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Effect of Mixing Sequence on Green Concrete Using Artifical Coarse Aggregate

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Abstract

The mixing method for green concrete with a mixture of Ground Granulated Blast Furnace Slag (GGBFS), Fly Ash and artificial coarse aggregate is an important thing that needs special attention to achieve a uniform mixture of materials. Testing the effect of the mixing sequence was carried out to obtain the optimum mixing sequence for the green concrete mixture. The experiment was carried out using 4 different methods, namely a combination of 25% fly ash, 25% GGBFS and 25% artificial coarse aggregate with different mixing sequences for cement material, coarse aggregate, fine aggregate, artificial aggregate as well as water and admixture dosages. Test results based on workability parameters, slump loss, compressive strength, split tensile strength, concrete shrinkage and heat of hydration show that mixing method 4 has 5% higher compressive strength results than other methods, and produces optimum workability and slump loss. Concrete mixed with GGBFS, Fly Ash and artificial coarse aggregate can reduce the heat of hydration by 15%. Artificial coarse aggregate reduces compressive strength by 7%, but has better concrete shrinkage.

Keywords

Mixing sequence, workability, slump loss, and compressive strength test

INTRODUCTION

Concrete mixing is one of the things that needs to be considered after determining the green concrete forming material with a mixture of Ground Granulated Blast Furnace Slag (GGBFS), Fly Ash (FA) and Artificial Coarse Aggregate. The use of Fly Ash and GGBFS in concrete can change the character of concrete in terms of workability and compressive strength. concrete shrinkage, and durability [1]. Apart from FA and GGBFS, artificial aggregates made from Fly Ash materials are also used to replace natural aggregates. Artificial aggregate made from Fly Ash has quite a good strength even though the weight of the aggregate is lighter than that of natural aggregate. [2]. Optimizing the strength of aggregates made from green concrete can be done by innovatively adding bacteria that produce the enzyme urease. [3][4]. The method of mixing the green concrete materials used will determine the workability, compressive strength and visuals of the resulting concrete [5]. Concrete mixing for readymix in concrete factories and laboratories in Indonesia generally uses mixing methods following ASTM C 94 [6]. ASTM C94 provides guidelines on the proper sequence of mixing concrete materials during the initial mixing process. First, coarse and fine aggregates are added, followed by a portion of water and cement, and then another portion of water and any other liquid mixtures. It is important to note that the efficacy of chemical additives, such as Superplasticizers (SP), can vary significantly depending on the order in which they are mixed. Generally, liquid chemical additives are added together with water, while dry additives are added together with other dry ingredients. [5].

Saeed [7] explained that the sequence method for mixing concrete materials has a 10-20% effect on concrete quality performance. The mixing method, speed and duration used affect the fresh concrete and the strength of the resulting concrete. Hiremath and Yaragal [8] explained that an effective material mixing method is first mixing cement, then adding 80% water and superplasticizer, and adding sand and 20% water. While Hentges, et al [9] obtained the results of mixing natural aggregate with water in the first order resulting in better bonding. Chang and Peng [10] someone pointed out that SP mixing with 2 stages, produces initial slump and slump flow that meet the requirements. In 45 minutes there was no significant decrease in slump, but there was a reduction in slump flow. Determining the appropriate method for mixing concrete materials can differ depending on the characteristics of the material, including cement, coarse aggregate, fine aggregate and other additional materials.

RESEARCH SIGNIFICANCE

This research aims to analyze the effect of mixing sequence on green concrete using combination of GGBFS, FA and artificial coarse aggregate.

METHODOLOGY

In this research, several experiments were carried out regarding the sequence method for mixing concrete materials which are listed in table 1. The tool used for mixing concrete was a 120 liter pan mixer (laboratory scale) with an average rotation speed of 50-80 rpm. Method 1 MS-PCC uses a sequence method for mixing concrete materials based on ASTM C94 [6] as a control. The 1,2,3,4MS-PFA method uses a mixture of FA, GGBFS and natural coarse aggregate with different mixing orders. The optimum results from the 4 green concrete mixture methods of FA, GGBFS and natural coarse aggregate will be used for the mixing method for mixing green concrete with artificial coarse aggregate.

and artificial coarse aggregates. Based on the test results in table 4, it shows that the coarse aggregate meets the standard requirements of ASTM C33, ASTM C29 and SNI 03-2834[17] [18] as a coarse aggregate for making concrete. Testing of the artificial coarse aggregate showed that the specific gravity of the artificial coarse aggregate was 2.09 gr/cm3 lower than the specific gravity of the coarse aggregate and the absorption of the artificial coarse aggregate was quite high, namely 16.87%. This is because artificial coarse aggregate has many pores and does not have the properties of natural coarse aggregate. However, even though it has a lower specific gravity, artificial coarse aggregate can be used as an alternative to coarse aggregate by experimenting with the use of this aggregate in concrete [4].

