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To cite this article: W M H Wan Nazri *et al* 2017 *IOP Conf. Ser.: Mater. Sci. Eng.* **271** 012024

# Alternative design of pipe sleeve for liquid removal mechanism in mortar slab layer

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**Abstract.** Porosity is one of the mortar's characteristics that can cause problems, especially in the room space that used high amount of water, such as bathrooms. Waterproofing is one of the technology that normally used to minimize this problem which is preventing deep penetration of liquid water or moisture into underlying concrete layers. However, without the proper mechanism to remove liquid water and moisture from mortar system, waterproofing layer tends to be damaged after a long period of time by the static formation of liquid water and moisture at mortar layer. Thus, a solution has been proposed to drain out water that penetrated into the mortar layer. This paper introduces a new solution using a Modified Pipe Sleeve (MPS) that installed at the mortar layer. The MPS has been designed considering the percentage surface area of the pipe sleeve that having contact with mortar layer (2%, 4%, 6%, 8% and 10%) with angle of holes of 60°. Infiltration test and flow rate test have been conducted to identify the effectiveness of the MPS in order to drain out liquid water or moisture from the mortar layer. In this study shows that, MPS surface area 10%, angled 60°, function effectively as a water removal compared to other design.

## 1. Introduction

Penetration of water into the concrete layer that exists in the form of moisture can significantly affect the durability of the building structure, such as wall and floor structure. High levels of moisture caused the corrosion of reinforcement bar inside the concrete, promoting growth of microorganisms due to migration of moisture through the wall and also shorten concrete structure's life [1 - 3]. This moisture penetration phenomenon is called leakage.

The term of leakage is defined as a way of fluid to escape outside containers, tanks or also pipes. While leakage in the context of structure is a way in concrete that permit the fluid or gases permeate across the concrete structure [4, 5]. Concrete leakage (especially used for hydraulic-concrete) is a key factor that deteriorating the concrete structures since leakage can aggravate the chemical corrosion and frost damage [6, 7]. Concrete leakage usually occurred at part of the building that significantly expose to water, normally observed in bathroom area.

Concrete leakage happens when the water able to penetrate the concrete layer through seepage, due to crack or porous design of the concrete or mortar. The main point source of this problem is from the bathroom, where most of the water (bath/shower) been used and dropped onto the floor surface. Although a slab finishing is a water resistant and waterproofing liquid has been applied to the slab surface, some portion of water still penetrate into the mortar layer via tiny pores due to the porosity of the mortar itself or the existence of crack. The hydraulic transport process of the water (in the form of moisture) from the mortar to the concrete layer could be characterized using three fundamental mechanisms, which are absorption, condensation and capillarity [8].

The applying of waterproofing coating between the concrete and mortar layer will prevent the fluid to seep into the concrete layer or in other words absorbs not more than 2.5% of moisture [9]. However, this will cause another problem. Fluid will get trapped into the mortar layer. This phenomenon will cause other serious problem such as corrosion of embedded metals, fungus at the structure surface, deterioration of concrete and so on [10].

Without proper treatment and immediate action, floor or slab leakage will cause more serious problems to the building in the future, such as corrosion of steel reinforcement, fungus attack on the wall surface, formation of stalactites from the concrete slab and disturbance of electrical wiring system. Therefore, the structures and infrastructures need to be maintained and inspected all the time.

As a result, the cost of maintenance will increase due to the needs of major repair to the affected building. A lot of resources have been employed in the rehabilitation of infrastructure. As an example, in Italy, the rehabilitation work total cost amounted to half of the expenditure invested in construction [11]. The repair cost for Algiers Airport was estimated about 3 Millions USD [12]. While in UK, corrosion-related cost in building and construction industry was estimated to be 250 Million GBP [13].

Based on the problems stated, new technology or innovation is needed to enhance the existing product and technology. Preventing the water penetration into deep layers of the concrete is not enough since the behaviour of water keeps searching the occurrence of seepage and flow through it. Thus, more investigation of hydraulic behaviour of the concrete and mortar is needed as fundamental knowledge to design the suitable product that could remove the liquid and moisture from the concrete system.

