Utilization of clinker (industrial waste) as a coarse aggregate substitution on the lightweight concrete

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Abstract. The Concrete starts to use material substitution to reducing its brittle character. The Material substitution is a substance that can change concrete which are coarse aggregate, fine aggregate, and cement with others materials, such as the Portland cement combine the steel slag, broken stone (coarse aggregate) with a pumice stone, etc. One of function from concrete material substitution method can exercise an industrial waste. The industrial waste can be an output of residue production from industrial activities, one of which is clinker (the waste of burning coals). The purpose of research is 1) Measure of the concrete compressive strength value between Destructive Test and Non-Destructive Test method on lightweight concrete with clinker as coarse aggregate replacements; 2) analyze the correlation of time variation on increased value of compressive strength of lightweight concrete which is tested by UTM, the hammer test, and UPV; 3) the lightweight concrete design with clinker on optimum strength for structural functions and building construction. The result of this research is to know precisely the compressive strength of lightweight concrete made from Clinker which has been tested by UTM, Hammer Test, and UPV. It provides an evaluation of the structures and building construction feasibility towards existing building as an effort to create buildings that are responsive and resistant to natural disasters.

1. Introduction

The use of concrete as a building material is very popular in Indonesia because it can utilize local materials such as sand, split stone, cement, and water which are easily obtained at relatively low prices. Generally, concrete is composed of four main constituent materials that are cement, coarse aggregate, fine aggregate, and water. With the increased development of infrastructure, it is expected that environmental aspects are also considered. The use of split stone and sand which are taken from nature should be limited.

Concrete is the main material used in building construction. Concrete is widely used because of its advantages. Concrete can be easily formed by construction needs, able to carry heavy loads, withstand high temperatures, and maintenance costs are small or easy to maintain. Besides being resistant to fire attack as mentioned earlier, concrete is also resistant to corrosion attack. The compressive strength of concrete can be achieved up to 14000 psi or more, depending on the mixture type, the aggregate properties, and the treatment duration and quality. The most commonly used concrete strength is around 3000 to 6000 psi, and commercial concrete with ordinary aggregate, its strength is around 300 to 10000 psi with a size of 6 x 12 inches.

In its development, concrete began to use substitute materials to reduce the brittle nature of concrete. Substitute material is a material that can replace concrete materials such as coarse and fine aggregates or cement with other materials like portland cement with steel slag, split stone (coarse aggregate) with pumice stone and others. One of the benefits of the concrete material substitution method is that it can
Use industrial waste. Industrial waste can be a result of the rest of the production and consumption of industrial activity. One is the clinker which is waste from coal combustion.

Clinker is a layer of clay around combusted coal sediment so that it hardens as a brick and can be used as a road hardener. Clinker can also mean blob-shaped ash material or porous mass resulting from coal combustion. Currently, the clinker from the rest of the combustion becomes industrial waste. This is because there are not many people who use the waste from coal combustion so that the remaining combustion is only disposed of which causes coal industry waste to accumulate over time. Based on the explanation above, the clinker which is only used as unused waste is very suitable if it can be used as a substitute for concrete mixes and evaluates the feasibility of the structure and construction of existing buildings as an effort to create buildings that are responsive and resistant to natural disasters.

2. Literature Review

Compressive strength is one of the concrete main performance. The compressive strength is the ability of concrete to be able to accept force per unit area. The strength value of concrete is known by testing the compressive strength of the cylindrical or cube test specimens which are loaded with compressive force until they reach the maximum load. The maximum load of the test obtained by using Universal Testing Machine.

Several factors affect the concrete strength quality, namely:
1. Water-Cement Ratio (FAS).
   Water-Cement Ratio (FAS) is the ratio between the amount of water to the amount of cement in a concrete mix.
2. The functions of FAS are:
   a. To enable the chemical reaction that causes the binding and hardening.
   b. Providing ease of concrete processing (workability). The higher the FAS value, the lower the strength of the concrete. But the lower FAS value does not necessarily mean that the strength of the concrete is getting higher. In general, the given FAS value is a minimum of 0.4 and a maximum of 0.65.
3. Aggregate property.
   The properties of aggregates greatly affect the concrete mixture quality. The aggregate properties that need to be considered such as water absorption, aggregate moisture content, density, aggregate gradation, fine grain modulus, aggregate durability, aggregate roughness and hardness.
4. The proportion of cement and the type of cement
   Related to the ratio of the amount of cement used during the manufacture mix design and the type of cement used by the designation of concrete that will be created. Determining the type of cement used refers to the place where the building structure using concrete materials is created, as well as on the planning needs whether at the time of the casting process requires a high or normal initial strength.
5. Additive.
   Additives are added during stirring. Additives are more widely used for cementing (cementitious), so they are used to improve performance.

