Research studies on composition of porous concrete on the sidewalk

S W Megasari, G Yanti* and Z Zainuri
Universitas Lancang Kuning, Riau, Indonesia

*gusneli@unilak.ac.id

Abstract. In infrastructure development, technology is needed that is powerful, effective, efficient in implementation time, efficient, and environmentally friendly. Porous concrete has a cavity that can flow water directly into the ground so that it can overcome the problem of water absorption. Porous concrete can be utilized in the pavement with light traffic loads such as the sidewalk. However, because porous concrete only consists of a mixture of cement, water, and coarse aggregate, porous concrete has a low compressive strength. The research is needed on the composition of porous concrete to be used on the sidewalk. Research using the ACI-522R-10 method with a variation of the ratio of cement and coarse aggregate is 1: 3, 1: 4, 1: 5, 1: 6 and cement water factor 0.30. The test results obtained the highest average compressive strength value of 16.027 MPa with an increase of 45.30% compared with no additives, as well as being in the classification of concrete brick of C quality which is suitable for the sidewalk. The results showed that an increase in the average compressive strength value along with a reduction in the amount of coarse aggregate was obtained both under conditions and with the addition of additives.

1. Introduction
Infrastructure development in the city of Pekanbaru especially in constructor and road facility are commonly using rigid pavement and flexible pavement [1]. However flexible pavement or waterproof rigid pavement have their weaknesses such as preventing water absorption to the ground, it impacts on a surface runoff become wider so it makes flooding in the wet season, land subsidence, and lack of water reserves in the dry season [2,3].

To overcome the development of these demand conditions, the latest technology in infrastructure development is needed that can meet the needs of construction that are better in terms of strength, effective and efficient in time implementation, economical and has a low price yet still environmentally friendly [1].

Porous Concrete is one of the innovations to overcome the problem of water absorption, this is because porous concrete has cavities that can flow water directly into the ground. This is because it has cavities that can drain water directly into the ground. The use of pavement using porous concrete can be applied to pavements with light traffic loads such as parking lots, parks, and sidewalk [2], [4-7]. The use of porous concrete in managing water runoff in cities is used on sidewalk and sidewalk surfaces. The results showed that the addition of fine grains can improve runoff quality, increase compressive strength, but have lower permeability and porosity [3,8].
Porous concrete, which is a mixture of cement, coarse aggregate, little or no fine aggregate, added material and water [9]. To make porous concrete, several components that will affect the characteristics of the porous concrete itself [10]. One of the components that affect the form of solid bonds in porous concrete are: the composition of the ratio of the amount of cement and coarse aggregate, the use of coarse aggregate with several different sizes, cement water factor as well as variations and the number of additives used. Additives added for concrete mixture do not change many other ingredients, because the purpose of adding additives is to add a compressive strength value without changing the composition of other ingredients [11,12].

However, because porous concrete can only be used in the pavement with light traffic loads and the number of components that will affect the quality of porous concrete, it is necessary to study the composition of porous concrete to be used on pedestrian paths by utilizing available materials in Kota Pekanbaru [13].

2. Research method
The method used in the manufacture of porous concrete is ACI-522R-10 and with the implementation of testing in the Laboratory. For coarse aggregates are using the mixtures 2-3 cm, 1-2 cm, 0.5-1 in a ratio of 20:40:40 [14], and coarse aggregates used in clean conditions without dust and water saturation. For the comparison of cement and coarse aggregate is using 1:3; 1:4; 1:5; 1:6 [15], with a cement water factor of 0.30 [16]. The percentage of the addition of SikaCim Concrete Additives was 0% and 0.7% to the weight of cement [17], after adding the additives the amount of water was reduced to 15%. Preparation of test specimens was carried out using cylindrical molds of 15 x 30 cm diameter. Details of test specimens can be seen in Table 1.

| The Ratio of Cement and Coarse Aggregate | Addition of Additive (%) | Amount of the Sample |
|----------------------------------------|--------------------------|----------------------|
|                                        | 0           | 0.7                  |                      |
| 1 : 6                                  | 3           | 3                    | 6                    |
| 1 : 5                                  | 3           | 3                    | 6                    |
| 1 : 4                                  | 3           | 3                    | 6                    |
| 1 : 3                                  | 3           | 3                    | 6                    |
| Total test specimens                   |             |                      | 24                   |

