EPI International Journal of Engineering
Volume 6, Number 2, Aug 2023, pp. 78-82
DOI: 10.25042/epi-ije.082023.04

*p*ISSN 2615-5109
*e*ISSN 2621-0541

Assessment of Stone Ash as a Lightweight Concrete Constituent Material with the Addition of Bestmittel Additives

Budiman[a], James Williams Tiranda Patanduk[b]

[a]Department of Civil Engineering, Polytechnic State of Fakfak. E-mail: budiman@polinef.id
[b]Department of Civil Engineering, Polytechnic State of Fakfak.

Abstract

Technological advances in the field of building construction have developed very rapidly, so we need a construction technology that can reduce exploitation of nature. Utilization of stone ash is one of the new material alternatives in concrete mixtures with the addition of the bestmittel additive to accelerate drying in concrete. The purpose of this study is to determine the aggregate characteristics, specific gravity and compressive strength of concrete. The method used is laboratory experimental research with variations in stone ash samples of 5%, 10% and 15% to the weight of sand with the addition of 0.6% bestmittell additive to the weight of cement. The results showed that stone ash and bestmittell additives affect the characteristics of the concrete. The value of specific gravity increases with increasing percentage of stone ash, namely 1898.77 kg/m^3 in normal concrete, 1911.35 kg/m^3 of 5% stone ash concrete, 1922.34 kg/m^3 of 10% stone ash concrete and 1927.06 kg/m^3 on 10% stone ash concrete. The compressive strength value of characteristic for the compositions AB 5%, AB 10% and AB 15% are 10.08 Mpa, 10.35 Mpa and 10.88 Mpa respectively, an increase compared to normal AB 0% concrete, namely 9.03 Mpa at 28 days.

Keywords: Compressive strength; bestmittel additive; stone ash; volume weight

1. Introduction

The development of the concrete industry in Indonesia is very advanced and developing. As development increases in a country, the use of construction materials increases. Concrete is a mixture consisting of cement, fine aggregate, coarse aggregate and air. The Principles of Infrastructure Asset Management say that infrastructure must be managed well so that it can always function well economically throughout its life [1].

Split stone industrial companies are needed a lot in construction, from the production of split stone with various size variants it will produce waste called stone ash waste. Stone ash is very abundant and less desirable as a material. Based on this problem, stone ash waste was raised in this research to provide innovation as an additive to good construction materials, in the form of using stone ash waste material in lightweight concrete mixtures with the addition of bestmittel. Therefore, concrete technological innovation is always required to answer the challenges of needs, including being environmentally friendly and having a low specific gravity (lightweight concrete). Lightweight concrete generally has a specific gravity of less than 1850 kg/m^3 [2].

Lightweight concrete is concrete whose specific gravity is smaller than normal concrete. According to [3], lightweight concrete is concrete that contains light aggregate and has a specific gravity of no more than 1900 kg/m^3, whereas according to [4] lightweight concrete has a specific gravity of between 1000-2000 kg/m^3. Lightweight concrete can be made using additional materials, namely lightweight aggregate, concrete without fine aggregate (non-sand) and foam concrete

Lightweight concrete can be defined as a type of concrete which includes an expanding agent in that it increases the volume of the mixture while giving additional qualities such as nailibility and lessened the dead weight [5]. It is lighter than the conventional concrete with a dry density of 300kg/m up to 1840 kg/m 87 to 23% lighter. It was first introduced by the Romans in the second century where 'The Pantheon' has been constructed using pumice ,the most common type of aggregate used in that particular year [6]. From there on, the use of lightweight concrete has been widely spread across other countries such as USA, UK and Sweden.

In recent years, more attention has been paid to the development of lightweight aggregate concrete [7]. The specific gravity of concrete can be lowered either by using porous, therefore lightweight aggregates instead of ordinary ones, or introducing air into the mortar, or removing the fine fractions of aggregate and compacting concrete only partially. In all cases, the main goal is to introduce voids into the aggregate and the mortar or between mortar and aggregate. A combination of these methods can also be made in order to reduce further the weight of concrete. The use of lightweight aggregates

*Corresponding author. Tel.: +62-812-7706-1052
Jalan TPA Imam Bonjol Atas Air Merah, Kelurahan Wagom Fakfak, Papua Barat, Indonesia 98611

is by far the simplest and most commonly used method of making a lightweight concrete [6].

