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17–19 May 2018, Zadar, Croatia

Road and Rail Infrastructure V

Stjepan Lakušić – EDITOR

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TESTING OF PERVIOUS CONCRETE WITH NON-DESTRUCTIVE METHODS

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Abstract

The paper presents the results of pervious concrete testing, made from natural and recycled aggregates, fractions 4/8 and 8/16mm, with a constant water-cement factor (0.35) and without the participation of mineral and chemical additives. In total, four pervious concrete mixtures were made in which the type of applied aggregate was varied. Compressive strength after 7 and 28 days was tested, and prior to pressure testing, tests were carried out using non-destructive methods, i.e. a sclerometer and ultrasound, and then a comparison of the results was performed. After analyzing the results of comparative studies, it was concluded that non-destructive methods can be applied to evaluate the mechanical properties of pervious concrete, regardless of the higher proportion of pores in these concretes.

Keywords: pervious concrete, non-destructive methods, recycled aggregate, natural aggregate

1 Introduction

Pervious concrete is considered as a concrete with high proportion of pores resulting in a complete absence or only the small presence of small particles of aggregates in its composition. According to Putman and Neptune [1], the porosity of this concrete ranges between 15% and 35%, as confirmed by other researchers [2-4]. A large amount of pores is the biggest shortage of pervious concrete or the cause of the reduction in compressive strength. The compressive strength of pervious concrete ranges from 20 to 30 MPa [5]. A large amount of pores provides such a concrete and some advantages over conventional concrete. The high porosity of this concrete contributes to good sound absorption [6]. Compared to conventional concrete, pervious concrete has a smaller modulus of elasticity and less pronounced shrinkage [7]. Due to its basic deficiency, reduced strength, pervious concrete tests are mostly focused on finding the optimal composition of pervious concrete in order to satisfy the criteria for achieving appropriate compressive strength. According to Yang and Jiang [5], the compressive strength can be improved by using fine particles of aggregates, silicate dust, as in conventional concrete, and by the addition of superplasticizers. Likewise, mentioned components positively influence the wear resistance and the cyclic freezing and defrosting of such a concrete. According to paper [8], fine particles of aggregates (sand) will adversely affect the tensile concrete strength, while the large particles of the aggregate will favorably influence its absorption capacity [9]. The first application of pervious concrete occurred in 1852 for the construction of houses in the United Kingdom and this concrete consisted of rough gravel and cement [10, 11]. After that, it appears in the construction of houses in Scotland in 1874 and other buildings until 1890. In the Netherlands, for the first time since World War I, a concrete was used as aggregate from crushed brick and cement as a binder [12].

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The testing of pervious concrete was based mainly on the basic physical-mechanical properties (compressive strength, flexural strength, frost effect, abrasion resistance, splitting tensile strength, water impermeability coefficient, porosity and modulus of elasticity), while non-destructive testing is poorly illustrated. In this study, the compressive strength test was performed after 7 and 28 days, as well as testing using non-destructive methods (sclerometer and ultrasound).

2 Non-destructive method

The ultrasound examination is carried out on the principle of the penetration velocity of longitudinal waves through pervious concrete cubes, since this is an important data used in non-destructive testing methods. For testing this method, it was used the standard SRPS EN 12504-4 [13]. The velocity of penetration of the waves through the samples depends on: stiffness, homogeneity and compactness. Measurement was performed using an ultrasonic Pundit apparatus with 82 kHz probes on the same samples at which compressive strength was determined. Testing of the samples was also performed by a bounce hammer, i.e. each sample was processed and then tested. The sclerometer measures the bounce index of the sclerometer needle, which depends on the concrete surface hardness. By analyzing the measured bounce index, it is possible to determine: uniformity of quality, homogeneity of concrete and especially compressive strength. The test was carried out using the standard SRPS EN 12504-2 [14]. All sclerometer tests were examined on cubes 15x15x15cm and 10 strokes for each sample, where the distance between the two striking points was 25mm and from the cube's edge was 30mm. The tenth stroke was randomly selected at some intermediate area of the test domain. The test domain on the test concrete cubes is shown in Figure 1. Testing with the Schmitt hammer method was carried out using the apparatus Matest Digital C386N.

