Development of Effective Lightweight Material for Construction Building.

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\textbf{Abstract}. Due to an increasing trend of building construction in Thailand, Lightweight concrete has been recently introduced into the structural engineering applications. This study was aimed to investigate two aspects; the first one is studying the properties of Cellular Lightweight Concrete (CLC) and verifying that the lightweight concrete satisfies Thai Industrial Standard (TIS Standard) \textsuperscript{[12]}. To verify with the TIS Standard, investigated properties of CLC are dry unit weight, water absorption and compressive strength. Researcher prepared admixtures with sand cement ratio (S/C), water cement ratio (W/C) and percentage of foam to collect statistical data and analyse. Verified by the standard, specimens that pass the standard criteria will be chosen for proper applications in manufacturing of prefabricated construction materials.

1. Introduction

Lightweight concrete is a concrete that has less unit weight than general concrete. Lightweight concrete is a new product produced from natural raw materials include portland cement, lime sand, gypsum, water, air entraining admixtures and design admixtures in a unique formula. Normally, the concrete has a unit weight around 2300 kg/m\textsuperscript{3} in dry conditions.

Nowadays, most of production technology and equipment are imported from abroad, such as Germany and Australia. Lightweight concrete is a new construction material with special properties which are lightweight materials, heat resistant, sound insulation, easy to trim. More benefits are working quickly, reduce construction time, construction structural costs and environmental impact. (Krisada Sutthiphan, 2014) \textsuperscript{[1]}

Lightweight concrete is widely used because it is an alternative material with advantages are lightweight, heat insulation and other features that are suitable for use rather than brick. Development of foamed concrete properties has become more various by using a new aggregate material for enhancing other construction requirement. This development of new innovations can reduce both direct and indirect costs within the household

2. Method

This study compares properties of cellular lightweight concrete. Specimen size is 5 cm wide, 5 cm long, 5 cm high. Specimens have admixtures which are water and cement ratio (w/c) at 0.4, 0.5 and 0.6, sand and cement ratio (s/c) at 0.5, 1.0 and 2.0 and percent foam per volume of specimen at 40, 60, 80 and 100% as shown in table 1. Then comparing with CLC standard (TIS. 2601 - 2556)
carried over for select admixture which pass the criteria. Lightweight prefabricated products in various parts of the household such as walls and roofs.

Table 1 Number of samples of each of the admixture

| Ratio   | Percentage of Foam |
|---------|--------------------|
| S/C     | W/C               |
| 0.5:1   | 0.4 12 12 12 12    |
| 1.0:1   | 0.4 12 12 12 12    |
| 2.0:1   | 0.4 12 12 12 12    |
| 2.1. The manufacturing process of lightweight concrete.  
1. Mixing cement, sand and water with the specified ratio.  
2. Produce CLC foam from foaming agent with foam generator machine and air pump. The foam can be mixed with mortar. The foam must be smooth and must be used immediately while the foam leaves from foam generator machine because foam’s quality will be decreased with increasing of time.

Fig 1 Foam for CLC

3. Mixes mortar and foam together in a temperature control room. Due to the high temperatures, water in the mortar will be evaporated more rapidly that accelerates the hydration reaction between water and cement and reduce workability.

4. Cast the mortar into the formwork to make the mortar fit well, then finishing the surface with a trowel, and then sealing the surface with plastic seal to prevent water evaporation.

5. Curing in the formwork for 24 hours and then remove the formwork. Then curing the samples by soaking them in water.

6. By the age is 28 days old, the specimens were brought out of the water. Wiping the skin to dry, then measuring the weight of the condition at saturated dry skin. Then take the sample to bake for 24 hours and then measure the weight that is completely dry. And measure the size on both sides of the length with the vernier caliper and then tested to compressive strength.
2.2. Unit weight and water absorption.

The specimens were brought out of the water when it completely cured and dry the skin then measure the weight of the samples to collect the saturated condition weight. Then dry the samples in the oven for 24 hours and collect the absolute dry condition weight. After that calculated the water absorption from the formula below.

\[
\%W = \left(\frac{SW-D}{DW}\right) \times 100 \%
\]  

(1)

- SW : Saturated weight, kg
- DW : Dry weight, kg
- %W : Water absorption, %

Then measure the sample size with Vernier Caliper. And calculate the density of the sample from the formula below

\[
\rho = \left(\frac{DW}{V}\right)
\]

(2)

