The Effect Of A/C Variation On Compressive Strength, Permeability And Porosity Of Pervious Concrete

Hanafiah, Saloma, Nicholas Ferdinand, Sutanto Muliawan, Mona Fadila Rachmah

Abstract: Pervious concrete is innovation of concrete that has high permeability, so pervious concrete can be passed by water. Porous formed in pervious concrete makes pervious concrete is permeable. This research used 10% silica fume as cement substitution, 7% sand as coarse aggregate substitution and ratio variation of cement aggregate (a/c). Ratio variation of cement aggregate were 2.0, 2.5, 3.0, 3.5, 4.0, 4.5 and 5.0. The test of properties aggregate, density, compressive strength and porosity used ASTM standard. The test of permeability used falling head method. The result of examining the slump in pervious concrete was 0 cm in all mixed variation and the result of maximum compressive strength test of 28 days of 15.66 MPa in the mixture with the value of a/c = 2.0 that had permeability of 0.26 cm/s and porosity of 14.7%.

Index Terms: pervious concrete, a/c, silica fume, sand, permeability, porosity

1. INTRODUCTION

Pervious concrete has been used in building construction field since 19th Century (Francis, 1995). The term of pervious concrete describes a material. However, in reference and the history of pervious concrete, it describes as concrete with no fine aggregate concrete or gap-graded concrete (ACI 522R-10). Pervious concrete plays role as filter to catch and remove pollutant from rainwater (Devi and Saini, 2015). Fine aggregate used in pervious concrete is to increase mechanic capacity of pervious concrete. Based on the result of the research from Wang et al (2006), it is suggested to use fine aggregate of 7% from the total of coarse aggregate weight. The research of Wang illustrates compressive strength and the ability of pervious strength to froze and melt that have significant enhancement with the additional of fine aggregate, in which permeability of the concrete is still taken precedence. The enhancement of fine aggregate is recommended 7% from total of coarse aggregate weight so that permeability still can be achieved. The using of cementitious material in pervious concrete mixture becomes alternative to increase compressive strength from pervious concrete. In the research of (Ravindrarajah, 2014) silica fume could increase compressive strength but it decrease porosity level and permeability coefficient of pervious concrete.

The factor of cement aggregate ratio is one of important factors that affect to pervious concrete's characteristic (Cheng et al, 2011). The comparison between aggregate and cement is very take affect to pervious concrete's characteristic. The higher cement content used, the higher compressive strength of pervious concrete, however it causes porous in concrete closes and reduces permeability properties of pervious concrete. Ajamu et al (2012) conducted the research by using two variations of aggregates size and three variations of a/c. With the aggregates size which is retained in sieve size 3/4" and 3/8" and variation a/c 6:1, 8:1, and 10:1. The result of the research (Ajemu et al, 2012) showed the relation of a/c with compressive strength and permeability of pervious concrete was the smaller ratio a/c, the higher compressive strength of pervious concrete. Otherwise, permeability and aggregate volume were decreased and the cement volume in the pervious concrete were increased. As the cement volume increases, the porous in pervious concrete is increasingly filled.

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2 MATERIALS AND METHOD

The research method used is experimental method. Experimental method in this research was using ratio variation of cement aggregate that were 2.0, 2.5, 3.0, 3.5, 4.0, 4.5 and 5.0. This research used substitution of 10% silica fume toward cement weight and 7% fine aggregate toward coarse aggregate weight in making composition of pervious concrete. The tests conducted in this research was fresh concrete test, compressive strength of pervious concrete test on 7 and 28 days, the test of permeability and porosity. The test of fresh concrete was tested by slump test. Permeability test used falling head method and the test of porosity used ASTM C 192 standard.