Several previous studies with added materials, both natural and artificial fibers, such as: [8] examined the opportunity for nutmeg shells as a replacement material for gravel in lightweight concrete, [9] examined the effect of a mixture of banana fiber on concrete. [10] researched the effect of coconut shell (endocarp) substitution in concrete mixtures as a sound dampening fiber material. [11] examined lightweight concrete from a mixture of styrofoam and sawdust. [12] researched the manufacture of lightweight concrete from artificial aggregates with the addition of plastic. [13] researched the effect of candlenut shells as a substitute for coarse aggregate on the mechanical properties of concrete. The research will be carried out using stone ash and the additive Bestmittel in lightweight concrete.

Additives are materials other than the main elements of concrete (water, cement and aggregate) that are added to the concrete mix. The aim is to change one or more properties of concrete while it is still fresh or after hardening, for example accelerating hardening, increasing ductility (reducing brittle properties), reducing hardening cracks, and so on [4].

This research uses stone ash as a building block for lightweight concrete by adding the additive besmittel. The research was carried out in the Fakfak State Polytechnic Civil Engineering materials testing laboratory. The aim of this research is to determine the characteristics, specific gravity and compressive strength values of lightweight concrete. rock ash composition of 5%, 10% and 15% with 0.6% besmittel. This research is a development of previous research. Previous research results have shown that stone ash can contribute as a replacement material for sand.

2. Literature Review

2.1. Light concrete

Lightweight concrete has a density of not more than 1900 kg/m^3 [14] and has a compressive strength value of 0.35-6.90 Mpa while [15] provides a limitation for lightweight concrete, namely concrete with a weight below 1800 kg/m^3. A according to [16] lightweight concrete has a density between 1000-2000 kg/m^3.

Table 1. Types of lightweight concrete by [14]

Weight concretes (kg/m^3)	Compressive strength (MPa)	Types lightweight concretes
240-800	0.35-6.9	Low-Density concretes
800-1440	6.9-17.3	Moderate Strength lightweight concretes
1440-1900	>17.3	Structural lightweight concretes

Table 2. Types of lightweight concrete by [15]

Weight concretes (kg/m^3)	Compressive strength (MPa)	Types lightweight concretes
1400-1800	>17	Structural lightweight concretes
500-800	7-14	Masonry concretes
<800	0.7-7	Insulating concretes

Types of lightweight concrete based on concrete weight and compressive strength [14], [15] as shown in Tables 1 and 2.

Normal concrete is obtained by mixing Portland cement, water and aggregate, while for lightweight concrete the constituent materials are very dependent on the type of lightweight concrete. According to [17] there are 3 types of lightweight concrete, namely lightweight aggregate concrete, foam concrete and concrete without fine aggregate. The same thing was also conveyed by [4], several methods that can be used to reduce the weight of concrete include the following:

1) Making gas / air bubbles in the cement mix.
2) Using light aggregate, for example fired clay, pumice stone or artificial aggregate.
3) Making concrete without using fine aggregate grains (non-sand concrete).

Several parameters that affect the fine aggregate (sand) in determining the quality of the concrete are sludge content, moisture content, volume weight, absorption, specific gravity, fineness modulus and organic content [16].

The level of sludge is the percentage of size that passes filter No.200 according to ASTM and British Standards or 80 DIN (Germany) or standard filter hole size = 0.075 mm. Laboratory testing is generally carried out by the washing method according to ASTM C-117 (2000 Sieve in Mineral Aggregate by Washing) Standard Test Method for Materials. Tolerance for testing the fine aggregate sludge content is 0.2%-6%.

The water content in the aggregate is greatly influenced by the amount of water contained in the aggregate. The bigger the difference between the original aggregate weight and the aggregate weight after oven drying, the more water is contained by the aggregate and vice versa. Tolerance of testing moisture content in fine aggregate is 3%-5%.

The volume weight is the ratio between the dry aggregate weight and its volume. The aim is to determine the weight of the fine aggregate. The test tolerance for fine aggregate is 1.4 kg/ltr-1.9 kg/ltr.

The absorption is the percentage by weight of water that can be absorbed by the material to the weight of dry aggregate. Tolerance of testing fine aggregate 0.2%-2% and coarse aggregate 0.2%-4%.

The specific gravity is the ratio between the weight of dry aggregate and the weight of distilled water whose content is the same as the aggregate content in a saturated state at a certain temperature. The test tolerance for fine aggregate is 1.6%-3.3%.

