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Compressive Strength and Water Absorption of Pervious Concrete that Using the Fragments of Ceramics and Roof Tiles

E. Prahara[1], Meilani[2]

[1] Bina Nusantara University, KH Syahdan 9, West Jakarta 11480, Indonesia
[2] Bina Nusantara University, KH Syahdan 9, West Jakarta 11480, Indonesia

Abstract. Pervious concrete was introduced in America in 2003, popularized by Dan Brown and used as a rigid pavement in the open parking lot. Rigid pavement using pervious concrete can absorb water in the surface to go straight through the concrete to the ground below.This water flow is one of the benefit of using the pervious concrete. Using of wastes such as broken roof and ceramics tiles are not commonly used in Indonesia. Utilization these kind of wastes is predicted lower the compressive strength of pervious concrete as they are used as a substitute for coarse aggregate.In this research, pervious concrete is made using a mixture of the fragment of ceramics and roof tiles.This research using broken ceramics and roof tiles with a grain size that loose from 38 mm sieve, retained on 19 mm sieve and the coarse aggregate from crushed stone that loose 12.5 mm sieve, retained on 9.5 mm sieve. The water cement ratio is 0.3 and to assist the mixing process, the addition of addictive in pervious concrete is used.The size of coarse aggregate used in the mixture affects the strength of pervious concrete. The larger the size of aggregate, the obtained compressive strength becomes smaller. It also affects the density of pervious concrete. The using of mixture of ceramics and roof tiles only reduce 2 MPa of pervious concrete compressive strength so this mixture can be used as a substitute for coarse aggregate with a maximum portion of 30 %. The high porosity of the specimens causes the reduction of pervious concrete density that affect the compressive strength. This high level of porosity can be seen from the high level of water absorption that exceed the required limit of water infiltration.

Keywords: pervious concrete, roof tile fragments, ceramics tile fragment, compressive strength

Introduction

Pervious concrete is an alternative that can help to enter a new era in the field of construction. This construction material has characteristic that can be penetrated by water, because of its concrete pores.It can be used as a means of soil water absorption so it can reduce surface runoff and add the groundwater reserves.The using of ceramics and roof tile fragments is one way to reuse wasted materials. But the use of substitute materials is still not popular in Indonesia. Maybe, this is because of the coarse and fine aggregate materials are easily obtained, but sooner or later these materials will be depleted so the price of these materials from year to year will be more expensive. The volume of coarse aggregate in concrete mixture reaches 78 % and coarse aggregate is the main filler in concrete mixture. Utilization the fragments of ceramics and roof tile as the substitution of coarse aggregate is expected to be one alternative in re-using the waste materials.

Research Significance

The objective of this research is to find out the compressive strength of pervious concrete that using the waste materials (such as the ceramics and roof tile fragments) as a coarse aggregate substitute and determine the ability of water absorption.

This research has an added value by using waste material such as ceramic and roof tile as a subtitute of coarse aggregate. Table below shown comparison to other research similar.

Table 1. Research Road Map

Variable	Portland Cement Association (PCA)	Hendry Febriyanto, 2006	This Research
Compressive Strength	3.5 – 27.5 MPa	22.5 MPa	10 MPa
Water – Cement Ratio	-	-	0.3
Additive	-	-	Sika 7060HE, 2% of cement weight
Coarse Aggregate	Normal	-	Using Tile and Ceramics
Fine Aggregate	Normal	-	Not applicable
Slump Value	-	-	Not applicable
Void Content	15-35%		15 - 20%
Water Seepage	1 – 7.5 liter per minute per mm2	1.6-2.6 liter per minute per mm2	4.8 liter per minute per mm2
Pervious Concrete Weight	1600 – 1900 kg/m3	-	1172-1198 kg/m3