TABLE 1
MIX DESIGN OF PERVIOUS CONCRETE

OPC (kg/m^3)	Water (kg/m^3)	Coarse aggregate (kg/m^3)	Fine aggregate (kg/m^3)	Silica fume (kg/m^3)
373.5	124.5	771.9	58.1	41.5
373.5	124.5	964.9	72.6	41.5
373.5	124.5	1,157.9	87.2	41.5
373.5	124.5	1,350.8	101.7	41.5
373.5	124.5	1,543.8	116.2	41.5
373.5	124.5	1,736.8	130.7	41.5
373.5	124.5	1,929.8	145.3	41.5

Mixture composition of pervious concrete was made by collecting data from journal and ACI. The material used in making composition consisted of cement OPC type I, fine aggregate, coarse aggregate that passing by 1/2 inch sieve size and retained in 3/8 inch, water and superplasticizer (SP) 500 mL per 100 kg of cement material. Mixture composition of pervious concrete can be seen in Table 1.

3 RESULT AND DISCUSSION

3.1 Fresh Concrete

The test of fresh concrete was slump test. Based on slump test on each variation of mixture got slump value that is 0 cm (Figure 1). Small slump value made work accident to pervious concrete became easier and formed porous that related to pervious concrete.

***Fig. 1**. Slump test of pervious concrete*

3.2 Density

Density test result of pervious concrete in 7 and 28 days did not have significant difference. The result in Figure 2, the heaviest in the mixture with label a/c = 2.0 in 7 days was 2,061 kg/m^3 and in 28 days was 2,054 kg/m^3, whereas the smallest density in mixture with a/c = 5.0 in 7 days was 1,773 kg/m^3 in age of 28 days was 1,748 kg/m^3. The result of the Crouch et al (2006) revealed that pervious concrete of density was about 1,681-1,917 kg/m^3 so that the result of research test in label a/c = 3.0, a/c = 3.5 and a/c = 2.0 did not include in range research in previous journal that was the biggest difference from the result of the research and concluded that density continuously decreases the density a/c value in mixture also decreases.

3.3. Compressive Strength

The compressive strength of test object was conducted in concrete 7 and 28 days. The result of the biggest in mixture variation compressive concrete of 7 and 28 days was in mixture variation a/c = 2.0 with compressive strength value of 7 days 12.89 MPa and age of 28 days 15.66 MPa. The comparison of this research and previous journal in examining test object of 28 days with label a/c = 4.0, the result of compressive strength obtained in this research was 8.14 MPa and the result of previous journal was 10.07 MPa. The difference in the test result from this research and previous journal were caused by the difference of material and mixture proportion by Mahalingam (2015). The result of the research ACI 522R-10, compressive strength of pervious concrete were about 2.8 - 28 MPa, so that the result on this research included the range of previous journal. Figure 3 was the test result of compressive strength. Compressive strength decreased as long as value of a/c from the mixture. The usage of a/c = 2.0 in pervious concrete mixture made thickness of paste in the concrete became thicker a lot, whereas in mixture of a/c = 5.0 paste level became fewer so that formed paste in pervious concrete was thinning, so that it can be concluded that value of aggregate cement ratio is inversely proportional with compressive strength achieved by pervious concrete. Exponential regression analysis was used to fit trend from test result. The relation of compressive strength of age 28 days toward variation a/c is showed in Figure 4, with determinant coefficient of 99.58%. The relation of compressive strength age of 7 days toward variation a/c is showed in Figure 4 with determinant coefficient of 90.26% that describes the result of examination.

3.4 Permeability

Permeability test result in pervious concrete changed significantly. In mixture of a/c = 3.0, permeability value was 0.26 cm/s and in mixture a/c = 5.0, the permeability value was 1.42cm/s. The result of Table 2 revealed that permeability value continuously increases as long as the enhancement of a/c value in the mixture. The enhancement of permeability value was caused by the enhancement of porous number in pervious concrete. The result test of this research and previous journal were seen in test of test object label a/c = 4.0. The result of permeability obtained on this research was 0.82 cm/s and the result from previous journal was 1.58 cm/s. The difference was 0.76 cm/s. The difference was caused by material and proportion mixture used on this research was not the same as previous journal by Mahalingam (2015). Based on ACI 522R-10, the result of permeability was about 0.14 - 1.22 cm/s, so that this research test result included the range of previous journal. Figure 5 is the result of permeability test that can be concluded that, the bigger value of a/c, value of permeability more increase because paste level decreased that made concrete has many porous and it is easy to be passed by water. The relation of permeability and a/c variation with determinant coefficient of 97.97% that describes test result.

