

The Study of Flowability and The Compressive Strength of Grout/Mortar Proportions for Pre-placed Concrete Aggregate (PAC)

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Abstract. This experimental study is focused on the performance of appropriate grout/mortar for pre-placed aggregate concrete (PAC) incorporating superplasticizer in the mortar mixture regarding the flowability and strength of grout or mortar. Twenty-one samples of specimens were prepared. The parameter tests consist of water-cement ratios, cement sand ratios and variation dosages of superplasticizer. To examine the flowability/fluidity of grout or mortar, the flow cone test was applied. The flow cone test result indicated that there were three proportional grout that can meet the requirement for fluidity according to ASTM C-939. The compressive strength of specimens was tested. It was concluded that the composition of grout with containing the percentage of 0.7% by weight of cement of superplasticizer as chemical admixtures at a water-cement ratio of 0.6 and a cement-sand ratio of 0.5 is the proper composition of grout for pre-placed aggregate concrete (PAC).

1 Introduction

Nowadays, concrete is a construction material that is overgrowing along the development of the construction industry. Concrete construction will be relatively cheaper if compared to the steel construction. Indonesia as a developing country consumes concrete for 54.19 million tons per year and likely to increase in the coming years. Many researchers develop the various technic technology of concrete continuously for finding the excellent behavior of concrete properties regarding strength, cost and the way to construct the new technic. One of the most widely used concrete technology for particular construction is pre-placed aggregate concrete (PAC). Pre-placed aggregate concrete (PAC) is entirely different from regular concrete regarding the concreting process. Pre-placed aggregate concrete (PAC) can be defined as a method of concreting process which consists of the two-stage process which the first process is the placement of coarse aggregates in the formwork and the second stage is fill in the voids with grout of mortar and usually using chemical admixtures for workability [1]. This technology was first known in 1940 in the USA. This method has many advantages such as internal vibration is not needed, can flow and fill the voids by itself. In other words, Pre-placed Aggregate concrete can be called by two-stage concrete (TSC). Pre-placed Aggregate concrete (PAC) is mainly for unique construction such as

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underwater construction, construction area with closely spaced bars and mass concrete [2]. For conventional or regular concrete, the need for internal vibration cannot be avoided, and it became a big problem for special construction as previously explained. The Pre-placed aggregate concrete (PAC) can be a solver solution for this problem. In Pre-placed Aggregate Concrete (PAC), coarse aggregate is not mixed with other materials in the concrete mixer, and it can diminish the consumption of energy in concrete mixing [1]. Based on concrete composition, Pre-placed Aggregate Concrete (PAC) and Self Compacting Concrete (SCC) consist of similar composition with regular concrete. However, the superplasticizer and additives will be added in the term for flowability for Pre-placed Aggregate Concrete (PAC) and Self Compacting Concrete (SCC). Moreover, the basic difference between Pre-placed Aggregate Concrete (PAC) with Self Compacting Concrete (SCC) is the way to mix at the construction site. All materials such as cement, water, fine aggregate, coarse aggregate, and superplasticizer will be mixed together in the concrete mixer for self compacting concrete (SCC). On the other hand, there is the two-stage method for pre-placed aggregate concrete (PAC) that can be depicted in Fig. 1. The coarse aggregate will be laid first, and the other mixture (grout) will be poured to the formwork through the pipe.