3. Results and discussion
In the stages of mixing the concrete, it done step by step, started by inserting coarse aggregate in cement, then add 50% of the total water and mix well for 30 second. Add the additive materials that have been mixed with the remaining amount of water and mix again for 30 seconds. After the test sample is molded, treatment is done by soaking for 28 days. The results of recapitulation of porous concrete compressing test, with the results of 0% additives can be seen in Table 2 and the results of recapitulation of porous compressing test results with the results of 0.7% additives can be seen in Table 3.
Table 2. Compressive strength of test specimen with 0% additive.

| The Ratio of Cement and Coarse Aggregate | Test Specimen | Samples Weight (kg) | Wide Press (cm²) | Load (kN) | Compressive Strength (MPa) |
|-----------------------------------------|---------------|---------------------|-----------------|-----------|---------------------------|
| 1 : 6                                    | 1             | 9.70                | 176.79          | 65        | 3.68                      |
|                                         | 2             | 9.65                | 176.79          | 85        | 4.81                      |
|                                         | 3             | 9.60                | 176.79          | 75        | 4.24                      |
|                                         | 1             | 9.90                | 176.79          | 130       | 7.35                      |
| 1 : 5                                    | 2             | 9.85                | 176.79          | 125       | 7.07                      |
|                                         | 3             | 9.90                | 176.79          | 125       | 7.07                      |
|                                         | 1             | 10.40               | 176.79          | 190       | 10.75                     |
| 1 : 4                                    | 2             | 10.35               | 176.79          | 190       | 10.75                     |
|                                         | 3             | 10.40               | 176.79          | 185       | 10.46                     |
|                                         | 1             | 10.85               | 176.79          | 200       | 11.31                     |
| 1 : 3                                    | 2             | 10.65               | 176.79          | 195       | 11.03                     |
|                                         | 3             | 10.70               | 176.79          | 190       | 10.75                     |

In the results of tests on the porous concrete sample without additives (0%), there are increases of the porous concrete compressive strength average value. Start with the composition of cement with coarse aggregate 1:6, 1:5, 1:4 and the highest is obtained by comparison 1:3 amount of 11.03 MPa.

Table 3. Compressive strength of test specimen with 0.7% additive.

| The Ratio of Cement and Coarse Aggregate | Test Specimen | Samples Weight (kg) | Wide Press (cm²) | Load (kN) | Compressive Strength (MPa) |
|-----------------------------------------|---------------|---------------------|-----------------|-----------|---------------------------|
| 1 : 6                                    | 1             | 9.85                | 176.79          | 95        | 5.37                      |
|                                         | 2             | 9.80                | 176.79          | 85        | 4.81                      |
|                                         | 3             | 9.90                | 176.79          | 100       | 5.66                      |
|                                         | 1             | 10.25               | 176.79          | 165       | 9.33                      |
| 1 : 5                                    | 2             | 10.30               | 176.79          | 140       | 7.92                      |
|                                         | 3             | 10.30               | 176.79          | 162       | 9.16                      |
|                                         | 1             | 10.70               | 176.79          | 235       | 13.29                     |
| 1 : 4                                    | 2             | 10.80               | 176.79          | 210       | 11.88                     |
|                                         | 3             | 10.75               | 176.79          | 200       | 11.31                     |
|                                         | 1             | 11.15               | 176.79          | 265       | 14.99                     |
| 1 : 3                                    | 2             | 11.10               | 176.79          | 275       | 15.56                     |
|                                         | 3             | 11.20               | 176.79          | 310       | 17.53                     |

In the results of tests on porous concrete samples with 0.7% additives obtained increases of the porous concrete compressive strength average value which is same as the test results without the addition of additives (0%). The average compressive strength value of porous concrete has increased along with the reduction in the ratio of the amount of coarse aggregate in the mixture. The compressive strength value of porous concrete increases start from the comparison of the composition of cement with coarse aggregate 1:6, 1:5, 1:4 and the highest is obtained by comparison 1:3 amount of 16.03 MPa. The total compressive strength value of porous concrete with additives of 0.7% higher than the average compressive strength value of porous concrete without additives.
From the results of the compressive strength test on the porous concrete specimens, it was found that the compressive strength value of the porous concrete will be increased along with the reduction in the ratio of the amount of coarse aggregate in the mixture [15]. If the amount of coarse aggregate composition is smaller in the mixture, the use of the amount of cement will be bigger [18]. High usage of cement will also result in high usage of water to maintain the cement water factor constant. High usage of cement also result in creating a lot of cement paste, this means that the cement paste could be used as an adhesive between coarse aggregate grains and create not only strong stickiness but also the high level of compressive strength.

