

The properties of preplaced
aggregate concrete technology
contain the industrial waste-
material and the various
shapes and sizes of coarse
aggregate

by Ahmad Saiful Haqqi

Submission date: 01-Feb-2023 02:42PM (UTC+0700)

Submission ID: 2003952109

File name: 9_OP_Conf._The_properties_of_preplaced_aggregate_concrete.pdf (1.18M)

Word count: 3139

Character count: 16092

PAPER · OPEN ACCESS

The properties of preplaced aggregate concrete technology contain the industrial waste-material and the various shapes and sizes of coarse aggregate

To cite this article: N Chairunnisa *et al* 2022 *IOP Conf. Ser.: Mater. Sci. Eng.* **1212** 012036

View the [article online](#) for updates and enhancements.

You may also like

- [Comparison of compressive strength and porosity of porous concrete using the coarse aggregates graded uniform with continuous gradient](#)
Arusmaleh Ginting
- [Study on Mechanical Properties of Concrete Using Plastic Waste as an Aggregate](#)
B Jaivignesh and A Sofi
- [Investigation on effects of aggregate roughness on bond strength of aggregate-bitumen systems](#)
V Mishra and D Singh

The properties of preplaced aggregate concrete technology contain the industrial waste-material and the various shapes and sizes of coarse aggregate

N Chairunnisa*, H Ruzhanah, Hairida and L.S Daniel

Engineering Faculty, Lambung Mangkurat University, Indonesia

*Corresponding author: nursiah.chairunnisa@ulm.ac.id

Abstract. The success of preplaced aggregate concrete technology depends on two main factors which are potential grout and coarse aggregate. This research was conducted experimentally to determine the effect of using two different fly ash sources as an alternative for the partial replacement of cement and several size and shapes of coarse aggregate on the compressive and tensile strength of PAC specimens. This involved the use of seven concrete mixes with a low water-cement ratio of 0.4 and cement to sand ratio of 1:0.75 to produce standard cylinder specimens of concrete containing rounded and crush aggregate. Moreover, fly ash was added at a dosage of 5% and 10% of cement weight while three shapes and sizes of a rounded and crushed aggregate at 20 mm, 30 mm, and a mixture of the two were also applied. The results showed the compressive strength of specimens with different sizes or a mix of rounded aggregate in PAC exhibited a similar performance with 30 mm of crushed coarse aggregate. Furthermore, the specimen with a higher content of calcium fly ash demonstrated a more rapid strength at an early age of seven days than those with lower content. Therefore, the partial replacement of cement with industrial waste material in the form of fly ash in preplaced aggregate concrete has the ability to save up to 10% of cement and also produce certain environmental benefits.

1. Introduction

Preplaced Aggregate Concrete is a simple concept of concrete technology consisting of two-stage casting. The first involves placing coarse aggregate into formworks while the second is injecting the potential grout into the void [1]. This method provides several benefits compared to the conventional concrete due to its flowability, absence of internal vibration, lower energy consumption, and cement weight [2-4]. However, one of the essential factors affecting PAC Technology is the quality of coarse aggregate and grout especially due to the influence of several factors such as the type of sand, cement-sand ratio composition, water-cement ratio, and cement for conventional grout [5,6].

The success of PAC depends on two main factors which are grout workability and coarse aggregate size void, especially due to the expectation of potential grouts to fulfill all coarse aggregate voids. According to [7], the recommended size of coarse aggregates in PAC was 38 mm. Previous research proposed using coarse aggregates of sizes smaller than 38 mm, with the aggregates being gap-graded and of multiple sizes [8]. Single-graded aggregates of different sizes were also applied in another study [9]. Meanwhile, the effects of using fly ash as a partial replacement of cement and sand in a 0.33 low water binder ratio grout and coarse aggregate gradation for PAC mixtures have been studied [10]. Fly ash, as a pozzolanic material, was also applied to improve the fresh properties of low water binder



grouts due to its abilities [2,11,12]. Its abundance as an industrial waste has led to its common use as concrete material.

This research was, therefore, conducted to determine the effect of size and shape of coarse aggregates, and fly ash as partial replacement of cement on the mechanical properties of PAC through the use of a series of laboratory experiments on grout workability, cylinder compressive strength, and splitting tensile strength.

