STUDY ON WATERPROOFING METHODS USED FOR CONCRETE SLABS

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Abstract: A building or a structure requires waterproofing, if the building materials are not watertight enough on their own. Therefore, waterproofing has become an essential component of a structure to protect its aesthetic appearance, prevent structural damages and for the safety of the occupants. For concrete slabs, major objective will be to stop the water intrusion into the interior of the building at various locations under various exposure conditions. Accordingly the type and the method of waterproofing required may vary with the location and exposure conditions. In the construction industry, many commercially available materials are used for waterproofing ground slabs, roof slabs and bathroom floors. In this research, field surveys were done to identify the types of waterproofing material, different methods of applications and quality controlling measures regarding to waterproofing. Furthermore, issues related to waterproofing were studied to identify common problems which can be arrived in a functioning building. Then the rectifying methods and their performance related to such issues were also studied. A laboratory test serieswas performed on commercially available waterproofing materials to check their suitability. After applying waterproofing materials ontest specimens, they were checked for water absorption under laboratory conditions for 24 hours. Furthermore specimens with integral admixtures were tested for compressive strength to identify any increase in their compressive strength due to crystalline formation.

Keywords: Waterproofing, Slabs, Crystallization, Integral waterproofing

1. Introduction

Waterproofing is a fundamental requirement of a structure in order to protect its aesthetic appearance, prevent structural damages and for the safety of the occupants. It is identified as a major requirement because the building materials (mostly reinforced concrete) will not be able to waterproof structure itself under different exposure conditions such as direct sunlight, direct rainfall during the lifetime of a building. So waterproofing can be simply defined as preventing water intrusion and extrusion from various parts of a structure. This can be achieved by providing an impermeable barrier specifically designed for the intended purpose.

Basically, there are two types of waterproofing materials used in the construction industry over the past decades. They are traditional materialsand modern materials. Examples of those materials are categorized in Table 1.

Table 1: Traditional & modern waterproofing materials

Traditional Materials	Modern Materials
Internal waterproofing compounds	Silicon based water repellent
Bitumen coating with sand sprinkling	Polymerized bitumen
Poly ethylene film	Waterproofing membrane
Aluminium foil	Waterproofing by crystallization

All these materials are more or less used for different kind of purposes in the construction industry and each method has its own properties, which can be used for different applications under different exposure conditions. Therefore, selecting a suitable waterproofing method and a material depends on various parameters. Before selecting a waterproofing method for a particular application, the ways which water can move within a structure to cause problems need to be studied. Basically water can move within a structure due to gravity, wind and surface tension. However this will depend on the exposure conditions as mentioned before. Therefore, it is required to study the possible ways of water entering paths and exposure conditions well before applying a particular waterproofing material.

Therefore, this research was carried out to study the waterproofing methods used for concrete slabs.

2. Waterproofing Methods

2.1 What is waterproofing?

Waterproofing can be achieved by the formation of an internal or external membrane which is capable of preventing water from entering or escaping through a permeable layer. Further it can be defined as the formation of an internal or external membrane which is capable of preventing water from entering or escaping through a permeable layer. There are many different means to provide internal or external membranes in the construction industry. Internal/integral membranes are provided via waterproofing admixtures, which are added to the concrete during the mixing process. External membranes are provided using sheet membranes and liquid coatings on the concrete surface (Biparva &Yuers).

External waterproofing membranes can be divided into two categories as liquid-applied membranes and sheet applied membranes. Liquid-applied products are cementitous coatings, which can be produced at site by mixing liquid and powder according to the given ratio. Sheet membranes are normally made from thermoplastics, vulcanized rubber and rubberized asphalts. These sheet membranes can be bonded to the surface or can be left un-bonded (Biparva &Yuers).

Internal/integral waterproofing can be considered as a technology which uses admixtures to prevent the movement of water by blocking the pores inside the concrete. There are two types of integral waterproofing compounds namely reactive and un-reactive. Reactive compounds truly waterproof structures by forming crystalizing compounds when moisture is penetrated to the concrete. On the other hand un-reactive compounds reduce the permeability of concrete by increasing the density of it. Like reactive compounds they do not reactivate in the presence of water. Generally integral waterproofing is considered as a one-time treatment (Biparva &Yuers).

