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Manufacture of Lightweight Concrete Coarse Aggregate

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--***ABSTRACT***--

In a concrete mixture, the coarse Aggregate composition provides the most influence on the weight of concrete (about 60%). Therefore, lightweight coarse Aggregates are required for lightweight concrete. The artificial lightweight coarse Aggregate is an alternative solution to produce lightweight concrete. A laboratory test has been conducted to the material characteristics (physical and chemical) that show the clay ball has the best physical and chemical properties as the main ingredient in the manufacture of lightweight coarse Aggregates than kaolin, fly ash, and boiler ash. Lightweight coarse Aggregates that formed with 19 different variations of composition is burned at a temperature of 1000^{o}C, obtained uniform round shape coarse Aggregates in size Ø10 mm - Ø25 mm. From physical and mechanical properties testing of all the variations, it has shown that the variations that fulfill the qualification in terms of weight/volume unit and wear are variations based on the rule of SNI and CEB / FIB, that is a mixture of 80% ball clay + 20% boiler ash, 80% ball clay + 20 % kaolin, 100% and 90% ball clay + 10% kaolin which suitable to be a lightweight coarse Aggregates as a stone substitute.

KEYWORDS;- *Artificial coarse Aggregate , ballclay, kaolin, boiler ash, fly ash.*

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I. INTRODUCTION

For the purpose of concrete construction in soft soil such as in Pontianak and its surrounding areas, the weight of concrete plays a very important role because it will greatly affect the cost of construction, especially the construction of concrete for high buildings that require large bearing capacity and large structural cross-section caused by its own heavy great structure. In a concrete mixture, the coarse aggregate composition has the greatest effect on the weight Headings of concrete mortar (about 60%) [9]. Therefore, mild Aggregate light is required for lightweight concrete. Aggregate lightly artificial aggregate is an alternative solution to produce lightweight concrete. In addition, it can be fabricated so it provides economy to the wider community indirectly because it is able to create new jobs. One of the coarse aggregates is clay (Kaolin), fly ash, and fly ash that has been burned as an alternative material for crushed or gravel. The clay soil in the Capkala District is one of the basic materials for the manufacture of similar ceramics; wherein the soil that is going to be used later comes from Capkala District. Furthermore, the remaining material of burning oil palm and coal are taken as burning ash from palm oils / oiled mill and steam power plant (PLTU). The utilization of these materials are certainly able to help the community and government in developing the home industry and to recycle the waste of power plants and palm oil mills [7].

II. METHOD

This research was conducted in the Parindu Sanggau District, West Kalimantan. This area was chosen as the research location with the consideration that the Dayak Ribun ethnic population in this sub-district is quite large and is spread over several villages within this sub-district. For the purposes of data collection, the determination of research informants was carried out using purposive sampling technique.

2.1. Lightweight Aggregate Material

2.1.1. Ballclay

Ballclay is a secondary type of clay (sediment/sludge) that has very fine particles, therefore the level of plasticity and dry strength is high, contains a lot of organic material.

Figure 1. Soil color ballclay

2.1.2. Kaolin

Kaolin, also called clay, is a type of primary clay (residue) as a major component in the making of porcelain blends and used in ceramic stoneware and white earthenware. Kaolin is used as a binder and ceramic body strength enhancer at high temperatures, porcelain, goods fireproof (refractory), also used as reinforcement material in the manufacture of glazes.

Figure 2. Soil color kaolin

2.1.3. Boiler Ash Oil Palm [5][9]

Boiler Ash is a primary solid waste of burning boiler oil palm PT. Parna Agromas. It is estimated that less than 2 tons of boiler ash per day are produced by PT. Parna agromas.

Figure 3. Boiler Ash

2.1.4. Fly Ash

Fly Ash is a part of the burning cole waste in the form of amorphous particles and ash. It is an inorganic material that is formed from mineral material in the area of burning processing.

Figure 4. Fly Ash

From the processing of burning coal, the boiler will be formed in two types of ash, those are fly ash and bottom ash. The resulting Fly Ash composition consists of 10-20% bottom ash, while the rest are about 80-90% as fly ash.

