An Example on the Use of Concrete Waterproof Agent of XYPEX in Pressure-Resistant Slabs

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1. Introduction

In the construction work at the subway station of Tsuen Wan West of Hong Kong KCR, for the waterproofing of concrete pressure-resistant slabs used in the station building, the waterproofing method by the use of a membrane was designated in the initial specifications. With respect to this, our company is proposing to switch to the use of the concrete water proofing material of XYPEX whose effectiveness has already been confirmed in Singapore. By using this material, not only work quality is assured, the period of construction can be shortened.

2. The Construction Work

Table 1 shows the structural parts where XYPEX concrete is used. The standard cross-section drawings are shown in Figures 1 and 2.

Table 1 Points of concrete deposition and the amount deposited

Points of Deposition	Thickness (m)	Depth of Establishment (m)	Volume of Concrete Deposited (m^3)	Period of Construction
Pressure-resistant slabs at station building	1.5	17	23,100	Jan 2001~ Oct 2001
Floor slabs at station building	0.4	0.6	14,000	Aug 2001~ Jan 2002
Tunnel excavation	1.2~1.75	9~23	89,800	Oct 2000~ Feb 2002
Roof of station building	0.175		3,500	Oct 2001~ Mar 2002

Figure 1

Figure 1 Standard Cross-section drawing of station building

Figure 2

Figure 2 Standard cross-section of tunnel excavation

3. Switching from membrane waterproofing to the use of a waterproof agent

3.1 Construction specifications and plans

The method of waterproofing required by the contract was the use of membrane. In other words, the waterproof membrane is laid, followed by the arrangement of bars and the setting up of moulds before the concrete is formed on it. As for the quality of the material, a 2-mm thick heavy-duty polyethylene (HDPE) with ribs was specified for the pressure-resistant slabs.

3.2 Problems of waterproofing with membrane

The method of waterproofing with membrane is common in underground structures of Singapore and Hong Kong. Its method of construction and quality control are also well established. However, cases of continuous leakage repairs upon completion are not rare.

As a method, waterproofing by membrane is common. However, the following problems exist:

- As the membrane joints are glued by heat treatment, work is affected by the weather and drainage conditions. For example, defect in a very small part will lead to water leakage. In general, from the completion of excavation to the formation of the first pressure-resistant slab concrete, a lapse of about a month is required.

- As the hardness of the HDPE membrane causes obstruction brought about by folding and bending, the parts joining the continuous wall, the underground hole, the floor slabs of the pit and irregular joints pose difficulty in construction work.

- After the membrane is laid, in the subsequent bar arrangement it may be damaged by the ends of reinforcing bars. Through negligence, it may be hit by a nail used to fasten the concrete mould. It is difficult to locate these defects one by one and have them repaired before depositing the concrete.

- By the time water is found leaking on the surface of the concrete, it is impossible to identify the damaged part of the membrane underneath the concrete (the part supplying the underground water). Therefore, injection is carried out at the point of water leakage but the leakage shifts to another weak point in the concrete. There is therefore the fear that such injection work must be repeated endlessly.

3.3 Proposal to use the waterproof admixture

From the above-mentioned reasons, it is thought that the pressure-resistant slab concrete itself is more effective in making a watertight condition than the membrane. We therefore propose the use of waterproof agent. There are two ways of using a waterproof agent: ① An application of the agent on the surface of the concrete and ② the waterproof agent is mixed with the concrete. In the said construction work, since the underground water pressure will be great, instead of waterproofing by surface application of the waterproof agent where waterproofing effect is limited to

the surface, the admixture where cross-sectional waterproofing effect of the pressure resistant slab can be expected is chosen [1].

[1] People are reluctant to place order for an application agent for waterproofing.

XYPEX is proposed as it has shown good performance in construction work in Singapore as a waterproof admixture. The proposed admixture was approved by the procurement consultant from two companies and the third party concrete consulting expert from one company through examinations by means of documents. The following are the major issues:

(1) Results

There are various types of waterproof admixtures in the market. XYPEX waterproof admixture (made in Australia) is the only product that comes complete with certificate of tests, documentation and certificate of performance. There is not much of reported performance from Hong Kong but there is increasing performance achievement in China, Southeast Asia and in particular, Australia. In fact, in 1997, the authors had the experience of using it on the underground pressure-resistant slabs in Singapore's Esplanade Theater with largely satisfactory results (90 cm thick, 20,000 m^3).

(2) Water leakage from cracks

At the stage of approval, a purchaser's greatest concern on XYPEX admixture is cracks. With regard to the prevention of cracks by mass concrete temperature, various conditions have been stipulated in details in the specifications. Temperature analysis is also a requirement. There will be water leakage if appearance of cracks still occurs even when the above have been satisfied. As described in 5 subsequently, this has been proven not to be a problem.

4. XYPEX

4.1 Effectiveness

XYPEX waterproof admixture is a grey powder. It is added to the concrete being mixed at the rate of 0.8%~1.0% of the cement by weight. According to the catalogue, crystals are produced by its chemical reaction with cement. These crystals block the tiny apertures in the concrete.

During the underground construction work of the Esplanade, the authors carried out various experiments on the effectiveness of XYPEX. Six experimental concrete blocks of 15-cm diameter and 5-cm thickness were prepared, 3 of them mixed with XYPEX and the other 3 without XYPEX. When water pressure of 7 atmospheres was applied, there was no water leakage in the blocks with XYPEX added while leaking was obvious in experimental blocks not mixed with XYPEX.