2. Materials and Method

2.1. Coarse and fine aggregates

Coarse aggregate is one of the important factors in achieving a successful preplaced aggregate concrete. Therefore, the coarse aggregates used in this study were in two shapes including rounded and crushed with three different sizes which were 20 mm, 30 mm, and a mixture of the two sizes which were produced locally in South Kalimantan as shown in Figure 1. Meanwhile, the fine aggregates used include natural river sand with zone 3 gradation from Barito river, South Kalimantan Province.

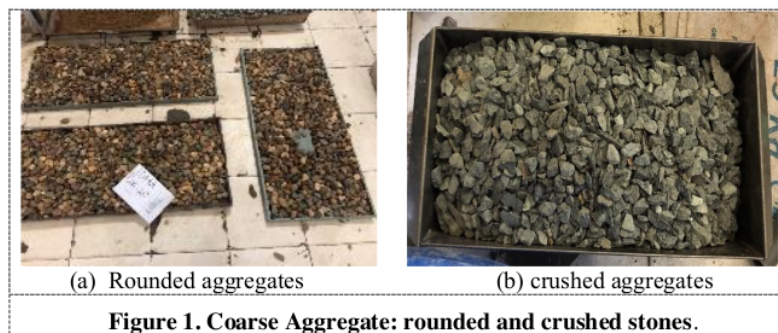


Figure 1. Coarse Aggregate: rounded and crushed stones.

2.2. Industrial waste- fly ash

Fly ash was locally sourced from two different locations in Kalimantan and added at 5% and 10% by weight of cement to determine their use as pozzolanic materials in a preplaced aggregate concrete. The FA-1 was obtained from PLTU Asam Asam while FA-2 was from Tamiyang Layang as indicated in Figure 2.



Figure 2. Locally-sourced Fly Ash

2.3. Chemical Admixture

Viscocrete 1003 type of superplasticizer imported by SIKA was used for all the mixes. This liquid chemical admixture was added at 0.7% by weight of cement [5].

3. Mix design and preparation of specimens

3.1. Mix design of specimens

A total of seven different mix proportions were designed to investigate the mechanical properties of preplaced aggregate concrete due to the effect of coarse aggregate size, shape, and fly ash. Moreover, 0.4 water-cement ratio, 1:0.75 sand cement ratio, and 0.7% weight cement of superplasticizer in accordance with previous experiments. The mix designs of PAC specimens are, therefore, summarized in Table 1.

Table 1. Mix design of PAC Specimens.

Type of mix	weight per cubic meter m ³						Superplasticizer	
	cement	sand	crush aggregate	rounded aggregate	FA-1	FA-2	water	% of cement weight
R-20	479.28	359.46	1455	-	-	-	191.71	0.7
R-30	455.31	359.46	1455	-	-	-	191.71	0.7
R20+30	409.78	359.46	1455	-	-	-	191.71	0.7
CFA-0%	455.31	359.46	1455	-	-	-	191.71	0.7
CFA1-5%	390.60	292.95	-	1641	23.96	-	156.24	0.7
CFA1-10%	390.60	292.95	-	1641	47.93	-	156.24	0.7
CFA2-5%	390.60	292.95	-	1641	-	23.96	156.24	0.7

3.2. Preparation of Specimen

The PAC specimens used were prepared using two stages with the first involved placing of coarse aggregates in 150 mm x 300 mm cylinder molds while the second was injecting the grout into the molds to fill the voids as shown in Figures 3 and 4.

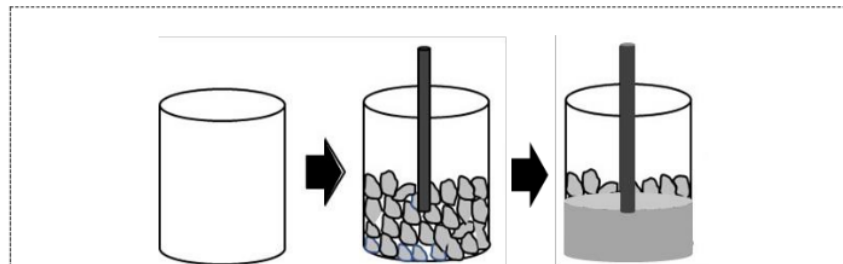


Figure 3. Preparation of PAC Specimens



Figure 4. PAC Specimens in the laboratory

4. Results and Discussion

4.1. Fresh properties of the grouts

The physical properties and chemical of different types of fly ash are presented in Table 2 and FA-1 was found to have a higher specific gravity compared to FA-2. It was also discovered to have more calcium oxide content which is classified between Class F and C according to the ASTM C618 [13]. Meanwhile, the instrument used to determine the flow time is shown in Figure 5.

