Experimental study on the waterstop with adhesive bonding

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ABSTRACT: In this study, experimental investigation was carried out on the waterproofing performance of waterstop with and without adhesive bonding between concrete and waterstop. During underground structure construction, waterstop is typically used to prevent the water percolating through the joints where consecutive concrete casting is infeasible. For example, waterstop is often adopted at the joint between two panels of diaphragm walls. Conventional waterstop, however, often fails to prevent water percolation as the waterstop does not fully bond to the concrete, often making water passage through the gap between waterstop and concrete. Artificial adhesive bonding between the waterstop and the concrete was, therefore, applied to improve bonding and reduce water percolation. High water pressure was applied to the two waterstop waterproofing systems, one with adhesive and another without adhesive, and comparison was made between the two systems.

Keywords: waterproofing, waterstop, adhesive bonding

1 INTRODUCTION

Water leakage is one of the crucial problems for underground structures. The water leakage has not only shortened the life of the structures, but also adversely affected on the service quality for users (Kubal, 2008). For this reason, controlling groundwater is essential, especially in metropolitan cities which have a high level of ground water table and complex underground linked systems such as subway, below-ground driveway, sewer and utility tunnels, and basements of buildings etc. Thus, some governmental authorities have set strong design criteria and managed construction qualities of the waterproofing system. For example, Land Transport Authority (LTA), a statutory board under the Ministry of Transport of Government of Singapore, has been requiring completely enveloped waterproofing design (not allowing drainage system) for underground structure construction (LTA, 2010). Also, British Standard CP 102 is regulating that all basement structures should be designed against the underground water pressure even if the construction site is determined to be a dry condition (BSCP102, 1973).

Waterstop is the most widely used waterproofing material to prevent the water percolation at the joints of the discretely consecutive concrete structures. However, poor workmanship of the contractors has contributed to improper installation of the waterstop in many cases, and it has been experiencing water leakage after completion of underground structures. Figure 1 illustrates the example of poorly installed waterstop in tunnel lining construction. Even with the best efforts in design and construction, water leakage may be inevitable, and partial failure of waterproofing system often leads to failure in the entire system (Kho et al., 2014). The waterproofing work is still highly dependent on the labor workmanship although many manufacturers have improved diverse types and materials of waterstop in the industrial fields.

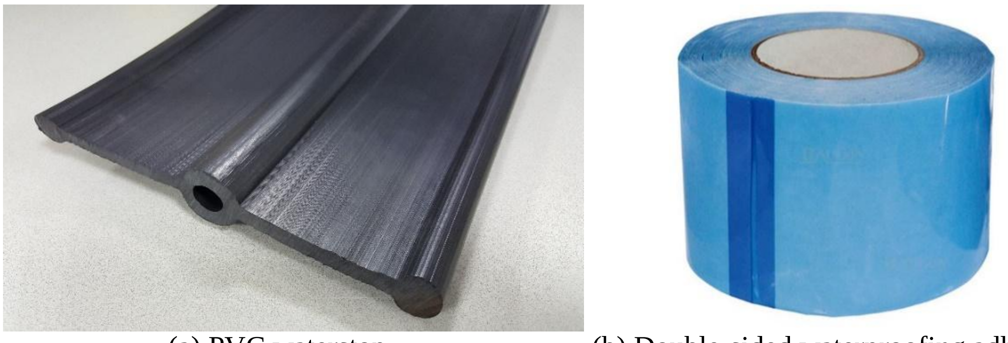
In this study, the water leakage test was conducted for a conventional Polyvinyl Chloride (PVC) waterstop to verify the waterproofing performance in the soundly constructed concrete structure. Likewise, the waterstop was modified by using a concept of adhesive bonding between the concrete and the surface of the waterstop to prevent the water percolation. The waterproofing performance of the modified waterstop was examined by comparing with the conventional one.