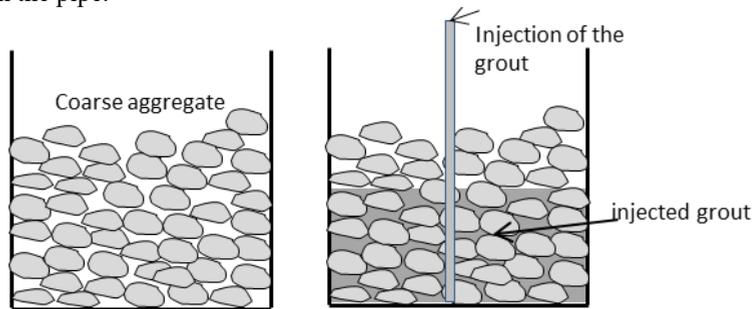


Fig 1. The Pre-placed aggregate concrete (PAC) mechanism : (a). Placement of coarse aggregate, (b) mortar/grout injection

According to [3], the mechanism of stress transmission of pre-placed aggregate (PAC) can be shown in Fig.2. According to [4], PAC can be assumed as a framework of coarse aggregate to support each other and after that mortar/grout filled to the internal voids.

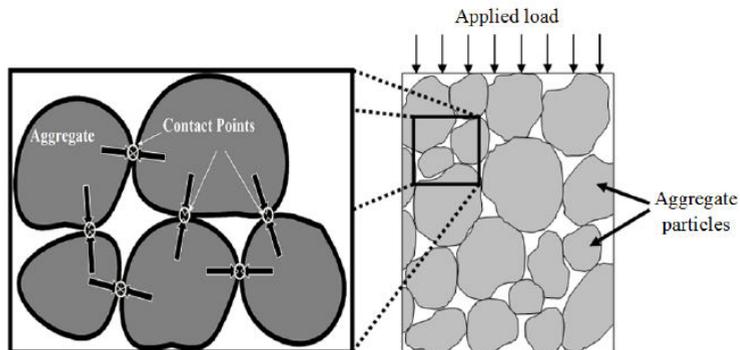


Fig 2. The mechanism of stress transmission [3]

The benefit of separate step in pre-placed aggregate concrete (PAC) can minimize the shrinkage of concrete. Moreover, it can lead the higher bond between all materials in the pre-placed aggregate concrete (PAC). The Pre-placed aggregate concrete (PAC) is

appropriate for structures that ordinary concrete is difficult for implementation such as underwater construction, excessively of reinforcement bars, repairing of dam and etc.

The primary key factor of the proper behavior of pre-placed aggregate concrete (PAC) the excellent quality of mortar/grout which applied to fill the internal voids around the coarse aggregate as the second phase of PCA. Mortars/grouts for pre-placed aggregate concrete (PAC) have to fulfill the requirements for strength, flowability and stability that recommended by guidelines ACI 304.1, 2005 [1] The proportioning mortar/grout mixtures for two-stage concrete (TSC) have to meet criteria the guideline of ASTM C-938-2010 [5] According to [6-7], the grout/mortar properties and the ability to flow for filling the voids around the coarse aggregate have an important role to achieve well behavior of the pre-placed aggregate concrete technic. Furthermore, to examine the level of fluidity mortars/grouts have to guided by ASTM C-939-2010[8] as the flow of grout for pre-placed aggregate concrete using flow cone method. The flow cone method is generally tested for measuring the flowability of mortar for pre-placed aggregate concrete (PAC). The flow cone test intends to determine the time of efflux of mortars/grouts by using standard testing for pre-placed aggregate concrete (PAC) which can be depicted in Fig.3. The time of efflux for mortar is ranged between 8s-35s. If the time of efflux exceeds 35s, the test of flowability of mortar is recommended by flow table according to ASTM C109/C109M [9].