2.2 Previous research

A collaborative experimental program has been carried out by Dias (2007) with FINCO (PVT) Ltd. to test the effectiveness of concrete waterproofing systems in Sri Lanka. In this experiment both admixture and coating waterproofing systems have been tested to check their suitability for water retaining structures. After preparing specimens using grade 40 concrete, permeability and sorptivity tests have been carried out to check their effectiveness. Two waterproofing products namely XYPEX Admix and XYPEX Coating have been tested with control specimens with added silica fume under this experiment. It has been found that XYPEX Admix give the best performance against a considerable water head implying that it is suitable for water retaining structures. Specimens with silica fume have given the best performance for the resistance against water penetration into unsaturated concrete. And according to the test results XYPEX Coating has not performed as well as expected.

Primary objective of a waterproofing membrane is to prevent water from entering to the occupant area during its life time. Therefore the performance of a water proofing membrane can be measured by the permeability of the membrane. In the research by Sahal and Ozkan (2004), they have presented a new performance-based laboratory test method to assess the vapour and water permeability of strained waterproofing membranes under hydrostatic pressure. In this test method they have simulated strain conditions using membrane test specimens in laboratory conditions. Other field conditions such as air and hydrostatic pressure are also simulated on the strained specimen and the vapour and water permeability of the specimen is measured in a test apparatus. This laboratory test method is considered to be a new approach that can help to estimate the vapour and water permeability of the waterproofing membranes in field conditions.

Al-Zahrani et al (2002),conducted a study to evaluate reinforcement corrosion and some physical properties of concrete specimens coated with two polymer-based, a cement-based polymer-modified, and cement-based waterproofing coatings. The coated and uncoated concrete specimens have been subjected to accelerated corrosion to determine the time taken to initiate corrosion. The physical properties were also evaluated by subjecting the concrete specimens to wetting/drying cycles and heating/cooling cycles for five months. The physical properties such as water absorption, water permeability, chloride permeability, and adhesion were also evaluated. The accelerated corrosion test results have clearly showed that the specimens coated with the polyurethane elastomer-based waterproofing material performed better than concrete specimens coated with other waterproofing materials. This has been followed by the specimens coated with cement-based polymer modified, epoxy-based, and cement-based coatings in descending order. The two polymer-based coatings have shown better performance than the cement-based polymer-modified and cement-based coatings in terms of the evaluated physical properties.

In most of the buildings, bituminous sheet membranes are used for the waterproofing purposes in roof slabs. These bituminous sheets are ideal for slabs having large spans so that it can cover a large area. However, when applying these sheets, lap joints will occur.Hence they will become the most critical areas in the waterproofing system. And also these lap joints are largely responsible for the defects which will occur with time. Therefore the dimensional stability of the sheets is one of the most important characteristics, as it can strongly influence the performance of the lap joints. In their research, Lopes et al (2010) have presented the results of an experimental study on the dimensional changes exhibited by bituminous sheets when subjected to temperature variations. This experiment has been done on different types of traditional and non-traditional sheets, with various types of bituminous mixtures. Experimental results have confirmed that the sheets with polyester reinforcement are much less stable than sheets reinforced with glass fibre.

As mentioned earlier, most of the flat roofs of the buildings are waterproofed by using bituminous membranes with a self-protection constituted by mineral granules. These granules constitute the barrier against the fundamental environmental agent of degradation, the UV radiation. Marques et al (2010),have presented an experimental study on the behaviour of the self-protection granule of bituminous membranes when subjected to environmental agents of degradation. Different types of bituminous membranes, with different finishing systems have been exposed to the effects of elevated temperature and water for up to 24 weeks and 4 weeks respectively. Following accelerated ageing, specimens of the different types of membranes were subjected to brushing tests in order to evaluate the adhesion of the self-protection granules. Experimental results have shown that the higher loss of self-protection granule of bituminous membranes occurs in membranes modified by Atactic polypropylene polymers. In addition, it has been concluded that the effect of water is much more severe than that of the elevated temperature.

3. Field Survey Results

In order to identify the waterproofing methods which are currently being used in the construction industry, a field survey was carried out. Industrial professionals were interviewed during the field survey to identify the issues related to waterproofing.

3.1 General Site Practices

Before applying the waterproofing, a surface preparation should be carried out properly. Surface should be free from debris, grout deposits and dust before applying the waterproofing material. After preparing the surface, any cracks or uneven areas should be filled with construction grout. Then a 45° fillet as shown in Figure 1 should be introduced with cement sand mortar along the edges where the slab meets vertical walls. This is done to ensure the proper continuity of waterproofing along edges.

