Study on Application of Simulated Air Pollution Dust the Permeable Concrete

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Abstract. Impermeable pavement is usually adopted in pavement construction in Taiwan. Porous asphalt concrete employs features as water retention, cooling and promoting draining effect. However, with the increase of traffic volume and service duration, its draining function will decrease gradually, wherein porosity blocking is one of the major problems. The research aims at the analogue experiment on pervious concrete subject to dust blocking, which discusses the blocking status and changes in permeability due to natural dust fall and clump dust fall after rainfall. The experiment prepares 4 groups of mixing ratio. The aggregates are coarse and fine bottom ashes from the refuse incinerator. The proportion of cement is 130kg/m³ and 200kg/m³. The experiment simulates the influence and in-situ water permeability changes of specimens with different porosities been blocked by natural dust fall and then the dust been rushed into specimens by rainfall. Before the analogue experiment, the water permeability of 4 groups of specimens is 1399.75~1412.91ml/15sec. The experiment adopts 2011 average monthly dust fall in Pingtung County and magnifies it by 10 to 20 times to simulate natural dust fall and clump dust fall on the pavement accordingly. It is known from the experimental results that due to the high porosity of pervious concrete, by ruling out other blocking factors, the natural dust fall has little influence on the water permeability of pervious concrete. While the simulation of clump dust fall is 15 times the natural dust fall, although water permeability the pavement is reduced sharply, it still meets the minimum 400ml/15sec of Japanese porous pavement technical indicator. It shows that the specimens have good permeability on future practical applications.

1. Foreword
Taiwan’s land development is expanding, and impermeable pavement is often adopted. While there has been a long application history of porous asphalt concrete pavement abroad. It employs features as water retention, cooling and promoting draining effect. The usage of porous asphalt concrete pavement is increasing in domestic traffic industry. The loss of draining function mainly divides into 2 reasons: dust blocking and closing-up of porosity. The blocking obstructions can be road sand dust, flying sand dust, mud and sand brought by vehicle or worn aggregates. The closing-up of porosity is due to the pavement surface moving caused by vehicle load and porosities been filled up step by step; or closing-up due to aggregates relocation. Fine sand or dust carried by vehicles or blown up by the wind floats into the air, then falls and accumulates on the road surface, where rain carries it into the
pores; after evaporation of water, they will block the porosities after a long time and causes loss of draining function.

2. Research Purpose
The research mainly discusses the influence of pervious concrete blocking by dust fall, which conducts blocking procedure and rainfall simulation, and then uses water permeability test to observe the performance change in permeability. The research purposes are as follows:

1. Determine physical properties of the refuse incinerator bottom ash.
2. Mix different coarse or fine aggregates of refuse incinerator bottom ash based on different ratios and discuss the relationship between different porosity rates influence on the dust fall blocking.
3. Conduct blocking test of natural dust fall and clump dust fall on the specimens to observe the change in water permeability after rainfall simulation.

3. Literatures Review

3.1 The Reason for Permeable Pavement Blocking
The major problem of permeable pavement is loss of draining function. The loss of draining function mainly divides into 2 reasons: porosity blocking and closing-up of porosity. The blocking obstructions can be road sand dust, flying sand dust, mud and sand brought by vehicle or worn aggregates. The closing-up of porosity is due to the pavement surface moving caused by vehicle load and porosities been filled up step by step; or closing-up due to aggregates relocation[1]. Fig. 1 and 2 show porous asphalt blocking due to sand obstruction and closing-up caused by vehicle load.

3.2 Influence of Dust on Pervious Concrete
The blocking materials often come from dust or sand beside the road, which will be spread onto the pavement by traffic or wind. The fall-out can be brought into the porosity by the rainfall [1]. In recent years, the fall-out quantity varies. The annual average value of airborne particle is lower than 65µg/m³ safety range. In fear that the dust fall could affect the water permeability of pervious concrete, dust fall-water permeability test is conducted to discuss whether the dust fall will block the pervious concrete and further impact the water permeability [3].

4. Methodology

4.1 Experimental Proportion
The research uses coarse and fine aggregates of the refuse incinerator bottom ash, which employs advantages as light-weight, good shape, high porosity, etc. It can effectively reduce cost and bring down the waste process. Therefore, the use of bottom ash aggregates can achieve waste recycling and control the impact of refuse incinerator’s waste. However, there have been no relevant standards or researches to define or determine the influence and severity of blocking to the environment in domestic at present. So the research simulates blocking of pervious concrete pavement and after rainfall influence, and then uses water permeability test to observe the change in water permeability. Table 1 is the experimental ratios. The coarse aggregate diameter is of 12.5~19mm and 4.75~12.5mm; and 2.36~4.75mm and 0.6~2.36mm for the diameter of fine aggregate as shown in Fig. 3.

