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Submission date: 27-Aug-2018 09:03AM (UTC+0700)
Submission ID: 993523450
File name: 3.The_Compressive_Strength.pdf (165.81K)
Word count: 3079
Character count: 16020

The Compressive Strength of Geopolymer Concrete Made with Baggase Ash and Metakaolin

Kuat Tekan Beton Geopolymer Yang Dibuat Dengan Abu Ampas dan Metakaolin

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ABSTRACT

Geopolymer concrete becomes popular and extensively developed material because this concrete is a friendly environmental material. Generally, material synthesized from geological material or by product material used as based material for geopolymer concrete. This paper present the experimental program of geopolymer concrete with based material of baggase-ash and metakaolin. The baggase-ash is the waste material of sugar mill, while metakaolin is the geological material. Three types of geopolymer concrete were made in this experimental program. The first is geopolymer concrete based on baggase-ash. The second is geopolymer concrete based on metakaolin. And the third is the one based on the mixture of baggase-ash and metakaolin. The compressive strength of the three types geopolymer concrete were tested and compared to each other. The cylinder with size of (70 mm x 140 mm) is used in this experimental program. The curing after casting the cylinder uses room temperature. The results show that the compressive strength of the three types of geopolymer concrete generally are very low. However, geopolymer concrete based on the mixture of baggase-ash with metakaolin gives the highest compressive strength compares to others and can be developed for future research.
Keywords : geopolymer concrete, baggase-ash, metakaolin, compressive strength

ABSTRAKSI

Beton geopolymer menjadi bahan yang populer dan berkembang pesat karena beton jenis ini termasuk bahan yang ramah lingkungan. Umumnya, bahan yang diperoleh dari sintesa material geologi atau dari bahan produksi digunakan sebagai bahan dasar beton geopolymer. Makalah ini mempresentasikan penelitian eksperimental beton geopolymer dengan bahan dasar abu ampas dan metakaolin. Abu ampas adalah bahan limbah dari penggilingan tebu, sedangkan metakaolin adalah bahan geologi. Tiga jenis beton geopolymer dibuat dalam eksperimen. Pertama adalah beton geopolymer dengan bahan dasar abu ampas. Ke dua adalah beton geopolymer dengan bahan dasar metakaolin. Dan ke tiga beton geopolymer dengan bahan dasar campuran abu ampas dan metakaolin. Kuat tekan tiga jenis beton geopolymer diuji dan dibandingkan. Benda uji seilinder ukuran 70mm x 140mm digunakan dalam pengujian. Perawatan setelah pencetaan sampeldilakukan pada suhu kamar. Hasil penelitian menunjukkan bahwa kuat tekan tiga jenis beton geopolymer cenderung sangat rendah. Akan tetapi, beton geopolymer dengan bahan dasar campuran abu ampas dan metakaolin memberikan kuat tekan tertinggi dibandingkan jenis yang lainnya dan dapat dikembangkan untuk penelitian selanjutnya.
Kata-kata Kunci : beton geopolymer, abu ampas, metakaolin, kuat tekan

INTRODUCTION

In order to reduce carbon dioxide (CO_2) emissions in the air as a side effect of producing ordinary portland cement, geopolymer concrete now is intensively developed. Roy (1999) reported that in producing one ton of ordinary portland cement will produce one ton of carbon dioxide released to the air and it gives contribution to global warming. Therefore, now geopolymer concrete becomes popular material, because it does not use ordinary portland cement for binder, but it uses natural material such as fly ash and rice hush ash as a binder. Davidovits (1994) stated that natural materials for replacing ordinary portland cement in geopolymer concrete must contain high of silica and alumina. These elements will react with alkaline liquid to make polymerrisation process in geopolymer concrete.

There were some researchers tried to develop geopolymer concrete (Hardjito et al. 2004, Hardjito and Rangan 2005, Triwulan et al. 2007, Sathia et al. 2008, Vijai et al. 2010). They used fly ash with low of calcium as a base material for developing geopolymer concrete. Lisantono and Hatmoko (2011) also tried to develop geopolymer concrete using fly ash with high of calcium.