3.5 Porosity

Porosity of pervious concrete changed significantly. Table 3 is porosity test result in pervious concrete. In mixture of label a/c = 2.0 was obtained porosity value of 12.72% and mixture of label a/c = 5.0 was obtained porosity value of 22.21%. Average of difference between test result of this research test and previous journal by Mahalingam (2015) was 0.43%. The difference was caused by different material and mixture proportion used on this research and the previous journal. Porosity test result ACI 522R-10 in pervious concrete was about 15 - 35%. So that the result of the test included in test range by previous journal. Figure 6 was porosity test result that can be concluded that the more value of variation a/c increase, the more increase porosity value from pervious concrete. It was because paste level got thinner that made pervious concrete has many porous than lower value a/c. The relation of porosity and variation a/c with coefficient with determinant 98.86% that describes the result of examination.

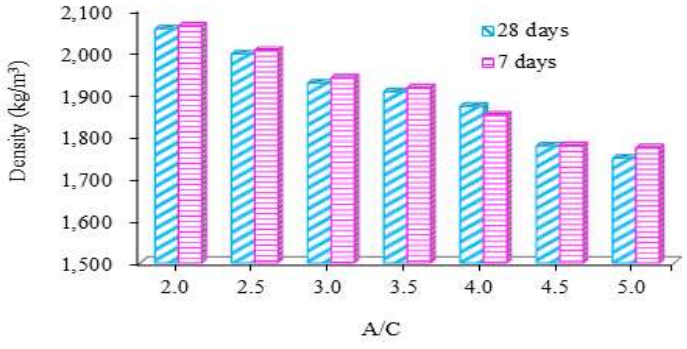

***Fig. 2**. Density of pervious concrete*

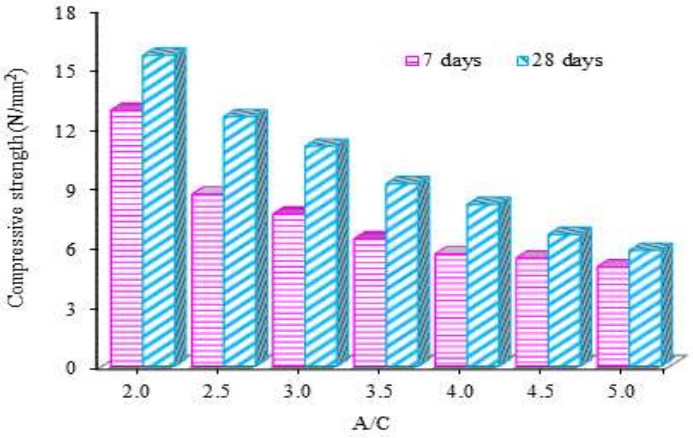

***Fig. 3**. Compressive strength of pervious concrete*

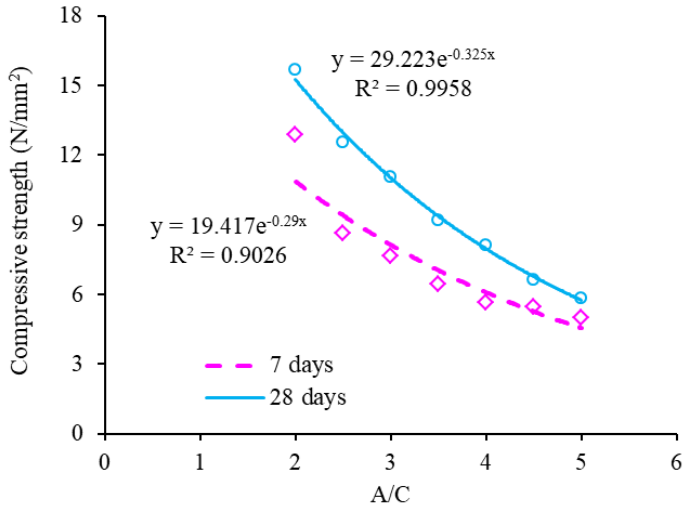

***Fig. 4**. Linear regression of compressive strength*

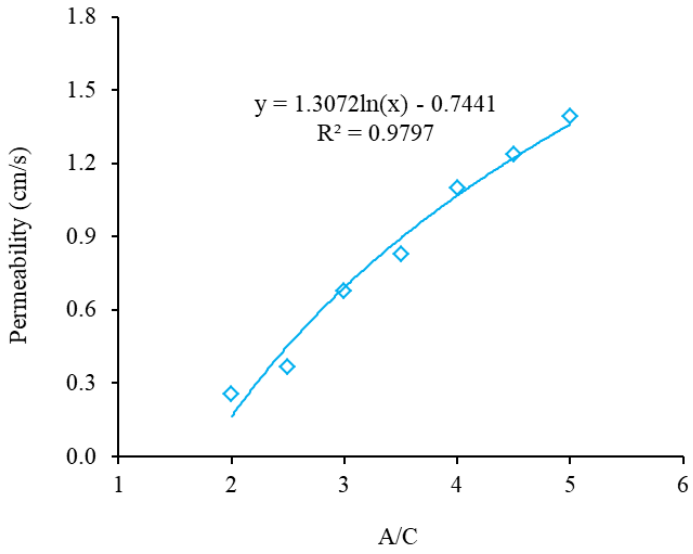

***Fig.5**. Permeability coefficient of pervious concrete*

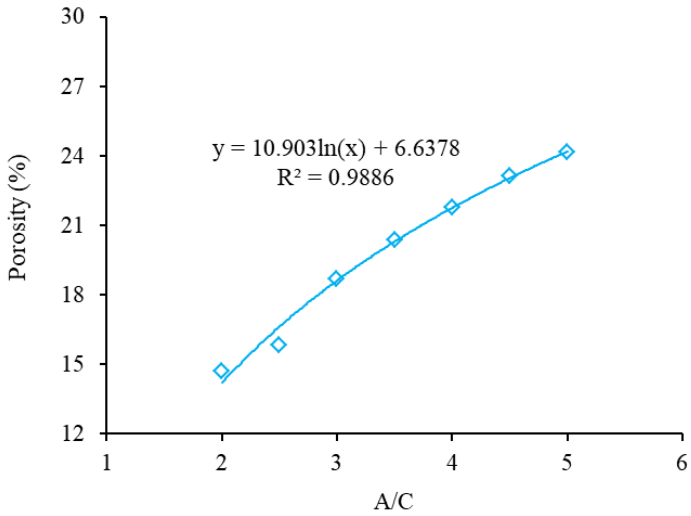