Figure 1. Poorly installed waterstop in tunnel construction

2 WATERPROOFING PERFORMANCE TEST

2.1 *Waterstop of concrete bonding type*

Figure 2 shows the waterproofing materials used in this experiment. Figure 2 (a) shows the waterstop which have been normally used in the diaphragm wall to prevent water percolation at the joint between two adjacent panels. Figure 2(b) is a specially designed double-sided waterproofing adhesive tape for application on blind-side waterproofing, usually consisting of one side with a pressure sensitive adhesive (PSA) to adhere to some object (herein, the surface of the PVC waterstop) and another side with the PSA composed of acrylate coating, which will be bonded with the concrete after casting. The "waterstop with adhesive bonding" was manufactured by adhering the double-sided adhesive tape to the flat surface of the PVC waterstop.

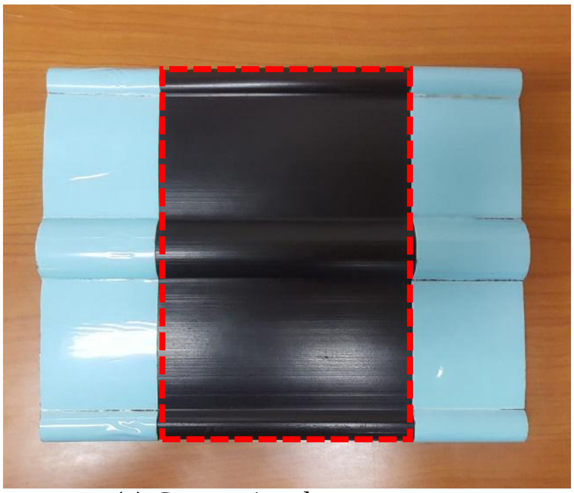


(a) PVC waterstop (b) Double-sided waterproofing adhesive tape

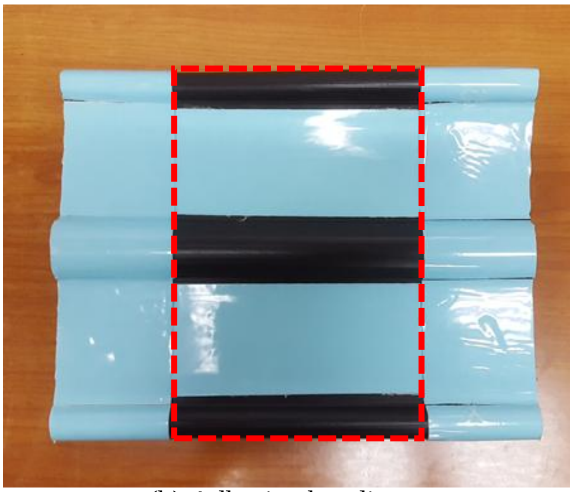
Figure 2. Materials used for the waterstop with adhesive bonding.

2.2 *Preparation of test specimens*

Figure 3 (a) and (b) illustrates the PVC waterstops of conventional and adhesive bonding types used in this experiment. The double-sided waterproofing adhesive tape was taped to the flat surface of the PVC waterstop to implement bonding to mortar as shown in the Figure 3 (b). Both ends of the PVC waterstops were surrounded by the double-sided waterproofing adhesive tape to satisfy consecutive boundary conditions.



