International Journal of Sustainable Construction Engineering & Technology
ISSN:2180-3242

REVIEWER EVALUATION

A: Basic Information

Title:	EXPERIMENTAL STUDY ON THE POTENTIAL USE OF PUMICE BRECCIA AS COARSE AGGREGATE IN STRUCTURAL LIGHTWEIGHT CONCRETE

B: Evaluation

Does the title accurately reflect the content and purpose of the paper?	Yes.
Abstract sufficiently summaries the paper's content?	Yes.
Adequacy and Relationship to Literature	The literature review was not concluded by noting the uniqueness of the present study from the previous one. Similar previous works on using lightweight aggregate to produced LWC were not reviewed.
Methodology / Material	Well explained.
Result and analysis	Acceptable.
Discussion and Implication of research	Acceptable.
Language and Quality of Communication	Need to be improved. Some grammar mistakes were noticed (see comments scribbled on the manuscript).
Originality and Contribution to the field	Significantly contribute to the knowledge in the area of lightweight concrete.

C: Recommendation (Please √ where appropriate).

Accept	
Accept with minor correction	√

International Journal of Sustainable Construction Engineering & Technology
ISSN:2180-3242

Accept with major correction	
Reject: (Please provide specific comment)	

Comments to Author:

As scribbled on the manuscript as attached.

International Journal of Sustainable Construction Engineering & Technology (ISSN: 2180-3242)
Vol xx, Issue xx, xxxx

EXPERIMENTAL STUDY ON THE POTENTIAL USE OF PUMICE BRECCIA AS COARSE AGGREGATE IN STRUCTURAL LIGHTWEIGHT CONCRETE

Abstract

Lightweight concrete application in construction works is growing rapidly in these recent years due to its advantages over ordinary concrete. In this research, pumice breccia which can be found abundantly in Indonesia is proposed to be utilized as the coarse aggregate. This paper experimentally examines the effects of aggregate compositions and partial replacement of portland cement with silica fume on the demoulded density and compressive strength of pumice breccia aggregate lightweight concrete. Nine groups of concrete test specimens were investigated. Test results indicate that he demoulded density of lightweight concrete tends to decrease inversely to the addition of the volume fraction of pumice aggregate into the mixes. Structural lightweight concrete can be produced when the mixes utilized 55% to 75% volume fraction of coarse pumice aggregate to the total aggregate, and the compressive strength of structural lightweight concrete can be improved proportionally up to 13.07% when the portland cement partially replaced with silica fume up to 9% by weight of cement.

***Keywords:** Hardened properties, Lightweight concrete, Pumice breccia, Silica fume*

1.0 Introduction

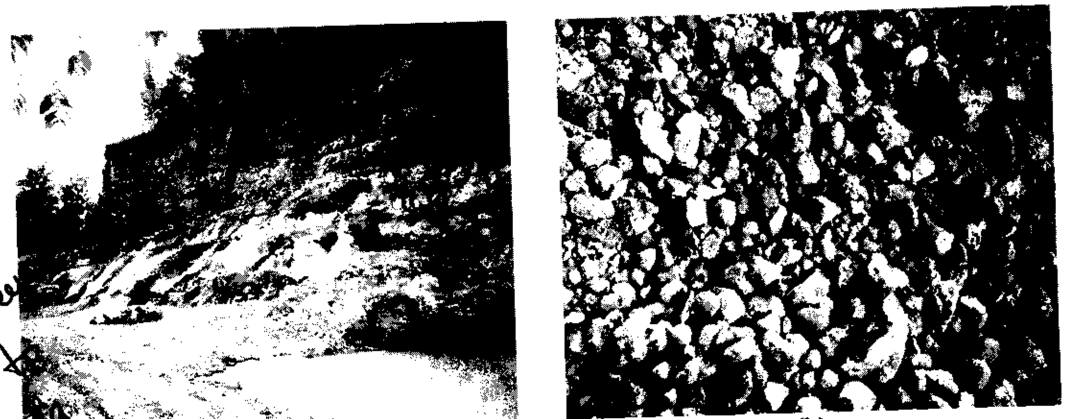
Lightweight concrete (LWC) application for construction works has been widely used in these recent years both for structural and non-structural purposes due to its advantages over ordinary concrete. The utilization of lightweight concrete in modern construction works is increasing, owing to the advantage that its lower density results in a significant benefit in terms of load bearing elements of smaller cross sections and a corresponding reduction in the size of the foundation. Furthermore, the reduction in weight by the use of lightweight concrete will be advantageous, especially for building structures which are located in seismic zones.