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Implementation of Research

This research was conducted based on the scope as follows:
1. Using Portland cement type I.
2. This research using broken ceramics and roof tiles with a grain size that loose from 38 mm sieve, retained on 19 mm sieve and the coarse aggregate from crushed stone that loose 12.5 mm sieve, retained on 9.5 mm sieve.
3.Local clay tile is made from molded clay, heated with hot coals with a certain degree, so it has good durability. The tile was destroyed following the coarse aggregate size at the number 2, loose from 38 mm sieve, retained on 19 mm sieve (for size 2-3 cm tile size fraction), and loose from the 12.5 mm sieve,retained on 9.5 mm sieve (for size of tile fragments 9 - 12 mm).
4.Ceramic (porcelain tiles) is the tile with the strongest resistance compared to another kind of tile, created by burning at high temperatures. In addition, the ceramic has a strong durability, low power absorption and suitable for use in the open space. The ceramic was destroyed following the coarse aggregate size at the number 2, loose from 38 mm sieve, retained on 19 mm sieve (for size 2-3 cm tile size fraction), and loose from the 12.5 mm sieve, retained on 9.5 mm sieve (for size of tile fragments 9 - 12 mm).

The Variation of Specimens

The specimens made of pervious concrete cube molds shaped to the size of 15x15x15 cm, with two stages:

1. Two variations of preliminary specimens, made without ceramics and roof tiles.
2. Research speciments with six variations of roof tile fragments and six variations with ceramics tile fragments.

Time of water seepage will be tested to all specimens.

Table 2. Variations, sizes of Aggregate and percentage of mixture of ceramics and roof tiles fragments

Name	Aggregate Size (mm)	Roof Tile Mixture (%)	Ceramics Tiles Mixture (%)
Variation A	9,5 – 12,5	0	0
Variation B	19 – 31	0	0
Variation C	9,5 – 12,5	10	0
Variation D	9,5 – 12,5	20	0
Variation E	9,5 – 12,5	30	0
Variation F	19 – 31	10	0
Variation G	19 – 31	20	0
Variation H	19 – 31	30	0
Variation I	9,5 – 12,5	0	10
Variation J	9,5 – 12,5	0	20
Variation K	9,5 – 12,5	0	30
Variation L	19 – 31	0	10
Variation M	19 – 31	0	20
Variation N	19 – 31	0	30

Resource : Analysis result

Compressive strength to be achieved at 28 days was 125-150 kg/cm2. The quality target of pervious concrete is adapted with concrete brick quality type C for light construction application, such as pedestrians, parking lot, sidewalks and parks, as required by SNI 03-0691-1996. Chemical additive material used is Sika products Viscocrete 7060 HE grading 2% by weight of cement in any mix of pervious concrete. Coarse aggregate analysis testing procedure is according to the standard of SNI-03-1968-1990 about coarse aggregate sieve analysis. Specivic gravity and coarse aggregate testing procedure is according to SNI-03-1969-1990 about specific gravity and absorption of coarse aggregate.

Test Results

Pervious concrete has void content of 20% and water cement ratio of 0.38.
The spesification test results of coarse aggregate with 9-12 mm diameter are as follow: the density obtained is 1.184 kg/dm3 with specific gravity of 2.53 and the water absorption rate of 3.06%. The spesification test results of coarse aggregate with 19-31 mm diameter are as follow: the density obtained is 1.211 kg/dm3 with specific gravity of 2.53 and the water absorption rate of 3.06% While the density of roof tile fragment is 0.899 kg/dm3 and 0.996 kg/dm3 for ceramics tile fragment.The result of A and B variation can be seen in following table:

Table 3. The Specification for 9-12 mm coarse aggregate

STEP 1			
b/bo	0,99	bagian	(from ACI 522 graphic)
Vt	1	m^3	
Weight (Wa)	1172,16	kg/m^3	
STEP 2			
W-SSD	1,208,028,096	kg/m^3	
STEP 3			
Void content	20	%	
Pasta	25	%	(from ACI 522 graphic)
V pasta	0,21	m^3	
STEP 4			
cement	3,021,582,734	kg/m^3	
STEP 5			
water	1,148,201,439	kg/m^3	
STEP 6			
V agregat	0,477481461	m^3	
V cement	0,095923261	m^3	
V water	0,114820144	m^3	
V solid	0,688224866	m^3	
STEP 7			
void correct	3,117,751,339	%	
STEP 8			
porosity	178	mm/min	(from ACI 522 graphic)
STEP 9			
Density	1,625,006,513	kg/m^3	