Table 2. Physical and chemical properties of fly ash (Laboratory data)

Parameter	Unit weight (%)		Parameter	FA-2	
	FA-1	FA-2		unit	value
SiO ₂	39.08	29.94	K ₂ O	0.77	0.84
Al ₂ O ₃	11.96	15.44	MnO ₂	0.34	0.22
Fe ₂ O ₃	22.22	15.84	TiO ₂	0.65	0.81
CaO	14.33	23.68	P ₂ O ₅	0.16	0.51
MgO	7.26	9.93	SO ₃	1.89	1.14
Na ₂ O	0.80	1.11			



Figure 5. Flow cone test.

The fresh properties of Preplaced Aggregate Grout mixtures used in determining the grout consistency are indicated in Table 3 with the flow times observed to be within the range of 26.12 to 33.38 seconds. Meanwhile, ASTM C939 [14] requires an efflux time of 8 seconds for pure water and 8-35 seconds for grout of PAC of flow time to drain 1725 ml using a flow cone test. This means the time reduced due to the partial replacement of cement with fly ash in the mixtures and all the specimens were found to have fulfilled the criteria of flowability from the test.

Table 3. Fresh Properties of Grout

Type of Grout	Superplasticizer (%)	Flow time (second)	Grout compressive strength	Type of coarse aggregate
R-20	0.7	32.64	-	rounded
R-30	0.7	27.77	-	rounded
R20+30	0.7	27.84	-	rounded
CFA-0%	0.7	26.12	34.73	crush
CFA1-5%	0.7	33.38	32.83	crush
CFA1-10%	0.7	29.62	29.42	crush
CFA2-5%	0.7	29.23	20.80	crush

4.2. Hardened concrete of PAC

The compressive strength of all specimens is shown in Figures 6 and 7 as well as Table 4 and they were all observed to have increased with curing days. Moreover, C-FA1-5%, C-FA1-10%, and C-FA2-5% were discovered to have lower values on the seventh day compared to the C-FA1-0% which is the control specimen without any fly ash content. Meanwhile, the C-FA1-5% specimen had a similar result with control at a later curing age of 28 days.

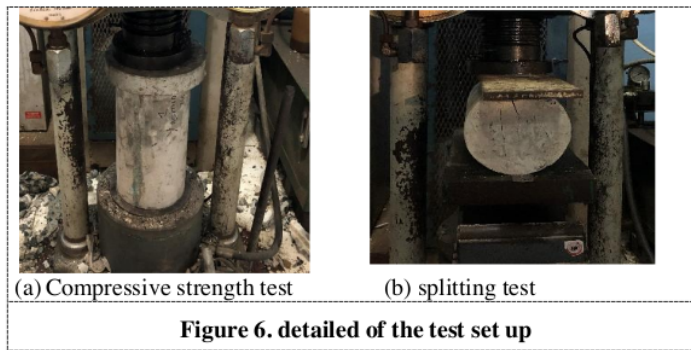
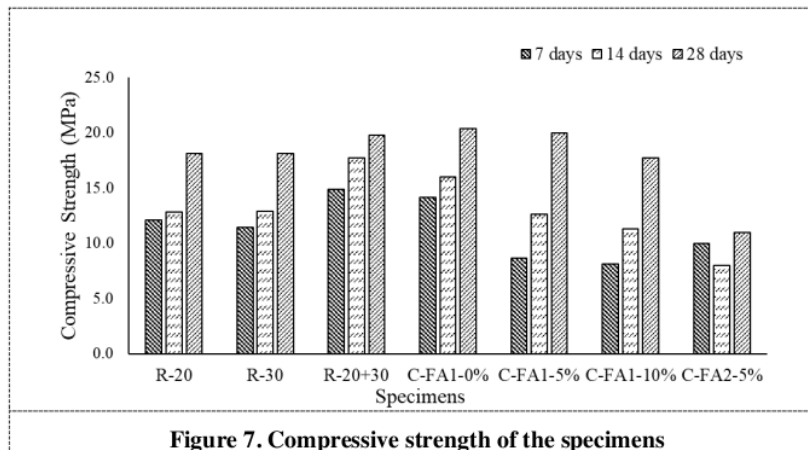


Table 4. Compressive and splitting tensile strength of specimen PAC.