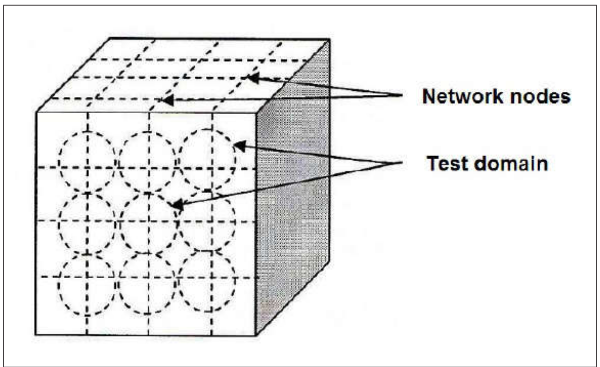

Figure 1 The test domain on the test concrete cubes

3 Production of concrete mix

Pervious concrete mixtures were made in a concrete mixer for concrete with a vertical axis, a volume of 50 liters, Figure 2. The mixing time of the concrete components was 3 minutes. For mixtures made of recycled aggregates, it is necessary to previously soaking aggregate with a certain amount of water, so that it stands for one day, prior to the preparation of pervious concrete mixtures. After that, the other component materials for the preparation of pervious concrete mixtures were added on the next day. Table 1 shows the marks and quantities of component materials for 1 m^3 of pervious concrete mixture with calculated values of the volume mass of the concrete. After concrete production, the consistency of all four concrete mixtures was tested. Consistency of fresh pervious concrete is determined by the slump test (Figure 3) in accordance with the standard SRPS EN 12350-2 [15]. It was found that the value of sagging is within the limits and that it belongs to consistency S1.

Table 1 Quantities of component materials for 1 m³ of pervious concrete mixture

Mark	m_c [kg/m³]	Water [kg/m³]		Aggregate [kg/m³]				Volume mass [kg/m³]
	CEM I 42.5R	m_v	$m_{v,dod}$	Recycled		Natural		
				4/8	8/16	4/8	8/16	
PB R4	400	140	75,27	1222	-	-	-	1837
PB R8	400	140	66,96	-	1222	-	-	1829
PB P4	400	140	-	-	-	1381		1921
PB P8	400	140	-	-	-	-	1381	1921

PB – pervious concrete, R – recycled aggregate, P – natural aggregate, 4 – II fraction (4/8mm), 8 – III fraction (8/16mm)

Figure 2 Preparation of a pervious concrete mixture

Figure 3 Measurement of consistency by the Slump test

After a certain consistency of concrete, embedding of pervious concrete mixtures into molds was carried out. Compacting was done using a rod as using of vibrating table leads to a large loss of pores, i.e. the cement paste is falling to the bottom of the mold. Samples were made of two layers, each layer was compound with 15 strokes per layer. After compacting, the samples were kept in molds for 24 hours, then taken out of the mold and treated in accordance with the appropriate care regimen. After extraction of the samples from the molds, all types of the mixture are marked with a specific color, as the cavities reduce the visibility of the written characteristics on the sample. The embedded samples in molds are shown in the Figure 4.

Figure 4 Concrete embedded in molds

4 Properties of hardened concrete

4.1 Compressive concrete strength

Compressive concrete strength is determined according to the standard SRPS EN 12390-3 [16] on samples of cube shape with edges 15 cm, at the age of 7 and 28 days as the mean value of the strengths obtained from three samples, for each type of concrete. The fracture force is determined by a hydraulic press with a capacity of 6000 kN, and the load application rate was 0.8±0.2 MPa/s. The compressive strength test is shown in Figure 5, and the strength values for the individual samples and the mean value are shown in Figure 6. It is noted from the figure that the compressive strengths vary from 6.88 to 20.94 MPa for samples at the age of 7 days, or from 11.19 to 28.68 MPa at the age of 28 days. The scattering of the results is considerable regardless of the age of the samples. During the test, there was a breakdown of samples through the cement matrix, and this was the case where a natural aggregate was used, while in the samples with the recycled aggregate a breakdown of samples reached through the cement matrix and grains of recycled aggregates wrapped with cement paste.