2.2. Research Preparation

2.2.1. Research Prosedure

The research procedures to be carried out are as follows:

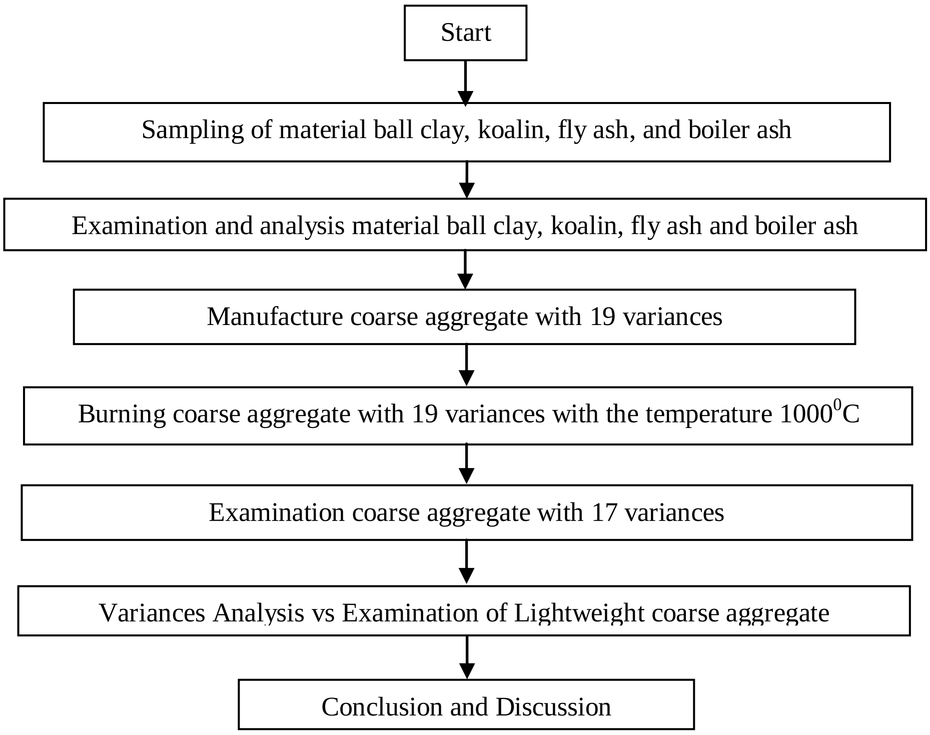

Figure 5. Research Procedure

2.2.2. Manufactured of Artifical Coarse Aggregate

The base material of artificial aggregate is kaolin combinate with variance according to weight ratio. First, the Capkala soil covers the ballclay and kaolin soils is groomed for 1 day to facilitate the mixing and in the elasticity conditions achieved. This mixture is made in 19 variants as in Table 1. After the kaolin soil and boiler ash are well mixed, add water so the dough is easily formed. After that, the dough is ready to be rounded manually by hand with a roughly artificial aggregate measure of artificial planned Ø10 mm - Ø25 mm size.[2][4][8][12][13]

Aggregates that have been formed are placed on top of the base, dried in the sun, and burned temporarily so that they are strong and not easily broken when burning later. Once dry, the aggregate is put into the combustion oven and burned for 9 hours until it reaches the temperature of 1,000^{o}C. After the temperature reaches 1,000^{o}C, the oven is turned off and cooled down to make it easier for the aggregate dispensing process from the oven. Lightweight artificial aggregate is ready for the next process that is the examination of physical and mechanical properties. [8][12][13]