Resource : Analysis Result

Table 4. The specification for 19-31 mm coarse aggregate

STEP 1			
b/bo	0,99	bagian	(dari grafik ACI 522)
Vt	1	m^3	
Weight (Wa)	1198,89	kg/m^3	
STEP 2			
W-SSD	1,235,576,034	kg/m^3	
STEP 3			
Void content	15	%	
Pasta	25	%	(dari grafik ACI 522)
V pasta	0,21	m^3	
STEP 4			
cement	3,021,582,734	kg/m^3	
STEP 5			
water	1,148,201,439	kg/m^3	
STEP 6			
V agregat	0,488369974	m^3	
V cement	0,095923261	m^3	
V water	0,114820144	m^3	
V solid	0,699113379	m^3	
STEP 7			
void correct	3,008,866,208	%	
STEP 8			
porosity	240	mm/min	(dari grafik ACI 522)
STEP 9			
Density	1,652,554,451	kg/m^3	

Resource : Analysis Result

From the analysis result, it's seen that the density of the proportion was still below the required 1780 - 1890 kg/m3 , automatically the compression strength result is also below the initial estimation.

Concrete Compressive Strength Test for A Variation and B Variation (Without Mixed Ceramics and roof Tile fragment)

Comparison of compressive strength test results between A and B variations can be seen in the following figure:

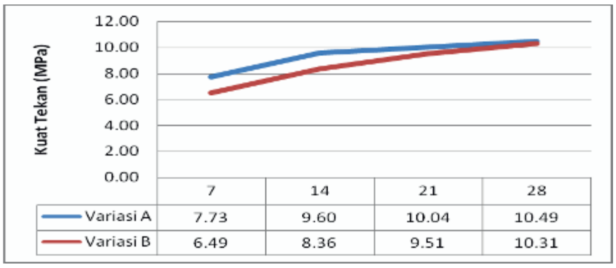

Fig. 1. Comparison compressive strength of A and B variations

The A variation with 9.5-12.5 mm sized aggregate has higher compressive strength compared to B variation, although the difference was not significant (approximately 1 Mpa).

Concrete Compressive Strength Testing With Roof Tile Fragment

Comparison of compressive strength beween variations with 9.5-12.5 mm coarse aggregate can be seen in the following figure:

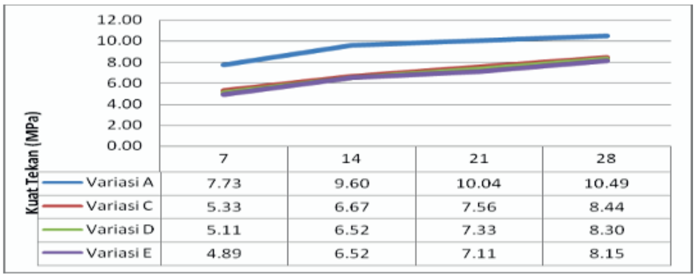

Fig. 2. Comparison compressive strength of each variation for 9.5-12.5 mm aggregate

There is a significant decrease (about 2 Mpa) for the concrete mixture with roof tile fragments. While the comparison of compressive strength between variations using roof tile fragments only has 0.1 Mpa difference.

Comparison of compressive strength beween variations with 19-31 mm coarse aggregate can be seen in the following figure:

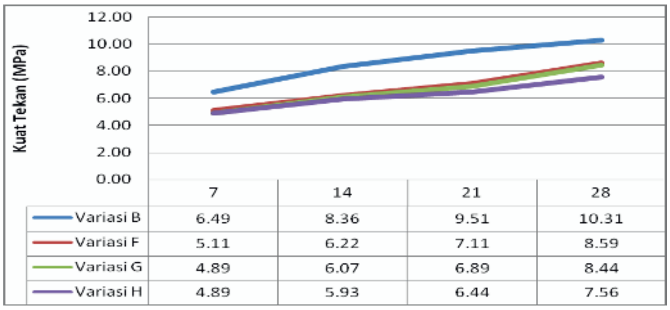

Fig. 3. Comparison compressive strength of each variation for 19-31 mm aggregate

There is a significant decrease (about 2 Mpa) for the concrete mixture with roof tile fragments.
While the comparison of compressive strength between variations using roof tile fragments only has 0.2 MPa difference.