This result is appropriate with previous research which research was about porous concrete using the coarse aggregate of local granite crushed stone of 10 mm-20 mm aggregate size. From research results, the highest level of compressive strength is shown in the proportion of cement and coarse aggregate 1:3 [15]. The coherence between the value of compressive strength of porous concrete with a comparison of the composition of cement and coarse aggregate can be seen in Figure 1.

Figure 1. The coherence between compressive strength of porous concrete average with variations in coarse aggregate composition.

From Figure 1, show that it obtained a trend increase in the value of the compressive strength of porous concrete by reducing the amount of coarse aggregate both in the samples without the addition of additives (0%) or with the addition of 0.7% additives. The samples without adding additive (0%) obtained equation \( y = -0.635x^2 + 5.564x - 0.869 \) with the amount of \( R^2 = 0.9779 \). While the test samples with the addition 0.7% additive obtained equation \( y = 3.559x + 1.669 \) with the amount of \( R^2 = 0.9992 \). In the picture of the relationship of compressive strength of porous concrete with a comparison of the composition of cement and coarse aggregate proves that there is an influence of changes in the composition of cement with coarse aggregate on the compressive strength value of porous concrete both with and without added ingredients.

According to the requirements of ACI 522R-10 concerning compressive strength of porous concrete which ranges from 2.8 - 28 MPa [10]. Then all the results of the compressive strength of porous concrete complete the requirements by ACI 522R-10. While the standard requirements regarding the quality of porous concrete have not been found on Standar Nasional Indonesia (SNI), so the compressive strength value of porous concrete is based on SNI 03-0691-2001 about concrete bricks [19]. Classification of concrete bricks is divided into 4 (four) types, any concrete brick quality requirements based on the minimum compressive strength shown in Table 4.
Table 4. Quality requirements for concrete bricks [19].

| Grade | Compressive Strength (MPa) | Use         |
|-------|---------------------------|-------------|
|       | Average | Minimum | |
| A     | 40      | 35       | Road       |
| B     | 20      | 17       | Parking    |
| C     | 15      | 12.5     | Sidewalk   |
| D     | 10      | 8.5      | Parks and other uses |

From the average compressive strength value of porous concrete obtained 4 (four) compositions that meet the quality requirements of D in SNI 03-0691-2001 which can be used in parks and other uses, namely at a ratio of 1:4 and 1:3 without additives, a ratio of 1:5 and 1:4 with the addition of 0.7% additive. While the highest compressive strength value of porous concrete is obtained at a ratio of 1:3 with the addition of 0.7% additive that is equal to 16.03 MPa. This value meets the requirements of SNI 03-0691-2001 quality C so that it can be utilized for sidewalk.

However, due to the large number of other components that can affect the characteristics of porous concrete, further research is needed by varying the composition of aggregate size, cement water factor, different added ingredients and the percentage of added material used, to obtain the characteristics of porous concrete which has more strength and durability well.

4. Conclusion

Variation in composition determines cement and coarse aggregate to determine the compressive strength value of porous concrete. The highest average compressive strength of porous concrete is obtained in the ratio of cement to aggregate variation of 1:3 and the addition of 0.7% additive with a value of 16.027 MPa that completed the requirements of SNI 03-0691-2001 for quality C so that it can be used for the sidewalk. All of the compressive strength values of porous concrete complied the requirements by ACI 522R-10 which ranges from 2.8 - 28 MPa. Obtained a trend to increase the compressive strength value of porous concrete will increase with the reduction in the amount of coarse aggregate. All of the compressive strength values of porous concrete with the addition of 0.7% additive are higher than without the addition of additives.

Acknowledgments

Acknowledgments to Lembaga Penelitian dan Pengabdian Kepada Masyarakat Universitas Lancang Kuning. And support in Program Studi Teknik Sipil Universitas Lancang Kuning.