***Fig. 6**. Porosity of pervious concrete at 28 days*

TABLE 2

PERMEABILITY COEFFICIENT TEST RESULT OF PERVIOUS CONCRETE

a/c	Time (s)	Permeability coefficient (cm/s)	
		Flow velocity principal	Darcy equation
2.0	117.47	0.25	0.26
2.5	81.67	0.37	0.37
3.0	42.94	0.68	0.69
3.5	35.08	0.83	0.84
4.0	26.51	1.10	1.12
4.5	23.49	1.24	1.26
5.0	20.95	1.39	1.42

TABLE 3

POROSITY OF PERVIOUS CONCRETE

a/c	Porosity (%)	
	Archimedes rule	ASTM
2.0	13.67	14.70
2.5	14.81	15.85
3.0	17.54	18.67
3.5	19.25	20.38
4.0	20.68	21.79
4.5	22.11	23.14
5.0	23.16	24.18

3.6 Relation between compressive strength and density of previous concrete

Figure 7 is the relation between compressive strength and density. In the test of pervious concrete, obtained the smallest compressive strength was 5.83 MPa that had density of 1748 kg/m3. Analysis in previous journal data that was compared to this research data that was obtained compressive concrete of 4.28 MPa with density of 1748 kg/m3 with density of 2054 kg/m3. The result of test on this research was according to previous journal trend by Ibrahim et al (2014). Based on Figure 7, it can be concluded that compressive strength and density in pervious concrete is directly proportional. The higher value of compressive strength, density in pervious concrete also became higher. It is because there was bond between stronger and thick aggregate and cement. The difference was

caused by the difference material and mixture proportion.

