Polyurethane waterproofing coating for building applications

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Abstract
In India problems of moisture leakage and dampness in buildings are widespread. Waterproofing treatments, including surface coating, have shown success to a varying degree. A two-component polyurethane system based on predominantly indigenous raw materials has been developed and thoroughly evaluated in the laboratory for its efficacy. Field trials have also been carried out and some results are reported.

It is the concern of every construction engineer to ensure that buildings are free from unwanted moisture/water through dampness, seepage and leakage. In practice, however, poor planning and designing in the pre-construction stage, poor workmanship and the use of substandard material during construction often result in leakage problems in Indian buildings.

The most effective approach for waterproofing is to adopt standard specifications combined with strict quality control. Practice has established that problems relating to dampness, seepage and leakage can be effectively tackled, or avoided to an appreciable extent, by employing skilled and experienced artisans using materials of acceptable quality. This is, however, relevant only to new structures. What about the improvement of structures already constructed with deficiencies?

Various methods are available to waterproof existing structures, but none can be regarded as particularly successful. These include admixtures, additives, coatings, sealants and many other combinations. It is difficult even for the professional to select and provide the appropriate solution to a specific problem. Table 1 lists some of the most widely used waterproofing methods in vogue in the Indian building industry, along with their advantages and limitations.

Table 1
Water proofing treatments used in the building industry

System/Materials	Advantages	Limitations
Brickbat coba with lime (Lime concrete terracing)	Allows for provision of slopes	Increases dead load on structure
	Thermal insulating properties	Non flexible
	Economical	Labour intensive and cumbersome application
Bitumen based tarfelt treatment	Flexible	Softens under heat
	Crack bridging capacity	Degrades to UV radiation and weathering
	Economical	Weak joints
Mud Phuska with tile	Allows for provision of slopes	Increases dead load on structure
	Thermal insulating properties	Non-flexible
	Economical	Labour intensive and cumbersome application
		Opening of tile joints

Polymers for waterproofing treatment

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, hypalon, PVC, rubberized asphalt – have been used for waterproofing of roofs in several countries.[1] Their high cost and unknown performance in tropical climates have, however, been reasons for non-acceptance of these materials so far in India.

In waterproofing by the surface coating method, polyurethanes offer superior characteristics with outstanding combinations of physical and chemical properties possible.[2] Polyurethane (PU) films are unaffected by water, oil and chemicals. They have excellent abrasion resistance, elasticity, low temperature flexibility, and resistance to micro organisms and bio-deterioration. A wide choice of raw materials, di-isocyanates and various polyols – such as polyesters, polyethers, castor oil and polybutadiene – allows PU polymers to be designed with desirable properties for specific end uses.

Chemistry of polyurethanes

Polyurethanes contain significant numbers of urethane groups (–NHCOO–) in their polymer chains. They are formed by the addition reaction of di- or polyisocyanates with compounds containing reactive hydrogens *eg* polyesters, polyethers, simple glycols and amines. In addition to the urethane groups, they may contain aliphatic, aromatic hydrocarbons, ester, ether, amide and urea groups. Amines generally react fastest with the isocyanate group (–NCO–). Others in order of decreasing reactivity are primary alcohols, water, secondary and tertiary alcohols, phenols, carboxylic acids, amides and urethanes. The chemistry of isocyanate reactions is described in detail in Reference 3.

Preparation and formation of PU coatings consist of

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Table 2
Important characteristics of PU waterproofing compound

Waterproofing	Two component system (Resin & hardener)
Mixing ratio	Resin 100 parts Hardener 20-25 parts (by wt.)
Pot life after mixing	2-3 hours at 27 ± 2°C
Method of application	By brush
Surface drying time	3-4 hours
Tack free time	6-8 hours
Hard tack free time	12-18 hours
Covering capacity First coat: Second coat:	 3 – 4m² per kg 5 – 6m² per kg

the reaction of polyols of molecular weight 1000-1500 with aromatic di-isocyanates. To improve the durability of the coating, standard fillers such as china clay, whiting, or titanium dioxide are incorporated. The PU compound is a two-pack system; polyol and isocyanate resins are mixed prior to application by brush. Hard and tack-free crosslinked film is obtained through the reaction of isocyanate groups with hydroxyls of the polyol; excess isocyanate reacts with the moisture in the atmosphere.

Experimental work at NCL and CBRI

A PU waterproofing coating for the building industry predominantly based on raw materials available in India has been developed by the National Chemical Laboratory, Pune and the Central Building Research Institute, Roorkee. The product has been extensively evaluated for waterproofing requirements using tests proscribed in different standards. Some field trials have also been undertaken to assess the performance of the material in 'real' conditions. More field trials are currently under way.

The important characteristics of the coating compound are given In Table 2. Tests for assessing the suitability of the PU waterproofing compound were divided into two parts: the first part consisted of tests related to film properties; the second part comprised an evaluation of the properties of a PU coating applied to a substrate.

Tests related to film properties

All tests are listed in Table 3. Scratch hardness, adhesion and flexibility and water resistance tests were carried out to Indian Standard IS:101.[4] Tensile strength and elongation of PU film were measured as specified in IS:2508.[5] Water vapour transmission (WVT) was measured on a 180 micron thick film of PU coating compound as in IS:7290.[6] Wet abrasion scrub resistance test was carried out for 10 000 cycles using a 2% detergent solution according to ASTM D-2486.[7]

The thermal coefficient of expansion of the PU compound was measured on 70×10×10 mm samples using a dilatometer (Malkin Co Ltd, UK) as per ASTM D-696.[8] The measurement was carried out in the air and the heating rate was kept at 6°C/minute.