Fig 3. Flow cone test

2 Methodology/Experiment

2.1 Material

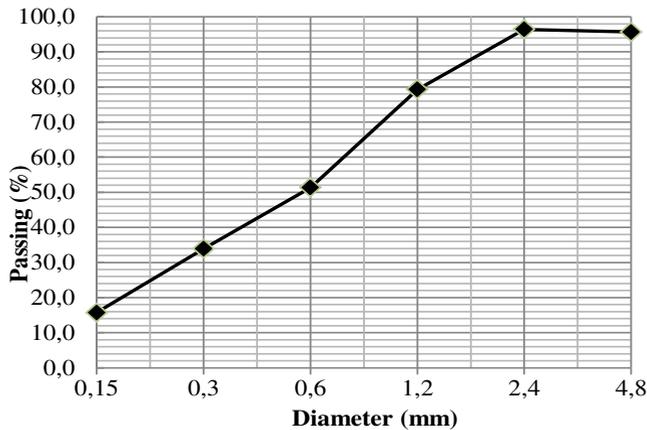
In the experimental test, all materials use to grout/mortar mixture were commonly obtained. The cement used is Portland Composite Cement (PCC) as a binding agent. PCC was produced based on the Indonesia standards SNI 15-7064-2014 [10] and ASTM C595-13 [11]. The properties of cement and fine aggregate is given in Table 1. Fine aggregate is obtained from Mount Merapi sand - Yogyakarta that free from impurities (< 4.75 mm) and categorized to Zone III according to ASTM. The particle size distribution of fine aggregate can be defined in Table 2 and Fig.1. The chemical admixtures use the superplasticizer, namely Viscocrete-1003. Viscocrete-1003 is concrete admixture which particularly used for high flow and self-compacting concrete. Table 3 shows the properties of superplasticizer.

Table 1. Properties of cement and fine aggregate

Properties	Cement	Fine Aggregate
Specific Gravity	3.15	2.74

Table 2. Sieve Analysis of Fine Aggregate

Passing through SNI sieve (mm)	Retained on SNI sieve (%)	Cumulative % retained	% Passing
4.8	4.33	4.3	95.67
2.4	3.58	7.91	92.09
1.2	17.12	25.03	74.97
0.6	27.95	52.98	47.02
0.3	17.44	70.42	29.58
0.15	18.20	88.62	11.38

**Fig 4.** Particle size distribution of Fine Aggregate**Table 3.** Properties of Superplasticizer (Sika - Viscocrete 1003)

Description	Property
Appearance/color	Liquid/brownish
Density (kg/L)	1.065 ± 0.01 kg/L (at 20°C)
Total Chloride Ion Content	< 0.1 % w/w
Chemical Base	Aqueous solution of modified polycarboxylate copolymers
Dosage For flowing and SCC	0.6-2.0 % by weight cement

2.2 Mix design and mixing process

A group of mortars was prepared. Seven mixtures of mortar with several parameters such as cement-sand ratio, a dosage of chemical admixtures and water-cement ratio were prepared. And tabulated in Table 4. There were two variation of cement : sand ratio such as 1:2 and 1:2.5. Furthermore, there was three type of water/cement ratio, specifically 0.4, 0.6 and 0.7.

The chemical admixture of superplasticizer namely discrete would be added of 0.7% and 1.4% by weight of cement in the mortar mixture. The proportion of mortars for a cubic meter were presented in Table 5. A total of 21 standard mortar cubes with dimension of 50mm x 50mm x 50mm were tested at 14 and 28 days.

Table 4. Seven mixtures of mortars/grouts in the research

No	Cement : sand ratio	Water /cement ratio	Chemical Admixture (% by weight of cement)
1	1:2	0.4	1.4
2	1:2	0.6	0.7
3	1:2	0.7	0.7
4	1:2.5	0.4	1.4
5	1:2.5	0.6	1.4
6	1:2.5	0.7	1.4
7	1:2.5	0.7	0.7

Table 5. Mix proportions of mortars/grouts for 1 cubic meter

Cement (kg)	Fine Aggregate (kg)	Water (ltr)	Viscocrete (% by weight of cement)
690.9	1381.8	276.4	9.67
607.0	1214.0	364.2	4.25
572.3	1114.6	400.6	4.01
613.5	1533.9	245.4	8.59
546.5	1366.2	327.9	7.65
518.2	1295.4	362.7	7.25
518.2	1295.4	362.7	3.63

3 Result and Discussion

The fluidity of fresh grout/mortar mixtures (cement, fine aggregate, and admixtures) was examined by flow cone test. Superplasticizer was used as the chemical admixture. The fluidity result is presented in Fig 5 and Table 6.