4.2 Specimen Blocking Test Procedure
The test adopts clay to simulate the dust fall. For the airborne particle’s diameter is extremely small, the clay chunk has been pulverized into fine powder by ball grinding machine (Fig. 5) and then used to simulate the dust fall. Generally, fall-out dust particle’s diameter is larger than 10µm, and street dust particle’s average diameter is 220 to 515 µm(0.22~0.515 mm) [5], in which the minimum particle is about the 0.15mm, the opening of #100 sieve. Thus, #100 sieve is chosen to simulate the natural dust fall. The dust fell off by tapping the sieve to imitate the natural dust fall off. During the test, 10 times
of dust fall was simulated, and the total amount of dust fall reached 17.2g. According to the results, with 100 tapping as a set, it can obtain 17.2g dust fall by 5 sets of tapping. And then, to conduct rainfall simulation, which applies total 4.095kg water in 5 times on a 15x15cm testing area, i.e. 0.819kg of water each time. After that, put the specimen into the oven for 1 hour for drying. The purpose of the drying procedure is to keep the dust staying in the specimen via the viscosity of the clay. Then the clay particles will stay in the specimen after the drying procedure. The pervious concrete prepared according to the above steps can handle 20 times more dust particles than the average monthly accumulation of dust particles on the road surface.

5. Result and Discussion

5.1 Basic Physical Properties of Refuse Incinerator Bottom Ash
Aggregate makes up a main portion in pervious concrete, so the aggregate’s basic physical properties will control performance of the pervious concrete. Table 2 shows the basic physical properties of the coarse and fine aggregates of the incinerator bottom ash. Because the bottom ash has higher porosity than those of general aggregates, therefore, its absorption capacity is certainly higher. Consequently, during the mixing, to prevent the high absorption capacity from affecting the designed water-cement ratio, the aggregates need to be prepared in considering its absorption capacity to make it near saturated.

5.2 Result of Porosity Rate and In-situ Water Permeability Test
Pervious concrete’s average porosity is as shown in Table 6. For Group B, C, and D containing no fine aggregates, their porosities are higher than that of Group A. Although Group B does not use fine aggregate, its cement ratio is higher than those of Group C and D, the increase in cement ratio caused the aggregate contact more with cement paste. The increase in binding agent and aggregate contact area can reduce the porosity. Consequently, Group A uses more cement and fine aggregate, its porosity rate is the lowest. Before dust fall test, the research conduct in-situ water permeability test (Fig. 9). Before the test, the peripheral area shall be sealed by oil-based clay and the specimen shall totally be in contact with the base plate and make sure the 4 corners are sealed with oil-based clay. The test result is as shown in Table 3. Groups A to D all exceed the minimum 400ml/15sec requirement of Japanese porous pavement technical indicator. The relationship between porosity rate and water permeability is shown in Fig. 10. Generally speaking, larger porosity rate results in higher water permeability and vice versa.

5.3 Result of Tapping Dust Fall Test
Currently, there is no relevant standard to specify the test procedure, so the research utilizes the foregoing designed test platform to simulate the dust fall. It uses #100 sieve as dust-fall simulation apparatus, and applies test dust (clay) onto the screen evenly. Each cycle of dust-fall simulation has 100 tapping, and weighing the dust every 10 taps. The simulation conducts 3 tests and obtains average 3.61g dust fallen onto the specimen surface evenly (Table 4). After confirming feasibility of the method which can get quantities of average monthly natural dust fall, 10 and 20 times natural dust fall test can be conducted. The research simulates rainfall after every dust fall simulation, and then puts the specimen into oven for 1 hour for drying to make sure the dust fall is brought into the porosity and stays in. Monthly dust fall quantity of Pingtung County is 1.72ton/km² in 2011, so the 10 times of it is 17.2g. According to the result of 4.6.1, each group of tapping can obtain 3.61g dust fall, so 17.2g dust fall can be obtained by 5 cycles of tapping. Further referring to the rainfall record of Pingtung Station, Central Meteorological Bureau (from October 2010 to March 2011), the simulated rainfall on the tested specimen is 4.095kg. The simulating rainfall is applied by using a pressure sprayer (Fig. 11), and Table 5 show the quantities of the applied dust and the permeability of specimens before and after the simulated rain fall. The relationship between porosity and permeability of pervious concrete is shown in Fig. 12. All 4 groups of specimen exceed the requirement of minimum 400ml/15sec of the
Japanese porous pavement technical indicator. Therefore, it suggests that blocking of 10 times natural dust fall has little influence on pervious concrete. 20 times dust fall simulation is shown in Table 6. The 20 times dust fall test is conducted by applying 10 times dust fall directly onto the previous tested specimen. The 20 times natural dust fall test appears to be close to those of the former tests. The relationship between porosity rate and water permeability before and after the test is shown in Fig. 13.