Varation	Capkala Soil		Boiler Ash	Fly Ash	Number of Samples
	Ballclay	Kaolin			
1	100%	0%	0%	0%	0.8 m3
2	90%	10%	0%	0%	0.8 m3
3	80%	20%	0%	0%	0.8 m3
4	70%	30%	0%	0%	0.8 m3
5	60%	40%	0%	0%	0.8 m3
6	50%	50%	0%	0%	0.8 m3
7	40%	60%	0%	0%	0.8 m3
8	30%	70%	0%	0%	0.8 m3
9	20%	80%	0%	0%	0.8 m3
10	10%	90%	0%	0%	0.8 m3
11	0%	100%	0%	0%	0.8 m3
12	90%	0%	10%	0%	0.8 m3
13	80%	0%	20%	0%	0.8 m3
14	90%	0%	0%	10%	0.8 m3
15	80%	0%	0%	20%	0.4 m3
16	0%	90%	10%	0%	0.4 m3
17	0%	80%	20%	0%	0.4 m3
18	0%	90%	0%	10%	0.4 m3
19	0%	80%	0%	20%	0.4 m3

Table 1 Number of Variations of Material Mixed Samples

Figure 6 Manual material mixing process

III. THE RESULT AND DISCUSSIONS

3.1. Examination of Base Material Lightweight Coarse Aggregates

3.1.1. Examination of Moisture Content

For the results of the examination of material coarse aggregates, the moisture content data has obtained as follows:

Lightweight Coarse Aggregates Material	Moisture Contents (%)
Ballclay	10,72
Kaolin	8,41
Boiler Ash	0

Table 2 Moisture Contents

From Table 2, it was found that the moisture content of the base material for the manufacture of lightweight coarse aggregates that have moisture content is found only in the capkala soil which includes Ballclay and Kaolin soils. The moisture content is between 8.41% - 10.72%. This is because the Capkala soil is obtained directly on the land that is affected by the water and soil conditions at the time of sampling.

While boiler ash and fly ash do not contain water because it is obtained directly from the factory that is not touched by weather and water conditions.

3.1.2. Examination of Weight Contents

For the results of the examination of material coarse aggregates, the weight of contents data has obtained as follows:

Lightweight Coarse Aggregates Material	Loose condition (Kg/m3)	Solid Condition (Kg/m3)	Weight Content (Kg/m3)
Ballclay	1,097	1,173	1,135
Kaolin	1,132	1,261	1,197
Boiler Ash	998.7	1,073	1,036
Fly Ash	1,150	1,280	1,215

Table 3 Weight Contents

From Table 3, it can be found that the weight of the base material volume in the making of the lightest lightweight aggregate is the boiler ash, while the heaviest is the fly ash, with the weight of base material of lightweight Aggregate 1,036 kg / m^3 – 1,215 kg / m^3.

3.1.3. Examination of Specific Gravity and Absorption

For the result of the examination of material coarse aggregates, the specific gravity and absorption data has obtained as follows :

Lightweight Coarse Aggregates Material	Specific Gravity (kg/m^3)	Absorption (%)
Ballclay	1,097	15.37
Kaolin	1,132	13.8
Boiler Ash	998.7	0
Fly Ash	2,150 - 2,600	0

Table 4 Specific Gravity and Absorption

From Table 4, it can be found that the specific gravity of the base material for the manufacture of the lightest lightweight aggregates is ballclay when compared to kaolin soils, with the specific gravity of lightweight Aggregate 998.7 kg / m^3 - 2,150 kg / m^3.

3.1.4. Examination of Plasticity Level

For the test results from rough aggregate materials, the index of plasticity data has obtained as follows:

Lightweight Coarse Aggregates Material	Plasticity Index	Level of Plasticity	Cohesive
Ballclay	21.5	High Plasticity	Cohesive
Kaolin	10.7	Medium Plasticity	Cohesive
Boiler Ash	4.1	Low Plasticity	Partial Cohesive
Fly Ash	5.4	Low Plasticity	Partial Cohesive

Table 5 Plasticity Index

From Table 5, it has shown that the ballclay soil has a high plasticity level so that the soil is cohesive. The cohesive soils greatly facilitate solidification and formation so that the results obtained will be maximal for lightly coarse aggregates.

3.2. Examination of Lightweight Coarse Aggregate

3.2.1. Check Form and Texture

All variations that have shown in the tables above are generally round with a size between ∅10 mm - ∅20 mm, with surface texture Light aggregate from slick (smooth) to less slippery (slightly rough). Where the slick is Various 1 and 12, while the other surface is rather coarse. As for the colors in general are gray / ash, Except variation 11 is white.

