Nat. Volatiles & Essent. Oils, 2021; 8(4): 5877-5889

Investigating The Temperature Effect On Clicker With 10% Substitution Of Basalt Characterization

Rajiman[1], Muhammad Amin[2], Roniyus Marjunus[3], Agata Ani R[4], David Candra B[5], M. Al Muttaqqi[6], Yulfriwini[7], Marlian R.A Simanjuntak[8], Anwar[9]

[1,7]Faculty of Civil Engineering, University of Bandar Lampung, Indonesia.

[2,5,6]Mineral Technology Research Center-LIPI, Lampung Selatan, Indonesia.

[3,4]University of Lampung,Faculty of Mathematics and Natural Science, Fakultas MIFA Jurusan Fisika, Indonesia.

[8]Universitas PelitaHarapan, Jakarta Selatan, Indonesia.

[9]University of Sang Bumi Ruwa Jurai Bandar Lampung, Bandar Lampung, Indonesia.

Email: rajimanmt@gmail.com

Abstract

This research was conducted to determine the effect of temperature on the chemical content and crystal structure of the cement clinker with a 10% substitution of basalt on the mass of limestone. The cement clinker is made from the composition of limestone, basalt stone, clay, silica stone and iron sand. Basalt stone used came from the East Lampung area. The basalt stone has fulfilled ASTM C618 standard with a total compound of SiO2 + Al2O3 + Fe2O3 of 79.2%. The raw material was then mixed, milled, formed into pellets with a size of 0.8 - 1.4 cm and continued with combustion at calcination temperatures of 1000 ℃, 1100 ℃ and 1200 with a holding time of 2 hours. Based on the results of the XRF test (X-Ray Fluorescence) of the three cement clinker samples with variations in temperature used, the example is closer to the standard at a temperature of 1000 ℃. Three types of crystal samples, including tetragonal, monoclinic, rhombohedral, and orthorhombic, have been considered for the XRD (X-Ray Diffraction) test. Based on the obtained results, there was a secure binding between iron sand, limestone, clay, and silica sand characterized by a smooth surface while basalt stones that look like black holes were not wholly bound.

Keywords: chemical content, crystal structure, cement clicker, element content, basalt stones

Introduction

Cement is an important construction material, which is widely used in civil engineering throughout the world (Laibao et al., 2013). As infrastructure development in Indonesia increases, so does the demand for the cement industry. The need of cement causes the increase of cement consumption level in Indonesia increaseby year (Putri and Indah, 2016). In order to improve the quality of cement, building construction continues to be improved including the quality of materials used

(Waani and Elisabeth, 2017). According to experts working on observations on global warming, 7% of the production of CO2 emissions in nature is derived from cement production. It is also known that about 1 ton of cement produces 1 ton of CO2 (Uzal, 2007) so this encourages experts in the field of building construction engineering to look for alternative materials to replace or substitute cement. In the manufacture of cement preceded in the manufacture of clinker that is the process of changing the physical and chemical raw materials into clinker, where the clinker has undergone a cooling process and then grinding (grinding process). Clinkers are "semi-finished" materials during cement production, produced by burning limestone and alumina-silicate-containing materials such as clay (Rahmawatie and Damayanti, 2017). In making cement, the readiness of the main raw materials such as limestone is very important, where limestone in the formation of cement requires a composition of 80%. So that if their needs are not met, the results will unmet demand and the cessation of the production process (Fitriadi and Wahyu, 2014). Therefore an alternative material is needed to prevent the scarcity of raw materials, but it has a composition that is similar to limestone, so it does not affect the quality of cement produced. Pozzolan material such as basalt is a material from the coal industry that can be used as a substitute material in cement (Waani and Elisabeth, 2017). The amount of basalt stone material reserves in Lampung Province is 318,480,000 tons and has not been explored optimally. Based on the analysis of the chemical composition of scoria basal stone material from Labuhan Maringgai, East Lampung, Indonesia, namely SiO2 + Al2O3 + Fe2O3 is 78.66%. Basuhan scoria Labuhan Maringgai East Lampung, Indonesia fulfills ASTM C618 (American Society for Testing and Materials C168) requiring that the chemical component is a SiO2 + Al2O3 + Fe2O3 minimum of 70% (Rajiman et al., 2018). So many reserves have only been used as a foundation for housing construction. By optimizing basalt minerals, the economic value will increase, for this reason it is necessary to conduct research on the characteristics of basalt minerals as an alternative raw material for cement clinkers (Amin and Suharto, 2017). When basalt reacts with other chemicals it does not produce reactions that are harmful to the environment. Therefore basalt is suitable for applications, especially in the field of ceramics (Sharma, 2016). Basalt is chemically rich in magnesium oxide, calcium, sodium, potassium, silicon and iron (Dhand et al., 2014). Basalt stone can be used as an alternative raw material for Portland cement (Andrade, 2010) especially as a substitute for clay raw materials in certain areas where clay resources have begun to be scarce. It is recommended that basalt stones can replace clay in 1: 1 proportions (Andrade, 2010). According to research by El-Desoky et al., 2017, clinker furnaces with temperatures around 1200-1450 ° C show good combustion. All samples that have been sintered at 1450 ° C have a unique clinker structure. The dominant mineralogical phases such as alit, winding, calcium aluminate, ferrite and lime crystallized to produce a peak of 2 Theta (2θ). The levels of various types of reactions in clinkers according to El-Hafiz et al., 1971, the levels of various types of reactions in clinkers that are affected by temperature are as follows:

100-500 °C	The clinker is dried and the water content evaporates.
500-600 °C	Dehydroxylation from clay $2SiO_2Al_2O_3.2H_2O \rightarrow 2SiO_2 + Al_2O_3 + 2H_2O \uparrow$
700 °C	Silicate activation and water evaporation
700-900 °C	Decarbation of calcium carbonate with the main combination of alumina, ferric oxide
900-1200 °C	Belite formation from $2CaCO_3 + SiO_2 \rightarrow C_2S + CO_2 \uparrow$
>1250 °C	Liquid phase formation (aluminate and ferrite)
1300 °C	The liquid phase appears and the C2S reaction with CaO forms to form C3S
1450 °C	As the reaction is complete, alite and belite increase scattered in several small sizes of limestone

Based on the problems and solutions above, the study is conducted to assess the effect of temperature in the processing of cement clinkers by substituting (10%) of basalt against the mass of limestone in the process of making cement clinkers. Cement clinker is made of the composition of substitution limestone basalt, clay, silica stone and iron sand.

The behavior of cement at high temperatures is influenced by several factors, including the rate of temperature rise and the aggregate type and stability. Abrupt temperature changes can cause cracking and spalling due to thermal shock, and aggregate expansion can also produce distress within the concrete. Totten, I. M. (2008).

High temperatures also affect the compressive strength of concrete. Above 212º F, the cement paste begins to dehydrate (loses chemically combined water of hydration), which gradually weakens the paste and paste-aggregate bond. Monroe, J., Wicander, R., & Hazlett, R. (2006).

The temperature that concrete has reached often can be determined by observing color changes in the aggregate. For example, limestone aggregates turn pink when they reach about 570º F, which can result in substantial loss of compressive strength. Perko, H. A. (2002).

Research Methodology

Sample preparation (Pellet making), procedure is based on the following steps:

Raw materials including limestone, basalt, clay, silica sand and iron sand were taken with a percentage of basalt (8% = 160 g), limestone (72% = 1440 g), clay (9 % = 180 g), silica as much (10% = 200 g), and iron sand as much (1% = 20 g). The composition of the raw material was prepared and then ground for 5-6 hours in a ball mill until it becomes a powder mixture. The powder was filtered using 270 mesh sieve, clinker pellet formation using a pelletizing machine with water added to the powder mixture that has been ground with a ball mill and formed into small granules with a size of 0.8-1.4 cm, pellets were dried for 1- 2 days at room temperature, the pellet was heated for 5-6 hours at 100 ℃. .

The reduction process (heat treatment), the reduction process was carried out with the following stages:

12 dried pellets as many as 12 grains on a gravitational disc were inserted into the mufle furnace with room temperature as the initial temperature, the temperature was raised slowly on the mufle furnace until it reaches the specified temperature that was at a temperature of 1000oC, 1100oC, 1200oC, the process of raising the temperature was stopped when the furnace reached the temperature specified number, sintering carried out for 2 hours, the sample was left at temperature room until the temperature in the sample was equivalent to room temperature.