3.7 Relation between compressive strength and permeability of previous concrete

Figure 8 is the relation between compressive strength and permeability test of pervious concrete. In pervious concrete examination, it was obtained the smallest compressive strength of 5.83 MPa that had permeability of 1.42 cm/s and the biggest compressive strength was 15.66 MPa had permeability value of 0.25 cm/s. Analysis result in previous journal data which was compared to this research data of compressive strength was 5.29 MPa with permeability of 1.42 cm/s and 20.75 MPa with permeability of 0.26 cm/s. This research test result was according to previous journal trend. The difference which was done by Maguesvari and Narasimha (2014) was caused by different material and mixture proportion. The relation between compressive strength and permeability can be concluded that the higher compressive strength, the lower permeability value from pervious concrete. It was because of pervious concrete that had compressive strength that the thickness of the paste was thicker and a lot, so that formed porous in concrete were fewer and made pervious concrete was hard to pass by the water.

3.8 Relation between compressive strength and porosity of previous concrete

Figure 9 is the relation between compressive strength and porosity in pervious concrete. In test of pervious concrete, it was obtained the smallest compressive strength of 5.827 MPa that had porosity of 22.21% and the biggest compressive strength was 15.656 MPa that had porosity of 12.72%. Result comparison obtained in the research with previous journal by Joshagani (2014) and Alam and Naz (2015) is this research result following previous trend and the difference between this research result and result of previous journal was caused by different material and mixture proportion. Figure 9 can be concluded that the relation between compressive strength and porosity is inversely proportional. The higher compressive strength, the lower porosity value. It was caused by formed porosity in pervious concrete with the smaller compressive strength having fewer paste level, so that formed paste in pervious concrete because thinner that made many porosity in pervious concrete.