The organic Ingredients, are materials contained in aggregates that can cause damage to concrete. The organic substances contained in fine aggregates generally come from destroyed plants, especially in the form of humus and organic sludge. Harmful organic substances include sugar, oil and fat. Sugar can inhibit cement binding and the development of concrete strength, while oil and grease can reduce cement binding capacity. The test tolerance for fine aggregates is less than a value of 3.

2.2. Stone ash

Stone ash is a fine aggregate that passes through a 4.75 mm diameter sieve and is retained on a 0.075 mm sieve, so stone ash is a waste that is useful as a mixture of construction building materials because stone ash can function as a fine aggregate to replace sand in concrete and asphalt mixtures.

2.3. Bestmittel

Bestmittel is a special formula that is very economical in the casting process so it makes concrete harden faster at a young age and reduces water usage during casting thereby increasing the quality/strength of the concrete and is very helpful for casting with a very tight time schedule because the concrete hardens quickly at an early age (7 – 10 days) and increases the quality/strength of concrete by 5% - 10% with a content used of 0.2% - 0.6% of the cement weight.

2.4. Compressive strength

Compressive strength [18] provides an understanding of the compressive strength of concrete, which is the amount of load per unit area, which causes the concrete specimen to crumble when loaded with a certain compressive force, which is generated by a compression machine.

3. Research Methodology

3.1. Research stages

The stages of research, prepare tools and materials. The main materials consist of gravel, sand, cement, stone ash and bestmittel. Testing the characteristics of coarse and fine aggregate and calculating the combination of fine aggregate and stone ash with a bestmittel percentage of 0.6% to obtain the appropriate composition. Designing a concrete mix (mix design) with an f'c of 10 MPa. Preparation of concrete mix composition with AB variations of 5%, 10% and 15% of the weight of sand. Concrete maintenance for 3, 7 and 28 days. The compressive strength values of the concrete were analyzed and concluded.

3.2. Characteristic testing

Aggregate characteristic testing uses study literature as shown [15] in Table 3.

3.3 Compressive strength testing

Concrete compressive strength test results using compression machine test were analyzed by using compressive strength equation [18] :

$$fc = \frac{P}{A} \tag{1}$$

where,

fc = compressive strength (kg/cm^2)

P = load (kg)

A= the weighted cross-sectional area (cm^2)

Table 3. Aggregate testing and method

No	Types of testing	Method
1	Filter Analysis	SNI 03-1968-1990
2	Specific Weight and Fine Aggregate Absorption	SNI 03-1970-1990
3	Specific Weight and Absorption of Coarse Aggregates	SNI 03-1969-1990
4	Water Content	SNI 03-1971-1990
5	Volume Weight	SNI 03-4804-1998

4. Results and Discussion

The results of testing the characteristics test of coarse (gravel) and fine (sand) aggregates are as in Tables 4 and 5.

Testing the characteristics of fine aggregate obtained a mud content value of 3.6% which meets the requirements and is suitable for use in concrete mixtures. According to [4], fine aggregate must not contain more than 5% mud and not contain organics that can damage concrete. Its use is to fill the space between coarse aggregates and provide workability. The sand fineness modulus value of 3.66 meets the requirements for zone 1 and is included in the coarse sand category. Likewise, testing the sludge content of coarse aggregate obtained a value of 0.27% which meets the requirements and is feasible. According to [19] coarse aggregate should not contain more than 1% silt. The coarse aggregate modulus is in the 4.75 - 40 mm zone. [20] A normal weight washed sand with a (4.75mm) maximum size is used as fine aggregates its use is to fill the space between coarse aggregates and provide discomfort.

To know the strength and quality of concrete using a stone ash (AB) composition of 0%, 5%, 10% and 15% with

Table 4. The result of coarse aggregate testing

No	Aggregate characteristics	Interval	Testing result	Description
1.	Mud leves	Maks. 1%	0.27 %	Meets
2.	Water content	0.5 - 5%	0.50 %	Meets
3.	Volume weight	1.6 - 1.9 kg/liter	1.61 kg/liter	Meets
4.	Absorption	Maks. 4%	4 %	Meets
5.	Specific weight			
	Dry-based S.W	1.6 - 3.3	2.45	Meets
	Dry-surfaced S.W	1.6 - 3.3	2.57	Meets
6.	Roughness modulus	5.5 – 8.5	6.74	Meets

