Cement-based grout mix design for preplaced aggregate concrete using pozzolanic materials

by Ahmad Saiful Haqqi

Submission date: 01-Feb-2023 02:39PM (UTC+0700)
Submission ID: 2003951302
File name: 8._AIP__Cement-based_grout_mix_design_for.pdf (702.42K)
Word count: 3558
Character count: 16032

Cement-based grout mix design for preplaced aggregate concrete using pozzolanic materials

Cite as: AIP Conference Proceedings **2291**, 020030 (2020); https://doi.org/10.1063/5.0022837
Published Online: 02 November 2020

N. Chairunnisa, R. Nurwidayati, S. H. Amaliya, and Y. Syifa

Cement-Based Grout Mix Design For Preplaced Aggregate Concrete Using Pozzolanic Materials

N Chairunnisa[1,a)], R Nurwidayati[1b)], S H Amaliya[2c)] and Y Syifa[2d)]

[1]*Civil Engineering Program, Faculty of Engineering, Lambung Mangkurat University, Banjarmasin, Indonesia*
[2]*Graduated Student of Civil Engineering Program, Faculty of Engineering, Lambung Mangkurat University, Banjarmasin, Indonesia*

[a)]Corresponding author: nursiah.chairunnisa@ulm.ac.id
[b)] ratninurwidayat@ulm.ac.id
[c)]hanaamaliya@gmail.com
[d)]yasmin.syifa@yahoo.com

Abstract. The use of sustainable materials is greatly essential for green construction. Cement-based grout composition can be arranged by partially replacing cement content with the pozzolanic material such as fly ash, bottom ash, or others. The investigation of the utilization of fly ash replacement partially for cementitious materials of grout for pre-placed aggregate concrete was summarized in this study. This experimental study focused on investigating the appropriate grout composition in term of flow time using flow cone apparatus and compressive strength of the grout. A water-cement ratio, cement-sand ratio, fly-ash dosage in the mixture are the variable of the test. Mechanical properties of grout for pre-placed aggregate concrete, including compressive strength at 7, 14, 28, and 60 days were evaluated. The result indicated that increasing the dosage of pozzolanic material of the grout used in pre-placed aggregate concrete can lead the shorter efflux time and has a significant effect in term of hardened properties of the grout.

INTRODUCTION

The rapid development of infrastructure currently provides the demand for concrete which is increasingly high.

The constrution field can bring many impacts on society in terms of environmental, economic and social effect. Cement production contributes 7% of total CO2 emissions in the environment [1]. The utilization of large amounts of concrete can bring negative impact in a greenhouse effect. Many researchers investigate the alternative suplementary material which can substitute constituent material of concrete [2-3]. Fly ash is the pozzolanic materials that include as industrial wastes which have an ability for reduction in energy consumption.

Turzillo and Wertz (1937) investigated an innovation concrete technology that can be mentioned as Preplaced Aggregate Concrete (PAC) technology. Pre-placed aggregate concrete can be defined as an alternative concrete technology which can be used where conventional concreting is very difficult for applying such as underwater concreting, repairing, the congested reinforcement structures. The quality of grout composition is one indicator of the success of Pre-placed aggregate concrete technology [4-5]. Usually, grout composition can be arranged by the mixing of cement, sand, and water. Sometimes, for achieving the special condition, the admixtures need to be added.

This method of Pre-placed aggregate concrete is a new innovative method of carrying out the concreting process technology which is implemented by placing the coarse aggregate first into formwork and injected the grout that consists of sand, cement, plasticizer, and water to fill the voids between the coarse aggregate composition. The research of pre-placed aggregate concrete was developed by many researchers [4–10]. For identifying the characteristic of grout for pre-placed aggregate concrete can be depicted by flowability of grout which can be examined by ASTM C-939-2010 [11] and ACI 304 [12]. The testing method with a flow cone method can be used for the grout, which having an efflux time of 35 seconds or less with the volume of grout composition is 1725 ml. The efflux time of pure water is 8 second, so the suitable of efflux time for determining flowability of grout is

Proceedings of Advanced Material, Engineering & Technology
AIP Conf. Proc. 2291, 020030-1–020030-8; https://doi.org/10.1063/5.0022837
Published by AIP Publishing. 978-0-7354-4023-4/$30.00

ranged between 8-35 second. Furthermore, if the flow time exceeds the requirements, it is recommended to determine by flow table according to the ASTM C109/109M [13]. The injected grout into the formwork can be divided into two systems, such as depend on gravity weight/own weight and using pressure system.