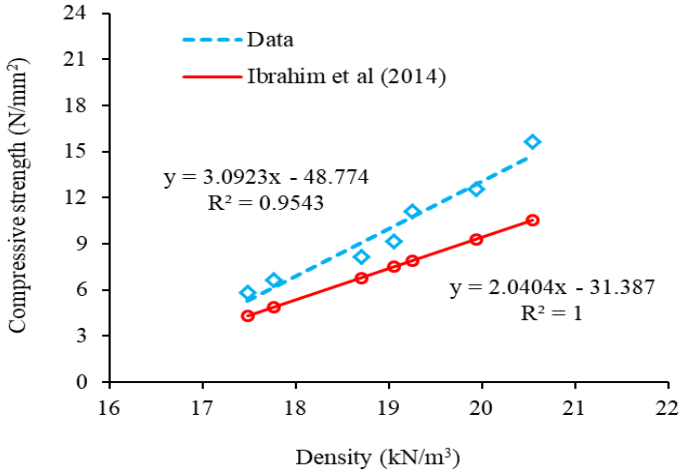

***Fig. 7**. Compressive strength vs density of pervious concrete*

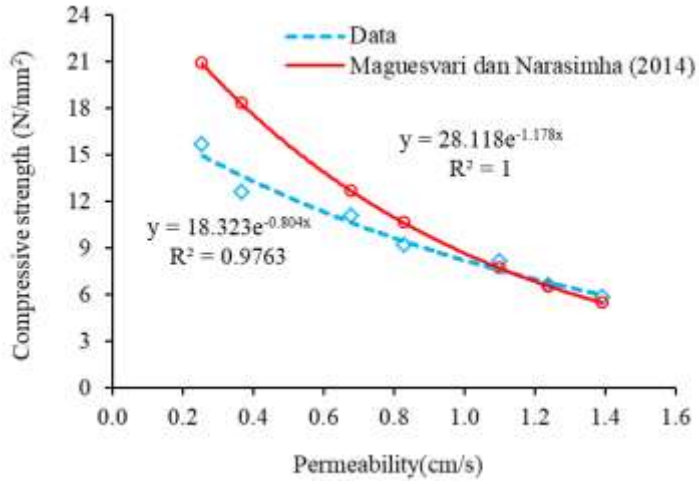

***Fig. 8**. Compressive strength vs permeability of pervious concrete*

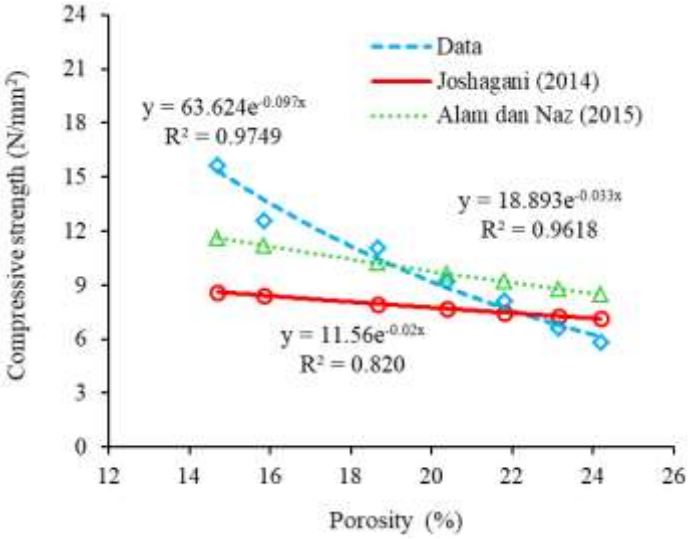

***Fig. 9**. Compressive strength vs porosity of pervious concrete*

3.9 Relation between compressive strength and porosity of previous concrete

Figure 10 is the relation between permeability and porosity in pervious concrete. In test of pervious concrete, it was obtained permeability value of 1.42 cm/s that had porosity of 22.21% and in permeability value of 0.26 had porosity value of 12.72%. The comparison of this research result and previous journal by Sriravindraraja (2012) and Chindaprasit (2014) was the result on this research had bigger permeability value than Chindaprasit's (2014) result, but it was smaller than Srivindraraja (2012). The difference occurred because of the difference of material and mixture proportion. Figure 10 can be concluded that relation between permeability value and porosity value in pervious concrete is directly proportional. The higher permeability value formed in pervious concrete, it had higher porosity value. It was because porosity formed in porosity test was also used for the path of water entry to permeability examination.

3.10 Relation between compressive strength and porosity of previous concrete

Figure 11 is a relation between density and permeability in

pervious concrete. In test of pervious concrete, it was obtained that density of 1748 kg/m3 had permeability value of 1.42 cm/s and in density of 2054 kg/m3 has permeability value of 0.26 cm/s. Figure 11 shows density that gets decrease if permeability value in pervious concrete was higher because permeability value in pervious concrete was influenced by density level and aggregate number containing in mixture, so the higher permeability, it would decrease density in pervious concrete. Comparison on this research test result with previous journal by Bonicelli et al (2014) was that previous journal was bigger than this research result and decreasing permeability in journal that was not significant like the result of this research. The difference between previous journal and the result of the this research occurred because of the difference of material and mixture proportion. Figure 11 can be concluded that the relation of density and permeability is inversely proportional. The higher density formed in pervious concrete, the permeability value was smaller because formed porous in pervious concrete was smaller.

3.11 Relation between compressive strength and porosity of previous concrete

Figure 12 is the relation between density and porosity in pervious concrete. In test of pervious concrete, it was obtained that density of 1748 kg/m3 had porosity value of 22.21% and density of 2054 kg/m3 had porosity of 12.72%. Density decreased if value from porosity in concrete increased more. It was because porosity value was influenced by density level and number of aggregate in the mixture, so it increased porosity value in concrete so the density decreased in pervious concrete. The comparison of this research result and previous journal by Rangelov (2001) and Wang K. et. al. (2006) was the result on this research was smaller than previous journal that was caused by different material and mixture proportion.