Table 1 *Mixing Sequence*

Code	Mixing Sequence					
	1	2	3	4	5	6
MS-PCC	AN + Fi.A	1/3W	C	1/3 W + SP	1/3 W	
MS1-PFAS	AN + Fi.A	1/3W	C + GGBFS + FA	1/3W + SP	1/3 W	
MS2-PFAS	AN + C + GGBFS	1/3W	1/3W+1/2 SP	Fi.A + FA	1/3 W+1/2SP	
MS3-PFAS	AN + C	1/3W	1/3W+1/2 SP	Fi.A + FA + GGBFS	1/3 W+1/2SP	
MS4-PFAS	AN + C	1/3W	1/3W+1/2 SP	Fi.A + FA	1/2SP	GGBFS + 1/3 W

Information :
AN : Coarse Aggregate
Fi.A : Fine Aggregate
FA : Fly Ash
GGBFS : Ground Granulated Blast Furnace Slag W : Water
SP : Superplasticizer

A. MATERIALS

The cement used is Portland Composite Cement (PCC) Type 2 according to SNI 7064:2014 specifications [11]. The Chemical analysis and physical properties of the material are listed in table 2. The superplasticizer used is Type F high early strength according to ASTM C494 [12]. The fine aggregate used has a fineness modulus or Fine Modulus of 2.31, included in zone 2 of the SNI-03-2843-1993 standard and a specific gravity of sand of 2.74 gr/cm3 according to ASTM C128-01 standard [13].The fine aggregate used has a fineness modulus or Fine Modulus of 2.31, included in zone 2 of the SNI-03-2843-1993 standard [14] and a specific gravity of sand of 2.74 gr/cm3 according to ASTM C128-01 standard [15]. The material properties test results are listed in the table. The fly ash used in this study is the concrete quality planned, namely concrete quality Fc 35 Mpa, the FA used comes from PLTU Paiton 5-6, GGBFS from Krakatau Steel Indonesia. Artificial coarse aggregate was made based on research by Junaidi, et al. The Fc 35 MPa concrete design mix follows the DOE method with the composition listed in Table 1.

A summary of the binder test results is listed in table 2. The FA used in this study included in class C based on ASTM C618-19 [16]. The results show that the specific gravity of FA and GGBFS is lower than that of PCC cement. SNI and ASTM do not explain the maximum and minimum requirements for the specific gravity of the binder material to be used in the concrete mixture.

The fine aggregate tests carried out include those listed in table 3. Based on the test results, the fine aggregate complies with ASTM C33 standards for specific gravity, fine modulus, sludge content and absorption. The gradation arrangement of fine aggregate falls into zone 2 according to SNI 03-2834. Table 4 shows the test results for natural

Table 2 Result of Binder Test

Compound (%)	**PCC**	**FA**	**GGBFS**
SiO_2	19.19	39.97	37.82
Al_2O_3	5.42	13.41	13.86
Fe_2O_3	3.11	14.35	0.53
CaO	63.08	18.13	42.61
MgO	1.77	7.91	1.91
Na_2O	0.22	2.22	0.36
K_2O	0.57	1.15	0.46
TiO_2	-	0.66	0.59
MnO_2	-	1.17	0.29
Cr_2O_3	-	0.01	0.01
P_2O_5	-	0.19	0.02
SO_3	1.54	1.43	2.15
C_3S	59.23	-	-
C_3A	9.13	-	-
C_4AF	9.44	-	-
C_2S	10.43	-	-
LOI	5.94	-	0.16
Specivic Gravity (gr/cm^3)	3.09	2.83	2.93
Pass 45 µm (%)	98.2	91.3	97.24
Retained 45 µm (%)	1.8	8.8	2.76

Table 3 Result of Fine Aggregate Testing

Testing	Result	Specification	Standart
Specific Gravity (gr/cm^3)	2.74	>2.5	ASTM C33
Gradation Arrangement	Zone 2	-	SNI 03-2834
Fine Modulus	2.31	2.1 - 3.8	ASTM C33
Mud Content (%)	2.06	<5	ASTM C33
Absorption (%)	1.37	<2.3	ASTM C33
Weight Volume (gr/cm^3)	1.42	-	ASTM C29