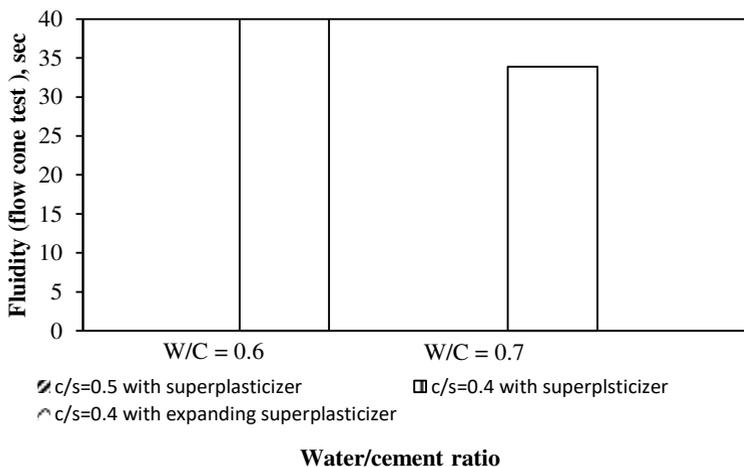


Fig 5. Flow cone test result

Table 6. Flow cone test result

No	Cement : sand (c/s) ratio	Water /cement (w/c) ratio	Viscocrete (%weight of cement)	Flow time (seconds)
1	1:2	0.4	1.4	-
2	1:2	0.6	0.7	24.0
3	1:2	0.7	0.7	35.0
4	1:2.5	0.4	1.4	-
5	1:2.5	0.6	1.4	Exceed 35.0 s
6	1:2.5	0.7	1.4	22.1
7	1:2.5	0.7	0.7	33.9

From Fig.5, it can be concluded that the increasing water-cement ratio without adding the percentage of superplasticizer in the grout/mortar mixture led to lower efflux time and exceeded 35s. Moreover, reducing the cement and sand ratio without the change in the composition of water cement ratio and percentage of superplasticizer demonstrated the constant result of flowability level. Lastly, the escalation of the percentage of superplasticizer in this grout composition indicated proper result for fluidity level.

The compressive strength of cubes specimens was determined at 14 and 28 days and can be tabulated in Table 7. Moreover, the compressive strength of grout specimens can be presented in Fig 6.

**Fig 6.** The compressive strength of grout specimens**Table 7.** The compressive strength of grout/mortar specimens

Cement/ sand (c/s) ratio	Water /cement (w/c) ratio	Viscocrete (%weight of cement)	Compressive strength of grout/mortar (MPa)	
			14 days	28 days
1:2	0.4	1.4	36.24	55.58
1:2	0.6	0.7	22.04	27.40
1:2	0.7	0.7	19.30	20.70
1:2.5	0.4	1.4	30.48	43.51
1:2.5	0.6	1.4	22.01	24.86
1:2.5	0.7	1.4	22.22	24.20
1:2.5	0.7	0.7	28.21	28.74

Based on the result, the composition cement-sand ratio of 1:2 with water cement ratio of 0.6 and 0.7% by weight of cement for viscoconcrete as superplasticizer was found to be the appropriate composition for normal compressive strength and can flow. It can be concluded that the quality of pre-placed aggregate concrete (PAC) is determined not only by the compressive strength but also the ability for flowing into the voids become primary key for the successful of pre-placed aggregate concrete technology.

4 Conclusion

Based on the experimental study about the grout/mortar composition for pre-placed aggregate concrete (PAC), it can be concluded that the appropriate composition for cement-sand ratio, water cement-ratio and additional of superplasticizer in the grout/mortar mixture have to be considered to meet criteria of flowability or fluidity for pre-placed aggregate concrete (PAC).

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