References

[1] Shah D S, Pitroda J and Bhavsar J J 2013 Pervious concrete : new era for rural road pavement Int. J. Eng. Trends Technol. 4 8 3495-3499
[2] Makmur A, Kusumawati B E, Parsono T, Tedjasukmana N, Nainggolan R, Sukarno P O and Paganggi W R 2017 Experimental study on porous concrete regarding to its aggregates variations of compositions shapes and types for sidewalk application Int. Conf. Appl. Sci. Eng. Business Linguist Inf. Technol. p 13-15
[3] Teymouri E, Mousavi S F, Karami H, Farzin S and Kheirabad M H 2020 Reducing urban runoff pollution using porous concrete containing mineral adsorbents J. Environ. Treat Tech. 8 1 429-436
[4] Moretti L, Di Mascio P and Fusco C 2019 Porous concrete for pedestrian pavements Water (Switzerland) 11 10
[5] Tripathi D P M, Hussain S M A and Madhav P 2017 An experimental study on pervious concrete (mix-ratio strength and porous properties) Int. J. Eng. Res. Technol. V6 12 100-103
[6] Paulino R S, Bussolotto G and Sequinel L F 2020 Porous Concrete as an Alternative for Problems with Waterproofing in Footwear and Light Traffic Tracks ENTAC2020
[7] Chen X D, Wang H and Najm H 2017 Environmental assessment and economic analysis of porous pavement at sidewalk *Proc. Pavement Life-cycle Assess Symp.* 2017 p 211-220

[8] Al Maawali M S N, Reddy N S and Al Hatali E M A 2017 A study on mechanical properties of porous concrete for its use in low traffic volume roads and parking areas in muscat *Int. J. Civ. Eng.* 4 5 40-46

[9] Cheng A, Hsu H M, Chao S J and Lin K L 2011 Experimental study on properties of pervious concrete made with recycled aggregate *Int. J. Pavement Res. Technol.* 4 2 104-110

[10] ACI 552R-10 2010 *Report on Porous Concrete* American Concrete Institute Committee 522 (USA)

[11] Megasari S W and Winayati 2017 The influence of addition of plastiment-VZ to concrete characteristics in riau province *IOP Conf. Ser. Earth Environ. Sci.* 97 1 p 0-6

[12] Zainuri, Zargustin D, Yanti G and Megasari S W 2020 Analysis palm oil midrib fiber brick against compressive strength cost of production and CO$_2$ emissions *IOP Conf. Ser. Earth Environ. Sci.* 469 1 0-6

[13] Sarwono D, Djumari, Rochim and Setyawan A 2017 The application of porous concrete filled with soil and sands for low volume traffic road *Procedia Eng.* 171 1429-1434

[14] Musthofa A S 2015 *Pengaruh Variasi Ukuran Gradsai Agregat Kasar terhadap Kuntan Beton Berpori* (Tugas Akhir) Program Sarjana Universitas Jember

[15] Dwita E, Manalu DF dan Sabri F 2017 Analisis pengaruh penggunaan batu pecah granit Pulau Bangka terhadap kuat tekan dan porositas beton berpori sebagai bahan penutup halaman *Jurnal Forum Profesional Teknik Sipil* 5 2 87-96 p-ISSN: 2338-2791 e-ISSN: 2621-1440

[16] Ginting A, Adi P dan Costa D O M 2017 Pengaruh penambahan pasir terhadap kuat tekan dan porositas beton porus *Jurnal Teknik* 4 2 81-163 ISSN: 2088-3676

[17] Jamal M, Widiastuti M dan Anugrah A T 2017 Pengaruh penggunaan SikaCim Concrete Additive terhadap kuat tekan beton dengan menggunakan agregat kasar bengalon dan agregat halus pasir Mahakam *Proceeding Seminar Nasional Teknologi IV* 1 1 p 28-36 p-ISSN: 2598-7410 e-ISSN: 2598-7429

[18] Lee J W, Il Jang Y, Park W S and Kim S W 2016 A study on mechanical properties of porous concrete using cementless binder *Int. J. Concr. Struct. Mater.* 10 4 527-537

[19] SNI 03-0691-2001 2001 *Bata Beton (Paving Block)* Badan Standarisasi Nasional Jakarta