The maximum density of concrete which allowed to be categorized as lightweight concrete in some European construction codes is limited to 1850 kg/m^3 [1], while the limitation in Indonesian National Standard is 1900 kg/m^3 [2], compared with that of 2400 kg/m^3 for normal weight concrete (NWC). According to most of the concrete structures codes in some American, European and Asian countries, mixtures of uncrushed and/or crushed grains for natural and/or manufactured minerals can be classified as lightweight aggregate when it has dry loose bulk density less than 1200 kg/m^3 for fine aggregate and 1000 kg/m^3 for coarse aggregate [1-6].

Some methods that widely used for lightweight concrete production include utilization of natural lightweight aggregates such as diatomite, volcanic cinders, and pumice or artificial by-products such as expanded shale, clay, slate, perlite, and sintered pulverized fuel ash (PFA). Lightweight concrete that developed using natural or artificial aggregate is classified by the ACI 213 (2003) into three categories based on its strength and density. The first category is termed low strength, corresponding to low density and therefore mostly used for insulation purposes. The second category is moderate strength which is used for filling and block concrete. The third category is structural lightweight concrete which can be utilized for reinforced concrete. According to the classification given by ACI 213 (2003), LWC for structural purposes is defined as concrete with a density range of 1120 to 1920 kg/m^3 and strength grade not less than 17 MPa [6]. In this research, pumice breccia which can be found abundantly in Indonesia proposed to be utilized as the coarse aggregate for the development of structural lightweight aggregate concrete. The main objectives of this research are: (1) optimizing the composition between natural sand that is used as fine aggregate and pumice breccia which is proposed to be utilized as coarse aggregate to develop lightweight aggregate concrete mixtures which aimed to meet the technical specification for structural applications, and (2) examining the effects of mineral admixtures addition on the hardened properties of lightweight aggregate concrete using pumice breccia as coarse aggregate.

2.0 Literature Review

Pumice breccia is a type of coarse grained pyroclastic rocks with its breccia fragments dominated by pumice with highly variable shape and size, white-gray color, and its matrix consisting of limestone with amorphous silica. Pumice breccia formed by the volcanism activity. Therefore, it can be found abundantly along the volcanic line in Indonesia. The location that had been identified as the largest pumice breccia deposit area is Semilir Formation. The Semilir Formation was typically originated from products of a very explosive volcanic activity. It is a widespread mountainous area at the southern part of Java Island. The formation is widely distributed from the west side at Pleret and Piyungan areas in Bantul Regency, Special Province of Yogyakarta until Eromoko area in Wonogiri Regency, Central Java Province in the east [7]. Based on the official data which is released by the center of investation resources development in the Indonesian ministry of public works, the Special Province of Yogyakarta has 2.50 billion m^3 deposit of pumice breccia which is located in Bantul, Gunung Kidul and Sleman region [8].



(a) (b)

Figure 1: (a) Part of Pumice Breccia Deposit in the Semilir Formation, (b) Crushed Pumice Breccia

ACI 213R-03, Guide for Structural Lightweight Aggregate Concrete defines structural lightweight-aggregate concrete made with structural lightweight aggregate as defined in ASTM C 330. The concrete has a minimum 28-day compressive strength of 2500 psi (17 MPa), an equilibrium density between 70 and 120 lb/ft^3 (1120 and 1920 kg/m^3), and consists entirely of lightweight aggregate or a combination of lightweight and normal-density aggregate. From the standpoint of workability and other properties, it is a common practice to use normal-weight sand as fine aggregate, and to limit the nominal size of the lightweight coarse aggregate to a maximum of 19 mm. According to ASTM C 330, fine lightweight and coarse lightweight aggregates are required to have a dry-loose weight not exceeding 1120 kg/m^3 (70 lb/ft^3) and 880 kg/m^3 (55 lb/ft^3), respectively [9].