As the waste of sugar factory, generally baggase ash is useless material and just put in the area around the sugar factory and made pollution (Lisantono and Hatmoko, 2011). The baggase ash can be developed to be potentially material and used as pozzolan for concrete (Wibowo and Hatmoko, 2001). Beside baggase ash, metakaolin is also potential material for making concrete (Khatib, 2009).

In this research the baggase ash and metakaolin are tried to use for developing geopolymer concrete. Not likes metakaolin, the published literature regarding to the use of baggase ash in geopolymer concrete were very limited. Therefore, this preliminary research can be made as the basis research for future research in developing geopolymer concrete using baggase ash and metakaolin.

RESEARCH METHOD

Materials

Fine aggregates were taken from Krasak River, Muntilan which located in the North of Yogyakarta Province. While coarse aggregates were taken from Clereng, Kulon Progo which is located the West part of Yogyakarta Province. The properties and

Table 1. Properties of fine aggregates

Properties	According to ASTM (1996)	Result
Bulk specific grafity	C. 127 - 79	2.6645
Bilk specific grafity SSD (saturated surface dry basic)	C. 127 - 79	2.7412
Apparent specific grafity	C. 127 - 79	2.8860
Absorbtion (%)	C. 127 - 79	2.8807
Unit weight SSD :		
a. rodded	C. 29 – 78T	1.5653
b. shoveled		1.3275

Table 2. Properties of coarse aggregates

Properties	According to ASTM (1996)	Result
Bulk specific grafity	C. 127 - 81	2,5304
Bilk specific grafity SSD (saturated surface dry basic)	C. 127 - 81	2,7996
Apparent specific grafity	C. 127 - 81	2,7233
Absorbtion (%)	C. 127 - 81	2,8000
Unit weight SSD :		
a. rodded	C. 29 – 78T	1,5653
b. shoveled		1,3669

gradation of fine aggregates and coarse aggregates can be seen in Table 1 and Table 2, respectively. It can be seen that the properties and gradation of both fine and coarse aggregates comply with ASTM (1996).

Baggase ash was taken from Madukismo Sugar Factory which is located in the South part of Yogyakarta Province. Baggase ash is waste of sugar mill, and had been used to burn molasses in sugar mill. Wibowo and Hatmoko (2001) stated that these baggase ash has very low silica and needs to be burnt to increase the contain of silica. According to Wibowo and Hatmoko (2001) that the optimum burning temperature is 500^0 Celsius during 25 minutes, where the contain of $SiO_2 + Al_2O_3 + Fe_2O_3$ can reach 85.21 % (the chemical composition can be seen in Table 3).

While metakaolin was taken from Gunungkidul County, Province of Yogyakarta. In this research metakaolin was also burnt at 500^0 Celcius during 25 minutes. The chemical composition of metakaolin burnt at 500^0 Celcius can be seen in Table 4. It can be seen from Table 4 also that the contain of $SiO_2 + Al_2O_3 + Fe_2O_3$ of metakaolin can reach 75.97 %.

Mix Design of Geopolymer Concrete

According to Vijai et al. (2010) in the design of geopolymer concrete mix that the coarse and fine aggregates were taken as 77 % of entire mixture by mass, and the fine aggregate was taken as 30 % of total aggregates. Vijai et all also stated that from the past literature the average density of fly ash-based geopolymer concrete is similar to that of Ordinary Portland Cement concrete. In this research, it was also assumed that the density of baggase ash-based geopolymer concrete is similar to the density of Ordinary Portland Cement concrete.