(a) Conventional type

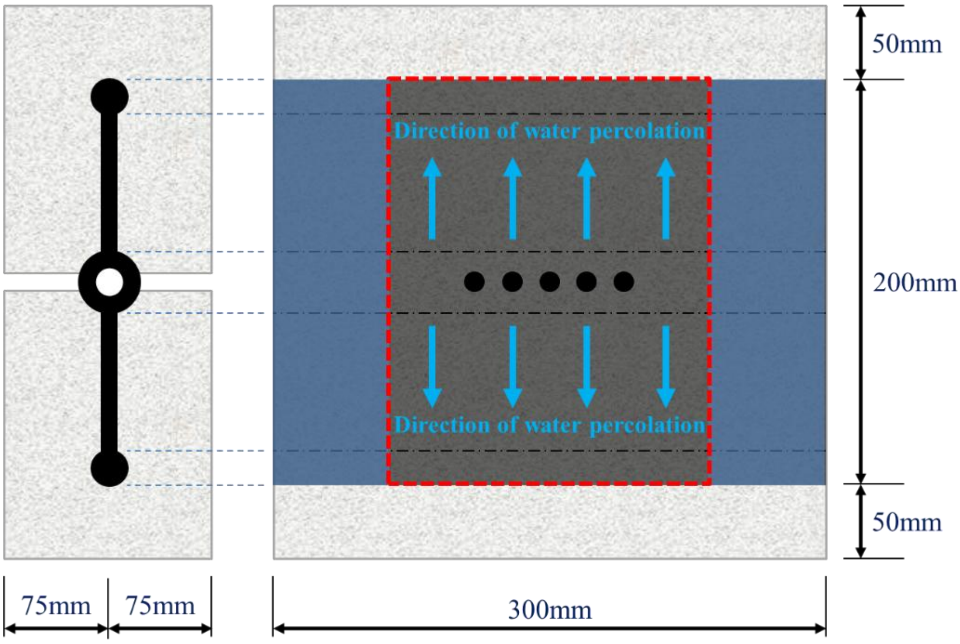


(b) Adhesive bonding type

Figure 3. Waterstops used in the waterproofing performance test

2.3 *Test scheme*

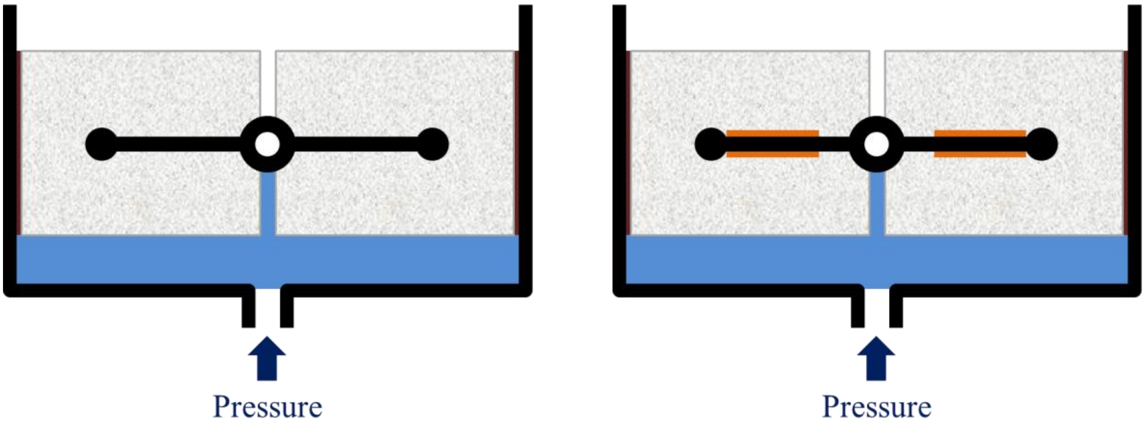
To verify the performance of the two waterproofing systems, hydrostatic pressure resistance tests for waterproofing membranes (ASTM, 2014) were slightly modified. For the performance test, two non-shrinkage mortar specimens were manufactured, one with the conventional waterstop and one with the concrete bonding waterstop. Figure 4 (a) and (b) illustrates schematic diagrams of the test specimens. The waterstop was placed in the midst (75 mm) of the mortar block, which is 300 mm in width and depth, and 150 mm in height. Five holes with a 7 mm diameter were created through the center of the mortar block, connecting to the central bulb of the PVC waterstop. This simulates the worst conditions in which mortar cannot prevent the water percolation at all and waterproofing is totally dependent on the waterstop. The double-sided waterproofing adhesive tape was applied at both ends of the PVC waterstop (shaded area in blue in the Figure 4 (b)) to bond between the mortar and the waterstop, so that, the consecutive boundary condition was implemented. In other words, the percolating water, if any, travels in the arrow direction as shown in the Figure 4 (b); the red dot-line box will be the effective testing area in this test.



(a) Side view (b) Projected plan view

Figure 4. Schematic diagrams of the test specimens

Figure 5 (a) and (b) represent schematic diagrams of the performance tests for the two types of waterstops. The non-shrinkage mortar specimens were placed in steel frames, and the peripheral gap between the mortar block and steel frame was filled and coated with a liquid type of waterproofing membrane which is cold-applied and elastomeric. The chamber enveloped by the mortar block and the steel frame was filled with water through the inlet placed at the center of the steel frame.