Silica fume (SF) is a byproduct of the silicon and ferrosilicon industry. The reduction of high-purity quartz to silicon at temperatures up to 2000 °C produces SiO_2 vapours, which oxidizes and condense in the low-temperature zone to tiny particles consisting of non-crystalline silica. Silica fume is a very reactive pozzolanic material because of its extreme fineness and very high amorphous silicon dioxide content. Mechanism of silica fume in concrete can be described basically under three roles: (i) pore-size refinement and matrix densification, (ii) reaction with free-lime, and (iii) cement paste–aggregate interfacial refinement. In concrete the characteristics of the transition zone between the aggregate particles and cement paste play a significant role in the cement-aggregate bond. Silica fume addition influences the thickness of transition phase in mortars and the degree of the orientation of the CH crystals in it. The thickness compared with mortar containing only ordinary Portland cement decreases and reduction in degree of orientation of CH crystals in transition phase with the addition of silica fume. Hence mechanical properties and durability are improved because of the enhancement in interfacial or bond strength [10]. A higher ultimate strength can be obtained by designing a mix with a low initial strength gain and cementitious additions. This is partially due to avoidance of micro-cracking associated with high thermal gradients. This effect can be facilitated if strength compliance is measured at 56 instead of 28 days [11].

3.0 Methodology

3.1 Materials and Mix Proportion

The mixtures were prepared with blended cement containing 23.13% of SiO_2, 8.76% of Al_2O_3, 4.62% of Fe_2O_3, 58.66% of CaO, 0.90% of MgO, 2.18% of SO_3, and 1.69% of loss on ignition which satisfies to the requirements in the Indonesian Standards for Pozzolan Portland Cement [10]. The coarse aggregate prepared using continuously graded crushed lightweight pumice breccia from Bawuran Mountain, Bantul District in the Special Province of Yogyakarta which is one of the largest pumice breccia deposits in Indonesia. This pumice breccia has dry-loose bulk density of 760 kg/m^3 with particle density of 1620 kg/m^3 which is satisfied to the technical specification of lightweight aggregate. Therefore, it is proposed to be utilized as coarse aggregate in the mixtures. The coarse aggregate with maximum size of 20 mm were pre-wetted and submerged in water in 24 hours and then air-dried to be in saturated surface dry condition before mixing process. Well-graded natural sand with specific gravity of 2.65 was employed as the fine aggregate. Silica fume, and naphthalene formaldehyde sulfonate based high range water reducer (HRWR) which is comply ASTM C 494-92 Type F were also utilized as concrete admixtures in this research. Detail of mixes proportion can be found in the following Table 1.

Table 1: Mixture Proportion

Mix Type	Cement (kg/m^3)	Silica Fume (kg/m^3)	Water (kg/m^3)	W/B	Pumice breccia (kg/m^3)	Sand (kg/m^3)	HRWR (lt/m^3)
M1	500	0	225.00	0.45	420.101	846.252	4.70
M2	500	0	225.00	0.45	513.456	692.388	4.70
M3	500	0	225.00	0.45	606.812	538.524	4.70
M4	500	0	225.00	0.45	700.168	384.660	4.70
M5	500	0	225.00	0.45	793.524	230.796	4.70
M6	485	15	225.00	0.45	606.812	538.524	4.70
M7	470	30	225.00	0.45	606.812	538.524	4.70
M8	455	45	225.00	0.45	606.812	538.524	4.70
M9	440	60	225.00	0.45	606.812	538.524	4.70

3.2 ~~Detail of~~ Experimental Works

Hardened properties of concrete mixes were evaluated based on its demoulded density and compressive strength. In order to ~~observe~~ the density on demoulding as declared in BS EN 8500:1 2006 [12], specimens' weight and dimensions were measured 24 hours after concrete casting. The compressive strength were evaluated after the hardened concrete specimens were cured with 56 days water immersion since some of the mixtures utilized silica fume as mineral admixture. Compressive strength and modulus of elasticity evaluation for all the variants of concrete were done on cylinders of 150 mm in diameter and 300 mm length, based on ASTM C-469 [13]. The compressive strength of the concrete was determined as the average of those three specimens for each variant.