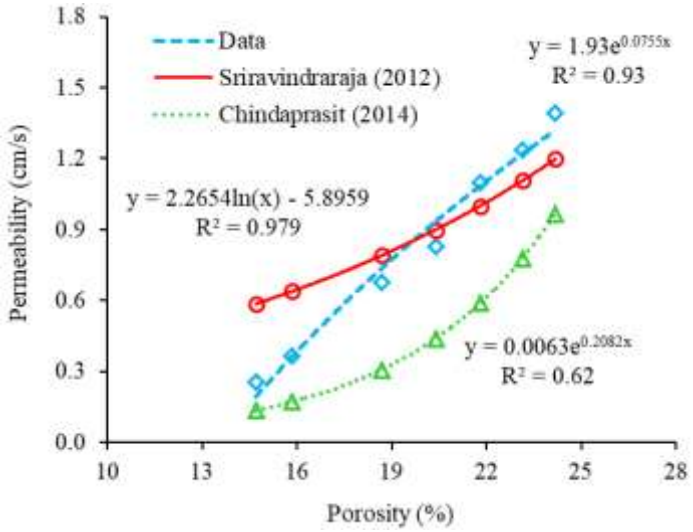

***Fig. 10**. Permeability vs porosity of pervious concrete*

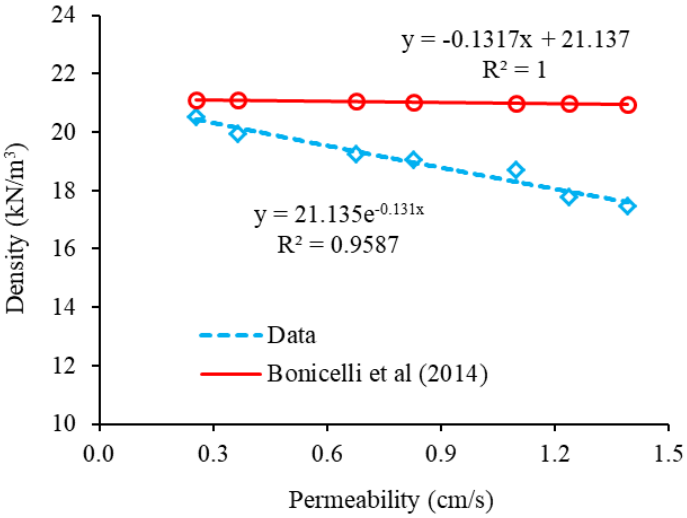

***Fig. 11**. Density vs permeability of pervious concrete*

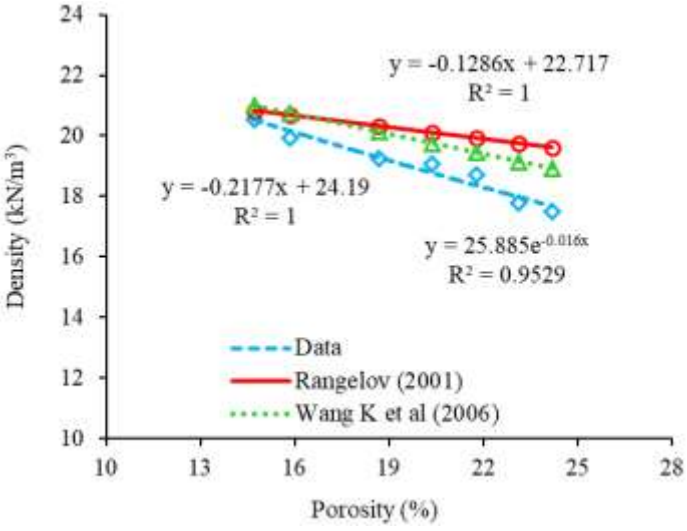

***Fig. 12**. Density vs porosity of pervious concrete*

4 CONCLUSION

The conclusion that can be taken as follow:

1. Influence of variation a/c toward compressive strength, permeability and porosity in mixture of pervious concrete as follow:
   a) Compressive strength value is decreasing as long as the enhancement of a/c value.
   b) Permeability value is increasing as long as decrease of a/c value.
   c) Porosity value is increasing as long as the enhancement of a/c value.
2. The relation of compressive strength, permeability and porosity in mixture of pervious concrete as follow:
   a) The relation of compressive strength and density of pervious concrete is directly proportional
   b) The relation of compressive strength toward permeability and porosity is inversely proportional.
   c) The relation of permeability and porosity is directly proportional.
   d) The relation of density toward permeability and porosity is inversely proportional.

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