(a) Conventional type (b) Adhesive bonding type

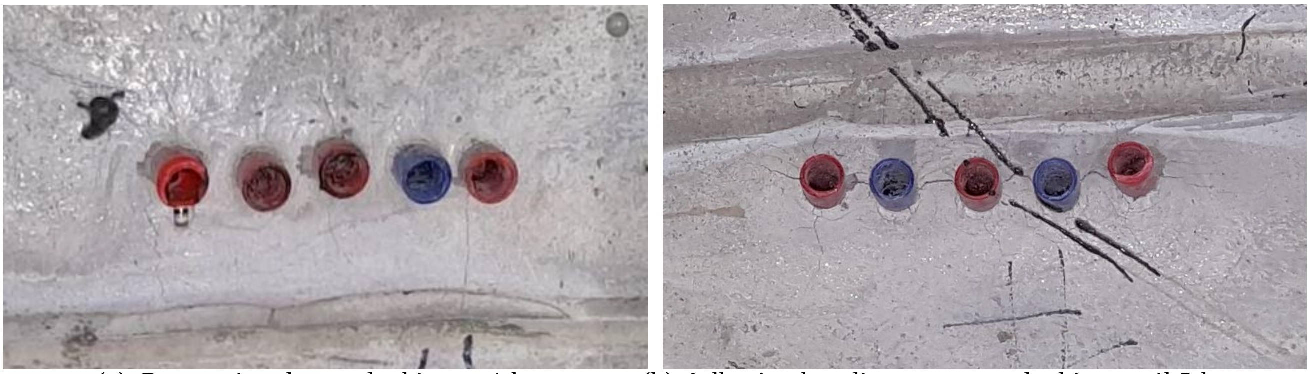
Figure 5. Schematic diagrams of the test setting for two different types of waterstop

Figure 6 shows the equipment assembly for the hydrostatic pressure resistance test. The non-shrinkage mortar specimen was tightly fastened by reaction beams and bolts, and an air hose was connected from the air compressor to the pressure inlet. The test was started to increase the air pressure to 1 bar (101.3 kPa), and the pressure was increased by 1 bar if no water leakage occurred for an hour. If the water leak is detected through the pre-installed holes at the expansion joints of mortar block, the test was halted and the maximum water pressure was recorded as the performance of the system.

Figure 6. Equipment assembly of the hydrostatic pressure resistance test

2.4 *Test results*

The hydrostatic pressure test for the conventional waterstop shows the water leakage at the first loading step, i.e. 1 bar (101.3 kPa and pressure head of 10 m), as shown in the Figure 7 (a). This implies the water percolates and migrates through the interface between the PVC waterstop and mortar block. The conventional PVC waterstop appears to be unsatisfactory at the pressure head of 10 m although the waterstop was properly installed and the mortar block was in place with special care with no void. In the same way, the mortar block was manufactured with concrete bonding waterstop, where the water leakage was not observed until 3 bar (pressure head of 30 m) as shown in the Figure 7 (b). Unfortunately, the test was stopped at the 3 bar because liquid type membrane was broken at the perimeter of the mortar block at the pressure. With the observation and the results, it can be concluded that concrete bonding waterstop successfully prevent the water percolation at the 3 bar of hydrostatic pressure.



(a) Conventional type: leaking at 1 bar (b) Adhesive bonding type: non-leaking until 3 bar

Figure 7. Results of the waterproofing performance test.

3 CONCLUSION

Waterproofing performance tests were carried out on the two different types of waterstops, one with conventional waterstop and one with concrete bonding waterstop. The test focused on the performance of the waterproofing system including waterstop, not on the waterstop product itself. The conclusions were drawn as follows:

- Laboratory test setup for waterproofing performance test was devised implementing the water leakage at the construction or expansion joint of concrete structures.
- The conventional waterstop could not waterproof at the pressure head of 10 m although the non-shrinkage mortar was soundly cast with special caution.
- The concrete bonding waterstop appears to resist the water percolation up to the pressure head of 30 m.

This is preliminary result for the waterstop of adhesive bonding in the underground structures. Further research is currently undertaken to implement the technology into the construction site.

ACKNOWLEDGEMENT

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