Porous Concrete using White Cement as Binding Agent

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Abstract: Porous concrete is made by mixing Portland cement, coarse aggregate, with or without fine aggregate, additives, and water. Concrete that uses white or colored cement creates a highly contrasting visual and enhances traffic safety. A study was carried out on porous concrete using white cement as a binding agent. There are 6 types of gravel/cement ratio by mass used, namely 4, 4.5, 5, 5.5, 6, and 6.5. There are 2 types of water/cement ratios used, namely 0.27 and 0.30. SicaCim concrete additives are used as chemical admixtures. The total test specimens were 36 pieces, and 3 pieces for each variation. The results show that increasing gravel / white cement ratio decreases compressive strength and increases porosity. Compressive strength of wcr 0.27 is smaller than wcr 0.30. Porosity of porous concrete in general with a wcr of 0.27 is greater than a wcr of 0.30. The effect of water cement ratio (wcr) and aggregate / white cement ratio is not too significant on the unit weight of porous concrete.

1 INTRODUCTION

Building construction and pavement in urban areas causes increase the impermeable areas so that surface runoff cannot infiltrate into the ground and cause flooding. The existing drainage system only floods downstream so that the urban drainage system leads to search for new technologies aimed at increasing infiltration and reducing surface runoff.

Pervious concrete is concrete with a slump near zero, uniform gradation, which is made by mixing Portland cement, coarse aggregate, with or without fine aggregate, additives, and water. Pervious concrete has interconnected pores and water can pass through it easily. Pervious concrete has porosity between 15 to 35%, and compressive strength between 2.8 to 28 MPa. Drainage levels vary depending on aggregate size and density of the mixture. Pervious concrete serves to reduce surface runoff, improve surface runoff quality, refill groundwater, and reduce the effects of urban heat islands (ACI Committee 522, 2010).

Other names for pervious concrete are porous concrete. Porous concrete can be used for parking lots, driveways, sidewalks, and greenhouse floors (NRMCA, 2004).

No-fines concrete pavement has several positive aspects such as increased slip resistance and high permeability but do not have the high strength required for high traffic areas. No-fines concrete have been shown to have properties suitable for use in low volume traffic areas (Harber, 2005).

The strength of no-fines concrete is lower than normal concrete, but it is sufficient for structural use. Because of the high continuous void ratio, this concrete has a high permeability (Abadjieva and Sephiri, 1988).

Water cement ratio for pervious concrete between 0.27 to 0.30 including proper chemical admixtures. The relation between water-cement ratio and compressive strength is clearly seen in conventional concrete, whereas in pervious concrete is not clear because the total pore is more than the total paste (Tennis et al., 2004).

Generally in pervious concrete, the mass ratio between aggregate and cement is 4 to 4.5 (Tennis et al., 2004), The greater the maximum aggregate size in porous concrete, decreases the compressive strength and increases porosity (Ginting, 2019).

For floors and walkways, decorative concrete can be used completely or only for surfaces. Decorative concrete floors made with white cement can be specified as a substitute for top-grade coatings because they are durable and attractive. For transportation projects, concrete that uses white or colored cement creates a highly contrasting visual and enhances traffic safety (PCA, 2014).

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White Portland cement is white hydraulic cement and is produced by grinding white Portland cement slag which is mainly calcium silicate and milled together with additives in the form of one or more crystalline forms of calcium sulfate compounds (BSN, 2004). White cement can be used to make concrete because the compressive strength of concrete produced is high enough (Temiz et al., 2013). Fresh concrete slump using white cement is greater than Portland cement type I. Initial setting time and final setting time using white cement is smaller than Portland cement type I . Compressive strength using white cement is greater than Portland cement type I at ages 1 and 28 days (Hamad, 1995).

Based on the description above, a study was carried out on porous concrete using white cement as a binding agent.

2 METHODOLOGY

The main material is white cement and gravel from the river Progo, Yogyakarta, Indonesia. Gravel has a maximum size of 40 mm. There are 6 types of weight ratio of gravel/white cement, namely 4, 4.5, 5, 5.5, 6, and 6.5. Water cement ratios (wcr) of 0.27 and 0.30 were used. The dosage of SicaCim Concrete Additives as admixtures is 7.5 ml per kilogram of white cement. The total cylinder specimens are 36 and 3 cylinders for each variation as shown in Table 1.

Some types of tests carried out include testing: gravel, compressive strength, porosity, and unit weight. The results of the gravel test are presented in Table 2 and Figure 1.

The equipment used is: concrete mixer, concrete compression machine, and falling head test apparatus.