By knowing the density of concrete, the combined mass of alkaline liquid and baggase ash can be arrived. Assuming the ratios of alkaline liquid to baggase ash as 0.4, mass of baggase ash and mass of alkaline liquid were found. To obtain mass of sodium hydroxide and sodium silicate solutions, the ratio of sodium silicate solution to sodium hydroxide solution was fixed as 2.5. Concentration of NaOH solution was taken as 8M. The mix proportion of baggase ash-based geopolymer concrete can be seen in the Table 5.

Table 3. Chemical composition of baggase ash burnt in temperature of 500^0 Celsius during 25 minutes. (Wibowo and Hatmoko, 2001)

Chemical element	Content (%)
SiO2	64.110
Al2O3	15.110
Fe2O3	5.990
SiO2 + Al2O3 + Fe2O3	85.210
Lost of ignition	0.440
CaO	5.810
MgO	2.260
SO3	0.000
K2O	3.620
Na2O	2.660
H2O	0.050

The proportion geopolymer concrete based on mateakaolin is the same as the proportion of geopolymer concrete based on baggase ash (see Table 3 in the column of baggase ash replaced by metakaolin). While the proportion of geopolymer concrete based on baggase ash mix with metakaolin is also the same except on the column number (2) on the Table 5 the proportion of baggase ash and metakaolin each was 50 % of 1875 gram.

Table 4. Chemical composition of metakaolin burnt in temperature of 500^0 Celsius during 25 minutes.

Chemical element	content (%)
SiO_2	66,398
Al_2O_3	4,498
Fe_2O_3	5,077
$SiO2 + Al_2O_3 + Fe_2O_3$	75,973
Lost of ignition	5,280
CaO	3,081
MgO	9,645
SO_3	0,275
K_2O	0,829
Na_2O	2,968
H_2O	1,950

Preparation of Specimens

To make sodium hydroxide solution of 8 molarity (8M), take 320 grams of sodium hydroxide flakes was dissolved in one litre of water. After sodium hydroxide was dissolved with water, then keep it at least one day before mix with sodium silicate solution. The sodium hydroxide solution is mixed with sodium silicate solution one day before mixing the concrete to get the alkaline solution.

To make baggase ash-based geopolymer concrete, this research followed the procedure of the research was done by Vijai et al. (2010). First the baggase ash and the aggregates were dry mixed in the pan mixer for about three minutes. Second, after dry mixing, alkaline solution was added to the dry mix and wet mixing was done for 4 minutes. Finally, the cylinder specimens were cast.

In this research, cylinder with diameter of 70 mm and height of 140 mm was used to make specimen. After casting the specimens, the specimens were kept for five days before demoulding. After demoulding, the specimens were kept for curing at room temperature.

While the procedurs to make metakaolin-based geopolymer concrete and geopolymer concrete based on baggase ash mix with metakaolin are the same as the procedure to make baggase-ash-based geopolymer concrete.

Table 5. Details of proportion baggase ash-based geopolymer concrete

Alkaline Liquid to Baggase Ash Ratio	Baggase Ash (gr)	Fine Aggregate (gr)	Coarse Aggregate (gr)	NaOH (gr)	Na_2SiO_3 (gr)	Water (gr)	Total Solids (gr)	Water to Solid Ratio
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
0.4	1875	2636.4	6151.6	214.3	535.7	787.5	2625	0.3

Table 6. Density of baggase ash-based geopolymer concrete

Type of Curing	Density (kg/m^3)			
	14 Days	Average	28 Days	Average
Room Temperature	1940.64		1988.01	
	1999.44	1984.11	1992.73	2001.13
	2012.24		2022.64	

Table 7. Density of metakaolin-based geopolymer concrete

Type of Curing	Density (kg/m^3)			
	14 Days	Average	28 Days	Average
Room Temperature	2017,509		2089,834	
	2147,431	2073,190	2037,279	2096,743
	2054,630		2163.117	

Table 8. Density of baggase ash-metakaolin-based geopolymer concrete

Type of Curing	Density (kg/m^3)			
	14 Days	Average	28 Days	Average
Room Temperature	2058,342		2091,860	
	2125,159	2118,353	2060,582	2077,403
	2171,560		2079,767	

Table 9. Compressive strength of baggase ash-based geopolymer concrete at 14 and 28 days.