Based on [14], the quality of grout is affected by several factors such as type of sand, the composition of cement-sand ratio, water-cement ratio, cement for conventional grout. This research carried out the composition of grout with using fly ash as pozzolanic materials which can partially replace cement as the constituent material of the grout. Therefore, it is important to develop research in term of the performance of grout using pozzolanic material for pre-placed aggregate concrete implementation. The mix design of grout can be predicted based on the weight and water-cement ratio. If the comparison cement-sand ratio is determined i.e., Wc:Ws=1:s and the water volume can be predicted using water-cement ratio wc=WwWc . Then according to the weight and water-cement ratio, the following equation (1) to (3) must be satisfied.

$$\frac{W_w}{G_w\gamma_w}+\frac{W_c}{G_c\gamma_w}+\frac{W_s}{G_s\gamma_w}=1 \quad (1)$$

Where W_w =weight of water, W_c= weight of cement, W_s= weight of sand, G_w= specific gravity of water, G_c= specific gravity of cement, G_s= specific gravity of sand. γ_w= unit weight of water, γ_c= unit weight of cement and γ_s= unit weight of sand.

$$\frac{W_w}{G_w\gamma_w}+\frac{W_c}{G_c\gamma_w}+\frac{W_s}{G_s\gamma_w}=1 \quad (2)$$

Or

$$W_c\left(\frac{\frac{w}{c}}{G_w\gamma_w}+\frac{1}{G_c\gamma_w}+\frac{s}{G_s\gamma_w}\right)=1 \quad (3)$$

EXPERIMENT PROGRAM

Materials and Methods

Fly ash cement-based grout mix design was applied in this research. There were four materials used in this experimental such as water, cement, fine aggregate, and pozzolanic material such as fly ash. All materials that were used as grout composition were commonly obtained. Particularly, Viscocrete 1003 from Sika Product was used as a chemical admixture for improving the workability of grout and the percentage of fly ash as pozzolanic material for replacing partial cement became the main purpose of this study. The main equipment that installed in this experimental test were a flow cone apparatus, a grout mixer, 50 mm cube grout molds and compressive testing machine. Three different variations of the water-cement ratio were studied, namely 0.4, 0.6, and 0.7. The dosage of admixtures in the grout is particularly 0.7% by weight of the grout's cementitious materials [15]. The cement-sand (c/s) ratio of 1:0.75, 1:1.5 and 1:2 with the dosage of fly ash were 5%, 10% and 15% of the weight of cement were used in this experimental phase. Only a type of sand was studied in this research and oven-dry condition of fine aggregate that implemented in the mixture..

The research objectives from the research were to determine the appropriate grout composition which can meet criteria of flow cone test. A specimen control without the addition of a chemical admixture was made by water-cement ratio 1:1.5 and cement-sand ratio 1:1.5 that based on Satyarno[14]. This grout mix can meet criteria for flowability using flow cone test for all types of sand, and the water-cement ratio minimum that can be used is 0.65 with a flow time of 10-13 seconds based on Table 1.

TABLE 1. The minimum water-cement ratio of grout which meets the requirements of flow cone test[14]

Sand grading	c/s	min w/c
Fine	1:0.5	0.50
	1:1.0	0.55
	1:1.5	0.65
	1:2.0	0.80
Rather fine	1:0.5	0.50
	1:1.0	0.55
	1:1.5	0.65
	1:2.0	0.70
Rather coarse	1:0.5	0.50
	1:1.0	0.55
	1:1.5	0.65
	1:2.0	*
coarse	1:0.5	0.50
	1:1.0	0.55
	1:1.5	*
	1:2.0	*

Note : does not pass flow cone test

The variables of grout mixture and the number of specimens and the weight composition of each constituent materials can be depicted in Fig 1. The mixture proportion of the pozzolanic-cement based grout for the water-cement ratio of 0.4 is shown in Table 2.