Specimens (ID)	Compressive strength on days			Tensile strength
	7	14	28	28
	MPa	MPa	MPa	MPa
R-20	12.08	12.83	18.12	1.910
R-30	11.42	12.93	18.12	2.087
R20+30	14.91	17.74	19.82	1.839
CFA-0%	14.15	16.04	20.38	2.310
CFA1-5%	8.68	12.64	20.00	1.930
CFA1-10%	8.12	11.32	17.74	1.840
CFA2-5%	10	8.00	11	1.840



Figures 8(a) and (b) showed the influence of the shape of coarse aggregate on PAC's compressive strength and no significant difference was found with the increase in rounded aggregate sizes from 20 mm to 30 mm. Meanwhile, the round aggregate specimen with mixed sizes or R-20+30 was found to have increased the compressive strength by $\pm 10\%$. Figure 8(b) further shows the uniformly rounded aggregates tend to exhibit lower performance compared to the crushing aggregate [9] while round mixed size (R-20+30) had similar values with C-FA1-0%. This was associated with the better mechanical interlocking between the different sizes which produced an efficient stress transfer through the aggregates [9, 15,16].

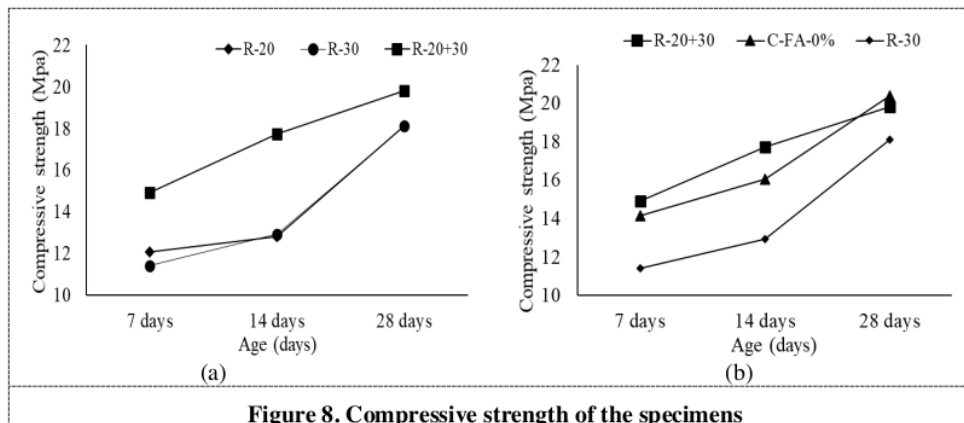


Figure 8. Compressive strength of the specimens

Figure 9(a) shows the increment in the percentage of fly ash in a mixture from 5% to 10% reduced the compressive strength of the PAC. This is similar to the findings of previous research which showed an increase in the partial replacement of OPC by FA decreased the compressive strength measured at the same date [12].

Figure 9(b) shows CFA2-5% had a lower performance compared to the CFA1-5% in terms of compressive strength. This is due to the different chemical properties of fly ash presented in Table 2 where the total percentage of CaO for FA-2 was observed to be more than 20% and classified as a cementitious material while FA-1 varied between 10 and 20% and categorized as a cementitious and pozzolanic material [14]. Therefore, CFA2-5% has a more rapid strength at the early ages of seven days than concrete with lower CaO such as CFA1-5% and this is in line with the findings of previous experiments [17]. Table 4 also shows the tensile strength of the specimens had a similar trend with compressive strength and analogous to the values obtained for the normal concrete. Moreover, the splitting tensile strength was found to be reducing as the fly ash content in the mixture increased. The splitting tensile strength is normally estimated using the compressive strength but it also several equations such as ACI 318-05 [18], ACI 363 [19], Eurocode 2 [20], Neville [8], Sofi et al. [21], Lee and Lee [22] formulated using Table 5 with f_t used to represent the splitting tensile strength (MPa) while f_c is the average compressive strength (MPa).

