

Characteristics and Durability of K-300 Concrete Mix for Earthquake-resistant Housing Infrastructure in Indonesia

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Abstract: This study investigated the performance of the properties of Ordinary Portland Cement (OPC) and Additive Bond Crete in housing infrastructure. Additive Bond Crete is commonly used to increase the compressive strength of concrete material and for economic concerns. In determining the strength of K-300 concrete mix that is suitable for earthquake-resistant housing infrastructure, it is necessary to research the materials to be used for proper quality and quantity so that the mixture can be directly applied to the resident's housing, in the quake zone. In the first stage, the examination/sieve analysis of the fine aggregate or sand, and the sieve analysis of the coarse aggregate or gravel will be carried out on the provided sample weighing approximately 40 kilograms. Furthermore, the specific gravity and absorbance of aggregates, the examination of the sludge content of aggregates passing the sieve no. 200, and finally, examination of the weight of the aggregate content. In the final stage, a compressive strength test of the K-300 experimental mixture is carried out, and subsequently the composition of the K-300 concrete mixture suitable for one sack of cement of 50 kg is obtained for the foundation of the proper dwelling. The composition is consists of use of Cement, Sand, Gravel, and Water.

1 INTRODUCTION

Concrete can be used in several applications such as pavement, building, foundation, pipeline installation, dam, and other civil building infrastructure (Piyamaikongdech, 2007; Zulkarnain and Ramli, 2011). One alternative to the mixture of concrete components is to use lightweight concrete while maintaining the compressive strength of the existing concrete, so this becomes the solution for the existing concrete mixture. Huang's research (2009) indicates that lightweight concrete can be used as structures in residential buildings by the addition of stiff fibers to concrete mixtures. This is to add strength especially on columns and also beams on building structures to withstand loads. Some researchers have tested in particular to increase the compressive strength of concrete versus normal concrete, as did Zulkarnain et al. (2016), by addition of paper and also foam to increase the compressive strength of concrete.

Research conducted by Kuehn (2010) in Canada shows that particles of 10 μm in size can be used for concrete mixtures in building structures. It can be argued that the results of the study are close to the

results obtained with ash for concrete mixtures, so the basis of that research is well suited for use in disaster areas. Furthermore, a study by Zulkarnain (2011) suggests that concrete mixtures can be increased in strength by adding silica powder, especially for lightweight concrete that can be used for houses in disaster areas with relatively fast processing and does not require a high cost for each building produced. Previous research by Karolina et al. (2014) concluded that the volcanic ash from Mt. Sinabung could be one of the aggregates in the concrete mix.

A study by Zulkarnain (2015) on the strength of concrete with the addition of volcanic ash indicates that this addition can increase the strength of the concrete in such a way that it is possible to reconstruct the earthquake-damaged housing around Mount Sinabung.

The innovation of the research in 2016-2018 produced a new K-300 concrete mix for earthquake-resistant housing infrastructure in Indonesia, which can be directly applied to the earthquake area. For the area of North Sumatra, for example, this is appropriate for housing around the safe area of Mount Sinabung, both for short-term and long-term.

2 LITERATURE REVIEW

Preliminary study by Zulkarnain et al. (2014) said that a mixture of palm oil can also be used for lightweight concrete mixtures. In this research, the increase of compressive strength value of concrete is obtained which can also be used for housing in disaster area. The results have been published in the Journal of Civil Engineering Research 2014.

In Proceedings of the 3rd International Conference on the Geohazard Information Zonation and 5th Seminar & Short Course of HASTAG (GIZ 2014-HASTAG 5), p. 90-98, Karolina et al. (2014) presented the results of research on ash of eruption of Mount Sinabung with the following conclusions: (1) It is found that the water cement factor is so high that it affects the compressive strength of the concrete produced. (2) The visual observation results show that the surface of the brick has the same shape as the particle equation, thus the surface of the brick becomes flat. (3) The use of brick material from the ash of Mount Sinabung resulted in the increase of absorption which in the study by 4.142%. (4) Based on the resulting compressive strength, the addition of 10% ash will result in a compressive strength of 211.01 kg/cm² with treatment and presence of SiO₂ dominance in concrete mixture. (5) From the research, it is found that Mount Sinabung ash can be used in the mix for brick making.

The use of ash of eruption of mount Sinabung in concrete mix will increase the compressive strength of concrete at 28 days of testing. The results of the compressive strength test at 28 days were 166.90 kg/cm² using no mixture (0%), the compressive strength at 28 days was 173.72 kg/cm² by 5% mixture, the compressive strength at 28 days was 207.14 kg/cm² by 10 % mixture, and the compressive strength at 28 days was 130.97 kg/cm² by 15% mixture. Other chemical compositions are: SiO₂ = 74.3%, AL₂O = 3.3%, CAO = 1.79% (Karolina et al., 2014).