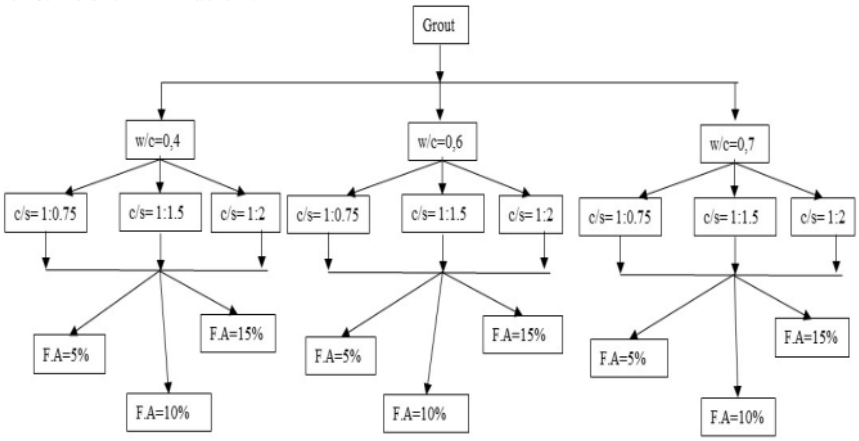

FIGURE 1. The twenty-seven grout mix composition of the research

TABLE 2. Fly ash-cement grout mixtures per 1m^3 (water-cement ratio of 0.4)

w/c	c/s	Material Requirements (m^3)				
		Fly ash	Cement	Sand	Water	Fly ash
		%	(kg)	(kg)	(liter)	(kg)
0.4	1:0.75	5%	951.56	751.23	400.66	50.08
		10%	901.48	751.23	400.66	100.16
		15%	851.40	751.23	400.66	150.25
	1:1.5	5%	742.62	1172.55	312.68	39.09
		10%	703.53	1172.55	312.68	78.17
		15%	664.45	1172.55	312.68	117.26
	1:2	5%	647.79	1363.77	272.75	34.09
		10%	613.70	1363.77	272.75	68.19
		15%	579.60	1363.77	272.75	102.28

Twenty-seven grout mix combination (see in Fig 1) were tested in the laboratory with different kind of ratios of constituent materials. Moreover, Fig 2 and Fig 3 described the phase of the actual test for determining efflux time and mechanical properties of grout using the flow cone test and compressive strength testing apparatus.

(a) Visual of fly ash (b) Flow cone test apparatus

FIGURE 2. The experimental test for determining efflux time of the grout.

(a) Visual of the specimen with and without FA in the grout (b) Compressive strength testing of the grout

FIGURE 3. The grout compressive strength apparatus

RESULT AND DISCUSSION

The Flowability Properties of Fly Ash – Cement Grout

After determining of grout mix proportion with using flow cone test, the grout would be poured to the 50mm cube mold to examine the compressive strength of grout. The flowability and the compressive strength of each grout mix proportion in this research was presented in Fig 4. From Fig. 4, it can be pointed out that the increasing percentage of fly ash in the grout mixture can decrease significantly of efflux time. For instance, in the water-cement ratio of 0.6, the supplementary 10% and 15% of fly ash in the grout mixture as partial replacement of cement achieve the target of flowability if compared to the grout mixture with additional 5% of fly ash. The grout mixtures w/c-s/c=0.4-0.75-10% and w/c-s/c=0.4-0.75-15% exhibited 11.3%, and 33.9% shorter efflux time compared to that w/c-s/c=0.4-0.75-5%. This can occur because fly ash with a characteristic spherical particle which has a smooth surface can reduce the frictional force between particles [16].

Fig. 5 described that there was six fly-ash-cement grout composition which can fulfill the criteria of flowability based on flow cone test. It can be concluded that the water-cement ratio and cement-sand ratio can affect the

flowability of the grout mixture for pre-placed aggregate concrete. At fact, increasing the water-cement (w/c) ratio can enhance the volume of free water in the grout mixture, which can behave as a lubricant between the solid particles. Finally, the grout mixture can lead the higher flowability properties [17].