B. LABORATORIUM TEST

In this study, laboratory tests were carried out including slump loss testing, compressive strength testing, flexural strength testing, hydration heat testing and concrete shrinkage testing. Slump loss testing to determine the consistency and workability of fresh concrete produced is based on SNI 03-1972-2008. The slump loss test in this study was carried out at three 15 minutes intervals for a total of 45 minutes. Concrete compressive strength testing was based on ASTM C-39. Flexural strength testing based on ASTM C78-02. The hydration heat test aims to determine the heat temperature resulting from the exothermic reaction of cement or cementitious material in concrete. The hydration heat test is carried out by dipping a thermocouple device into fresh concrete to record the initial temperature of the concrete being poured until the concrete hardens or final setting. Autogenous shrinkage testing was carried out to determine the effect of mixing sequence on the shrinkage of green concrete mixed with FA, GGBFS and artificial coarse aggregate.

RESULTS

The slump loss test on MS-PCC normal concrete, and 4 methods of green concrete with natural coarse aggregate had a stable decrease in slump loss and at 45 minutes there was no significant decrease. Initial slump value green concrete mixed with Fly Ash and GGBFS is higher than normal concrete (MS1-PCC). Visual observation in Figure 1, it can be seen that the use of FA and GGBFS has a good influence on workability, slump loss and homogeneous level of concrete. [1].

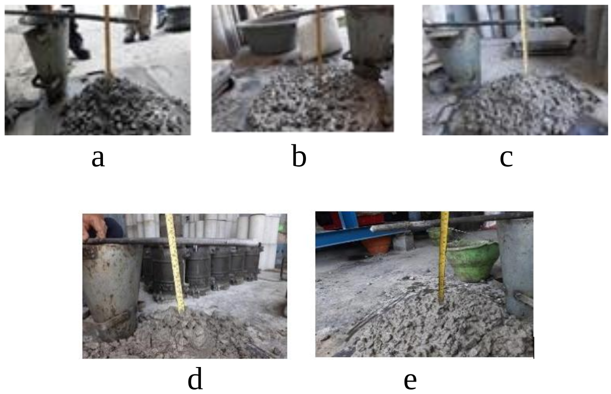


Figure 1 The Visual of concrete in the initial slump test (a) normal concrete MS1, (b, c, d, e) green concrete mixed with FA, GGBFS and natural aggregate, and (f) green concrete mixed with FA, GGBFS and artificial coarse aggregate. MS-PCC MS1-PFAS MS2-PFAS MS3-PFAS MS4-PFAS

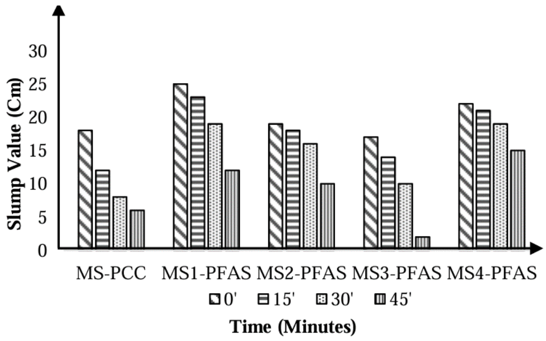


Figure 2 MS-PCC Slump Loss Test Results and 4 MS-PFA methods (concrete mixed with FA and GGBFS)

Table 4 Result of Coarse Aggregate Testing

Testing	Result			
	Nature Aggregate	Artificial Aggregate	Specification	Standart
Specific Gravity (gr/cm^3)	2.72	2.09	>2.5	ASTM C33
Gradation Arrangement	Fulfilled	Fulfilled	max. 20 mm	SNI 03-2834
Fine Modulus	6.73	6.58	6.0 - 7.1	ASTM C33
Mud Content (%)	1.13	0	<3	ASTM C33
Absorption (%)	1.08	16.87	<2	ASTM C33
Weight Volume (gr/cm^3)	1.4	0.97	-	ASTM C29
Los Angeles Abration	12.45	35	<50	ASTM C33

Table 5 Mix Design Composition

Composition	Code	Material						
		PCC (kg)	FA (kg)	GGBFS (kg)	Sand (kg)	AN (kg)	AA (kg)	SP (ltr)
PCC	MS1	358.75	0.00	0.00	969.28	1042.39	0.00	3.417
50 PCC: 25 FA:25 GGBFS (100%AN)	MS2,3,4,5	179.38	89.69	89.69	969.28	1042.39	0.00	3.417
50 PCC:25 FA:25 GGBFS (25%AA)	MS6	179.38	89.69	89.69	969.28	781.79	232.81	3.417