## 2. Methodology

### *2.1. Sample preparation*

Five mortar specimens installed with Modified Pipe Sleeve (MPS) have been cast with dimension of 300mm x 300mm x 50mm. The weep-holes surface area were applied on the pipe sleeve as percentage shown in table 1. Table 1 tabulates the varieties design of the MPS and their abbreviations.

**Table 1**. Designs of MPS and abbreviation.

| Angle | Weep-Holes Surface Area (%) | Abbreviation |
|---|---|---|
| 60° | 0 | Conventional |
| 60° | 2 | A |
| 60° | 4 | B |
| 60° | 6 | C |
| 60° | 8 | D |
| 60° | 10 | E |

*2.1.1 Modified pipe sleeve design.* The detail dimensions of the MPS are as can be seen in figure 1.

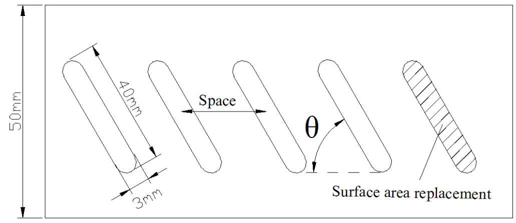


**Figure 1.** Detail dimension of MPS.

Table 2 and table 3 show the number of holes and the spaces between holes for every type of MPS.

**Table 2.** Number of holes.

| Weep-Holes Surface Area (%) | No. of holes |
|---|---|
| 0 | 0 |
| 2 | 3 |
| 4 | 6 |
| 6 | 9 |
| 8 | 12 |
| 10 | 15 |

**Table 3.** Space between holes.

| No. of holes | Space between holes (mm) |
|---|---|
| 0 | 0 |
| 3 | 115 |
| 6 | 58 |
| 9 | 38 |
| 12 | 29 |
| 15 | 23 |

*2.1.2 Model preparation.* As usual, Ordinary Portland Cement (OPC) was used as a binder. River sand was used as fine aggregate must passing 3mm sieve size. Table 4 indicates the mix design composition for mortar based on [14] with fixed water-cement ratio (w/c) at 0.5.

**Table 4.** Mortar mix design composition.

| Materials | Mix Composition (kg) |
|---|---|
| Ordinary Portland cement | 18.9 |
| Fine aggregate | 37.8 |
| Water (0.5 w/c) | 9.45 |

*2.2. Experimental work*

There are two main parameters have been conducted in this study which are infiltration and flow rate. The infiltration test was conducted to obtain the infiltration rate of water that penetrates in mortar layer that installed with 5 varieties design of the MPS. Three liters of water were pond on the mortar surface in a period of 12 hours and the result was recorded for every 30 minutes. Figure 2 reveals the infiltration rate test.

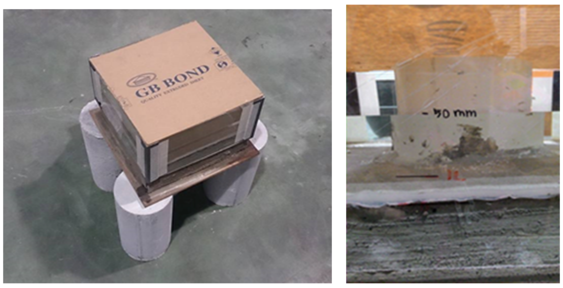


**Figure 2**. Infiltration test.

The flow rate test was conducted to determine the flow rate of water that drain out from the mortar layer through MPS. It is conducted simultaneously with infiltration test. Water pond that penetrates into the mortar layer will be drained out through the MPS. The drained out water then will be collected and measured. The test was carried out for 12 hours and the result was recorded for every 30 minutes. Figure 3 demonstrates the flow rate test that has been conducted.

**Figure 3**. Flow rate test.

## 3. Results and discussions

### *3.1. Infiltration test to the mortar*

Table 5 represents the cumulative volume of water infiltrate for the 10% surface area design pipe sleeve for every 30 minutes.