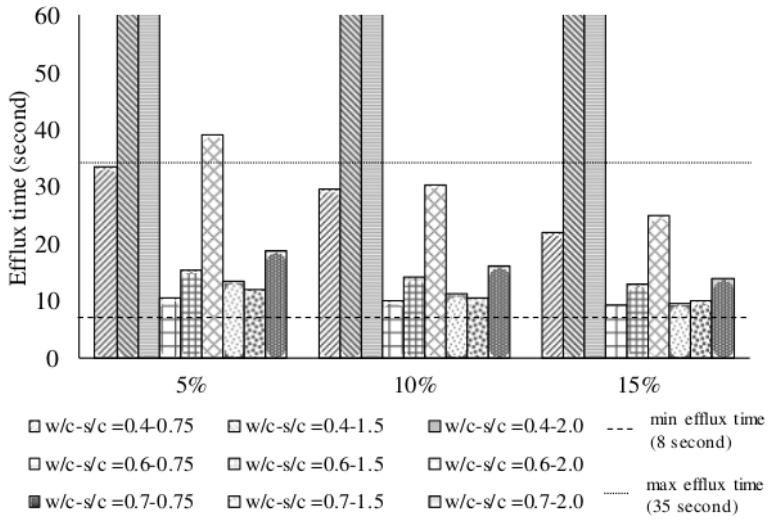

FIGURE 4. Efflux time of all specimens based on the flow cone test

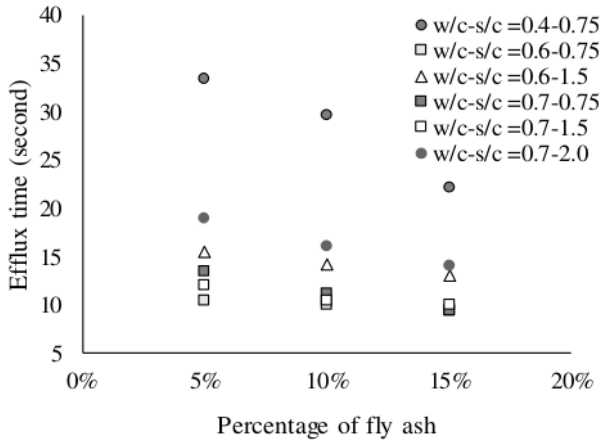

FIGURE 5. Correlation between flowability and the percentage of pozzolanic material

The Mechanical Properties of Fly Ash – Cement Grout

It should be emphasized that the main subject of this research was the properties of the grout, such as flowability and mechanical properties. The compressive test of grout of the various percentages pozzolanic material can be drawn in Fig. 6.

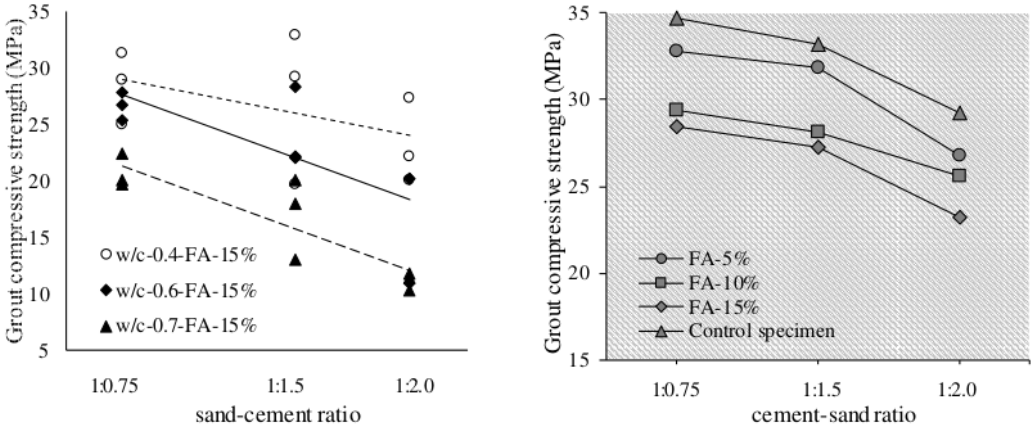

FIGURE 6. Correlation cement-sand ratio to the grout compressive strength

From Fig. 6(a), it can be summarized that the lower sand cement ratio and water-cement ratio can increase the compressive strength of grout significantly. The higher water-cement ratio can decrease the compressive strength of grout. Furthermore, According to Fig. 6(b) and Table 3, it can be observed that the percentage of fly ash in the grout mixture of 5% to 15% of cement weight can alleviate the strength capacity of grout, Contrastly, based on the previous analysis, the adequate performance of flowability can be reached.

TABLE 3. The grout compressive strength of fly ash-cement grout.

w:c	c:s	Grout compressive strength (MPa)			
Percentage of fly ash		0%	5%	10%	15%
0.4	1:0.75	34.72	32.82	29.41	28.44
0.4	1:1.5	33.19	31.85	28.17	27.29
0.4	1: 2.0	29.26	26.79	25.58	23.24

The compressive strength of grout of certain days also was investigated in this research. Table 4 and Fig 7 represented the strength capacity of pozzolanic material of grout in certain days. Fig. 7 showed the enhancement of grout capacity for the water-cement ratio of 0.4 and cement-sand ratio of 1:0.75 and 1:1.5 with the different percentages of fly ash.