6. Conclusion
For the bottom ash aggregate employs porosity, the purposed pervious concrete has higher porosity, 24.6~28.1%. The in-situ permeability test results in 1399.75 ~1412.91 ml/15sec, which meets the minimum 400ml/15sec required by Japanese porous pavement technical indicator. It is known that the pervious concrete has good permeability performance. The tapping test shows 3.61g dust is close to the average monthly dust fall of Pingtung County during year from 2000 to 2011. In consideration of the natural dust fall, permeability of the 4 groups of pervious concrete, containing incinerator bottom ash aggregate, keeps 1403.01 ~ 1426.32 ml/15sec after 10 times natural dust fall simulation, and 1397.59 ~ 1428.62 ml/15sec for 20 times simulation. Thus, it suggests that natural dust fall has little impact on the blocking of pervious concrete.
Fig. 7 Pressured Sprayer

Fig. 8 Rainfall Simulation by Styrofoam Sealing the

Fig. 9 In-situ Water Permeability Test Apparatus

Fig. 10 Relationship between Porosity Rate and Water Permeability

Fig 11. Pressure sprayer simulates rainfall diagram

Fig 12. Relationship between porosity and local water permeability before and after the test
Table 1. Proportions of Pervious Concrete

| No. | I-type Cement | Coarse Aggregate Dia. (mm) | Fine Aggregate Dia. (mm) | Water |
|-----|---------------|-----------------------------|--------------------------|-------|
| A   | 200           | 400                         | 880                      | 160   | 160 | 84.6 |
| B   | 200           | 400                         | 1200                     | -     | -   | 84.6 |
| C   | 130           | 800                         | 800                      | -     | -   | 55   |
| D   | 130           | 400                         | 1200                     | -     | -   | 55   |

Table 2. Basic Physical Properties - General Aggregate vs. Bottom Ash

| Aggregate             | SSD sp. gr. | Absorption Capacity (%) | Dry Rodded Unit Wt. (kg/m³) | Water Absorption in 30 min. (%) |
|-----------------------|-------------|--------------------------|-----------------------------|---------------------------------|
| General - Coarse      | 2.62        | 0.7                      | 1631                        | -                               |
| General - Fine        | 2.68        | 1.8                      | 1616                        | -                               |
| Bottom Ash - Coarse   | 2.36        | 5.3                      | 1266                        | 4                               |
| Bottom Ash - Fine     | 2.23        | 9.2                      | 1125                        | 4.2                             |

Table 3. Average Porosity Rate of Each Group

| Group | Coarse Aggregate (kg/m³) | Fine Aggregate (kg/m³) | Cement (kg/m³) | Porosity Rate (%) |
|-------|--------------------------|-------------------------|----------------|-------------------|
| A     | 1280                     | 320                     | 200            | 24.6              |
| B     | 1600                     | 0                       | 200            | 27.4              |
| C     | 1600                     | 0                       | 130            | 27.7              |
| D     | 1600                     | 0                       | 130            | 28.1              |

Table 4. Dust Fall Quantity after Tapping (Unit: g)

| Group | Tapping Count |
|-------|---------------|
| I     | 0.47 0.51 0.50 0.41 0.40 0.37 0.29 0.16 0.19 0.16 | 3.46 |
| II    | 0.74 0.54 0.55 0.40 0.34 0.32 0.23 0.19 0.26 0.18 | 3.75 |
| III   | 0.55 0.45 0.52 0.46 0.36 0.33 0.26 0.23 0.23 0.23 | 3.62 |
| Average | 0.59 0.50 0.52 0.42 0.37 0.34 0.26 0.19 0.23 0.19 | 3.61 |
Table 5. Test Result – 10 Times Monthly Dust Fall Simulation

| No. | A  | B  | C  | D  | Rainfall Simulation (kg) |
|-----|----|----|----|----|--------------------------|
| 1   | 3.5| 3.5| 3.1| 3.3| 0.819                    |
| 2   | 3.7| 3.5| 3.4| 3.7| 0.819                    |
| 3   | 3.2| 3.2| 3.6| 3.1| 0.819                    |
| 4   | 3.3| 3.8| 3.5| 3.3| 0.819                    |
| 5   | 3.3| 3.4| 3.7| 3.4| 0.819                    |
| Total| 17.0| 17.4| 17.3| 16.8| 4.095                   |

Permeability before Test (ml/15sec) 1399.75 1415.11 1422.94 1412.91 -
Weight before Test (kg) 18.322 18.589 18.774 18.193 -
Permeability after Test (ml/15sec) 1403.01 1408.52 1419.59 1426.32 -
Weight after Test (kg) 18.137 18.346 18.604 18.067 -

Table 6. Test Result – 20 Times Monthly Dust Fall Simulation

| No. | A  | B  | C  | D  | Rainfall Simulation (kg) |
|-----|----|----|----|----|--------------------------|
| 1   | 3.8| 3.6| 3.7| 3.3| 0.819                    |
| 2   | 3.1| 3.3| 3.4| 3.5| 0.819                    |
| 3   | 3.3| 3.6| 3.5| 3.8| 0.819                    |
| 4   | 3.5| 3.4| 3.6| 3.6| 0.819                    |
| 5   | 3.7| 3.2| 3.4| 3.4| 0.819                    |
| Total| 17.3| 17.1| 17.6| 17.6| 4.095                   |

Permeability before Test (ml/15sec) 1403.01 1408.52 1419.59 1426.32 -
Weight before Test (kg) 18.137 18.346 18.604 18.067 -
Permeability after Test (ml/15sec) 1397.59 1414.01 1422.96 1428.62 -
Weight after Test (kg) 17.997 18.223 18.521 17.913 -

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