Table 5. The result of fine aggregate testing

No	Aggregate characteristics	Interval	Testing result	Description
1.	Mud leves	Maks. 5%	3.60 %	Meets
2.	Water content	0.5 - 5%	2.24 %	Meets
3.	Volume weight	1.4 - 1.9 kg/liter	1.51 kg/liter	Meets
4.	Absorption	0.2 – 2%	1.08 %	Meets
5.	Specific weight			
	Real S.W	1.6 - 3.3	2.33	Meets
	Dry-based S.W	1.6	2.28	Meets
	Dry-surfaced S.W	1.6	2.30	Meets
6.	Roughness modulus	1.5 – 3.8	3.66	Meets

a bestmittel percentage of 0.6% with a planning cement water factor (W/C) = 0.45 as shown in Tables 6-9.

The calculating the planning results above, it is obtained that the percentage of natural sand aggregate required with an AB percentage of 5% can save the use of natural sand by 4.99%, for AB 10% it can save the use of natural sand. natural sand of 9.99% while AB 15% can save the use of natural sand of 14.99% of the total planned sand without using stone ash (AB). This plan value shows that the higher the percentage of stone ash (AB) with a percentage of 0.6% bestittle used in the concrete mixture, the lower the need for natural sand aggregate. The results of testing the weight of fresh concrete mixed with AB concrete with 0.6% bestmittel with an air correction factor value of 0.45 obtained the average value of the volume weight of cylindrical test objects as in Table 9 and Fig. 1.

Table 6. The results of concrete mix design abu batu (AB) 0% with bestmittel 0.6%

Concrete material	Weight (kg/m^3)	Ratio to the amount of the cement (kg)	Weight for one sample (kg)	Weight for nine sample (kg)
Water	232.543	0.742	1.479	13.314
Cement	311.111	1.000	1.979	17.812
Sand	484.516	1.557	3.082	27.741
Coarse	1121.82	3.605	7.136	64.230
Amount	2150.00		13.678	123.099

Table 7. The results of concrete mix design abu batu (AB) 5% with bestmittel 0.6%

Concrete material	Weight (kg/m^3)	Ratio to the amount of the cement (kg)	Weight for one sample (kg)	Weight for nine sample (kg)
Water	232.543	0.742	1.479	13.314
Cement	311.111	1.000	1.979	17.812
Sand	460.291	1.479	2.928	26.354
Coarse	1121.82	3.605	7.136	64.230
AB+bestmittel	24.225	0.077	0.1541	1.386
Amount	2150.00		13.678	123.099

Table 8. The results of concrete mix design abu batu (AB) 10% with bestmittel 0.6%

Concrete material	Weight (kg/m^3)	Ratio to the amount of the cement (kg)	Weight for one sample (kg)	Weight for nine sample (kg)
Water	232.543	0.742	1.479	13.314
Cement	311.111	1.000	1.979	17.812
Sand	436.065	1.401	2.774	24.967
Coarse	1121.82	3.605	7.136	64.230
AB+bestmittel	48.451	0.155	0.308	2.773
Amount	2150.00		13.678	123.099

Table 9. The results of concrete mix design abu batu (AB) 15% with bestmittel 0.6%

Concrete material	Weight (kg/m^3)	Ratio to the amount of the cement (kg)	Weight for one sample (kg)	Weight for nine sample (kg)
Water	232.543	0.742	1.479	13.314
Cement	311.111	1.000	1.979	17.812
Sand	411.839	1.323	2.620	23.580
Coarse	1121.82	3.605	7.136	64.230
AB+bestmittel	72.677	1.232	0.462	4.160
Amount	2150.00		13.678	123.099

Figure 2 shows the weight of fresh concrete AB + 0.6% bestmittel which has the effect of decreasing concrete weight sequentially, namely AB 5%, 10% and 15%, the greater the percentage of stone ash used, the lighter the weight of the concrete volume itself. This practice will allow achieving certain properties of fresh and hardened concrete [21]. As also emphasized by [22] the use of appropriate mix proportions of materials for on-site concrete production will allow achieving appropriate mix proportions for a given strength characteristic rather than the usual procedure of using non-approved mix ratios for the design target strength.