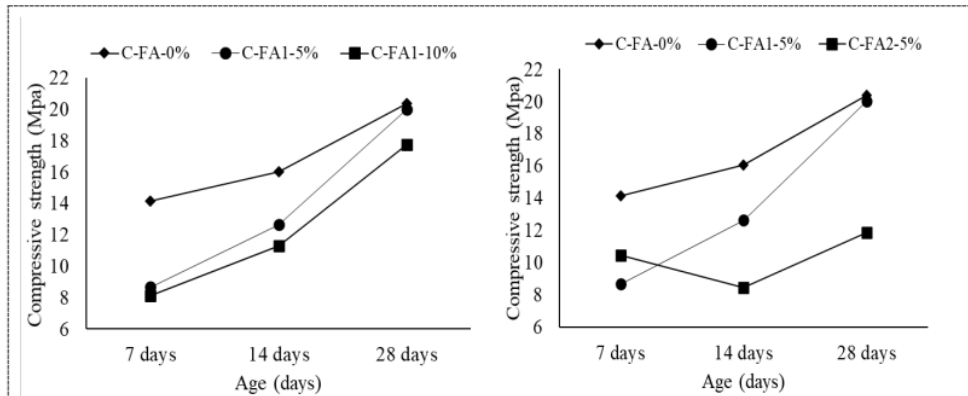


Figure 9. Compressive Strength of specimens

Table 5. Prediction models for splitting tensile strength

code	Equation (SI Unit)	Equations
ACI 318	$f_t = 0.56\sqrt{f_c}$	Equation 1
ACI 363	$f_t = 0.59\sqrt{f_c}$	Equation 2
Eurocode	$f_t = 0.33f_c^{2/3}$	Equation 3
Sofi et al.	$f_t = 0.48\sqrt{f_c}$	Equation 4
Lee and Lee	$f_t = 0.45\sqrt{f_c}$	Equation 5
Neville	$f_t = 0.23f_c^{0.67}$	Equation 6

Figure 10 shows the splitting tensile strength value obtained in this research is lower than all prediction models with ACI 318, ACI 363, and Eurocode [18-20] significantly overestimated. Meanwhile, the tensile strength for all the PAC specimens was observed to be slightly closer to the value for both Equations 5 and 6. It is, however, important to note that the proposed prediction models are strongly influenced by several factors such as the chemical and physical properties of raw materials.

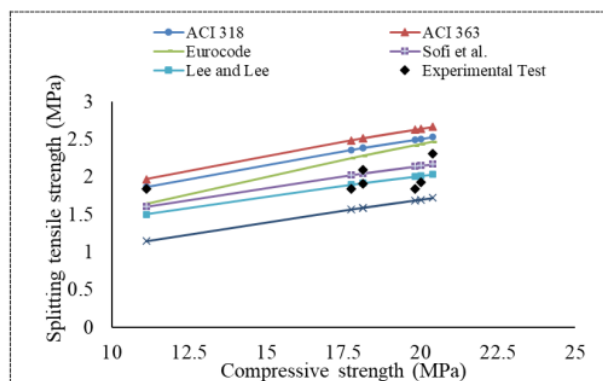


Figure 10. Comparison of the experimental and predictions model of splitting tensile strength

5. Conclusion

The relationship between the compressive and splitting tensile strengths of preplaced aggregate concrete produced using fly ash as a partial replacement of cement and coarse aggregate was determined in this study. Specimens with rounded shape aggregates at different sizes exhibited a similar performance with a 30 mm crushed aggregate. Moreover, specimens with higher calcium fly ash had more rapid strength at an early age of seven days while the tensile strength for all samples was slightly closer to the value for prediction models and previous experiments. Therefore, the partial replacement of cement with industrial waste material in the form of fly ash in preplaced aggregate concrete has the ability to save up to 10% of cement and also produce certain environmental benefits.