- V : Volume = cm \times 10^{-4} = m^3
- \rho : Unit weight, kg/m^3

2.3. Compressive Strength

1. Taking the finished curing samples measure in width, length and height by vernier caliper.
2. Weighing samples and taking notes.
3. Taking samples into the concrete compression testing machine. Prepare to perform compression tests.
4. Applying the compression to the specimens at a constant rate in the range of 0.14 - 0.34 Newton per square millimeter per second to the point of failure. And collect compressive strength data to calculate compressive stress from formula below. [TIS 409-2525][11]

Calculation

\[
\sigma = \frac{F}{(L \times W)}
\]

(3)

- W : Width of the sample(cm.)
- L : Length of the sample(cm.)
- H : Height of the sample (cm.)
- F : Compressive force (kg.)
- \sigma : Compressive strength (ksc.)
2.4. Analysis results

From the experiments, the properties were compared with CLC criteria (TIS. 2601 - 2556). Specimens which pass the standard shall be considered for engineering construction.

3. Result

From the testing results, the density of specimens show that density is inversely proportional to percentage of foam.

From Figure 3, the average unit weight and foam (%), w/c and s/c relationship as shown. The standard density is 800 to 1600 kg / m$^3$, i.e. s/c 0.5 at w/c 0.4, 0.5 and 0.6, s/c 1.0 at w/c 0.5 and 0.6.
From the results of the experiment to find compressive strength was found that compressive strength is inversely proportional to percentage of foam.

Figure 4 describes average compressive strength and foam (percent), w/c and s/c relationship. For density range 801 - 1200 kg/m$^3$ the compressive strength values according to standards is not less than 25.5 ksc. and density range 1201 - 1600 kg/m$^3$ values is not less than 51.0 ksc. The results show that every specimen has average compressive strength is greater than the standard. Consequently, all specimens pass this criterion.

From the experiment, water absorption is proportional with percentage of foam.
This tendency is elaborated in figure 5, the average water absorption, foam (percent), w/c and s/c relationship. The standard of water absorption is not greater than 23% by volume between the density 801 - 1200 kg/m$^3$ and not greater than 20% by volume between the density 1201 - 1600 kg/m$^3$. All specimens except a specimen at s/c 0.5 at w/c 0.5 and 0.6 has average water absorption over 25%. The remaining sample passes the criteria because it is lower than 23%.

4. Result

By comparison, the three CLC properties : unit weight, compressive strength and water absorption. The specimens which pass all criteria were labeled in the table below.

| Type | Average Dry Unit weight, (kg/m$^3$) |
|------|-----------------------------------|
| C6   | 501 - 600                         |
| C7   | 601 - 700                         |
| C8   | 701 - 800                         |
| C9   | 801 - 900                         |
| C10  | 901 - 1000                        |
| C12  | 1001 - 1200                       |
| C14  | 1201 - 1400                       |
| C16  | 1401 - 1600                       |

Table 2 CLC classification by TIS Standard

| S/C  | W/C | 40% | 60% | 80% | 100% |
|------|-----|-----|-----|-----|------|
| 0.5:1| 0.4 | C16 | C16 | -   | C14  |
|      | 0.5 | -   | -   | -   | -    |
|      | 0.6 | -   | -   | -   | -    |
| 1.0:1| 0.4 | C16 | C16 | C14 | C14  |
|      | 0.5 | -   | -   | C14 | -    |
|      | 0.6 | -   | C14 | -   | C14  |
| 2.0:1| 0.5 | -   | -   | -   | -    |
|      | 0.6 | C16 | C14 | C14 | -    |

Table 3 Admixtures which classified by TIS standard (1. unit weight, 2. compressive strength and 3. water absorption)

The relationship between the admixture of CLC and the properties. Can classify specimens with average dry density by table 2.

As TIS standard, specimens were classified to C14 and C16, which C14 will be applied as a wall structure with the advantages are sound and heat insulation. And C16 will be applied as concrete roof structure due to the sample type C16 has compressive strength around 250 ksc. Therefore, this is a good option to be applied in engineering because it has a light weight and has a close air-void pore pattern to preventing water permeability.
5. Conclusion

The specimens which passed all criteria can be classified in CLC standard. From the analysis, the specimens have unit weight ranges between 1201 - 1400 kg/m$^3$ are C14 type and 1401 - 1600 kg/m$^3$ are C16 type. The specimens at s/c 0.5 are light weight samples, but average water absorption is over the standard. Therefore, these samples were rejected. From the table 3 displaying exclusively specimen passes all criterion. To summarize, specimens passing all standard criteria are suitable for prefabricated constructions as shown within this research.

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