Figure 5 Determination of compressive strength

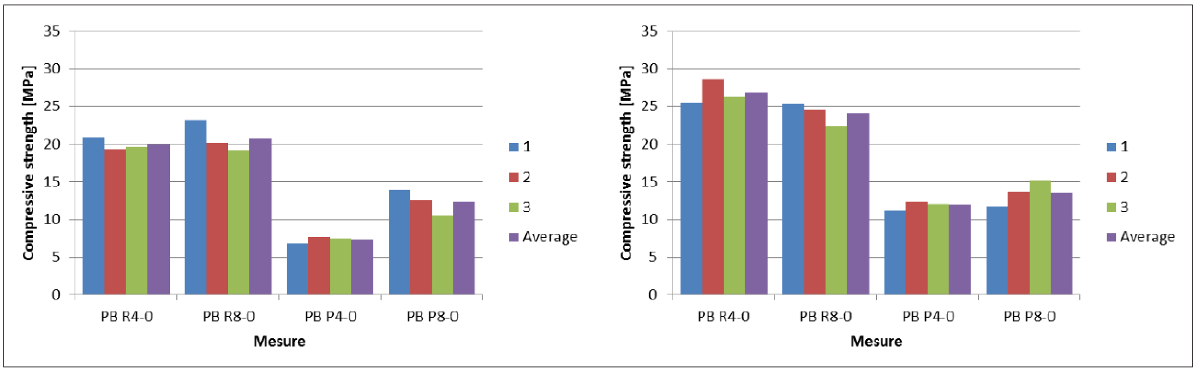

Figure 6 The compressive strength test after 7 days (left) and 28 days (right)

4.2 Determination of the pervious concrete strength by non-destructive method

4.2.1 The testing with sclerometer

The results of the sclerometer index were made in the form of a diagram, and the dependences between the mean value of the sclerometer and the tested compressive strength are shown in Figure 7. Beside the coefficient of correlation, the obtained equations for the given dependence are also shown.

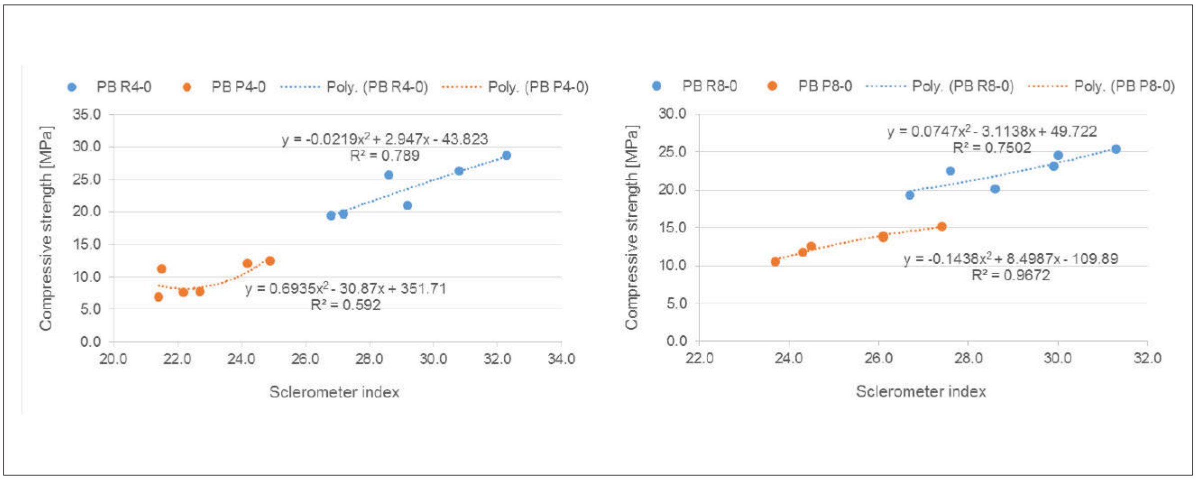

Figure 7 Dependence of compressive strength and the sclerometer index for pervious concrete mixtures: PB R4-0, PB P4-0, PB R8-0 and PB P8-0