4.0 Results and Discussions

In order to evaluate the effects of the aggregate composition and utilization of silica fume as mineral admixture on hardened properties of LWC with pumice breccia aggregate, demoulded density, the compressive strength of the concrete specimens were tested after 56 days of water immersion to achieve more representative results of concrete strength. The following Table 2 shows the results of the tests.

Table 2: Effects of Aggregate Composition and Silica Fume Addition on Hardened Properties of Lightweight Concrete with Pumice Breccia Aggregate

Mix type	Demoulded density (kg/m^3)	Compressive strength (MPa)
M1	1995.146	29.514
M2	1897.910	24.198
M3	1845.090	18.424
M4	1755.056	18.376
M5	1738.850	16.476
M6	1824.682	20.110
M7	1851.092	20.228
M8	1861.896	20.832
M9	1854.093	18.701

Effects of the volume fraction of pumice breccia aggregate which was used as coarse aggregate to the total volume of concrete aggregate on the demoulded density of hardened lightweight pumice breccia aggregate concrete can be observed in Figure 2. The demoulded density tends to decrease inversely to the addition of the volume fraction of pumice aggregate into the mixes. It can be clearly predicted in the mix design calculation since pumice breccia has lower density compared to the normal fine aggregate and normal concrete density.

Concrete mixes which are acceptable to be classified as lightweight concrete based on the maximum limit of lightweight concrete density which is required in the Indonesian national standard and most of the International standards can be achieved when the mixes utilized 55% and more volume fraction of coarse pumice aggregate to the total aggregate.

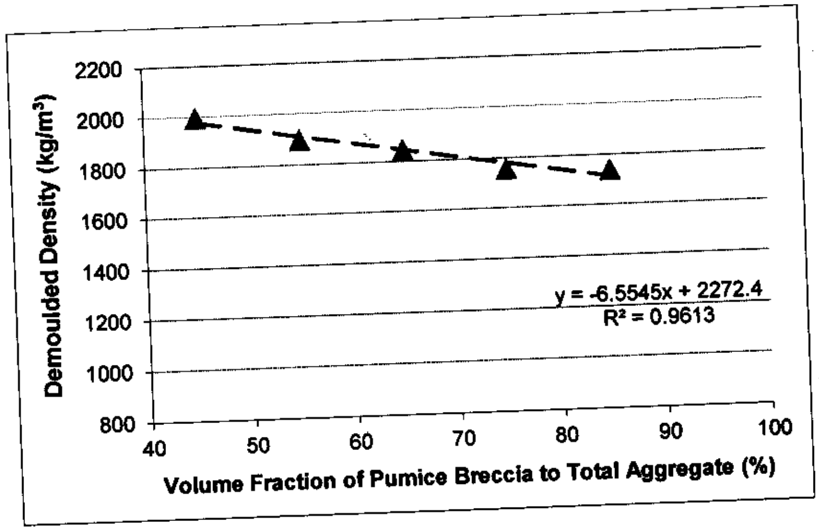


Figure 2: Effect of Aggregate Composition on the Demoulded Density of Hardened Lightweight Concrete using Pumice Breccia Aggregate