Fig 1 depicts the flowchart regarding the steps to analyze the effect of temperature on samples:

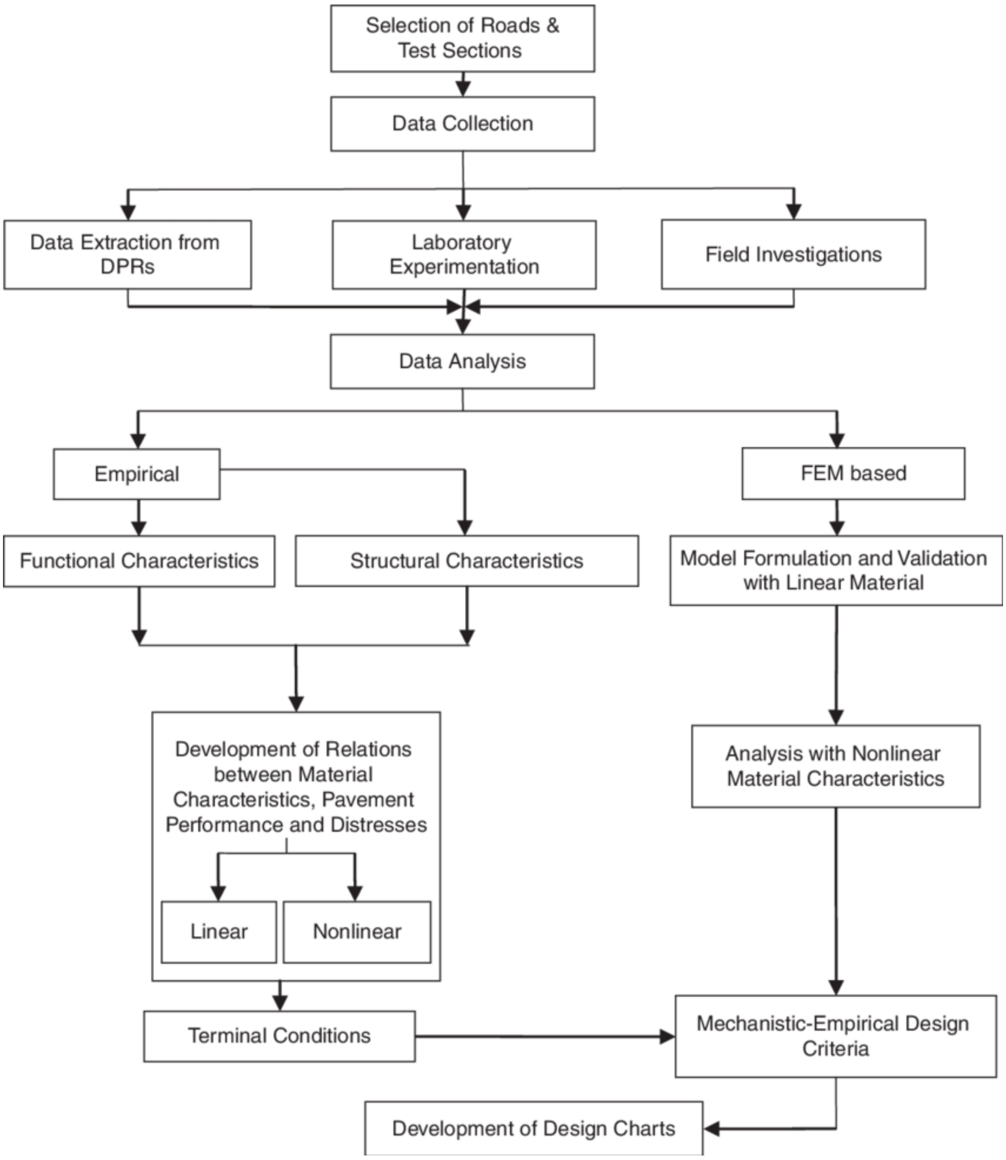

Figure 1. Procedure for data analysis

Results and Discussion

The raw material used in making cement clinker was characterized by using the XRF method, the results of the XRF analysis on the raw material for making cement clinker are shown in Table 1

Table 1: Results of XRF analysis of raw materials for cement clinker

Component	Basalt Stone	Lime Stone	Silica Stone	Iron-sand	Clay	Unit
SiO_2	47,3	4,036	95,2	18,7	53,8	%
Al_2O_3	18,9	1,653	3,1	6,3	27,4	%
Fe_2O_3	12,9	0,552	0,4	58,0	15,5	%
CaO	10,9	92,973	0,8	3,1	0,2	%