Specimen	Compressive Strength (N/mm^2)			
	14 Days	Average	28 Days	Average
1	0.336		0.366	
2	0.425	0.325	0.329	0.344
3	0.213		0.336	

Table 10. Compressive strength of metakaolin-based geopolymer concrete at 14 and 28 days

Specimen	Compressive Strength (N/mm^2)			
	14 Days	Average	28 Days	Average
1	0.715		0.759	
2	0.467	0.560	0.507	0.721
3	0.497		0.898	

Table 11. Compressive strength of baggase ash-metakaolin-based geopolymer concrete at 14 and 28 days

Specimen	Compressive Strength (N/mm^2)			
	14 Days	Average	28 Days	Average
1	0.427		0.720	
2	0.473	0.380	0.950	0.852
3	0.239		0.886	

RESULT AND DISCUSSION

Density of Geopolymer Concrete

Density of baggase ash-based geopolymer concrete, metakaolin-based geopolymer concrete, and baggase ash-metakaolin-based geopolymer concrete can be seen in Table 6, Table 7, and Table 8, respectiveliy. Table 6 shows that the density of baggase ash-based geopolymer concrete in the range of 1940.64 kg/m^3 and 2022.64 kg/m^3. The average density of 14 days and 28 days are 1984.11 kg/m^3 and 2001.13 kg/m^3, respectively. It was found that the density of baggase ash-based geopolymer concrete is less than the density of Ordinary Portland Cement concrete.

Table 7 and 8 show that the density of metakaolin-based geopolymer concrete and the density of baggase ash-metakaolin-based geopolymer concrete at 28 days were 2096,743 kg/m^3 and 2077,403 kg/m^3, respectively. It was found that the average density of the metakaolin-based geopolymer concrete and the baggase ash-metakaolin-based geopolymer concrete are also less than the density of Ordinary Portland Cement concrete. When the comparison of the average density is taken among the three geopolymer concrete, it can be seen that the density of metakaolin-based geopolymer concrete is higher than the others.

Compressive Strength of Geopolymer Concrete

The compressive strength of the baggase ash-based geopolymer concrete, the metakaolin-based geopolymer concrete, and the baggase ash-metakaolin-based geopolymer concrete at 14 days and 28 days can be seen in Table 9, 10, and 11, respectively.

Table 9, 10 and 11 show that the compressive strength of the baggase ash-based geopolymer concrete, the metakaolin-based geopolymer concrete, and the baggase ash-metakaolin-based geopolymer concrete at 28 days were 0.344 MPa, 0.721 MPa and 0.852 MPa, respectively.

Because of the cylinders in this research used the size of (70 mm x 140 mm), according to Troxell and Davis (1956), the results must be converse by the factor of 0.86. Therefore, the average compressive strength of 14 days and 28 days on the Table 9, Table 10 and Table 11 must be multiplied by the factor of 0.86. Therefore, the compressive strength of the baggase ash-based geopolymer concrete, the metakaolin-based geopolymer concrete and the baggase ash-metakaolin-based geopolymer concrete are 0.296 MPa, 0.620 MPa and 0.733 MPa, respectivelyIt can be seen that the compressive strength of the baggase ash-metakaolin-based geopolymer concrete is the highest compare to the others. It indicated that the mixture of baggase ash with metakaolin might give higher compressive strength when it was used as the binder of geopolymer concrete.

CONCLUSIONS

Based on the obtained experimental results, the following conclusions can be drawn :

The density of geopolymer concrete based on baggase ash, metakaolin and mix of baggase ash and metakaolin in the average is lower than Ordinary Portland Cement concrete. In comparison with others, the density of metakolin-based geopolymer concrete is the highest.