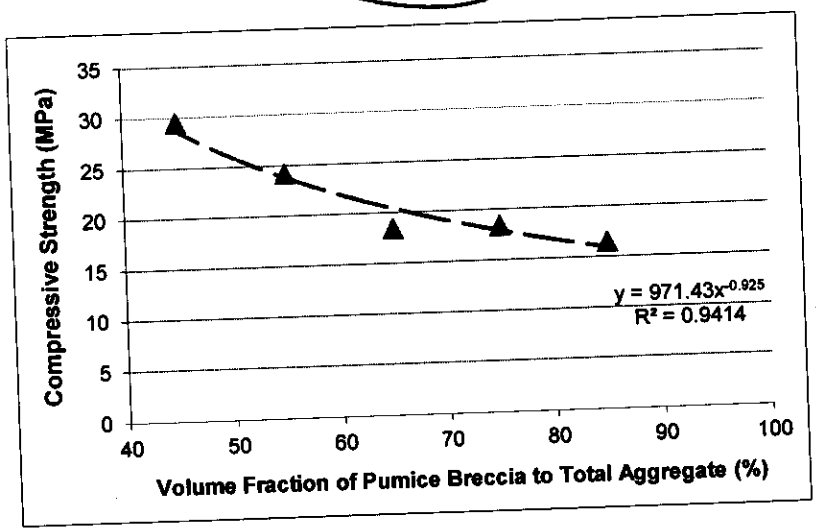


Figure 3: Effect of Aggregate Composition on the Compressive Strength of Lightweight Concrete using Pumice Breccia Aggregate

Effects of the volume fraction of pumice breccia aggregate which was used as coarse aggregate to the total volume of concrete aggregate on the compressive strength of hardened lightweight pumice breccia aggregate concrete can be observed in Figure 3. The compressive strength tends to decrease inversely to the addition of the volume fraction of pumice aggregate into the mixes. It can be predicted earlier since pumice breccia has lower strength compared to the normal aggregate.

Concrete mixes which are acceptable to be classified as structural lightweight concrete based on the minimum limit of compressive strength which is required in the Indonesian national standard and most of the International standards can be achieved when the mixes utilized 75% and less volume fraction of coarse pumice aggregate to the total aggregate.

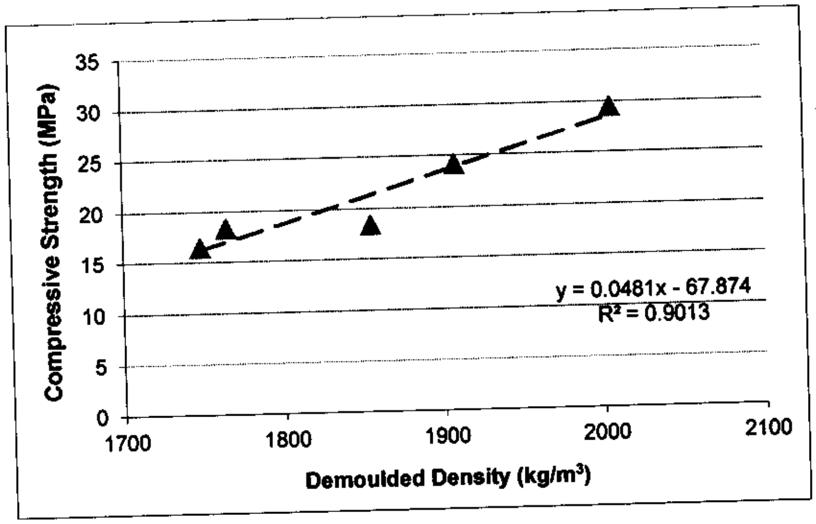


Figure 3: Correlation between Demoulded Density and Compressive Strength of Lightweight Concrete using Pumice Breccia Aggregate