3.2.2. Specific Gravity and Absorption

For the test results of Aggregate variations, specific gravity and absorption of artificial aggregates data has obtained as follows:

Variation	Specific Gravity (kg/m^3)	Absorption (%)
1	1.097	25,37
2	1.101	23,96
3	1.104	24,11
4	1.108	24,27
5	1.111	24,43
6	1.115	24,59
7	1.118	24,74
8	1.122	24,90
9	1.125	25,06
10	1.129	25,21
11	1.132	23,80
12	1.087	27,69
13	1.077	26,98
14	1.202	27,06
15	1.308	27,14
16	1.119	27,21
17	1.105	27,29
18	1.234	27,37
19	1.336	27,45

Table 6 Specific Gravity and Absorption

From Table 6, it was found that the lightest density was variation 13 which was 1,077 kg / m^3, while the heaviest was variation 19 with a density of 1,336 kg / m^3. So, it was obtained for all variations made for the specific gravity, which is 1,077 kg / m^3 - 1,336 Kg / m^3.

From Table 6, the smallest absorption of the smallest aggregate is 11, which is 23.80%. Meanwhile, the greatest is variation 12 with absorption of 27.69%. Therefore, it is obtained for all variations made for absorption, which is 23.80% - 27.69%.

In contrast to the normal aggregates, water uptake in small aggregates is greater due to the pore space in it. When aggregates are submerged, the water will seep through the surface area and occupy its porch space. The amount of water absorbed depends on the condition of the pore structure (pored structure) and the internal pore volume. Aggregate pore space of small size separate or interconnected to form a gap in it so that the nature of absorption is high.

Water absorption is a function of the time at which the initial absorption rate but will decrease with increasing time. Generally, absorption in mild rough aggregates within 24 hours ranges from 5 to 30% of the total pore volume due to lightly tight surfaces.

Light aggregate on dry conditions (Oven Dry) after absorbed water increases weight according to percentage uptake. Therefore, the percentage of uptake above 50% is less suitable for concrete aggregates. Besides adding the weight of aggregate, the water absorption also affects the amount of concrete water requirement. The free water expected by the hydration process will be absorbed by the aggregate.

In concrete with a high w/c cement factor, this absorption effect increases the compressive strength of the concrete, but at low w/c otherwise, it reduces its strength.

From the research that has been conducted, the result of absorption is 23.80% - 27.69%. Thus all variations are suitable to be Aggregate stone replacement in the manufacture of concrete as below 50%.

3.2.3. Weight Contents

For the test results of the aggregate variation, the data of Artificial Coarse Aggregate weight has obtained as follows:

Varation	Loose (kg/m^3)	Solid (kg/m^3)	Average (kg/m^3)
1	962	1072	1017
2	1015	853	934
3	1002	800	901
4	1014	859	936
5	991	812	902
6	1034	869	952
7	908	781	845
8	999	824	911
9	967	801	884
10	896	722	809
11	988	821	904
12	1.060	1.146	1.103
13	998	1.073	1.036
14	1.116	1.215	1.165
15	1.216	1.323	1.269
16	1.097	1.160	1,128
17	1.082	1.151	1.116
18	1.266	1,367	1.316
19	1.366	1,471	1.418

Table 7 Weight Contents

Standard	Dry Weight OD (kg/m^3)
ACI	550 – 880 (35 – 70 lb/m^3)
SNI	700 – 1100
CEB/FIB	650 – 1100 (40 – 70 lb/m^3)

Table 8 Standard Weight Volume of Lightweight Coarse Aggregate dry state OD [1][3][10]

According to existing standards for the lightweight coarse aggregates as in Table 8, then it is obtained from the research that has been done as follows :

Standard	Appropriate Variations OD
ACI	10 and 7
SNI	10, 7, 9, 3, 5,11 ,8 ,2 ,4 ,6 ,1 , 13 and 12
CEB/FIB	10, 7, 9, 3, 5,11 ,8 ,2 ,4 ,6 ,1, 13 and 12