The graph of the decrease in slump value in the slump loss test is shown in Figure 2. The results of compressive strength testing aged 7, 14, 28 and 56 days can be seen in Figure 3. At 7 days it can be seen that the compressive strength of MS2- PFAS concrete has the same compressive strength value as normal concrete but higher than green concrete with other mixing methods, namely 38 Mpa. Meanwhile, at the ages of 28 days and 56 days, the compressive strength of MS4-PFAS concrete had the highest compressive strength. Based on the compressive strength results in Figure 3, and the slump loss test results in Figure 2, the most optimal mixing method for green concrete with a mixture of FA and GGBFS is drawn, namely the 4th MS4-PFAS method. The MS4-PFAS method is used to mix green concrete with a mixture of FA, GGBFS and 25% artificial coarse aggregate. The comparison concrete mixing method for FA and GGBFS green concrete with natural coarse aggregate and artificial coarse aggregate is listed in table 6.

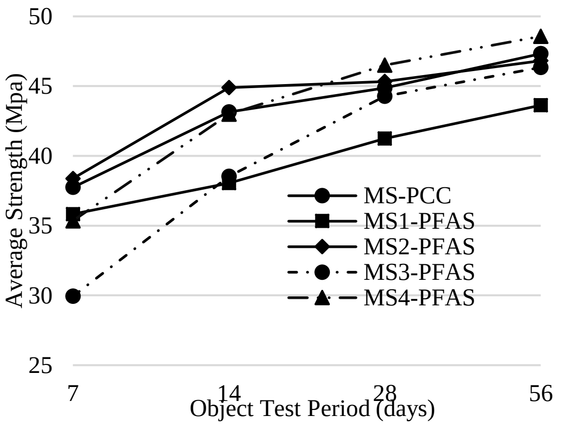


Figure 3 MS-PCC Compressive Strength Test Results and 4 MS PFA methods (concrete mixed with FA and GGBFS)

Table 6 Mixing Sequence for Normal Concrete, Mixed Green Concrete FA, GGBFS and Artificial Coarse Aggregate

Mixing Sequence	Code		
	MS-PCC (Control)	MS4-PFAS	MS-PFASA
1	AN + Fi.A	AN + C	AA + AN + C
2	1/3W	1/3W	1/3W
3	C	1/3W+1/2 SP	1/3W+1/2 SP
4	1/3 W + SP	Fi.A + FA	Fi.A + FA
5	1/3 W	1/2SP	1/2SP
6		GGBFS + 1/3 W	GGBFS + 1/3 W

Information:
MS-PFASA : Concrete mixing method with a mixture of FA, GGBFS, and 25% artificial coarse aggregate.
AA : Artificial Aggregate

Figure 4 shows that the initial slump value of green concrete with a mixture of 25% artificial coarse aggregate is the same as concrete without artificial coarse aggregate. However, concrete with artificial coarse aggregate had a significant decrease at 15 minutes, namely 18% of the initial slump. This could be because artificial coarse aggregate has higher absorption than natural coarse aggregate.

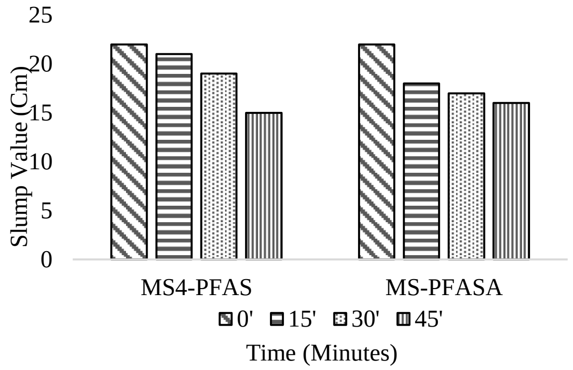


Figure 4 Graph of MS4-PFAS and MS-PFASA Slump loss Test Results

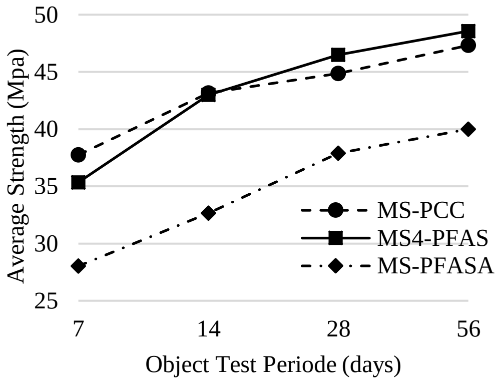


Figure 4 Comparison graph of compressive strength test results for MS4-PFAS and MS-PFASA concrete

strength of green concrete with natural aggregate and artificial coarse aggregate is shown in Figure 4, where green concrete mixed with artificial coarse aggregate obtained 17% lower compressive strength than concrete with natural coarse aggregate. The flexural compressive strength results for MS4-PFAS and MS-PFASA concrete are listed in Figure 4, where the flexural compressive strength results show that the flexural compressive strength coefficient of 0.04 for MS4 PFAS concrete is greater than MS-PFASA concrete, namely 0.01.