TABLE 4. The compressive strength of the grout of fly ash-cement grout.

w:c	c:s	FA	The grout compressive strength in certain days (MPa)			
		%	7	14	28	60
0.4	1:0.75	0	27.24	30.60	34.72	34.95
	1:0.75	5	22.06	24.14	32.83	39.78
	1:0.75	10	21.37	23.51	29.42	35.81
	1:0.75	15	18.21	25.07	28.44	35.80
	1:1.5	0	22.06	26.97	33.20	35.77
	1:1.5	5	24.98	26.41	31.85	37.66
	1:1.5	10	23.78	26.70	28.17	36.34
	1:1.5	15	20.37	25.82	27.30	36.23
	1: 2.0	0	21.38	24.11	29.26	34.36
	1:2.0	5	19.76	25.79	26.80	33.82
	1:2.0	10	18.38	24.56	25.59	31.36
	1:2.0	15	18.23	22.74	23.24	29.53

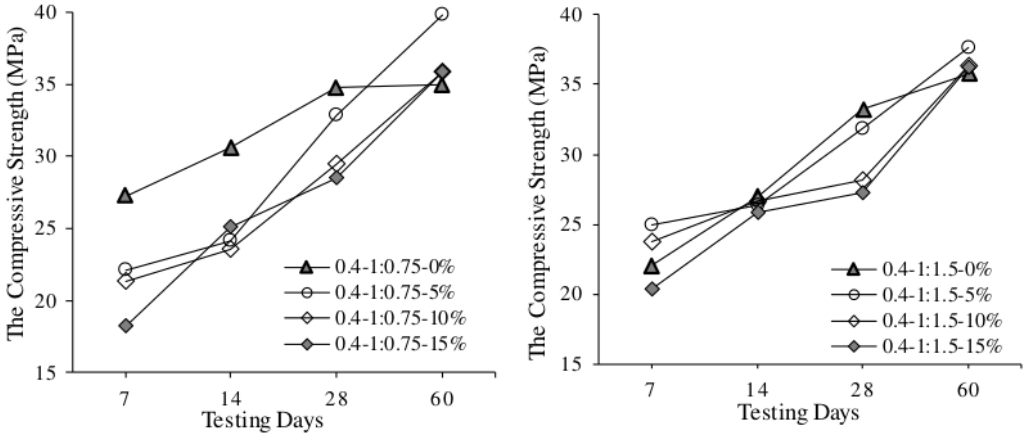

FIGURE 7. The compressive strength of the grout in certain days, (a). c:s ratio of 1:0.75 and (b) c:s ratio of 1:1.5

From Fig. 9, it can be observed that the utilization of pozzolanic material such as fly ash in the grout composition has potential value in term of flowability and the strength capacity. This statement was indicated by the increasing of grout compressive strength of fly-ash specimen in the 60 days, which can reach the similar strength capacity of control specimen. The pozzolanic material reaction of fly ash is lower than the normal specimen without replacement of fly ash in the grout composition. Contrastly, the compressive strength of the grout of fly ash specimens were similar and slightly higher than the conventional one.

The strength activity index (SAI) of the mixture composition with the replacement of pozzolanic material such as fly ash was shown in Table 5. All grout composition of the mixture was arranged with a similar mixture proportion, only with the addition of superplasticizer to achieve efflux time of 8 – 35 second. It can be shown that the compressive strength of grout of 7, 14, 28, and 60 days have similar strength due to the replacement of pozzolanic material up to 15%. Moreover, the lower rate of pozzolanic material reaction at the early age could generate the strength activity index (SAI) value of the grout mixture was lower and could reach SAI up to 113.82% for later age at 60 days