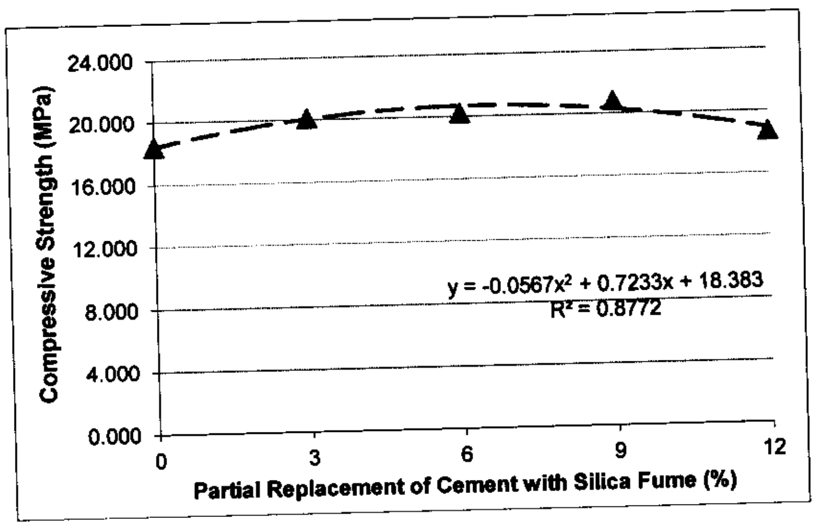


Figure 4: Effect of Portland Cement Partial Replacement with Silica Fume on the Compressive Strength of Lightweight Concrete using Pumice Breccia Aggregate

Effects of silica fume which was used as partial replacement of the portland cement on the compressive strength of hardened lightweight pumice breccia aggregate concrete can be observed in Figure 4. The compressive strength tends to increase in accordance with the addition silica fume into the mixes until 9% by weight of portland cement, but tends to decrease after 12%. Test results indicate that the optimum compressive strength can be achieved when the portland cement partially replaced with silica fume in a dosage of 9% by weight. The compressive strength of lightweight concrete that utilized pumice breccia as coarse aggregate can be improved due to the partial replacement of portland cement with silica fume, will produce chemical reaction between silica with free-lime that leads to pore-size refinement and matrix densification, and cement paste–aggregate interfacial refinement.

The demoulded density of lightweight concrete tends to increase in accordance with the improvement of compressive strength which was affected by silica fume that utilized as partial replacement of portland cement in the concrete mixes. The demoulded density increased caused by pore-size refinement and matrix densification in the hardened concrete. Even though the demoulded density of LWC with pumice breccia aggregate increasing due it can be observed that the density of the lightweight concretes are still acceptable to be classified as lightweight concrete based on the maximum limit of lightweight concrete density which is required in the Indonesian national standard and most of the International standards as shown in Figure 5.

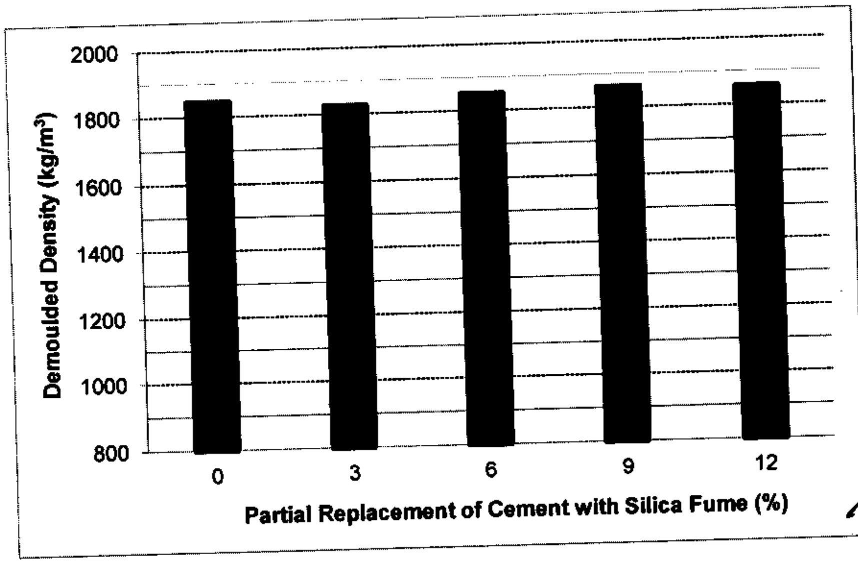


Figure 5: Effect of Portland Cement Partial Replacement with Silica Fume on the Demoulded Density of Lightweight Concrete using Pumice Breccia Aggregate