The compressive strength of geopolymer concrete based on baggase ash, metakaolin and mix of both baggase ash and metakaolin on the average is very low less than 1 MPa. It is still required an effort of research in the future how to increase the compressive strength of geopolymer concrete based on baggase ash and metakaolin.

In comparison with others, the average compressive strength of baggase ash-metakaolin-based geopolymer concrete is the highest. It indicated that the mixture of baggase ash and metakaolin can be developed for future research to get higher compressive atrength.

ACKNOWLEDGMENT

The research work reported herein was made possible due to funding from the University of Atma Jaya Yogyakarta. The authors gratefully acknowledge this support. The authors thank the Laboratory of Structures and Materials, Civil Engineering Departement, Faculty of Engineering, University of Atma Jaya Yogyakarta for the use of their research facilities. The authors also thank to Tami, Evan, Sukaryantoro and Beni Antana for their help during the experimental program was carried out. Special thank is given to Dr. Djwantoro Hardjito from Petra Christian University for fruitful discussion with the authors during the research was carried out.

REFERENCES

ASTM. (1996). *Annual Book of ASTM Standards*, Section 4 Construction, Volume 04.02 Concrete and Aggregates, ASTM 100 Barr Harbor Drive, West Conshohocken, PA 19428.

Davidovits, J. (1994). *Properties of Geopolymer Cements. First International Conference on Alkaline Cements and Concrete*, Kiev, Ukraine, SRIBM, Kiev State Technical University.

Hardjito, D., Wallah, S.E., Sumajouw, D.M.J. and Rangan, B.V. (2004). "Factors Influencing The Compressive Strength of Fly Ash-Based Geopolymer Concrete." *Jurnal Dimensi Teknik Sipil*, Vol. 6, No. 2, September, pp. 88-93.

Hardjito, D. and Rangan, B.V. (2005). "Development and Properties of Low-Calcium Fly Ash-Based Geopolymer Concrete." *Research Report GC1*, Curtin University of Technology, Perth, Australia.

Khatib, J.M. (2009). "Low Temperature Curing of Metakaolin Concrete." *Journal of Materials in Civil Engineerin, ASCE*, Vol. 21, No. 8, pp. 362-367.

Lisantono, A. and Hatmoko, J.T. (2011). "The Compressive Strength of Baggase Ash-Based Geopolymer Concrete." *Proceeding of The 3rd International Conference of European Asian Civil Engineering Forum (EACEF)*, 20-22 September 2011, Universitas Atma Jaya Yogyakarta., pp. B.156-B.160.

Roy, D.M. (1999). "Alkali-Activated Cements, Opportunities and Challenges." *Cement and Concrete Research*, pp. 249-254.

Sathia, R., Babu, K.G. and Santhanam, M. (2008). "Durability Study of Low Calcium Fly Ash Geopolymer Concrete." *The 3rd ACF International Conference-ACF/VCA*, pp. 1153-1159.

Triwulan, Ekaputri, J.J. and Adiningtyas, T. (2007). "Analisa Sifat Mekanik Beton Geopolymer Berbahan Dasar Fly Ash dan Lumpur Porong Kering Sebagai Pengisi." *Jurnal Teknologi dan Rekayasa Sipil "Torsi"*, Nopember, pp. 33-45.

Troxell and Davis. (1956). *Composition and Properties of Concrete*. McGraw Hill, New York.

Wibowo, N. and Hatmoko, J.T. (2001). "Pemanfaatan Abu Ampas Tebu Sebagai bahan Tambah Beton Mutu Tinggi." *Laporan Akhir Penelitian DCRG*, Nomor Kontrak : 057/ DCRG/URGE/2000, Proyek Penelitian untuk Pengembangan Pascasarjana/URGE, Dirjen Dikti, Depdiknas, Indonesia.

Vijai et al. (2010). "Influence of Curing Types on Strength of Geopolymer."*Research Report GC1*, Curtin University of Technology, Perth, Australia.

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