Figure 5 shows a comparison of the shrinkage test results for MS4-PFAS and MS-PFASA concrete. Based on these results, data was obtained that MS-PFASA had 21% greater shrinkage than MS4-PFAS and MS-PCC normal concrete.

Concrete shrinkage testing is very important to determine the effect of using fly ash and GGBFS, as well as artificial coarse aggregate in concrete so that initial mitigation can be carried out to reduce concrete shrinkage. One material that can be used as internal curing concrete to reduce concrete shrinkage is lightweight aggregate [19]. Based on the results of the heat of hydration test in Figure 7, it shows that the addition of FA, GGBS and artificial coarse aggregate can reduce the heat of hydration in concrete.

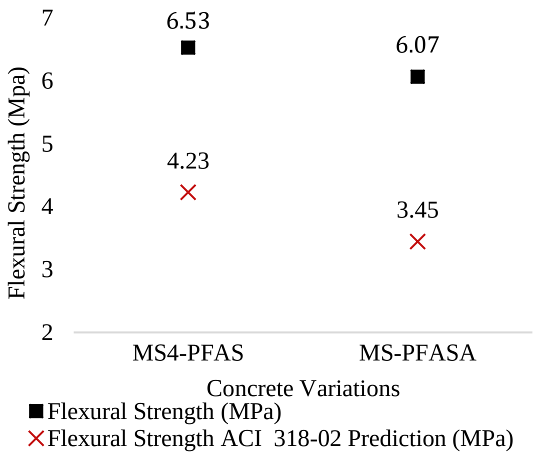


Figure 5 Comparison Chart of Flexural Compressive Strength Results for MS4-PFAS and MS-PFASA Concrete

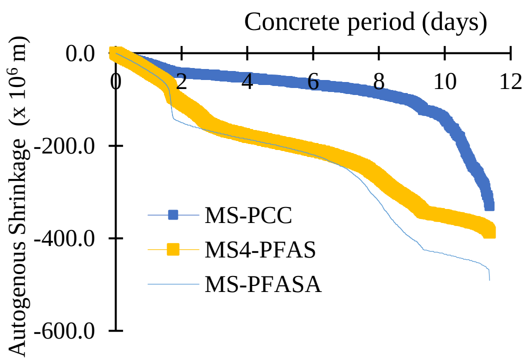
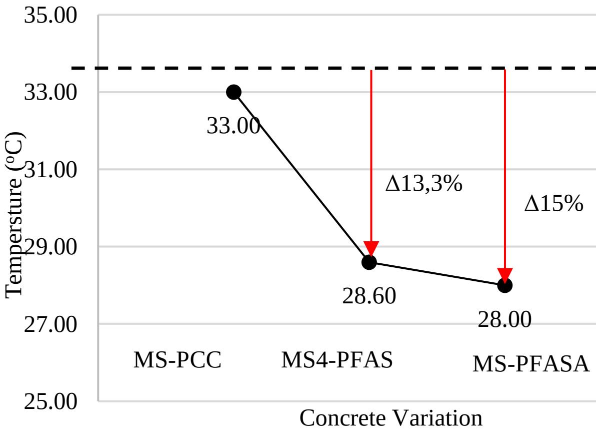


Figure 6 Result of Autogenous Shringkage Test



CONCLUSIONS

This paper has presented the result of experimental testing of mixing sequence on green concrete using FA, GGBFS and artificial coarse aggregate with variations in method of mixing. The result of the discussion carried out are the optimum method for mixing green concrete with a mixture of FA, GGBFS, and artificial coarse aggregate is pouring the coarse aggregate at the initial stage, dividing the admixture dose, and separating FA and GGBFS. So the conclusion that can be drawn from this study are as follows.

1. The usage of FA, GGBFS, artificial coarse aggregate as a concrete mixture can reduce compressive strength by 7% but can increase the workability of concrete.
2. Artificial coarse aggregate can increase concrete shrinkage, but internal curing can be used as a method to reduce this shrinkage.
3. Concrete mixed with GGBFS, Fly Ash and artificial coarse aggregate can reduce the heat of hydration by 15%.

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