MgO	4,4	0,399	-	4,8	0,3	%
TiO_2	1,3	0,105	0,1	6,7	1,3	%
K_2O	0,5	0,104	-	0,2	0,8	%
Na_2O	2,8	-	-	-	-	%
MnO	0,1	-	-	0,5	-	%
SO_3	-	-	-	0,5	-	%
V_2O_5	-	-	-	0,3	-	%
Cr_2O_3	-	-	-	0,1	-	%
Eu_2O_3	-	-	-	0,2	-	%

Data in Table 1 gained by XRF analysis it shows that the chemical content in limestone was dominated by CaO compounds as much as 92.9%, while the remaining compounds were SiO2, Al2O3, MgO, K2O, TiO2, and Fe2O3. For silica stones, thus the chemical content mainly is from by SiO2 compounds of 95.2% and the rest were Al2O3, CaO, TiO2, and Fe2O3 compounds. For iron sand, the highest chemical content was found in Fe2O3 compound at 58.0%, while the rest were MgO, Al2O3, SiO2, SO3, K2O, CaO, TiO2, V2O5, Cr2O3, MnO, and Eu2O3. For the most prominent clay compounds, SiO2 was 53.8%, and Al2O3 was 27.4%, while the rest were MgO, Fe2O3, K2O, CaO and TiO2 compounds. As for the chemical content in basaltic rocks, the SiO2 mixture was dominated by 47.3%, Al2O3 is 18.9%, and Fe2O3 is 12.9%. Based on ASTM C168 pozzolan requirements, the minimum SiO2 + Al2O3 + Fe2O3 compound content was ± 70%. However, basalt stone had all three compounds of 79.2%. Thus basalt had fulfilled the requirements as a raw material for pozzolan for making cement clinker. Furthermore, an analysis of the cement clinker results from combustion, XRF analysis results of the chemical content of the cement clinker sample to the combustion temperature variation that was sintered for 2 hours with a substitution of 10% basalt stone to the mass of limestone is shown in Table 2.

Table 2 : Data analysis of XRF analysis of raw materials for cement clinker

Compound	**Combustion Temperature Variations**				
	1000°C	1100°C	1200°C	ASTM C150	Unit
CaO	60,93	55,64	55,75	65,5 - 66,2	%
SiO_2	21,18	25,38	26,36	21 - 22	%
Fe_2O_3	6,84	7,11	7,45	4 – 4,5	%
Al_2O_3	8,22	7,57	7,08	5 – 5,5	%
MgO	1,31	1,48	1,86	Max 1,5	%

SO_3	0,27	1,39	-	Max 1	%
TiO_2	0,64	0,69	0,67	-	%
MnO	0,12	0,27	0,13	-	%
K_2O	0,28	0,26	0,39	-	%

Based on the results of the XRF analysis in Table 5.2, the cement clinker sample powder with the treatment temperature closest to the ASTM C150 standard for CaO content was at 1000 °C, SiO2 was at 1000 °C, Fe2O3 was at 1000 °C, Al2O3 was at 1200 °C MgO was at 1000 °C and SO3 was at 1000 °C. So that it can be said that the cement clinker content with temperature variations closer to ASTM C150 was at a temperature of 1000 °C.

Characterization of the crystal structure of cement clinker samples in powder form was carried out using PANRlytical XRD. The cement clinker sample was inserted into the holder then an XRD analysis was performed to see the compounds arranged in the cement clinker sample after the reduction process. The process of reducing the cement clinker was done by heating it in a furnace. In this test using three samples of cement clinker namely cement clinker heated at temperatures of 1000 °C, 1100 °C, and 1200 °C. Each sample was heated for 2 hours. The results of the cement clinker characterization can be seen in Figure 1, 2 and 3

XRD test results of cement clinker samples at a temperature of 1000 °C, for cement clinker samples carried out by heating at a temperature of 1000 °C with a holding time of 2 hours and XRD test results obtained as in Figure 1

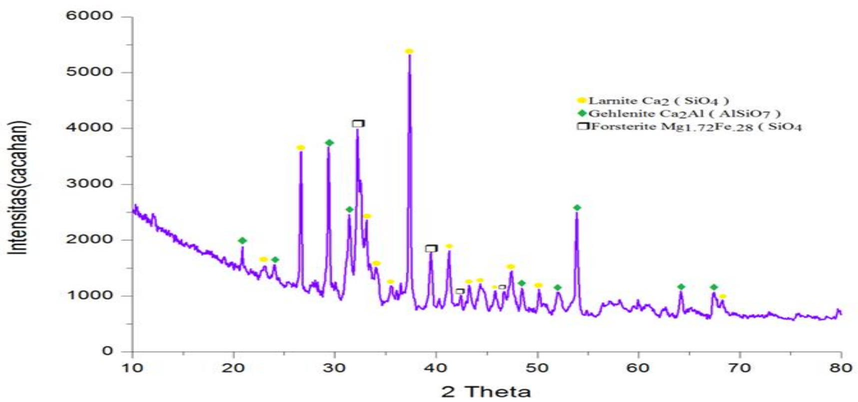

Figure 2. The compounds are arranged in a cement clinker sample at a temperature of 1000 ° C with a holding time of 2 hours.