Zulkarnain F. (2015), through internal research in Muhammadiyah University of North Sumatra (UMSU), has examined the strength and resilience characteristics of concrete mixtures using silica powder for housing development. Thus, the preliminary study for this research is very supportive and can be the basis for research of K-300 concrete mix for earthquake-resistant housing infrastructure in Indonesia.

Inspection of materials becomes the decisive factor in increasing the compressive strength of the tested sample. Selection of materials and techniques

or ways of mixing is also a matter of priority before samples are tested. Samples will be tested with cube and cylinder molds for each planned age of up to 28 days. From the test results will be obtained a good value and used as a reference for the mixture of concrete in the disaster area.

In the last section, the composition of the concrete mix for every 1 sack of 40 kg cement can be determined based on the volume of the mixture for 1 sack of 40 kg cement. Comparison of volume of mixture for 1 sack cement of 40 kg and final composition of cement: sand: gravel: water can be achieved for earthquake-resistant housing infrastructure in Indonesia.

3 METHOD OF IMPLEMENTATION

Primary data is data obtained from the results of research conducted in the laboratory which, among others, are:

- a) The materials prepared in the study for mixing of concrete, among others, are: sand, aggregate and Bond Crete supplements. Examination of the materials in the preparation of the study are: Sieve analysis or filtration of coarse aggregate, sieve analysis or filtration of fine aggregate or sand, specific gravity and aggregate absorbance, mud content of aggregate or passing sieve no. 200, and the weight of the aggregate content.



Figure 1. Materials for testing

- b) Planning of Concrete Mix design using the *DoE* Method that has been adapted to the conditions of Indonesia.
- c) Several types of alternatives are used for the preparation and making of cylindrical test objects which include:
 - Planning used for development or construction of residential houses. The

material used is Andalas cement, weighing ± 40 kg per sack.

- The schedule of activities undertaken in this study include: Characteristic examination, Planning of the composition of the mixture, Preparation of experimental mixture at the initial stage of this study (3 cubes of 15 cm x 15 cm, and 3 cylinders of 15 cm in diameter and height of 15 cm), Quality Inspection of Experimental Concrete Mix with 7 days of age.

In general the resume of design of concrete mix is as follows:

1. Data on Ingredients

- 40 kg Bosowa Cement.
- Additive Bond Crete.
- Water at Public Laboratory of Medan.
- Aggregates as follows:

Aggregate examination	Fine aggregate	Coarse aggregate
- Type	Natural sand	Natural gravel
- Gradation	Zone 2 BS	-
- Maximum diameter	-	40 mm
- Specific gravity of SSD	2.58	2.61
- Absorbance	2.17 %	0.93 %
- Mud content	1.69 %	0.52 %
- Weight of content	1426.86 Kg/m ³	1472.47 Kg/m ³

1. Data for Planning:

- Quality of K-300 concrete.
- Planned slump of 6-9 cm.
- Planned standard deviation of 50 kg/cm².
- The planning method of *DoE* has been adapted to the conditions of Indonesia.

2. Results of Planning:

Composition of mixture per 1 m³ of concrete (Aggregate in state of SSD).

- Cement = 448.72 kg
- Fine aggregate (sand) = 614.70 kg
- Coarse aggregate (gravel) = 1141.58 kg
- Water = 175.00 Litre

3. Making of Experimental Mixture:

Day/Date	Monday/August 7, 2017
Site	Civil Engineering Laboratory of Public Polytechnic of Medan
Type of Mixture	K-300
Object Test	3 cubes of 15 x 15 cm and 3 cylinders of $\phi = 15$ cm, height of 15 cm
Additive	Bond Crete
Water content of fine aggregate (sand)	5.82 %
Absorbance of fine aggregate (sand)	2.17 %
Water content of coarse aggregate (gravel)	0.72 %
Absorbance of coarse aggregate (gravel)	0.93 %
Slump obtained	8.17 cm

4. The results of examination of the compressive strength of experimental concrete at age 7 days (estimated 28 days)

5.

		7 days
Average compressive strength	Kg/cm ²	369.48
Standard deviation	Kg/cm ²	5.99
Characteristic compressive strength	Kg/cm ²	459.67

6. Recommendations:

- Based on examination of experimental mixtures, the resulting mixture composition

according to the planning can meet the required quality.

- 2) In the implementation is required to conduct supervision of the quality of the materials of mixture and the quality of concrete by way of sampling according to the provisions and conduct testing of samples in the laboratory.
- 3) For the purpose of correction of moisture content of the mixture, the examination of the moisture content of the aggregate shall be carried out prior to mixing.



Figure 2. The compaction process uses a vibrating engine on all samples.