The results of the analysis of concrete compressive strength test values using stone ash (AB) with 0.6% bestmittel have an influence on the concrete compressive strength values. The higher the percentage of AB given to

Table 10. The weight volume of freshly concrete

No	Sampel Concrete	Volume of Freshly Concrete (kg/m^3)
1	AB + Bestmittel 5%	1927.06
2	AB + Bestmittel 10%	1922.35
3	AB + Bestmittel 15%	1911.34

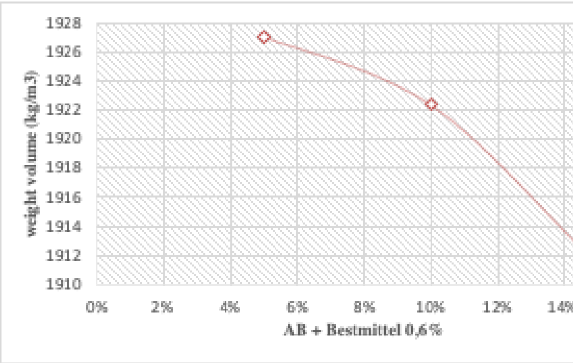

Figure 1. Graphic of weight volume

Table 11. The value of compressive strength Characteristics of concrete

No	Sample Concrete	Value f'c (kg/cm^2)
1	AB + Bestmittel 5%	102.88
2	AB + Bestmittel 10%	105.52
3	AB + Bestmittel 15%	111.04

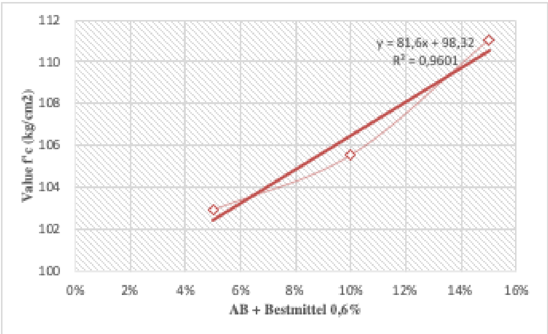

Figure 2. The f'c value

the concrete mixture, the higher the compressive strength value. The characteristic compressive strength values of concrete at 28 days are as in Table 10 and Fig. 2.

Figure 2 shows the compressive strength value of concrete using stone ash (AB) added with 0.6% bestmittel as a partial replacement for natural sand to improve the quality of the concrete. The higher the percentage, the more compressive strength value increases. The compressive strength values of rock ash concrete in the composition of AB 5%, 10% and AB 15% were obtained at 102.88 kg/cm^2, 105.52 kg/cm^2 and 111.04 kg/cm^2, increasing at 28 days. These results prove that stone ash can function as a fine aggregate to replace sand for lightweight concrete mixture formulas, while bestmittel has the role of accelerating concrete hardening and increasing concrete strength.

According to [14] lightweight concrete is concrete that has a compressive strength value of around 6.9-17.3 Mpa. Based on the range of compressive strength values, it shows that the research results of concrete without AB are included in the lightweight concrete category, namely 9.83 Mpa, as well as concrete using 5%, 10% and 15% AB at 28 days has values of 10.08 Mpa, 10.35 Mpa and 10.88 respectively. Mpa so it was concluded that the use of stone ash (AB) with the additive Bestmittel 0.6% increased the compressive strength value of the concrete.

Lightweight concrete according to [21] lightweight concrete has a density between 1000-2000 kg/m^3 with types of lightweight concrete consisting of structural, lightweight and very light structural concrete. Lightweight concrete from rock ash (AB) with 0.6% bestmittel has an average weight of 1920.25 kg/m^3 and a maximum compressive strength value of 10.88 MPa so that the concrete is included in the lightweight structure category.

Classification of lightweight concrete based on the weight of concrete If referring to [16], then most of the weight of light concrete in this study is classified as light structure as an insulator, [14] includes concrete with low density, the classification of [15] includes heat-resistant lightweight concrete and [17] includes lightweight aggregate concrete .

5. Conclusions

The use of nutmeg skin as a coarse aggregate material in the concrete mixture affects the volume weight of the concrete. The weight of the concrete gets lighter along with the higher the percentage used. The average volume weight obtained was 1810,06 kg/m^3. Based on the weight of the concrete sample, it is classified as light structure, includes concrete with low density and includes lightweight aggregate concrete. The compressive strength values for the characteristics of concrete at a composition of 10%, 20% and 30% were obtained at 28.42 kg/cm^2, 31.65 kg/cm^2 and 32.68 kg/cm^2 which increased while the use of nutmeg shells at 40% and 50% compositions was obtained. values of 29.09 kg/cm^2 and 27.38 kg/cm^2 decreased at the age of 28 days. The increase in the value of the compressive strength of concrete (fck') occurred starting at the composition of 20% and 30% at 10.20% and 13.03% and begin to decrease at the composition of 50% by 3.65%.