References

- [1] ACI Committee 304.1 2005 *Guide for the use of preplaced aggregate concrete for structural and concrete applications* (Farmington Hills, Michigan, USA)
- [2] Mirza J, Mirza M S, Roy, V, Saleh K. 2002, Basic rheological and mechanical properties of high-volume fly ash grouts. *Constr. Build. Mater.* **16** 353–363.
- [3] Najjar M F, Soliman A M and Nehdi M L 2014 Critical overview of two-stage concrete: Properties and applications. *Constr. Build. Mater.* **62** 47–58
- [4] Jing Lv, Tianhua Zhou and Kunlun Li 2020. Development and investigation of a new low-cement consumption concrete—Preplaced Aggregate concrete *Sustainability* **12** 1080
- [5] Chairunnisa N and Fardheny A F 2019 The study of flowability and the compressive strength of grout/mortar proportions for preplaced concrete aggregate (PAC) *MATEC web of conference* **280** 04010
- [6] Satyarno I, Solehudin A P, Meyarto D, Hadiyatmoko D, Muhammad P, and Afnan R 2014. *Procedia Eng.* **95**, 356–365
- [7] S. Champion and L. Davis. 1958 Grouted concrete construction," *Reinf. Concrete Rev.*
- [8] Neville A M 1995 *Properties of concrete* 4th Ed London Pearson Education Limited 443 (846) London
- [9] Kunal K Das and Siu S. E. Lam 2019 Effect of Coarse Aggregate Size and Grouting Process on Properties of preplaced Aggregate Concrete *Proc. Of. the 4 World Congr on Civil, Structural, and Environmental Engineering (CSEE'19)*
- [10] Coo M and Pheeraphan T 2015 Effect of sand, fly ash, and coarse aggregate gradation on preplaced aggregate concrete studied through factorial design *Constr. Build. Mater* **93** 812-821
- [11] Ganaw A 2012 *Rheology of grout for preplaced aggregate concrete* PhD Thesis (UK, University of Bradford)
- [12] Najjar M F 2016 *Innovating two-stage concrete with improved rheological, mechanical and durability properties* PhD Thesis (The University of Western Ontario)
- [13] ASTM C618-12a 2012 *Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete* ASTM International West Conshohocken PA
- [14] ASTM C939 / C939M-16a 2016 *Standard Test Method for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method)* ASTM International, West Conshohocken PA
- [15] Abdelgader H S 1999 How to design concrete produced by a two-stage concreting method, *Cem Concr Res.* **29** 3 331-337.
- [16] Malley J O and Abdelgader H S 2010 Investigation into viability of using two-stage (pre-placed aggregate) concrete in Irish setting, *Front Struct Civ Eng in China* **4** 1 127-132.
- [17] Burden D 2006 *The durability of concrete containing high levels of fly ash.* MSc Thesis (Illinois: Portland Cement Association University of New Brunswick)
- [18] ACI Committee 2011 *Building Code Requirements for Structural Concrete and Commentary.* ACI Farmington Hills Mich pp 111.
- [19] ACI 363 R-92, 1999. *State-of-the-Art Report on High-Strength Concrete* American Concrete Institute, Farmington Hills, Mich

- [20] Eurocode 2 2004 *Design of Concrete Structures-Part 1-2: General Rules-Structural fire Design* (London: European Standard).
- [21] Sofi M, Van Deventer J S J, Mendis P A, Lukey G C 2007 Engineering properties of inorganic polymer concretes (IPCs), *Cem. Concr. Res.* **37** (2) 251–257
- [22] Lee N K and Lee H K 2013 Setting and mechanical properties of alkali-activated fly ash/ slag concrete manufactured at room temperature, *Constr. Build. Mater.* **47** 1201–1209.

The properties of preplaced aggregate concrete technology contain the industrial waste-material and the various shapes and sizes of coarse aggregate

ORIGINALITY REPORT

13%

SIMILARITY INDEX

12%

INTERNET SOURCES

7%

PUBLICATIONS

3%

STUDENT PAPERS

MATCH ALL SOURCES (ONLY SELECTED SOURCE PRINTED)

6%

★ sam.ensam.eu

Internet Source

Exclude quotes Off

Exclude matches < 2%

Exclude bibliography On