4 RESULTS OF TESTING

4.1 Design of K-300 Concrete Mix

The data and materials used during the research process are as follows:

- a. Quality of concrete : **K-300**
 - b. Planned slump : (6 – 9) cm
 - c. Materials
- Fine aggregate: Type = natural sand
Specific gravity of SSD = 2.58
Absorbance = 2.17%
Gradation = zone 2 BS
 - Coarse aggregate : Type = natural gravel

4.2 Planning of Cement Water Factor (CWF)

Estimation of compressive strength of concrete (kg/cm²) with CWF of 0.5 corresponds to type of cement and aggregate using Table 1.

Table 1. Planning of Cement Water Factor (CWF)

Type of Cement	Type of Aggregate	Compressive Strength (kg/cm ²)			
		3 days	7 days	28 days	91 days
Ordinary Portland Cement (Type I)	Natural (Not destroyed)	200	280	400	460
	Crushed stone	230	320	450	530

Based on the graph of the relationship between Compressive Strength with Cement Water Factor, the CWF value of 0.52 is obtained. Maximum value of CWF for this planning is limited to 0.39 so that the CWF value used is 0.39.

4.3 Planning of Concrete Free Water (Liter/m³)

Estimates of the amount of free water (kg/m³) required for different levels of work can be determined using Table 2.

Table 2. Plannin of Concrete Free Water (Liter/m³)

Aggregate		Planned Value of Slump (mm)			
Diameter max. (mm)	Type	0	10	30	60
		10	30	60	180
20	Natural	135	160	180	190
	Crushed stone	170	190	210	225
40	Natural	115	140	160	175
	Crushed stone	155	175	190	205

The rough aggregate used is a natural type with a maximum diameter of 40 mm and a natural fine aggregate. With planned value of slump of 6-9 cm, it

is planned to use free water as much as 175.00 liters/m³ of concrete.

4.4 Planning of the Amount of Cement

Based on the smallest CFW value and Free Water then the planned use of cement is as much as:

$$\text{Total Cement} = \frac{\text{Free Water Content}}{\text{CFW}} = \frac{175.00}{0.39} = 448.72 \text{ kg/m}^3$$

4.5 Maximum Cement Level

The minimum cement quantity for this planning is set at 400 kg/m³. Thus, the amount of cement used is the calculated amount of cement which is equal to 448.72 kg/m³.

4.6 Adjusted Cement Water Factor

Since the amount of cement used does not change, the value of CWF does not need to be adjusted so that the CWF value remains at 0.39.

4.7 Estimated Aggregate Composition

From the graph of the relationship between the maximum size of coarse aggregate (30 mm), the gradation of fine aggregate (Zone 2 BS), planned value of slump (10 ± 2 cm) and CWF = 0.42 then the composition is obtained:

Fine aggregate : Coarse aggregate = 35% : 65%

4.8 Estimated Weight of Concrete Content

From the graph of the relation between the relatively specific gravity of the dry aggregate of the surface and the amount of free water, it is estimated that the weight of the wet concrete content is 2380 kg/m³.

4.9 Calculation of the Composition of the Concrete Mixture

From the above planning steps for the mixture, the composition per mixed m³ (aggregate in a state of SSD) is obtained as follows:

- Cement : 448.72 kg
- Fine Aggregate (Sand) : 614.70 kg
- Coarse Aggregate (Split): 1141. 58 kg
- Water : 175.00 liter

4.10 Calculation of Correction of the Mixture for Various Water Content

The composition of the mixture per m³ of concrete in step 8 above is based on the assumption that the aggregate used is in the state of SSD (saturated surface dry). For aggregates not in the state of SSD, the correction of the mixture is carried out as follows:

- Cement : Fixed
- Fine Aggregate (Sand) : Sand of SSD + (Water Content of sand – Degree of Saturation of sand) × Sand of SSD
- Coarse Aggregate (Split) : Gravel of SSD + (Water Content of gravel – Degree of Saturation of gravel) × Gravel of SSD
- Water : Water of SSD – Sand Correction – Gravel Correction

With the description of the research road map above, the results we will achieve in the research will be as expected. This has been done by previous researchers, with the same methods and workings, but the number of molds is increased overall, so a better result is obtained to determine the strength of columns and beams on the main housing/settlement structures. And this can be used in the reconstruction of housing in the vicinity of Mount Sinabung, North Sumatra.

The subsequent process after consideration is to test the compressive strength of each specimen, so that the strength of the sample is known. Testing of compressive strength is also performed on the cylinder by using a cover on the top, so that the flat portion is obtained for more accurate data resulting from the test.

5 CONCLUSIONS

Some results are obtained from testing for both cube and cylinder sample forms according to the age of the plan, including:

1. Based on examination of experimental mixtures, the composition of the mixture as a result of planning can meet the requested quality.
2. The K-300 mix with additive of 1% Bond Crete can be used for earthquake-resistant housing infrastructure in Indonesia.
3. In the implementation is required to perform quality control of materials of mixture and quality of concrete by way of sampling

according to the provisions and conduct testing of samples in the laboratory.

4. For the purpose of correction of moisture content of the mixture, the examination of the moisture content of the aggregate shall be carried out prior to mixing.

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