According to ASTM C 494 / C494M - 05a, the type of chemical additive can be divided into seven types, namely:
1. Water reducing admixtures
2. Retarding admixtures
3. Accelerating admixtures
4. Water reducing and retarding admixtures
5. Water reducing and accelerating admixtures
6. Water reducing and high range admixtures
7. Water reducing, high range and retarding admixtures
The compressive strength of concrete is obtained from a concrete compression test which is adjusted to the hardening time of the concrete. In the regulation, the concrete compression test can be carried out for 28 days.

Crushing compressive strength of the individual is the ability of the test object to withstand the compressive force or the maximum ability of the test specimen in resisting the force which causes destruction. Several factors including influence the concrete compressive strength

1. Type and quality of cement
2. Type and surface texture of aggregate
3. Treatment
4. Temperature

Universal Testing Machine (UTM) is a testing tool that serves to test the tensile and compressive strength of concrete. This tool requires an object to be tested on a testing machine with a given compressive force or tensile force, which in turn presses or pulls the specimen so that it becomes short or long. The UTM test is testing the compressive strength of concrete by applying a certain pressure to the concrete until the specimen breaks. Through the test, the value of concrete compressive strength can be known.

Ultrasonic Pulse Velocity (UPV) is a method used to measure the conductivity of ultrasonic pulses that pass through concrete as seen in [1]:
The UPV test is used to indirectly test the concrete compressive strength by measuring the propagation speed of longitudinal electronic waves on concrete media. The implementation can be done in three ways, namely: (1) direct, (2) semi-direct, and (3) indirect. The way the test works is by giving longitudinal wave vibrations through electro-acoustic transducer through coupling fluid which is in the form of fat or a type of cellulose paste, which is applied to the concrete surface before the test begins. When the waves propagate through different media, fat, and concrete, on the boundary of fat and concrete will occur the reflection of waves that propagate in the form of shear and longitudinal waves. Shear waves propagate perpendicular to the trajectory and longitudinal waves propagate parallel to the trajectory. A longitudinal wave is the first to reach the receiving transducer. By transducer, this wave is converted into an electronic wave signal that can be detected by the receiver transducer so that the wave travel time can be measured. The T travel time needed to propagate waves on the concrete path along L can be measured so that the formula can search the wave velocity.

3. Method
The method used in this research is experimental qualitative. Data analysis technique based on three variables that are concrete curing methods, age of concrete, and types of additives

4. Result and Discussion

4.1 Characteristic Test.
The test results on the coarse aggregate characteristics as follows:

| Characteristic Test     | Weight | Unit |
|-------------------------|--------|------|
| Water Content           | 2.8    | %    |
| Sludge Level            | 0.9    | %    |
| Density                 | 2.31   | %    |
| Absorption              | 1.38   | %    |
| Volume Weight           | 1.34   | Kg/m3|
### Table 2. Clinker

| Characteristic Test | Weight | Unit |
|---------------------|--------|------|
| Water Content       | 1.3    | %    |
| Sludge Level        | 0      | %    |
| Density             | 2.3    | %    |
| Absorption          | 2.12   | %    |
| Volume Weight       | 1.32   | Kg/m³|

#### 4.2 Mix Design.
For ordinary concrete or normal concrete specimens using materials according to the design in Table 1

### Table 3. Mix design of Normal/Reference Concrete in Cubic Meters

| Description | Weight in 1 m³ | Unit |
|-------------|----------------|------|
| Cement      | 375            | Kg   |
| Coarse      | 1071           | Kg   |
| Aggregate   |                |      |
| Fine        | 699            | Kg   |
| Aggregate   |                |      |
| Water       | 195            | Ltr  |

For the lightweight concrete test object, it uses the material from the normal / reference concrete mix design which includes:

### Table 4. Mix Design of Lightweight Concrete Using Clinker as Coarse Aggregate in Cubic Meters

| Description | Weight in 1 m³ | Unit |
|-------------|----------------|------|
| Cement      | 375            | Kg   |
| Clinker     | 1071           | Kg   |
| Fine        | 699            | Kg   |
| Aggregate   |                |      |
| Water       | 195            | Ltr  |

In this section, the use of clinker is intended as a substitute for coarse aggregate.