Figure 4 illustrates, the cumulative volume of water infiltrates in 6 hours for each surface area percentage pipe sleeve design. For pipe sleeve E, the cumulative volume of water infiltrate was increased rapidly in 6 hours. This is because the higher percentage of surface area will design a pipe sleeve with more holes to drain out water. So, the number of holes will influence the infiltration rate of water in the mortar. The total volume of water infiltrates for 6 hours for pipe sleeve E is 945 ml. Same goes to pipe sleeve D, the cumulative volume of water was increased rapidly but the total volume infiltrates for the last 6 hours was less than pipe sleeve E which is 810 ml. Next, the cumulative volume of water infiltrates for the pipe sleeve C was increased gradually in 6 hours with the total volume of water infiltrates 720 ml. While for pipe sleeve A, B and Conventional, the cumulative of water infiltrates was increased gradually with the total volume of water infiltrates 270 ml, 225 ml and 180 ml. Based on the data collected for infiltration rate test, it shows that the higher the percentage area of holes of the pipe sleeve design, the higher the total volume of water infiltrates in 6 hours. So that, the design holes can affect the result of the volume of water infiltrates.

**Table 5.** Cumulative volume of water infiltrates for pipe sleeve E.

| Time (min) | Height of water (mm) | Volume of water (ml) | Volume of water infiltrates (ml) | Cumulative volume of water infiltrates (ml) | Percentage of infiltration of water (%) |
|---|---|---|---|---|---|
| 0 | 40.0 | 3000 | 0 | 0 | 0 |
| 30 | 39.0 | 2910 | 90 | 90 | 2.50 |
| 60 | 38.0 | 2820 | 90 | 180 | 5.00 |
| 90 | 37.5 | 2775 | 45 | 225 | 6.25 |
| 120 | 37.0 | 2730 | 45 | 270 | 7.50 |
| 150 | 36.0 | 2640 | 90 | 360 | 10.00 |
| 180 | 35.0 | 2550 | 90 | 450 | 12.50 |
| 210 | 34.0 | 2460 | 90 | 540 | 15.00 |
| 240 | 33.5 | 2415 | 45 | 585 | 16.25 |
| 270 | 32.0 | 2280 | 135 | 720 | 20.00 |
| 300 | 31.0 | 2190 | 90 | 810 | 22.50 |
| 330 | 30.0 | 2100 | 90 | 900 | 25.00 |
| 360 | 29.5 | 2055 | 45 | 945 | 26.25 |

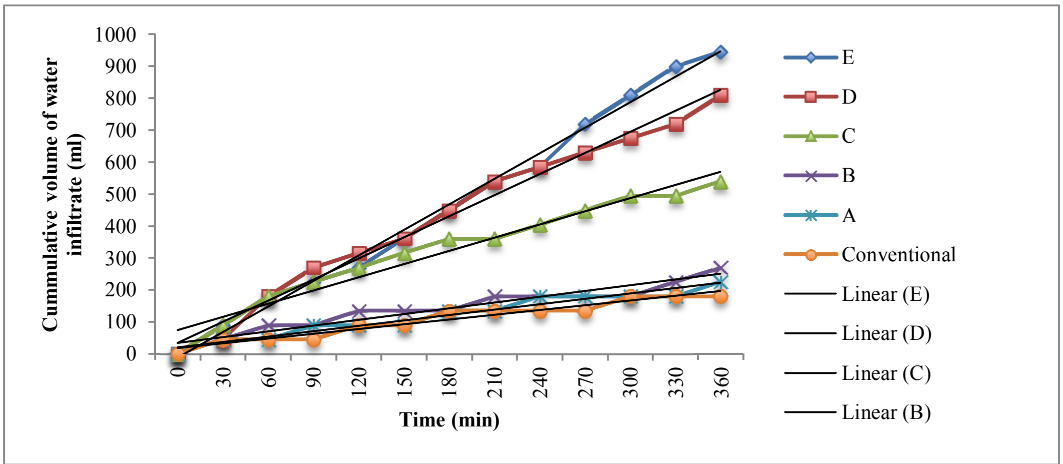


**Figure 4**. Cumulative volume of water infiltrates for each surface area percentage pipe sleeve design.

Figure 5 demonstrates the mortar layer that using pipe sleeve E design gives the highest infiltration result which is 79.863 ml/min. This is because of the water have an alternative way to drain out from the mortar layer which is the designated number of holes. Then, the infiltration rate of mortar for pipe sleeve D is less than pipe sleeve E which is 66.016 ml/min. The infiltration rate of mortar for pipe sleeve C was 41.291 ml/min. While the infiltration rate of the mortar layer of B, A and Conventional pipe sleeve design were 18.049 ml/min, 16.813 ml/min and 14.835 ml/min respectively. It is proved that the infiltration rate of mortar was influenced by the surface area percentage of the pipe sleeve design as the increase of surface area percentage of the pipe sleeve design, the increase the infiltration rate of mortar layer. The most effective design of pipe sleeve is pipe sleeve E as the infiltration rate of mortar layer was the highest among others.