Concrete cylinder mold diameter of 150 mm and height of 300 mm. Concrete mixture is placed in 3 layers, each layer is consolidated with tamping rod 25 times, after consolidation is complete the surface of the concrete is leveled, then the specimen mold is sealed with plastic. Specimens removed from the mold after 24 hours, then soaked in a soaking tub filled with water of 25 ° C (BSN, 1990).

Concrete compressive strength testing refers to (ASTM C 39, 2009). The testing procedure is as follows:

1. Compression tests are carried out after the test specimens have been removed from depository.
2. The moisture of the test specimen must remain stable until the test is carried out.
3. Placing the specimen.
4. Apply the load continuously and without shock.
5. The load is applied increasing until it reaches the maximum load and is stopped after the load has decreased and the crack pattern is clearly visible.
6. The compressive strength of concrete is obtained by dividing the maximum load by the average cross-sectional area.

Table 1: Concrete cylinder specimens.

Gravel/White Cement Ratio	wcr	Numb. Cylinder Specimen
4.0	0.27	3
	0.30	3
4.5	0.27	3
	0.30	3
5.0	0.27	3
	0.30	3
5.5	0.27	3
	0.30	3
6.0	0.27	3
	0.30	3
6.5	0.27	3
	0.30	3
		36

Table 2: Gravel test results.

Types of tests	Unit	Results
Water content	%	1.48
Density (SSD)	-	2.47
Absorption	%	3.38
Unit weight	gr/cm^3	1.71
Fineness modulus	-	7.25
Abrasion	%	43.70

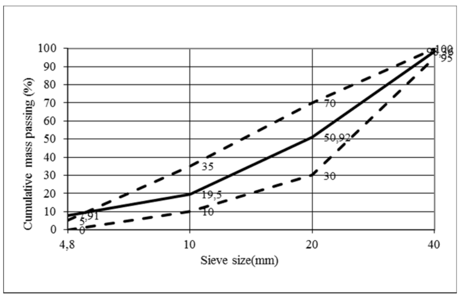

Figure 1: Gradation of gravel.

The porosity testing can be seen in Figure 2.

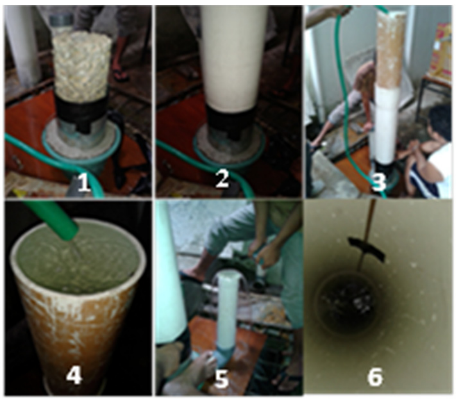

Figure 2: Porosity testing.

Testing porosity of concrete with falling head method steps as follows:

1. At the bottom of the porosity test apparatus is placed the concrete cylinder.
2. A pipe with a length of 1m is connected to the bottom of the porosity test apparatus, so that concrete cylinder is inside the pipe.
3. The drain pipe is closed, fill the water as high as a concrete cylinder.
4. Water is added to the pipe up to 1 m, then open the drain pipe.
5. Measured time for water to fall to 0.5 m.
6. The flow rate is obtained by dividing the volume of water that reduces with time.

3 RESULTS AND DISCUSSION

Compressive strength is shown in Table 3 and Figure 3.

Table 3: Compressive strength.

Ratio of gravel / white cement	wcr	Compressive Strength (MPa)
4.0	0.27	16.08
	0.30	17.30
4.5	0.27	8.36
	0.30	13.44
5.0	0.27	8.49
	0.30	13.68
5.5	0.27	3.30
	0.30	8.54
6.0	0.27	2.72
	0.30	8.05
6.5	0.27	2.22
	0.30	7.39

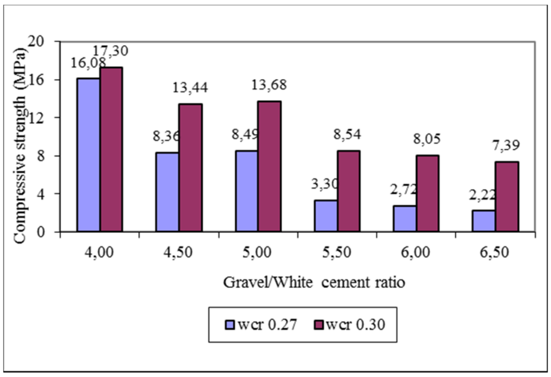

Figure 3: Compressive strength.