OD < 1100 Kg/3	17, 16, 14, 15, 18, and 19

Table 9 Appropriate Variations Standard (OD)

3.2.4. Gradation Lightweight Coarse Aggregate

Test results of the aggregate variation shown the data for the fineness modulus of the coarse aggregate between 5,89 - 6,00. This result belongs to the medium-coarse aggregate because the fineness modulus of the coarse aggregate is between 3 - 14. Thus, the aggregate can be cavities between the grains. The coarse aggregate may be filled with fine aggregates, the gradation distribution of the mixture between the coarse and fine aggregates shall satisfy the specified standard gradation curve thereby resulting in a lightweight concrete having the strength according to plan. Gradations that are qualified to be used on concrete can have a beneficial effect on fresh concrete as well as the strength of hard concrete.

3.2.5. Moisture Content

Moisture content on lightly aggregate made for all 0% variations. This is because lightweight coarse aggregates are made in the oven for ± 9 until it reaches the temperature of 1000oC. Because the long burning and high temperatures affect the water in the aggregate for all variations so it does not contain water anymore (dry conditions of the oven).

3.2.6. Abrasion Lightweight Coarse Aggregate

Variation	Destruction (%)
1	21,5
2	25,1
3	35,31
4	41,16
5	52,12
6	64,92
7	72,16
8	83,13
9	87,98
10	92,95
11	99,69
12	32,16
13	33,19
14	37,98
15	39,32
16	47,97
17	48,92
18	48,21
19	48,32

Table 10 Destruction

Hardness, abrasion resistance, and resistance to pebbles relate to the strength of the concrete that will be made. Therefore, that the aggregates we make must meet the requirements of rough aggregate hardness that can be seen in Table 11 below:

Concrete Strength	The vessel Rudeloff Maximum shattered parts, pierce the sieve 2 mm (%)		Los Angeles Machine Maximum shattered parts, pierce the sieve 1,7 mm (%)
	Grain Size 19 -30 mm	Grain Size 9,5 – 19 mm	
Class I Concrete and quality B0 and B1	22 - 30	24 – 32	40 - 50
Class II concrete and 12.5 MPa,	14 - 22	16 - 24	27 - 40

17.5 MPa, and 22.5 MPa qualities			
Class III Concrete and quality > 22,5 MPa or Prestressed concrete	Less than 14	Less than 16	Less than 27

Table 11 Coarse Aggregate hardness requirements for concrete [6][11]

The results of the Aggregate variation test show the Aggregate data that meets the requirements in the manufacture of lightweight concrete with artificial aggregate as follows:

Concrete Strength	Variations that Fulfill Tests Aus Los Angeles Machine, Maximum crushed parts, penetrate a 1.7 mm sieve (%)
Destruction> 50%	5, 6, 7 ,8, 9 10 and 11
Class I Concrete and quality B0 and B1	4, 16, 17, 18, and 19
Class II concrete and 12.5 MPa, 17.5 MPa, and 22.5 MPa qualities	12, 13, 3, 14 and 15
Class III concrete and quality > 22.5 MPa or prestressed concrete	1 and 2

Table 12 Test Results Aus Los Angeles

IV. CONCLUSION

The Aggregate of variation 1 to 19 that tested with the Los Angeles machine ≤ 40% is a mixture of 90% ball clay + 10% boiler ash, a mixture of 80% ball clay + 20% boiler ash, 80% ball clay + 20% kaolin, 90% ball clay + 10% fly ash, 80% ball clay + 20% fly ash, 100% and 90% ball clay ball clay + 10% kaolin. Thus, these variations can be used to make lightweight coarse Aggregates in manufacturing lightweight concrete with a compressive strength of ≥22.5 MPa. The optimum composition to be lightweight coarse Aggregates is a ball clay 80% + kaolin 20% with an average weight volume of 901 kg/m^3. This composition is very good for coarse Aggregates used in the manufacture of lightweight concrete with a compressive strength of ≥ 22.5 MPa, with a unit weight/volume of lightweight concrete produced ≤ 901 kg/m^3.

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