Figure 1: 45° fillet along the edges

Then those edges and gully areas are reinforced by using fibre glass nets, so that the waterproofing can be made flexible along the edges. After mixing the powder and the liquid to the given ratio, thin slurry can be obtained to apply on the surface of the slab. Then the first coat is applied using the brush application method according to manufacturer's specifications. Second coat can be applied as soon as the first coat is dried. To ensure water tightness, second coat is applied orthogonally to the direction of first coat. Then the curing is carried out for 1 or 2 days according to the manufacturer's specifications. At the end, ponding test will be carried out to check for any leakages. After filling the slab area with water, visual inspection will be done to detect any kind of leakage. If the waterproofing is satisfactory, slab area will be covered with a cement sand mortar to protect the waterproofing from foot traffic and other impacts.

3.2 Common Issues

Most issues in waterproofing occur in bathrooms and roof slabs as they are directly exposed to water.

3.2.1 Issues in Bathroom Areas & Solutions

Bathrooms are very vulnerable to water leakages if the correct procedure is not followed. Due to the discontinuity of the concrete slab at the edges cracks can develop around the fillets. Therefore, water can leak from the mortar joint under the brick wall. Same thing can happen around the gully, where a weak plane can develop with time.

According to the discussion,many problems in waterproofing can be avoided if the correct procedures are followed. One example is the placement of the gully pipe to avoid permanent ponding, which can stop water leakages around gulley. Sometimegulley pipe can be placed above the floor level to allow the drainage of water from the bathroom. But the problem occurs when the water is leaked from the tiles to the slab through the waterproofing which can lead to permanent ponding. Water under the tile cannot escape through the gulley pipe if it is placed above the slab level. Then the water patches will appear on the soffit of the slab. Therefore, waterproofing companies ask the client to place the gully pipe as shown in Figure 2.

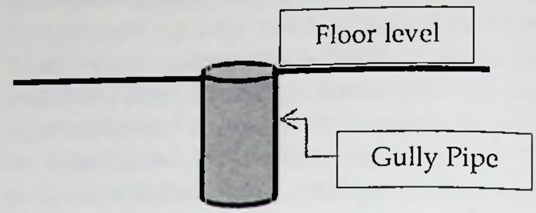

Figure 2: Correct placement of gully pipe

Apart from that another type of water leakage can occur under the door step of the bathroom. Most of the times, door steps are made out of bricks which can lead to a weak joint between the door step and the concrete slab. Therefore, with time water can leak to the adjacent bed room. If a slab drop is not provided for the bathroom area, water can leak to the adjacent bedroom also. Therefore, this can be avoided by providing a concrete door step if a slab drop is not provided.

3.2.2 Issues in Roof Slab Areas& Solutions

Most of the time, waterproofing in roof slabs is done by using bituminous membranes. This is a popular method for waterproofing slabs with long spans including roof slabs and ground slabs. According to gathered data during field survey, with time these bituminous membranes will lose the bond with the surface due to the temperature especially when they are placed in roof slabs. Therefore, once the water enters through a damaged part of the membrane, it can flow anywhere under the membrane. With time this water can leak through the concrete to create water patches on the slab soffit. So, when a leakage occurs, it isdifficult to find a location to treat in such a case.Therefore, whole membrane should be removed and repaired in such a case.

Another problem that can occur in roof slabs is due to the leakage from the parapet wall. These kinds of leakage are hard to identify, because a ponding test would not detect cracks in the parapet wall.In such a case, crack should be sealed by using a fibre glass mesh and a binder in order to stop the water flow. One such crack found in a parapet wall is shown in Figure 3.

Another type of problem that can occur in roof slab is the leakage that occurred from the edge of the slab. If the leakage is severe, slab soffit can also be damaged due to the water patches. This will destroy the aesthetic appearance of the building and reinforcement corrosion could also occur. By providing a concrete step or a parapet wall, this type of leakage can be prevented by continuing the waterproofing membrane up to some height.

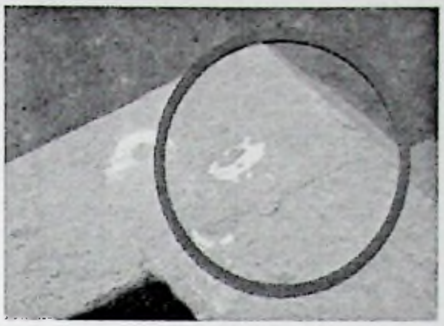

Figure 3: Crack appeared in a parapet wall

4. Laboratory Experiments

4.1 Introduction

In order to identify the effectiveness of the commercially available waterproofing materials laboratory experiments were carried out. Cementitous coating type and integral waterproofing type materials were tested under the laboratory experiment series.