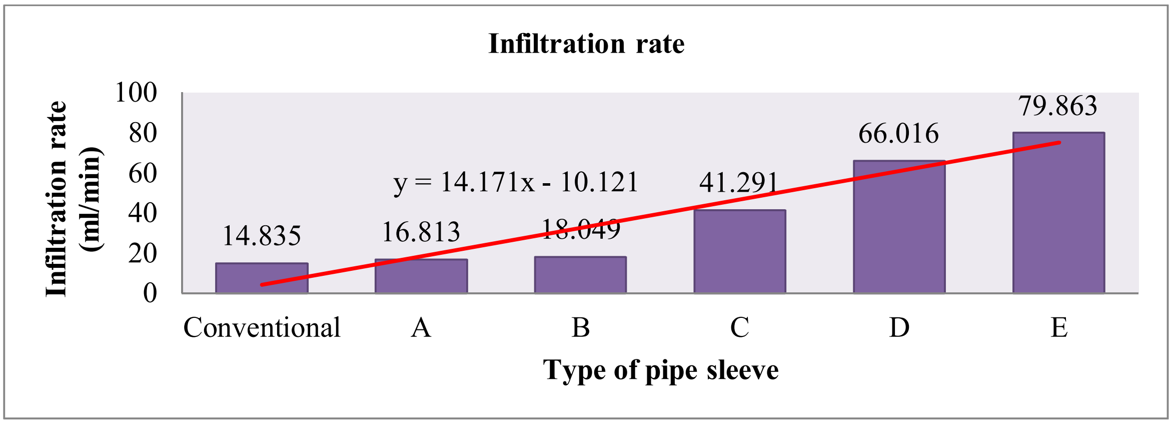


**Figure 5**. Infiltration rate of water.

### *3.2. Flow rate test to the mortar*

Table 6 reveals the volume of water that flow out through the 10% surface area design pipe sleeve for every 30 minutes.

**Table 6**. Volume of water that flow out through pipe sleeve E.

| Time (min) | Volume of water collected (ml) |
|---|---|
| 0 | 0 |
| 30 | 40 |
| 60 | 70 |
| 90 | 100 |
| 120 | 125 |
| 150 | 170 |
| 180 | 210 |
| 210 | 250 |
| 240 | 290 |
| 270 | 340 |
| 300 | 360 |
| 330 | 400 |
| 360 | 460 |

Figure 6 shows the volume of water collected in six hours for every design pipe sleeve. For pipe sleeve E, it shows that the volume of water that flow out was increased rapidly in six hours in time. While for pipe sleeve D, the volume of water collected was a bit slow for the first hour as it remains at zero value and then for the next hour, it was gradually increased for the next five hours. For C, the volume of water flow out was increased slowly but in constant mode for the six hours. Lastly, the volume of water collected for B, A and Conventional pipe sleeve were in the same state which was constantly in zero as there is no water collected for the six hours period of time. Pipe sleeve E shows the highest volume of water flow out in the period of six hours because it covers more surface area percentage resulting the higher number of holes to flow out the water from the mortar.