The graph in Figure 1 shows the crystalline phase of the cement clinker sample at 1000 °C with a holding time of 2 hours. The formation of monoclinic crystalline structure with the highest peak of

Ca at an angle of 37,3784o with the Larnite phase with chemical compound Ca2 (SiO4). In addition to the position 37.3784 ° other peaks were at position 2θ (23.1018o, 26.6473o, 28.2071o, 32.5529o, 33.1172o, 34.1503, 41.2621o, 42.4464o, 43.2717o , 44,3655 o, 45,818 o, 47,3915 o, 50,1739 o, 58,1511 o, and 68,2573 o). In addition to the Larnite phase the Gehlenite compound with the Ca2Al (AlSiO7) chemical compound formed a tetragonal crystal structure. In the tetragonal crystal structure with the highest peak was formed with an angle position of 29.33873o. Other peaks are also in the position of 2θ (20.8718o, 24.0519o, 31.4276o, 48.4707o, 52.0544o, 53.8732o, 61.0135o, 64 , 1404o and 67.3556o). Then orthorhombic crystal structure formed with the mineral First-ratewith the chemical compound Mg1.72Fe.28 (SiO4) with a peak of 2θ at 32.2177o, and the other peak was also at position 2θ (35.5826o, 36.5026o, 39.4885o, 40.2782o, 46.6843o, 56.581o and 62.6267o.

Cement clinker sample at a temperature of 1100 °C, the cement clinker samples were heated at a temperature of 1100 °C with a holding time of 2 hours and XRD test results are obtained as in Figure 2.

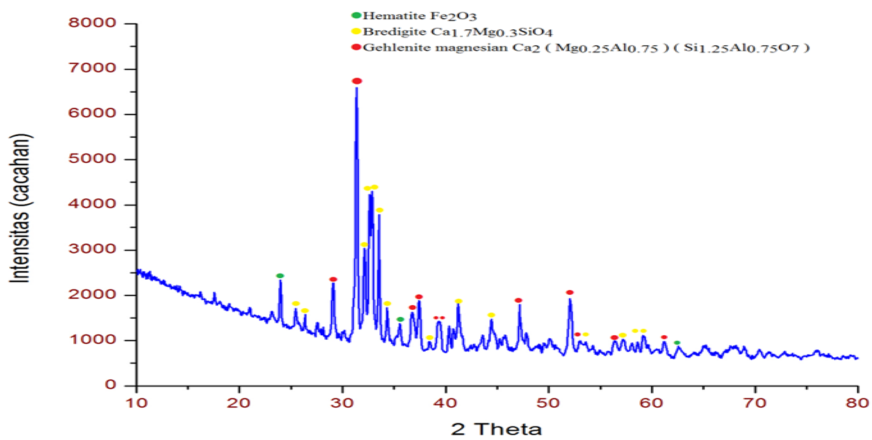

Figure 3. The compounds arranged in a cement clinker sample at 1100 ° C with a holding time of 2 hours

The graph in Figure 2 shows the highest crystalline phase that was a cement clinker sample with temperature of 1000 °C and with a holding time of 2 hours. The formation of a tetragonal crystalline structure with the highest peak belonging to Ca at position 270 31.3703o of magnesiangehlenite phase with chemical compounds that was Ca2 (Mg0.25Al0.75) (Si1.25Al0.75O7). In addition to the 31.3703o position, the other peaks were also in the position of 2θ (23.18181, 29.0868o, 36.6901 °, 37.431o, 39.2519o, 39.4928o, 45.8021o, 47.1941o, 50.1135o, 52.0715o, 53.2772o, 56.33382o, 61.1777o, 65.1016o, 67.949o, and 76.0103o). In addition to the magnesiangehlenite phase, Bredigite compounds with the chemical compound Ca1.7Mg0.3 SiO4 were also formed, orthorhombic crystal structures. In this crystal structure the highest peak was formed with an angle position of 32.624o. Other peaks were also in position 2θ (25.4684o, 26.3603o, 27.5439o, 30.1388o, 32.1386o, 32.9119o, 33.5333o, 34, 3317o, 38.4329o, 40.3272 o, 40.7599o, 41.2256o, 43.6143o, 44.4113o, 45.2331o, 47.8456o, 49.5264o, 54.2678o, 57.1423o, 58.6335o , 59.1218o, 68.9647o and 70.4678o). Then formed a rhombohedral crystal structure such as the mineral Hematite with a chemical compound Fe2O3 had a peak with a position of 2θ at 23.9873o, with another peak at position 2θ (35.5688o, 62.589o).