4.2 Materials

It was decided to use grade 30 concrete to prepare concrete specimens for the test. As most of the building slabs are constructed using grade 25 or 30 concrete, results would demonstrate the actual site conditions if grade 30 is used. Waterproofing materials given in table 2 were tested under this laboratory test series.

Table 2:Selected waterproofing materials

Admixture type waterproofing	Cementitous coating type waterproofing
Xypex admix	Brushbond
Tamseal admix	Xypex Concentrate
Penetron admix	K11 flex

4.3 Methodology

Tests were carried out using 150 mm x 150 mm x150 mm concrete specimens of grade 30 concrete. For each waterproofing product, three cubes were cast and three control specimens were also cast separately. Therefore, altogether 21 cubes were tested under this test.

Admixture type waterproofing products should be added to the concrete when it is batched. So, it was decided to cast all the 21 specimens on same day, and add the admixtures separately for the required 9 cubes at the time of batching. Cementitous coating type materials were applied on the specimens after 14 days.

4.4 Testing Procedure

It was decided to check the effectiveness of waterproofing materials by checking the water absorption of each product. There are many laboratory test methods to check the different parameters of the waterproofing products. But there is no specific test developed to measure the water absorption of waterproofing materials. However, to check the effectiveness of waterproofing materials, test for water absorption of concrete (BS 1881-122:1983) was adopted in this research.

Initially a water absorption test was carried out on specimens without the oven drying procedure. Then the same test was carried out on specimens after oven drying them for 72 hours. This was done to check whether the oven drying procedure causedany damage to waterproofing materials.

Final experiment was carried out to check the compressive strength of specimens, for which crystallizing admixtures were added. This was done to see whether the compressive strength has been increased due to the crystallization effect. All the specimens with admixtures were tested using the compressive strength testing machine. Control samples were also tested to compare with the specimens cast using admixtures.

5. Test Results and Discussion

5.1 Water Absorption Test 1

Test results of the water absorption test after 24 hours without oven drying procedure are given in Table 3. According to the results it can be seen that all the specimens, which were waterproofed have performed better than the control specimens. Among them K11 Flex specimens gave the best results (0.19%) compared to control specimens (0.57%). Also, it can be seen that the liquid-applied waterproofing materials have given the best results compared to integral waterproofing compounds.

Table 3: Water Absorption Test Results (1) [After 24 hours]

Material	Cube Name	Initial Weight (g)	Mass of water absorbed (g)						Water Absorption (%)	
			15 min	30 min	60 min	180 min	420 min	1440 min	Value	Average
Tamseal Admix	TA-1	8440	10	10	15	35	35	35	0.41	0.41
	TA-2	8450	0	0	0	15	25	35	0.41	
	TA-3	8620	10	10	15	20	35	35	0.41	
Xypex Admix	XA-1	8520	15	15	15	15	30	30	0.35	0.37
	XA-2	8380	20	20	20	20	20	40	0.48	
	XA-3	8465	5	5	5	15	20	25	0.30	
Penetron Admix	Pe-1	8605	10	10	10	15	25	35	0.41	0.37
	Pe-2	8470	0	5	15	15	25	30	0.35	
	Pe-3	8490	5	15	15	15	25	30	0.35	
Xypex Concentrate	XC-1	8685	15	15	15	15	15	25	0.29	0.27
	XC-2	8900	5	5	5	5	10	20	0.22	
	XC-3	8780	5	5	5	5	15	25	0.28	
Brushbond	B1	8710	5	5	5	10	20	35	0.40	0.41
	B2	8925	5	5	10	15	25	40	0.45	
	B3	9145	0	5	5	10	20	35	0.38	
K11 Flex	K-1	8935	0	0	0	0	5	20	0.22	0.19
	K-2	9055	0	0	0	5	10	15	0.17	
	K-3	8960	0	0	0	0	10	15	0.17	
Control cubes	C-1	8560	10	30	30	30	40	55	0.64	0.57
	C-2	8315	15	20	25	30	35	45	0.54	
	C-3	8565	15	20	20	40	40	45	0.53	

5.2 Water Absorption Test 2

Test results of the water absorption test after 24 hours with oven drying procedure are given in Table 4. When compared with the test results of the first experiment, it can be seen that the water absorption has significantly increased in the specimens of the second experiment. This is due to the oven drying procedure carried out prior to the test. Oven drying was done in order to obtain a constant mass of the specimens. However, according to the test results some specimens have absorbed more water than the control specimens. It can be assumed that the waterproofing has been damaged due to the oven drying procedure. However, in the second experiment also, K11 Flex specimen gave the best results compared to others.