Concrete Compressive Strength Testing With Ceramic Tile Fragment

Comparison of compressive strength beween variations with 9.5-12.5 mm coarse aggregate can be seen in the following figure:

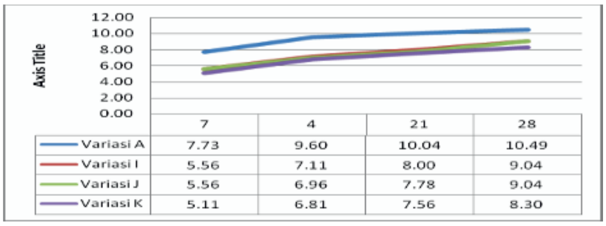

Fig. 4. Comparison compressive strength of each variation for 9.5-12.5 mm aggregate

There is a significant decrease (about 2 Mpa) for the concrete mixture with ceramic tile fragments. While the comparison of compressive strength between variations using ceramic tile fragments only has 0.2 MPa difference.

Comparison of compressive strength beween variations with 19-31 mm coarse aggregate can be seen in the following figure:

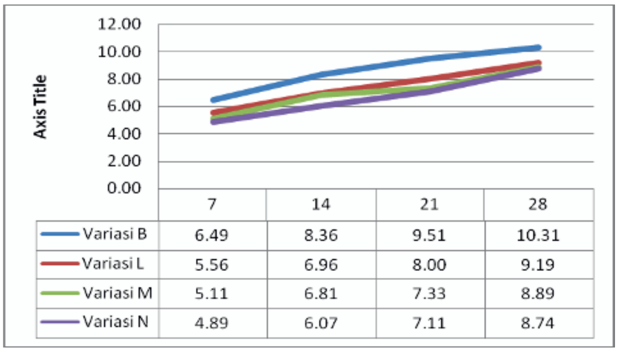

Fig. 5. Comparison compressive strength of each variation for 19-31 mm aggregate

There is a significant decrease (about 2 Mpa) for the concrete mixture with ceramic tile fragments.
While the comparison of compressive strength between variations using ceramic tile fragments only has 0.2 MPa difference. The test results of compressive strength all are below the planned strength (15 Mpa). Without the ceramics and roof tile framents mixture, the average result of compressive strength is about 10 Mpa (belong to pervious concrete D category), and the minimum compressive strength is 8.5 Mpa.

Water Infiltration Test

The test is done by pouring one liter of water and measure the time required by water to flow through the specimen (in seconds). All the specimens are tested with water infiltration test and the average from each variation is noted.
The water infiltration test is done as follow:

Fig. 6. Water infiltration test

The water infiltration test result for each variation and the average flow time can be seen as follow:

Table 5. The test results of water infiltration for each variation

No	Variation	Average Water Seepage (seconds)
1	A	12.49
2	B	12.35
3	C	12.88
4	D	12.79
5	E	12.63
6	F	12.32
7	G	12.74
8	H	12.61
9	I	12.93
10	J	12.84
11	K	13.01
12	L	12.62
13	M	12.68
14	N	12.39

From the result, it’s seen that there is no significant difference between each variation. The experimental results showed that the water absorption is obtained around 0.08 liters per second per mm2 or about 4.8 liters per minute per mm2. It means the resulted pervious concrete has large enough pore and this affects the concrete compressive strength.

Conclusions and suggestions

Based on the test results, the following conclusions are drawn:

1. The size of coarse aggregate used in the mixture affects the concrete compressive strength. The larger the size of the aggregate, the compressive strength obtained becomes smaller. It also afects the pervious concrete density.
2. The using of the mixture of ceramics and roof tile fragments only decreases the compressive strength around 2 MPa, so the using of the mixture of ceramics and roof tile fragments can be done for maximum 30 %
3. The specimens' high porosity decreases the concrete density, affecting the compressive strength.The high level of porosity can be seen from the high water absorption that exceeds the required limit of water infiltration.

Suggestions

1. To reach the required compressive strength, the pervious concrete density should be maintained at about 1780 to 1890 kg/m3 or about 22% lower than normal concrete. This density can be achieved by using the aggregate size of about 9.5 to 12.5 mm.

2. Considering that water absorption of specimen is high, automatically the level of porosity is high and the density of the specimen is low. The required water absorption is 100-750 liter per m3 per m2. By increasing the concrete density, it's expected that the concrete compressive strength becomes higher.

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