5.0 Conclusions

Based on the tests results of the hardened properties of lightweight pumice breccia aggregate concrete, the following conclusions can be drawn:

(1) The demoulded density of lightweight concrete tends to decrease inversely to the addition of the volume fraction of pumice aggregate into the mixes.
(2) Structural lightweight concrete can be produced when the mixes utilized 55% to 75% volume fraction of coarse pumice aggregate to the total aggregate.
(3) The compressive strength of structural lightweight concrete can be improved proportionally up to 13.07% when the portland cement partially replaced with silica fume up to 9% by weight of cement.

Acknowledgement

The authors highly appreciate the financial support from Universitas Negeri Yogyakarta (Yogyakarta State University), and the Directorate General of Higher Education, Ministry of Education and Culture. The support of the Building Material Laboratory staffs at the Faculty of Engineering, Universitas Negeri Yogyakarta for their assistance in conducting the experimental works are also gratefully acknowledged.

References

[1] EuroLightCon, "Definitions and International Consensus Report," European Union–Brite EuRam III, 1998, http://www.sintef.no/static/BM/projects/EuroLightCon/BE3942R01.pdf.

[2] Badan Standarisasi Nasional, "SNI: 03-2847-2002: Tata Cara Perhitungan Struktur Beton untuk Bangunan Gedung", BSN, 2002. (In Indonesian).
[3] S.M.F. Green, N.J. Brooke, L.G. McSaveney, and J.M. Ingham, "Mixture Design Development and Performance Verification of Structural Lightweight Pumice Aggregate Concrete," Journal of Materials in Civil Engineering, Vol. 23, No. 8, pp. 1211-1219, 2011.
[4] N. Kabay, and F. Akoz, "Effect of Prewetting Methods on Some Fresh and Hardened Properties of Concrete with Pumice Aggregate," Cement & Concrete Composites, doi:10.1016/j.cemconcomp.2011.11.022, 2011.
[5] L. Xiaopeng, "Structural Lightweight with Pumice Aggregate," Master Thesis, National University of Singapore, 2005.
[6] ACI Committee 213, "ACI 213R-03: Guide for Structural Lightweight-Aggregate Concrete," American Concrete Institute, 2003.
[7] S. Bronto, S. Mulyaningsih, G. Hartono, and B. Astuti, "Waduk Parangjoho dan Songputri: Alternatif Sumber Erupsi Formasi Semilir di daerah Eromoko, Kabupaten Wonogiri, Jawa Tengah," Jurnal Geologi Indonesia, Vol. 4 No. 2, pp. 79-92, 2009. (In Indonesian).
[8] Pusat Pembinaan Sumber Daya Investasi, "Sistem informasi Sumber Daya Investasi: Potensi Material Konstruksi Propinsi DI Yogyakarta," Kementerian Pekerjaan Umum, http://www.pusbinsdi.net/main.php?page=potensi_material&type=&op=detail&id_prop=12, accessed: September 14, 2013. (In Indonesian).
[9] P.K. Mehta and Monteiro, P.J.M., "Concrete Microstructures, Properties, and Materials," McGraw-Hill, 2006.
[10] Siddique, R., "Utilization of Silica Fume in Concrete: Review of Hardened Properties," Resources, Conservation and Recycling 55, pp. 923– 932, 2011.
[11] BCA Academy, "Design Guide of High Strength Concrete to Singapore Standard CP 65," Building and Construction Authority, 2008.
[12] British Standard, Concrete - Complementary British Standard to BS EN 206-1-Part 1: Method of Specifying and Guidance for the Specifier, BS 8500-1:2006, BSI, 2006.
[13] ASTM C-143, C-469, C-496, and C-293, "Annual Book of ASTM Standard, Volume 04.02: Concrete and Aggregates", ASTM International, West Conshohocken, Pa, USA, http://www.astm.org/.