4.2 Competitive price

As it is an admixture, comparison of the competitiveness of its price with a membrane is dependent on the thickness of the slab. In other words, the greater the thickness, the greater will be the amount of concrete used and the amount of

admixture used will also increase. While the quality of the membrane for comparison also counts, when the thickness of the slab is greater than 60~90 cm, it may not be economically advantageous to use the admixture. Despite this, the reason for using it in the said construction work is because of its ability to greatly reduce the cost for floor slabs and the roof. In particular, since it allows us to omit waterproofing work with asphalt on the roof and floor of the station building, it can be said to be anew attempt.

4.3 Combinations

As XYPEX admixture itself has the property of being a delaying agent, minor adjustments must be made in its usual combinations. Besides, from the point of view of concrete manufacturers, a foreign substance has been added and they want to be exempted from the responsibility with regard to strength. For the said construction work, to clearly state the responsibility for concrete strength, XYPEX admixture was added on the construction site. In other words, at the construction site and under the watchful eyes of the purchaser, the company supplying XYPEX measured out both the admixture and water and dissolved the admixture in water which flowed into the mixer truck (refer to Pictures 1 and 2).

Table 2 Table showing the combinations of XYPEX concrete (per m^3)

Name	Use	Strength (MPa)	Slump (mm)	Cement (kg)	PFA (kg)	Coarse aggregates (kg)	Fine aggregates (kg)	Water (kg)	Water reduction agent (l)	XYPEX* (kg)	W/C
S3a	Station building	40	100	315	170	1,010	615	183	4.85	3.88	0.39
S3b	Tunnel	45	100	325	175	1,000	610	183	5	4	0.38

* XYPEX is dissolved in 7 kg of water and mixed at the site. The amount of water used per unit is 190 kg.

Picture 1

Picture 2

4.4 Quality control

For quality control during combination, to ensure that addition of XYPEX admixture was not forgotten before the concrete was deposited, a voucher was taken and retained when the mixer truck entered the construction site. An identification card would be placed at the driver's seat after the admixture had been blended into the concrete. As the truck was leaving the site after depositing the concrete, the identification card was exchanged for the voucher. When making slumps and experimental blocks, checking was carried out before and after adding XYPEX.

The concrete was deposited by a pump vehicle. The question of insufficient strength did not arise in all the concrete deposited.

5. Mass concrete and cracks

As was described in 3.3 (2), possible water leakage from cracks is the main hindrance in approving a waterproof agent. Waterproof agent and cracks have to be considered separately. However, if water leakage occurs, the waterproof agent is taken to be ineffective at the points of leakage.

In conclusion, for cracks up to 0.3 mm, in the presence of water leakage, reaction with the water resulted in self-recuperation. Thus, with merely minor repair work such as painting or without any repair at all, the water leakage stopped in about 3 weeks. As for cracks bigger than 3 mm, repair was carried out in advance.

As a preventive measure against cracks due to temperature, the following were carried out mainly based on the specifications and temperature analyses. As for the design of arrangement of reinforcing bars, 0.25mm is the reference crack under conditions of limitation of use.

- The temperature of concrete deposition was assumed to be below 25^0C.
- 20mm plywood with good heat-retention property was used for the moulds.
- For joint treatment, at the part where the mould must be taken out, on the day after the deposition of concrete, styrene foam was installed after carry out treatment at the joints.
- Curing by a film was done immediately after concrete deposition. Water was applied the following morning. In order to bring down the highest temperature, upon deposition, after 30 hours of heat radiation, the surface was covered with 100-mm thick styrene foam.
- During the period of curing, the interior temperature was allowed to rise to 40^0C which took 7~10 days after deposition.
- A temperature gauge was inserted regularly to control the temperature. The condition of keeping the internal temperature difference below 20^0C must be satisfied.
- For parts where it was considered necessary, reinforcing bars were added to the points of cracking.

With regard to the cracks, on the pressure-resistant slabs, cracks of 4~5 m long at intervals of about 3~4 m at a right angle to the normal line of the continuous wall were recognised. Most of them were cracks of less than 0.3 mm. Cracks above 0.3 mm were repaired by the injection of polyurethane.

6. Treatment of construction joints

Besides cracks, there are potential weak points for waterproofing. These include points of joining of concrete and points surrounding a penetrating pipe. The methods of construction work are as follows:

(1) Joint between new and old concrete
Waterproof boards and application type XYPEX were used together. In the important parts shown on the plan, an injection hose was fitted on the side of the old concrete. Acrylic resin was chosen for repeated injections in the future.

(2) Points of connection between the continuous wall and the pressure-resistant slab
3 layers of expanding sealing material were applied. In addition, application type XYPEX was then used together with the seal.

(3) Penetrating pipe for temporary drainage pump, etc
A 5-cm flange was designed at 3 points.

(4) Bolts for tightening moulds on the tunnel walls
The type with rubber flange in the centre was used. After removal of the mould, application type XYPEX was applied before non-shrinking mortar was used for filling.

7. Conclusion

When construction work is completed, in theory, the pressure-resistant slab comes under a water pressure of 2 atmospheres without serious water leakage problem. As has been described, since water proofing can result from self-recuperation, quality can be assured. Furthermore, by switching from waterproof membrane to concrete admixture, it is possible to shorten the period of construction by a month.

Finally, we would like to thank the Business Office and all those who have helped in the construction.