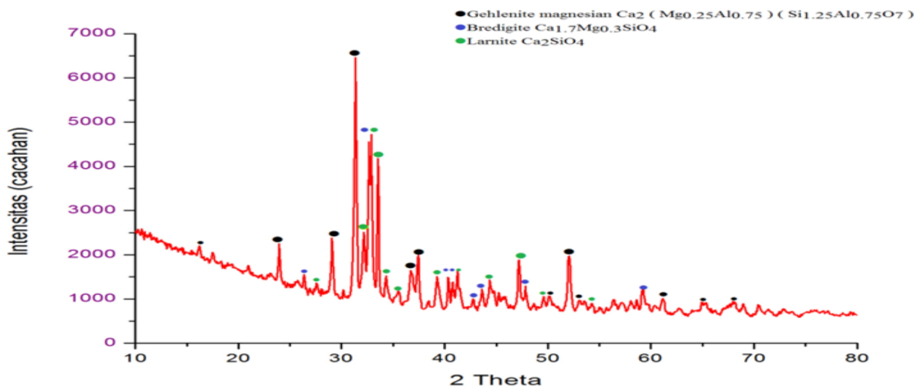

Figure 4. The compounds arranged in a cement clinker sample at 1200 ° C with a holding time of 2 hours

The graph in Figure 3 shows the highest crystalline phase in a cement clinker sample at 1200 °C with a holding time of 2 hours. The formation of a tetragonal crystalline structure with the highest peak of Ca at an angle of 31.3624o phase of the magnesian Gehlenite phase with chemical compounds was (Mg0.25Al0.75) (Si1.25Al0.75O7). In addition to the 31.33624o position, the other peaks were also in the 2θ position (16.1989o, 23.9696o, 29.0925o, 36.6928o, 37.4274o, 50.1295o, 52.0412o, 53.0452o, 61.2588o, 62.7966o, 65,0009o and 68.0865o). In addition to the magnesian Gehlenite phase formed Bredigite compounds also had a chemical compound Ca1.7 Mg0.3 SiO 4 formed orthorhombic crystal structure. In the orthorhombic crystal structure the highest peak was formed with an angle position of 32.6371o. Other peaks were also in the position of 2 26 (26.3765o, 33.5475o, 40.3495o, 40.7646o, 42.7593o, 43.6319o, 45.2609o, 47 , 2165o, 47.8648o, 59.1833o, 68.961o, 70.4598o and 72.8017o). Then the Larnite Ca2SiO4 mineral formed with monoclinic crystal structure has a score of 33 with the highest peak of 32.9118o. In addition, Larnite minerals had other peaks at position 2θ (27.5745o, 32.1555o, 34.2929o, 35.5609o, 39.2466o, 41.2265o, 44.33657o, 45.6496o, 49.5934o, 54.2816o, 56.4078o, 57.2068o, and 58.6243o).

The type of cementitious material, the structural member size, and the curing climate were shown to significantly affect the initial internal temperature of mass concrete structures. Elevated temperatures did not affect the early-age strength gain of concrete made with ordinary Portland cement cured under summer weather conditions, but the concrete made with belite-rich Portland cement or fly ash showed a significant increase in early-age strength development. Elevated temperatures resulted in long-term strength loss for all materials.

The bound water content of core specimens cured at elevated temperatures was larger than that of the standard specimen at early ages. However, the bound water content was lower than that of the standard specimen after 7 days for the OPC sample and after 28 days for the BPC and FPC samples. This trend could be correlated to a similar trend in compressive strength.

The use of fly ash in mass concrete structures reduces the amount of calcium hydroxide due to the pozzolanic reaction. The pozzolanic reaction accelerates with an increase in the initial internal temperature and hence less calcium hydroxide was present under summer curing conditions.