Looking at Figure 7, it is noticed that the natural aggregate in both cases has a lower value of the sclerometer index, and a lower value of compressive strength. For mixtures that are made from the second fraction of the aggregate (Figure 7 on the left), the recycled aggregate gives better dependence on the natural aggregate, since the correlation coefficient for the recycled aggregate is 0.888, while for the natural aggregate it is 0.769, which is about 13 % less. The mixtures that are made from the third aggregate fraction (Figure 7 on the right) show completely reversed conclusions, that is, the value of the correlation coefficient for the natural aggregate is 0.983 and 0.866 for the recycled aggregate, which represents a 11.9 % lower correlation coefficient for the recycled aggregate relative to the natural one.

4.2.2 Ultrasound examination

After determining the velocity of penetration of the waves through the concrete cubes and determining the compressive strength, dependences were made, and correlations were established for all the tested samples. Correlations are all linear functions. Figure 8 shows the dependence on all concrete samples.

Figure 8 shows the testing results of the pervious concrete PB R4-0 and PB P4-0 (on the left), and PB R8-0 and PB P8-0 (on the right). It is noticeable that all tested concrete samples have a reliable correlation and have a reliable established linear function. The correlation coefficient values belong to a strong correlation group.

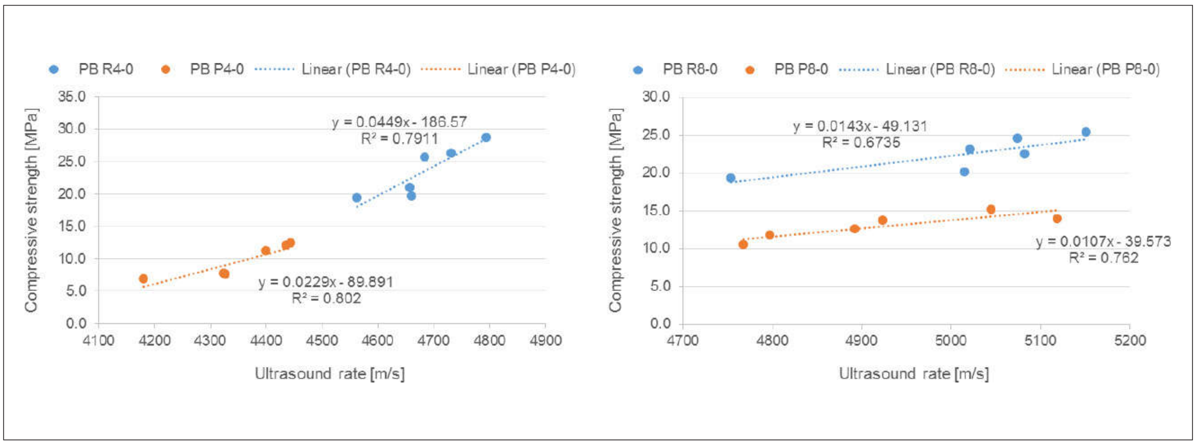

Figure 8 Dependence of compressive strength and ultrasound velocity for mixtures: PB R4-0, PB P4-0, PB R8-0 and PB P8-0

5 Conclusions

On the basis of this research, it has been concluded:
- Using of recycled aggregate for the production of pervious concrete mixtures, results in better compressive strength results compared to samples that are produced from a natural aggregate;
- Using of ultrasound method, shows a reliable correlation with the values of compressive strength, but it also shows a lot of time consumed, because the content of the pores can change the penetration velocity of waves;
- The sclerometer method shows quite unfavorable compressive strength relationships because the sclerometer index is variable due to the test site. If the aggregate grain is hit, or even the place where cement paste is prevailing, a good score of the sclerometer index is obtained, and it often happens that the test is performed at the place where the cavities are, so the results are quite unreliable.

Acknowledgements

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