Research suggestions as further research is needed in determining the appropriate composition for both lightweight concrete and normal concrete. Further research is needed using a smaller percentage interval and It is recommended to use nutmeg shell as coarse aggregate in light concrete with a low density scale and intended for light structures, besides saving costs, it can also reduce waste that has an impact on the environment.

References

[1] R. A. A. Soemitro and H. Suprayitno, "Pemikiran Awal tentang Konsep Dasar Manajemen Aset Fasilitas," *J. Manaj. Aset Infrastruktur Fasilitas*, vol. 2, pp. 1–14, 2018.

[2] L. J. Murdock and K. M. Brooks, *Bahan dan Praktek Beton*, 4th ed. Jakarta: Erlangga, 1999.

[3] "SNI- 03-2847-2002: Tata Cara Perhitungan Struktur Beton untuk Bangunan Gedung," Bandung, 2002.

[4] K. Tjokrodimuljo, *Teknologi Beton*, 3rd ed. Yogyakarta: Yogyakarta Biro penerbit KMTS FT 2012, 2012.

[5] M. L. Zakaria, *Materials and Development, Language and Library Board*. 1978.

[6] M. R. Sarmidi, "First Report Research Project on Light Weight Concrete," Universiti Teknologi Malaysia, 1987.

[7] T. Y. Lo, W. P. Tang, and H. Cui, "The Effects of Aggregate Properties on Lightweight Concrete," *Build. Environ.*, vol. 42, no. 8, pp. 3025–3029, 2007.

[8] Budiman, Imran, and W. T. P. James, "The Use of Nutmeg Shell as a Lightweight Concrete Material," *INTEK J. Penelit.*, vol. 7, no. 2, pp. 116–122, 2022.

[9] S. Hani and Rini, "Pengaruh Campuran Serat Pisang Terhadap Beton," *Educ. Build. J. Pendidik. Tek. Bangunan dan Sipil*, vol. 4, pp. 40–45, 2018.

[10] D. E. Putra and R. Karolina, "Pengaruh Subtitusi Tempurung Kelapa (Endocarp) pada Campuran Beton sebagai Material Serat Peredam Suara," *J. Tek. Sipil USU*, vol. 2, 2013.

[11] R. B. Anugraha and S. Mustaza, "Beton Ringan dari Campuran Styrofoam dan Serbuk Gergaji dengan Semen Portland 250, 300 dan 350 kg/m^3," *J. Apl.*, vol. 8, pp. 57–66, 2010.

[12] E. Rommel, "Pembuatan Beton Ringan dari Aggregat Buatan Berbahan Plastik," *J. GAMMA*, vol. 9, pp. 137–147, 2013.

[13] E. Febriani, "Pengaruh Pemanfaatan Pecahan Beton sebagai Alternatif Pengganti Agregat Kasar sebagai Campuran Beton K 250 KG/CM^2," *KURVAS J. Keilmuan dan Apl. Tek. Sipil*, vol. 1, 2013.

[14] N. K. Raju, *Design of Concrete Mixes*. New Delhi: CBS, 1985.

[15] J. A. Dobrowolski, *Concrete Construction Handbook*. New York: McGraw-Hill, 1998.

[16] A. M. Neville, *Concrete Technology*. Jhon Wiley & Sons, 1987.

[17] "SNI 03-3449-2002: Tata Cara Perancangan Campuran Beton Ringan dengan Agregat Ringan," Jakarta, 2002.

[18] "SNI 03-1974-1990: Metode Pengujian Kuat Tekan Beton," Jakarta, 2011.

[19] Z. Li, *Advanced Concrete Technology*. New York: John Wiley & Sons, 2011.

[20] O. H. Zinkaah, "Influence of Steel Fibers on the Behavior of Light Weight Concrete Made from Crushed Clay Bricks," *Am. J. Civ. Eng.*, vol. 2, pp. 109–116, 2014.

[21] K. O. Olusola, A. J. Babafemi, A. A. Umoh, and B. J. Olawuyi, "Effect of Batching Methods on the Fresh and Hardened Properties of Concrete," *Int. J. Res. Rev. Appl. Sci.*, vol. 13, no. 3, pp. 773–779, 2012.

[22] A. T. Goldbeck and J. E. Gray, *A Method of Proportioning Concrete For Strength Workability and Durability*. National Crushed Stone Association, 1965.