Table 3 and Figure 3 show that at the same water cement ratio (wcr), compressive strength decreases with increasing gravel/white cement ratio. This is because the amount of white cement decreases with increasing gravel/white cement ratio. The highest compressive strength will occur at the maximum amount of cement as long as the cement used has not reached the optimum limit.

In all white gravel/cement ratios, compressive strength of porous concrete with wcr 0.27 is smaller than wcr 0.30, theoretically the highest compressive strength will be obtained at the lowest wcr. At water cement ratio (wcr) 0.27 compressive strength is smaller than 0.30 due to the amount of water that is too few so that the hydration process does not work perfectly.

Porosity is shown in Table 4 and Figure 4.

Table 4: Porosity.

Ratio of gravel / white cement	wcr	Flow rate (lt/sec/m^2)
4.0	0.27	25.25
	0.30	18.23
4.5	0.27	44.27
	0.30	18.03
5.0	0.27	43.55
	0.30	38.27
5.5	0.27	74.82
	0.30	44.26
6.0	0.27	71.57
	0.30	52.82
6.5	0.27	69.87
	0.30	78.01

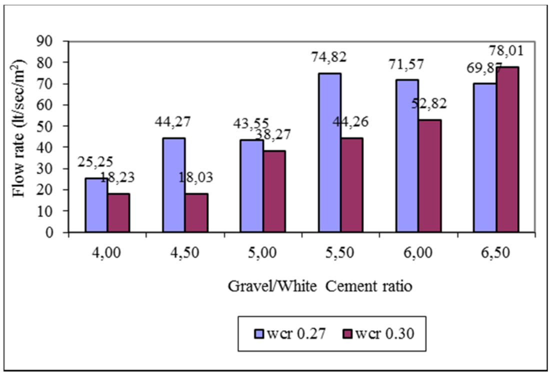

Figure 4: Porosity.

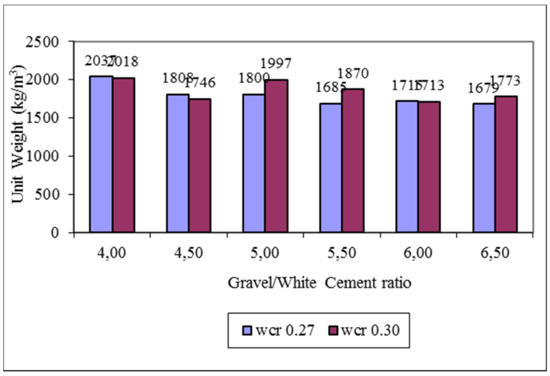

Figure 5: Unit weight.

Table 4 and Figure 4 show that at the same water cement ratio (wcr), in general an increase in the ratio of gravel/white cement results in an increase in porosity of porous concrete. This happens because the greater the ratio of gravel/white cement results in less amount of cement. A small amount of cement will produce a small amount of paste, so that the cavity covered by the paste is not too large so that the porosity is still high.

In all gravel/white cement ratios, porosity of porous concrete in general with a wcr of 0.27 is greater than a wcr of 0.30. This happens because porous concrete with wcr 0.27 is thicker than wcr 0.30. A mixture that is too liquid causes the cement paste to flow to the bottom resulting in sedimentation and a decrease in porosity.

Unit weight is shown in Table 5 and Figure 5.

Table 5: Unit weight.

Ratio of gravel / white cement	wcr	Unit weight (kg/m^3)
4.0	0.27	2037
	0.30	2018
4.5	0.27	1808
	0.30	1746
5.0	0.27	1800
	0.30	1997
5.5	0.27	1685
	0.30	1870
6.0	0.27	1715
	0.30	1713
6.5	0.27	1679
	0.30	1773

Table 5 and Figure 5 show that the unit weight varies between 1679 to 2037 kg/m^3. Porous concrete has a lower unit weight and some are higher than lightweight concrete in general, which is around 1800 kg / m^3. The effect of water cement ratio (wcr) and aggregate/white cement ratio is not too significant on the unit weight of porous concrete.

4 CONCLUSION

From the study porous concrete using white cement as binding agent be obtained that compressive strength decreases with increasing gravel / white cement ratio. At water cement ratio (wcr) 0.27 compressive strength is smaller than 0.30. Increase in the ratio of gravel / white cement results in an increase in porosity. In general, porosity with a wcr of 0.27 is greater than a wcr of 0.30. The effect of water cement ratio (wcr) and aggregate / white cement ratio to unit weight is not too significant.

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