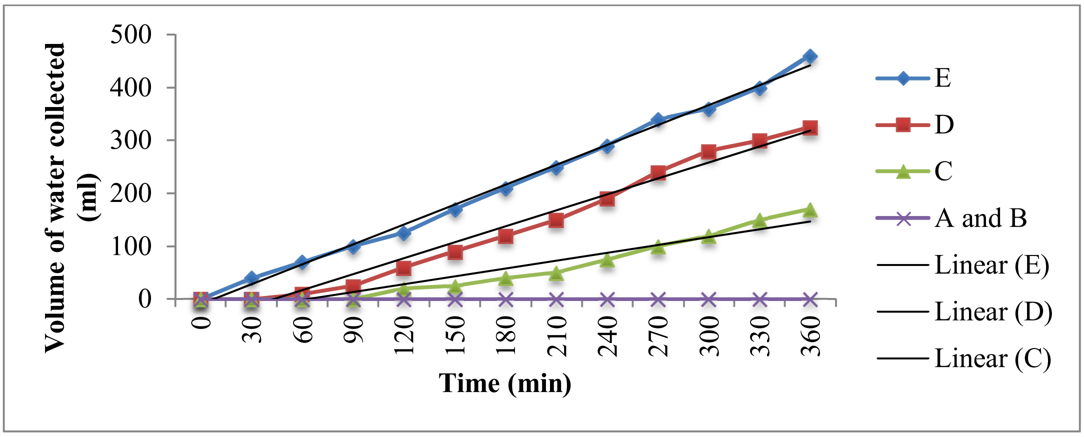


**Figure 6**. Volume of water collected in six hours for every design pipe sleeve.

As depicted in figure 7, the flow rate of water in the mortar layer that using pipe sleeve E was the highest among all of them all. It is clearly shown that the alternative holes provided by pipe sleeve design at mortar layer were able to drain out the water from mortar layer. The flow rate that remains at zero value shows that the surface area covered was too small and it required more time to drain out water. Then, the flow rate of water in a mortar layer only started to increase when the pipe sleeve C has been used. The flow rate of water for C is 14.753 ml/min. Then, the flow rate of water increased rapidly for the D and E which is 30.192 ml/min and 37.637 ml/min respectively. The flow rate of water for pipe sleeve E recorded the highest rate and it shows that it was the best design compared to the other design.

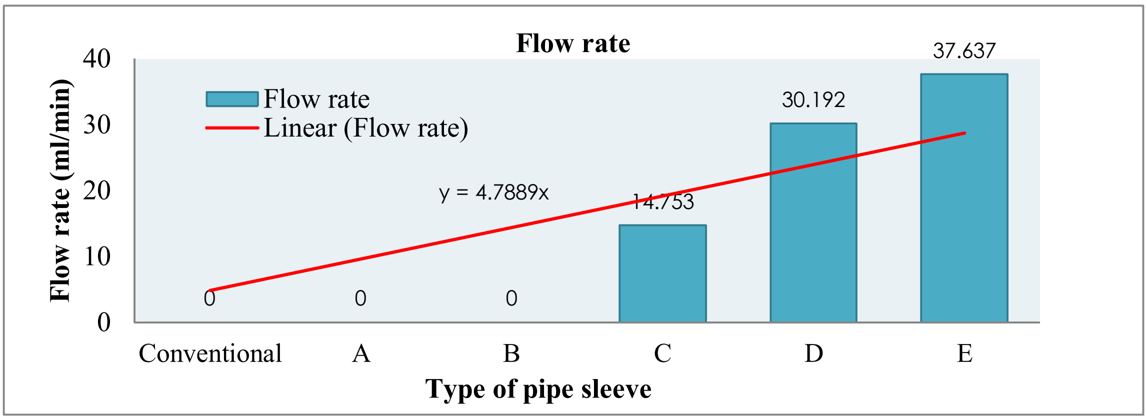


**Figure 7**. Flow rate result.

## 4. Conclusion

The pipe sleeve design was to enhance innovative product for problem solving in Malaysia, thus to help in reducing the moisture content of the building structure problem. Refer to the problem of slab leakage, this study can be a solution to reducing this problem. This study has achieved the objective to identify the performance of the ordinary pipe sleeve system and the MPS in order to remove water in the mortar layer where the performance of MPS is better compared to ordinary pipe sleeve.

Based on this study also, the MPS system absolutely can drain out water effectively that trapped in the mortar. This will help in reducing the moisture content of the slab structures, thus decreased the structure failures probability in future. This MPS can be an alternative solution for existing solution of leakage problem such as waterproofing and other solution.

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## Acknowledgments

This paper was partly sponsored by the Centre for Graduate Studies UTHM. The author would like to thank Universiti Tun Hussein Onn Malaysia for their financial support in term of grant, Short Term Grant (STG) for vote number of U344 and Geran Pembangunan Produk (GPP) for vote number of B064. Special thanks to Research, Innovation, Commercialization and Consultancy Management Office UTHM and Department of Structural and Material Engineering (FKAAS), for supporting this research.