**Figure 1. Material that has been mixed design**

In the researchers' experiments, the specimens used based on the Decree of SNI T - 15 - 1991 - 03. The specimens were cylindrical which tested their compressive strength by using destructive methods with UTM machine. As for the non-destructive method, the Hummer Test and Ultrasonic Pulse Velocity tools were used. The cylinder size is 10 cm in diameter and 20 cm in height with the number of objects each of which is 20 cylindrical and 2 cuboids shaped with a size of 30x30x30 cm. The size of the concrete cylinder and concrete cube used is the same size between normal / reference concrete and clinker lightweight concrete.
Figure 2. The testing process of the concrete test specimen’s strength with the Universal Testing Machine (UTM) and Ultrasonic Pulse Velocity (UPV) and Hummer Test tools.

The concrete compressive strength is the magnitude of the load per unit area of the test object which causes the test object to be destroyed when given a load with a certain compressive force through the Universal Testing Machine (UTM). Compressive strength test based on ASTM C-39-86 and SNI Decree (Table 3).

Table 5. The results of normal concrete compressive strength with destructive and non-destructive methods

| Concrete Type | UTM | UPV | Hammer |
|---------------|-----|-----|--------|
| H-3           | 4,14| 1,98| 1,2    |
| H-7           | 8,31| 3,22| 2,6    |
| H-14          | 15,19| 6,45| 4,0    |

Figure 3. Comparison of normal concrete compressive strength to concrete age

Description: OC (N) = Ordinary Concrete
COLC (CN) = Clinker Ordinary Lightweight Concrete.

The lightweight concrete in this research is intended as the utilization of waste material which in this case is clinker from bottom ash. Clinker bottom ash as a substitute for coarse aggregate. From the results of the test specimen, the obtained results as in table 4.
Table 6. The results of lightweight concrete (Clinker) compressive strength with destructive and non-destructive methods

| Concrete Type | UTM   | UPV   | Hammer |
|---------------|-------|-------|--------|
| H-3           | 2.45  | 1.11  | 0.80   |
| H-7           | 4.81  | 1.70  | 0.85   |
| H-14          | 8.02  | 6.43  | 1.05   |

Figure 4. Comparison of lightweight concrete compressive strength to concrete age

Figure 5. Weight Comparison of Normal (N) and Lightweight (CN) Concretes to Concrete Age

The results of the compressive test with the Universal Testing Machine (UTM) which starts from 7 and 14-days old concretion the concrete cylindrical specimens of the normal and lightweight concrete types through the destructive method obtained a temporary comparison as seen in Figure 3 and Figure 4.

5. Conclusion

From the experimental results that the author has done in the attempt to make and test lightweight concrete with the comparison used is normal concrete through several studies in the form of physical studies, it can be concluded as follows:

1. Until the age of 14 days, normal concrete has reached compressive strength capability of 15.19 Mpa.
2. Until the age of 14 days, lightweight concrete using clinker has reached compressive strength capability of 8.02 Mpa.

3. At the age of 14 days, normal concrete weight reaches 15.19 kg/cm$^3$

4. At the age of 14 days, lightweight concrete weight reaches 8.02 kg/cm$^3$

By looking at the development of lightweight concrete strength, it can be assumed that as the age of lightweight concrete increases, the carrying capacity of concrete tends to increase. Likewise with the weight of the concrete itself. As the age of the concrete increases, the weight of lightweight concrete tends to increase. This is due to the decreasing absorption of water in the clinker that is used instead of coarse aggregate.

**Acknowledgments**

Authors wishing to acknowledge assistance or encouragement from colleagues, special work by technical staff or financial support from organizations should do so in an unnumbered Acknowledgments section immediately following the last numbered section of the paper.

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