Table 4: Water Absorption Test Results (2) [After 24 hours]

Material	Cube Name	Initial Weight (g)	Mass of water absorbed (g)						Water Absorption (%)
			15 min	30 min	60 min	180 min	420 min	1440 min	
Tamseal Admix	TA-2	8130	150	190	220	290	315	330	4.06
Xypex Admix	XA-3	8160	150	185	225	275	300	310	3.80
Penetron Admix	Pe-2	8195	135	170	200	235	255	270	3.29
Xypex Concentrate	XC-2	8560	160	205	245	295	315	330	3.86
Brushbond	B-1	8350	115	160	195	270	335	380	4.55
K11 Flex	K-2	8740	50	70	85	125	165	230	2.63
Control cubes	C-1	8245	165	215	260	305	330	350	4.24

5.3 Compressive Strength Test

Results of the compressive strength test of each cube are given in the Table 5.

Table 5: Compressive Strength Test Results

Cube Name	Density (kg/m^3)	Compressive Strength (MPa)
TA-1	2440	51.17
TA-2	2489	35.59
TA-3	2548	44.60
XA-1	2502	38.04
XA-2	2474	47.39
XA-3	2519	34.02
Pe-1	2449	50.82
Pe-2	2454	32.72
Pe-3	2469	40.30
C-1	2460	37.60
C-2	2476	39.38
C-3	2451	40.86

According to the test results it can be seen that the compressive strength of specimens with admixtures has been slightly increased compared to control samples. Average compressive strength of each set of specimens is given below. (Strength of oven dried samples are not considered for average compressive strength)

1).TAMSEAL Admix- 47.89 MPa
2).XYPEX Admix- 42.72 MPa
3).PENETRON Admix- 45.56 MPa
4).Control Samples- 40.12 MPa

A graphical representation of the average compressive strength of each product is given in the Figure 4.

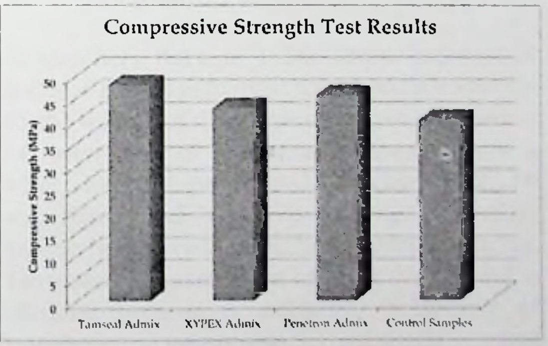

Figure 4: Comparison of Compressive Strength

From the comparison it can be seen that the average compressive strength of specimens with TAMSEAL Admix has been increased by 20% compared to control samples. PENETRON Admix has given a 14% increase in compressive strength while XYPEX Admix has given a 6.5% increase in compressive strength compared to control samples.

6. Conclusions

According to the field survey data, it can be concluded that the selection of waterproofing type for a particular application depends on the location of the structural element and the exposure conditions. Therefore, special care should be taken when selecting a waterproofing material for a new construction. However, problems which can occur in the construction stage are minimal.

Most of the waterproofing issues occur during the functioning period of the building. These issues arise due to poor selection of waterproofing materials and poor workmanship. Therefore, the efficiency of waterproofing system cannot be guaranteed just by selecting a good quality waterproofing material as long as poor workmanship is involved.

Liquid-applied membranes are the most common waterproofing systems which can be used to waterproof bathrooms, kitchens and balconies. Integral waterproofing admixtures are widely used nowadays to waterproof ground slabs, sump areas and lift cores. From the above mentioned waterproofing systems, integral waterproofing system is considered as a one-time treatment.

According to the laboratory experiments, liquid-applied waterproofing systems perform better than the integral waterproofing systems. However, this conclusion is based on the water absorption test carried out on waterproofed specimens. More comprehensive tests should be done to check the effectiveness of waterproofing systems under different exposure conditions.

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