The total porosity of the core specimens cured under elevated temperatures was higher than that of the standard specimen. The porosity appeared to rise after 7 days in the OPC material and after 28 days in the BPC and FPC materials. The total porosity of the concrete made under winter weather conditions was smaller than that made under summer weather conditions. Due to the elevated internal temperatures in the structures, the peak of the pore size distribution curve was shifted toward the direction of smaller pores and the number of smaller pores was increased.

Conclusion

Based on research that has been done, it can be concluded that the variation of combustion temperature can affect the crystal structure and chemical content of the cement clinker. The element content obtained from the XRF test was dominatedby CaO, SiO_2, Fe_2O_3, and Al_2O_3. Based on ASTM C150 results from the three temperature variations used, the cement clinker sample is closer to the standard at 1000 °C. Based on the XRD test results, the three samples had tetragonal, monoclinic, rhombohedral, and orthorhombic crystal structures. The highest peaks were at 1100 °C and 1200 °C with tetragonal crystalline phase. As for the MO test results, there was a strong binding between iron sand, limestone, clay, and silica sand characterized by a smooth surface while basalt stones that look like black holes were not completely bound.

Acknowledgement

The author would like to thank the Head of the Mineral Technology Research Institute - LIPI for granting the author's permission to conduct research and granting the researcher's permission to use research infrastructure.

References

Amin, M. dan Suharto. 2017. Pembuatan Semen Geopolimer Ramah LingkunganBerbahan Baku Mineral Basal GunaMenuju Lampung Sejahtera. BPTM-LIPI TanjungBintang. Lampung Selatan.

ASTM C618. 2008. Standard Specification For Coal Fly Ash And Raw Or CalcinedNaturalpozzolan For Use In Concrete. American Society For Testing And Materials. West Conshohocken, PA (USA): ASTM International.

Andrade F. R. D., M. Pecchio, D. P. Bendoraitis, T. J. Montanheiro4, and Y. Kihara. 2010. Basalt Mine-Tailings As Raw-Materials For Portland Clinker. Ceramica. Pp 39-43

Ardiantono, F. A., Nana Dyah S, danLintangKaruniaPutri. 2018. KarakterisasiKomponenAktifPozzolanUntukPengembangan Portland Pozzolan Cement (PPC). JurnalTeknik Kimia. Vol. 12 No. 2 Pp 52-56

Bendersky, Leonid. 2001. Handbook of Powder Metallurgy 2nd Edition. New York: Chemical Publising Co.

Benmohamed, M., Rabah A., AmelJmayai, Abdesslem Ben H. A., and Hafsia Ben R. 2016. Morphological Analysis of White Cement Clinker Minerals: Discussion on the Crystallization-Related Defects. International Journal of Analytical Chemistry. Pp 1-10

Chirikure, Shadreck., Robert B. Heimanndan David Killick. 2016. The Technology of tin Smelting in The Rooiberg Valley, Limpopo Provience South Africa, Ca. 1650-1850. Journal Of Archaeological Science. Pp 1656-1669

Dhand, V., Garima Mittal, Kyong Y.R., and David H. 2014. A Short Review on Basalt Fiber Reinforced Polymer Composites. Accepted Manuscript. Pp 1-63

El-Desoky, N.I., N.M. Hashem., A. Elkomydan Z. R. Abo-elezz. 2017. Physiological Response and Semen Quality of Rabbit Bucks Supplemented With Moringa Leaves Ethanolic Extract during Summer Season. The Animal Consortium. Vol. 11 Pp 1549-1557

El-Hafiz, Nabil A., Mohamed W. Abd El-Moghny., Hatem M. El-DesokydanAtef A. Afifi. 2015. Characterization and Technological Behavior of Basalt Raw Materials for Portland Cement Clinker Production. International Journal of Innovative Science, Engineering & Technology. Vol. 2, No. 7, ISSN : 2348-796

Fitriadi, RatnantodanWahyu Yoga Utama. 2014. Optimisasi Tingkat PersediaanBahan Baku BatuKapur Di PT Semen Indonesia Unit Tuban I. SimposiumNasionalTeknologiTerapan.ISSN : 2339-208X.

Ishlah,T. 2008. PeluangPendirianIndustriSkala Kecil di Kepuluan Maluku dan Wilayah Papua. BuletinSumberDayaGeologi. Vol. 3 No 3

Kahn, Bruce E. 2002. Hand Out Scanning Electron Microscopy. Jerman Institute. Germany.