TABLE 5. The strength activity index (SAI) of pozzolanic material cement based grout [18]

c:s	Cement (kg)	FA (kg)	The grout compressive strength in certain days (MPa)				Strength Activity Index (SAI)(%)			
			7 days	14 days	28 days	60 days	7 days	14 days	28 days	60 days
1:0.75	1001.64	0	27.24	30.60	34.72	34.95	0	0	0	0
1:0.75	951.56	50.08	22.06	24.14	32.83	39.78	80.98	78.89	94.56	113.82
1:0.75	901.48	100.16	21.37	23.51	29.42	35.81	78.45	76.83	84.74	102.46
1:0.75	851.40	150.25	18.21	25.07	28.44	35.80	66.85	81.93	81.91	102.43
1:1.5	781.70	0	22.06	26.97	33.20	35.77	0	0	0	0
1:1.5	742.62	39.09	24.98	26.41	31.85	37.66	113.24	95.93	95.93	105.28
1:1.5	703.53	78.17	23.78	26.70	28.17	36.34	107.80	84.85	84.85	101.59
1:1.5	664.45	117.26	20.37	25.82	27.30	36.23	92.34	82.23	82.23	101.29
1:2.0	681.88	0	21.38	24.11	29.26	34.36	0	0	0	0
1:2.0	647.79	34.09	19.76	25.79	26.80	33.82	92.42	91.59	91.59	98.43
1:2.0	613.70	68.19	18.38	24.56	25.59	31.36	85.97	87.46	87.46	91.27
1:2.0	579.60	102.28	18.23	22.74	23.24	29.53	85.27	79.43	79.43	85.94

CONCLUSIONS

In this research, the flowability properties and the mechanical properties of grout incorporating various percentages of alternate cementitious material with different kinds of water-cement ratios and cement sand ratios was studied. The following closing remarks can be concluded from the actual test:

1. This study present that the actual test results of grout mixtures which using alternate cementitious material on the grout can be applied in pre-placed aggregate concrete technology.
2. The utilization of pozzolanic material such as fly ash for partial replacement of cement in the grout composition has potential value in term of the flowability of grout than can be applied as grouting for pre-placed aggregate concrete.
3. The fly ash pozzolanic cement grout exhibit low strength capacity at the early curing age and quite intensify at the later curing age of 60 days

REFERENCES

1. A. Pal, J. Inst. Eng. Ser. A. 99(3), 433–447 (2018)
2. I. Ismail, N. Jamaluddin, and S. Shahidan, J. Teknol. 78(5), 29–35 (2016).
3. A. Lahri and S. Dixit, , 6(10), 50–56 (2015).
4. H. S. Abdelgader and A. A. Elgalhud, Struct. Concr. 9(3), 63–170(2008).
5. M. Şahmaran, H. A. Christianto, and I. O. Yaman, Cem. Concr. Compos. 28(5),432–440 (2006).
6. J. O'Malley and H. S. Abdelgader, Front. Archit. Civ. Eng. China. 4(1), 127–132 (2010).
7. M. Najjar, "Innovating Two-Stage Concrete with Improved Rheological, Mechanical and Durability Properties" (Western University, 2016).
8. H. S. Abdelgader and A. S. El-Baden, IOP Conf. Ser. Mater. Sci. Eng. 96(1), (2015).
9. K. K. Das and S. S. E. Lam, Proc. 4th World Congr. Civil, Struct. Environ. Eng (2019).
10. P. Hakim, S. Abdelgader, P. Jamal, M. Khatib, and A. S. El-baden, ISBS (2015).
11. ASTMC939-10, "Standard Test Method for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method)"(ASTM International, 2010).
12. R. a Kelsey, W. C. Krell, G. R. Mass, and R. E. Tobin, Concrete, 96, 1–8 (2004).
13. W. Devices, Glass, 4, 1–6 (1999).
14. I. Satyarno, A. P. Solehudin, C. Meyarto, D. Hadiyatmoko, P. Muhammad, and R. Afnan, Procedia Eng. 95, 356–365 (2014).
15. N. Chairunnisa and A. F. Fardheny, MATEC Web Conf. (2019).
16. H. Y. Wang, W. Ten Kuo, C. C. Lin, and C. Po-Yo, Constr. Build. Mater. 41, 532–537 (2013).
17. M. Kismi, J. Saint Claude, and P. Mounanga, Constr. Build. Mater.28, 747–758 (2011).
18. ASTMC618, "Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete" (ASTM Standard, 2005).

Cement-based grout mix design for preplaced aggregate concrete using pozzolanic materials

ORIGINALITY REPORT

12%	8%	7%	0%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

MATCH ALL SOURCES (ONLY SELECTED SOURCE PRINTED)

6%

★ www.researchgate.net

Internet Source

Exclude quotes	Off	Exclude matches	< 2%
Exclude bibliography	On		