Abrasion resistance studies on PU coating films (35-50 μm thick) were carried out using a Taber Abrasion Tester (Model 503) with CS-10 abrading wheels and at a load of 1000 g for 1000 cycles.

Table 3 Characteristics of PU coating film

Name of test	Results obtained	Standard followed
Scratch hardness	1.1 kg	IS:101[4]
Adhesion & flexibility	Passed 6.25 mm Mandrel	IS:101
Water resistance	Passed	IS:101
Tensile strength	2.32 N/mm²	IS:2508[5]
Elongation at break	37 percent	IS:2508
Water vapour transmission (WVT)	0.436 g/24 hr/m²	IS:7290[6]
Impact test	Passed	BS:3900
Wet abrasion scrub resistance (10 000 cycles)	No failure	ASTM D-2486[7]
Coefficient of thermal expansion (per °C) (from RT to T_g)	13.5×10⁻⁶	ASTM D-696-1970[8]
Abrasion resistance (Tabers)	65 mg	–

RT = Room temperature
T_g = Glass transition

Table 4 Characterisation of PU waterproofing compound applied on a substrate

Name of test	Result obtained	Standard followed
Pull-off test for adhesion (breaking strength)	Concrete 2.2 N/mm² Brick 2.0 N/mm²	BS:3900[9]
Water impermeability test	No dampness/ leakage up to 30 days	IS:5913[10]
Pond test	No dampness/ leakage up to 30 days	–
Natural weathering test (six months)	No failure except slight change in colour	–
UV exposure test	No film failure	–
Salt spray test (1) Mild steel panel coated without primer	No film failure No film cracking/loss of adhesion from substrate	IS:2074[11]
(2) Mild steel panel coated with red oxide primer	No film failure No film cracking/loss of adhesion from substrate	IS:2074

Evaluation of PU coating on a substrate

Properties of PU coatings applied on a substrate were also evaluated. Results are listed in Table 4.

A "pull-off" test for adhesion of the coating was carried out as listed in BS:3900 part E-10.[9] Two substrates were used in this test – 1:2:4 concrete and a brick tile surface. The test result shown is the minimum tensile stress necessary to break the weakest interface/component (adhesive/cohesive failure). Water impermeability test was carried out as described in Indian Standard IS:5913.[10]

Table 5 *Water spray test on brick panel plastered with 1:4 cement mortar*

Test specimen	Rate of water spray (litres/min)	Total water fall (equivalent rain fall) (mm)	Time of first appearance of dampness (hr)	Total dampened area in 7 hrs (%)	Remarks
Control panel	4.5 equivalent 12 mm/min	5040 (7 hrs)	3	30	Highest rainfall in Bombay recorded over 10 years during 1962-1972 = 1.2 mm/min.
Coated panel	4.5 equivalent 12 mm/min.	15120 (21 hrs.)	Nil	Nil	Maximum rainfall at Cheerapunji – 11420 mm/yr.

A "Pond Test" was carried out by making a water pond of 2.5 cm height of 1:2:4 concrete coated with PU. Visual observations for leakage of water were recorded. To assess weathering effects, brick panels (90x75 cm) were plastered with cement mortar and coated with PU compound. The panels were made to stand in exposed conditions and regular visual observations were made for cracking, blistering, chalking, peeling *etc.*

Ultra-violet (UV) exposure tests were carried out on PU coated asbestos cement sheets which were exposed for 8 days of 10 hours of polychromatic light per day. Salt spray tests were performed on mild steel coated panels, with and without primer, according to IS:2074.[11]

Durability test

Cement mortar panels of size 15×5×1.25 cm were coated and later subjected to alternate heating and wetting cycles to assess the durability of the coating. One hundred test cycles were completed in each of three different sets. The first set involved heating for 18 hours in an oven at 60°C followed by 6 hours cooling in air. In the second set, coated mortar panels were heated at 60°C for 18 hours, cooled in air at room temperature for 2 hours and then immersed in water for 4 hours. In the third set coated panels were immersed in water for 6 hours directly after taking out from heating in the oven for 18 hours at 60°C. No flaking, chalking, cracking, blistering or peeling of coating were found after any of the tests. The only noticeable change was in colour – from grey to pale.

Water spray test

An artificial rain penetration test was carried out by spraying water on coated panels (150 × 95 cm) for different periods. The results were compared with uncoated panels and are reported in Table 5.

Results and discussion

The polyurethane film has excellent adhesion, hardness, flexibility, abrasion and scrub resistance as shown by the results. Water vapour transmission of PU film has been found to be low, which is an important characteristic of any waterproofing membrane.[12] The coefficient of thermal expansion has been found to be comparable with cement mortar/concrete, which is in the range of $7.2\text{-}19.8\times10^{-6}$ per °C. This shows that the film possesses enough flexibility to cope with thermal and moisture movement of the substrates. Durability tests on the coated panels, carried out up to 100 cycles, have given excellent results without any deterioration. Water spray tests on coated wall panels showed no appearance of dampness, even on exposure to a total rainfall of 15 120 mm. Uncoated panels, on the other hand, show the first appearance of dampness within three hou

The coating compound appears to be an excelle treatment for checking leakage and seepage of wa in buildings and construction.

The waterproofing coating has since been applied a few leaking roofs showing permanent moist dampness and leakage. These roofs were differe types, such as RCC slab, cellular cement concrete a RCC channel units with lime concrete terracing. T roofs have been behaving satisfactorily for over one ye

Conclusions

The polyurethane coating developed can find applic tion for waterproofing of terraces, *chajjas* , pipes a bathroom floors. Cement tanks and asbestos roofin can be coated with PU resin. Because the film has go resistance to chemicals and salt spray test, it may al be used as an anticorrosive coating for steel structu in biogas and chemical plants. More field trials a required to establish the suitability of the treatment the different application areas.

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