Laibao, L., Zhang Yunsheng., Zhang Wenhua., Liu Zhiyong., dan Zhang Lihua. (2013). Investigating The Influence Of Basalt As Mineral Admixture On Hydrationand Microstructure Formation Mechanism Of Cement. Construction and Building Materials. 48 (13). Pp 434–440

Marzuki I. 2009. AnalisisPenambahan Additive BatuGampingTerhadapKualitasKomposisi Kimia Semen Portland. JurnalChemica. Vol. 10 No 1. Pp 64-70

Ningsih, T., R. Chairunnisa, and S. Miskah. 2012. PemanfaatanBahan Additive Abu SekamPadiPada Cement Portland PT. Semen Baturaja (Persero). JurnalTeknik Kimia UniversitasSriwijaya. 4 (18): 59-67

Oktamuliani S., Samsidar, NasriMz., dan Nehru. 2016. Identifikasi Mineral PadaBatuan Granit Di GeoparkMeranginProvinsi Jambi Menggunakan X-Ray Diffraction (XRD) Dan Scanning Electron Microscopy. JoP. Vol 1 No. 1 Pp 12-17

Patty, Diana J. 2013. PenentuanUnsurDalamRambutBerdasarkanKarakteristikPolaFlouresensiSinar X (XRF). Prosiding FMIPA UniversitasPattimura. Pp 219-225

Putri, Nilda Tri dan Indah KurniaRamdhani. 2016. PenjadwalanCement Mill BerbasisMinimasiFaktorKlinkerDalam Proses Pembilasan Dan ImporKlinker. JurnalOptimasiSistemIndustri. Vol. 15, No. 1, ISSN : 2088-482.

Rahmawatie, BudhydanRetnoWulanDamayanti. 2017. PengendalianKualitasProdukKlinkerPada PT. XYZ DenganMenggunakanGrafik T^2Hotteling.JurnalProsiding Seminar danKonferensiNasional. ISSN : 2579-6429

Rajiman., Alisjahbana., Sofia W., Riyanto., Hery; Hasyim,Cholil; Setiawan, M. Ikhsan; Harmanto, Dani; Wajdi, and MuhBaridNizarudin. 2018. Substitution Local Resources Basalt Stone Scoria Lampung, Indonesia, As A Third Raw Material Aggregate To Increase The Quality Of Portland Composite Cement (PCC). International Journal of Engineering & Technology. 7 (2): 484 - 490

Saraya, Mohamed El-ShahateIsmaiel. 2014. Study Physico-Chemical Properties Of Blended Cements Containing Fixedamount Of Silica Fume, Blast Furnace Slag, Basalt And Limestone, Acomparative Study. Construction and Building Materials. 72 (14): 104-1012

Suryanarayana, C dan Norton M G. 1998. X-Ray Diffraction. Plenum Press. New York.

Uzal B, Turanli L, dan Mehta PK. 2007. High-Volume Natural Pozzolan Concrete for Structural Applications. ACI Materials Journal. 104(5):535–538

Waani, JoiceElfridadanLintong Elisabeth. 2017. Subtitusi Material PozolanTerhadap Semen padaKinerjaCampuran Semen. JurnalTeoritisdanTerapanBidangRekayasaSipil. Vol. 24 No. 3, ISSN : 0853-2982

Widyawati, N. 2012. Analisa Pengaruh Heating Rate Terhadap Tingkat Kristal Dan Ukuran Butir Lapisan BZT Yang Ditumbuhkan Dengan Metode Sol Gel. Universitas Sebelas Maret. Surakarta

Totten, I. M. (2008). An Earth science course for pre-service teachers. Journal of Geoscience Education, 56(5), 456-465.

Monroe, J., Wicander, R., & Hazlett, R. (2006). Physical geology: exploring the earth. Nelson Education.

Subramaniam, A. P. (1956). Mineralogy and petrology of the Sittampundi complex, Salem district, Madras State, India. Geological Society of America Bulletin, 67(3), 317-390.

Farahani, J. N., Shafigh, P., Alsubari, B., Shahnazar, S., & Mahmud, H. B. (2017). Engineering properties of lightweight aggregate concrete containing binary and ternary blended cement. Journal of cleaner production, 149, 976-988.

Perko, H. A. (2002). Theoretical and experimental investigations in planetary dust adhesion (Doctoral dissertation, Colorado State University).