Olefin (TPO)

Flexible PVC membrane in the thermoplastic category & EPDM in the thermo set category are becoming quite popular though Neoprene, thermoplastic Olefins are also being used for specific requirements.

10. Active polymer technology

The predominate problem with conventional thermoplastic waterproofing membranes is that since they are installed loose laid they require an expensive grid anchoring system to isolate water infiltration due to an installation defect or puncture. But some advanced technology has evolved where if the thermoplastic membrane is punctured, its Active Polymer Core (APC) activates with the water to seal the breach thus preventing water infiltration in to the structure. Active Polymer Core Technology activates and seals water breach through the thermoplastic membrane – automatically and reliably. Unlike conventional thermoplastic waterproofing membranes, expensive grid containment systems are not required to maintain or control water infiltration. Additionally, the APC geo textile layer provides a protective cushion to decrease the potential of the thermoplastic membrane to be punctured from irregular substrate surface texture. Figure 4 shows advantage of APC technology over the conventional technology.

A new concept in waterproofing material has come up which forms a gel that expands and adheres to any leaking area upon contact with water. This gel is formed by combining a polymer resin of rubberized asphalt with special adhesives. It seeks out leaks and expands to repair damaged layers. It absorbs movement and vibration to minimize damage and separation. This material can be applied as a membrane sheet or a repair material in any environment (Refer Figure 5).

The benefits attained with such materials are as mentioned below

- Responsive to substrate movement and absorbs vibration due to the gel's flexibility and dampening cap-abilities
- Materials are non-degradable and thus maintain a continuous waterproofing layer
- Not affected by foreign substance, maintaining consistent adhesive, stable waterproof coating
- Self-sealing and expands upon contact with water
- Workability in wet conditions or underwater structures
- Superior tensile strength and tear resistance
- Superior repetitive fatigue resistance
- Soft sheet facilitates work on bent parts
- Excellent viscosity

Nano technology in waterproofing building materials- The new development in science & technology has allowed

using the latest Nano technology to produce eco-friendly Organ-Silicon products to waterproof practically all the different kinds of building materials. Nano technology has ensured that service life of this approach will lead to life cycles beyond 20 to 30 years at very economical cost. There are two classes of waterproofing products

a. **Film Formers:** The economics and the ease of application have led to widespread use of film forming water repellents. The products like acrylic paint, silicon polymers are commonly used in the world for waterproofing application. These film formers have particle size greater than 100 nm, which will not allow them to penetrate inside the pores of the building materials but form a film covering and preventing the surface from water absorption.
b. **Penetrants:** Most penetrants are solvent based, soluble monomeric material with less than 6nm size. They easily penetrate inside the pores and sub-branches of the pores. There are two types of penetrants i.e. non-reactive and reactive.

Experimentally it has been seen that Silane based water-proofing products are desirable for long-term performance. Silanes and Silane/Siloxanes are known as new class of waterproofing products. These products are used in USA and Europe for last 30 years. However only last few years they became available in India. The solvent based silane waterproofing compounds are proven to provide long lasting performance and are used very widely in USA and Europe. The various alkyl silanes that are used for waterproofing are (i) isobutyltrialkoxysilane (ii) n-octyltrialkoxysilane. Therefore, these types of products impart water repellency by modifying surface characteristics from hydrophilic to hydrophobic.

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

In addition 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.

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.

Table 3

Lists of Advance Technology Methods for Waterproofing systems	
Standards Reference	Type of Water Proofing system
IS 1346 (1991)	Code of practice for Waterproofing of roof with bitumen felts.
IS 3067 (2010):	Code of practice for general design, details and preparatory work for damp proofing and waterproofing of buildings.
ASTM C836 (2015)	Standards specification for "High solid contents, Cold liquid – Applied Elastomeric Water – proofing Membrane for use with separate wearing course.
ACI 515.1 – 1985	ACI guide to the use of waterproofing, Damp-proofing, Protective and Decorative barrier system in concrete
ASTM D146 (2003)	Standard Test Methods for Sampling and Testing Bitumen-Saturated Felts and Woven Fabrics for Roofing and Waterproofing1
ASTM D7832 (2014)	Standard Guide for Performance Attributes of Waterproofing Membranes Applied to Below-Grade Walls / Vertical Surfaces (Enclosing Interior Spaces)
ASTM D5076 (2019)	Standard Test Method for Measuring Voids in Roofing and Waterproofing Membranes
ASTM D3767 (2014)	Standard Practice for Rubber—Measurement of Dimensions
ASTM C957 (2017)	Standard Specification for High-Solids Content, Cold Liquid-Applied Elastomeric Waterproofing Membrane With Integral Wearing Surface
ASTM D6083 (2018)	Standard Specification for Liquid Applied Acrylic Coating Used in Roofing
ASTM D3105 (2017)	Standard Index of Methods for Testing Elastomeric and Plastomeric Roofing and Waterproofing Materials
ASTM D3468 (1999)	Standard Specification for Liquid-Applied Neoprene and Chlorosulfonated Polyethylene Used in Roofing and Waterproofing
ASTM D6694 (2015)	Standard Specification for Liquid-Applied Silicone Coating Used in Spray Polyurethane Foam Roofing Systems
ASTM D5385 (2014)	Standard Test Method for Hydrostatic Pressure Resistance of Waterproofing Membranes

11. 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 pre-pour preparations for slab castings, to supervise at the batch plant, to supervise at the concrete placement, to check pre-pour 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.

12. Suggested preventive measures

From the study, we can suggest following preventive measures are:

- Prevent leakage or passage of water and water vapor.
- Provides protection against penetration through the exterior enclosure of buildings of groundwater and

rainwater.

- Prevent water to penetrate into a building via capillary action and hydrostatic pressure.
- Waterproofing membranes are applied to the outside or "positive" side, of the structure.
- A selection of a waterproofing material should consider the cost, site condition (a soils engineer should be consulted to determine the types of soil that are present and how they will impact the system's performance, while a waterproofing consultant offers guidance on problem soils), expected performance qualities of the waterproofing material (in terms of withstand hydrostatic pressure, chemical attack and vapour permeably) and life expectancy.
- Other factors include ease of application, problems with protecting the material during construction, availability in local condition and, of course, side of application.

13. Conclusion

The construction industry must make every effort to solve the problems that are inherent in the use of current materials and technologies. In recent times the increasing cost of new construction as well as of repairs and restoration of constructed buildings, led essentially by escalating raw materials and labour costs, is making project developers and owners opt for effective and advanced waterproofing products and solutions. There is also an increasing perception amongst the project developers and owners that the long-lasting concrete structures alone should not suffice. The requirement of waterproofing should be coupled with “aesthetics” and also with the “environmental demands”.

14. References

1. IS 1346. Code of practice for Waterproofing of roof with bitumen felts, 1991.
2. IS 3067. Code of practice for general design, details and preparatory work for damp proofing and waterproofing of buildings, 2010.
3. Dr. Fixit Healthy Construction Booklets Constructs your Ideas. (Waterproofs for new roofs and Terraces).
4. ASTM C836. Standards specification for “High solid contents, Cold liquid – Applied Elastomeric Water – proofing Membrane for use with separate wearing course, 2015.
5. ACI guide to the use of waterproofing, Damp-proofing, Protective and Decorative barrier system in concrete. (ACI 515.1 – 1985).
6. Advances in Waterproofing Materials and Technology. (Master Builder Journal)
7. Personnel Experience shares during working on Oil and gas mining and Renewal Energy Projects.