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Impact of Wet and Air Curing Methods on Developing Compressive Strength in Concrete

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Abstract

Concrete curing is a process fulfilling compressive strength value for the material used. There are several techniques to cure concrete, such as ponding or immersion, curing the mold, plastic sheeting, sprinkling or spraying, curing compounds, and steam curing. The principle is to provide sufficient moisture to the concrete structure during the hydration reaction. This research aims to study the effect on compressive strength development of concrete under curing conditions in wet and air. The compressive strength of the sample, which was cured by a different method, was investigated by comparing with the rising trend of curing time and water consumption in the improving compressive strength of concrete in each curing time. The cylindrical concrete samples of 10 cm diameter and 20 cm height were cast to evaluate compressive strength at the curing duration of 3, 5, 7, 14, 21, and 28 days as 60 samples. They were compared compressive strength with a different curing condition between room temperature (air curing) and wet curing. As ACI standards, controlled samples had a compressive strength of 350 kg/cm2 at 28 days of curing. The results revealed that the wet-cured samples had more compressive strength than the air-cured samples, as 359.26 kg/cm2 and 311.46 kg/cm2 after 28 days of curing. These were the highest value of compressive strength according to the increase in curing periods of 0 to 28 days. It indicated that moisture was a vital variable in the compressive strength development of concrete due to the hydration reaction.

Keywords: compressive strength, wet curing, air curing

1. Introduction

The construction has been increasing due to the economic expansion and related factors reasons (1). In order to respond the demand from a large number of customers for construction resulted in the quality control of construction standard. Almost all high-rise buildings currently use high-pressure (post-tension) technology (2) buildings in each floor. While as concrete construction is continuing, the samples will be tested as appropriate methods. The data collection had been done by derived a curing data as soaking water, unlike the concrete, in the work site did not cure a mortar by soaking moisture and a post-tensioning floor which has a large surface area cause prompt evaporation of moisture and resulted in a smaller concrete mass than previously designed (3).

Even though concrete is a long-term material, the current construction still faces multiple mechanical and durability problems. One of the problems was concrete curing, as incomplete compressive strength development and age-dryness, affecting capacity and declining structural age (4).

Concrete curing is controlling and preventing speedy evaporating from the concrete setting. (5) Since water is the most important element for hydration control certainly affects concrete strength to maintain the remaining humidity for at least 7 days. The concrete strength will be increased as long as the sufficient moisture allowing cement reacted with water. After concrete pouring and leaving without marks, it immediately makes precise curing. The skin will not be exposed to sun or hot air, it will not be disturbed especially within the first 24 hours to ensure good and required qualities and will preventing losing water body from new concrete pouring otherwise drills will cause tension on the skin from fast contraction affecting to wrinkles concrete. The periods are preventing and maintaining moisture inside with a bath is called curing period (6).

The strength rising rapidly in the first phase and slowdown later because of the right humidity and temperature reasons caused (7). The correlation can be seen after air curing and wet curing, the capacity higher in wet curing day and night time. In fact, it cannot be accomplished by wet curing for (8) a long time due to limitations of the construction. Therefore, 7-14 days for continuously wet curing was already appropriate for concrete capacity about 70% of designed (9).

The temperature used to concrete curing should be between 15-39 degrees Celsius. The curing should not be lower than 4 degrees Celsius owing to slower concrete temperature (10), high temperature and dry air will cause evaporation from its. The concrete is rapidly being crushed and could easily break. The concrete curing time depends on the type of cement used to mix concrete to the required concrete structure size and shape. Temperature and humidity during the curing has to measure from the day the concrete is finished in 24 hours. In general, exposed slippery surfaces with bright cement should be checked in for at least 7 to 14 consecutive days (11-14).

Despite the curing requirements not matching in the actual construction situation, the concrete curing process was not standardized. The problem was that the hot climate in Thailand makes it more difficulty to cure in low efficiency. Some types of concrete such as concrete with low water to binder ratio (w/b), high strength concrete, Self-compacting concrete which is a large concrete structure resulted in the water can absorb less concrete into the interior (15).

The construction team must immediately continue to access the area, seeing the concrete poured into it will be crushed by the weather every day and will be subjected to heavy loads of construction equipment, including vibrations from process affect the concrete capacity has been greatly reduced (16).

For these reasons, the research focuses on studying the impact of compression on the concrete casing derived from wet and air curing, providing the basic information for designing the concrete casing in the future engineering.

2. Materials and Experiment

2.1 Materials

2.1.1 Concrete mix

The reinforced concrete quality assessment standard defines the compressive strength of concrete at 28 days curing in accordance with ASTM C 192 (12), the compressive strength of concrete used in general structural applications. The deflection value of the concrete is in the range of 7.5 ± 2.5 cm. The calculation methodology for concrete mixing proportion is in accordance with the ACI standard.

2.1.2 Aggregates

The research studied into 2 types as fine and coarse aggregates to identify the concrete compressive strength, abrasive resistance, particle shape, gradation, bulking of sand and fineness modulus with ASTM C 136. The two type of aggregate can be divided as;

2.1.3 Fine Aggregate, sand used in general construction. the humidity must be controlled by drying before further testing.

2.1.4 Course Aggregate, a limestone used in general construction, not over 20 mm fitting the mold by sifting through a sieve and then testing the properties of the material (13).

2.1.5 Water, clean and able to drink.

2.2 Methods

The coarse and fine aggregate unit weight testing compliant to ASTM C 23 and ASTM C 128 respectively (16-17)

The research experimental process concluded two sections as concrete mixing design and concrete compressive strength as follows;

2.2.1 Concrete Mixing Design

The calculation of concrete mixing design according to ACI standards.

The controlled concrete mixture was selected with compressive strength of 350 kg/cm^2 at 28 days curing tested with cylindrical samples, collapse ranged between 8 -10 cm.

The properties of material used in the experiment.

1) Cement Portland Type I with specific gravity at 3.15.

2) Coarse aggregates, the largest size is 20 mm with specific gravity 2.70, absorption value 0.44%, dry weight unit 1,595 kg/m^3 and moisture 0%

3) Fine aggregate, specific gravity at 2.60, absorption value 0.74%, modulus resolution 2.80 and moisture 0%.

The procedure for calculating the mixing ratio of concrete

1) Collapse value selection. The required concrete collapse value depends on the type of work, the method of transportation, the pouring and compaction

2) The largest size of coarse aggregate. In general, try to use coarse aggregates or rocks as large as possible reducing cement quantity for the maximum size of the coarse aggregate should be according to the table.

3) Estimate the amount of water and air bubbles.

2.2.2 Water to cement ratio

The strength and durability of concrete depends on the water-cement ratio.

2.2.3 The calculation the amount of cement, from the water content and the water to cement ratio, the amount of cement can be calculated.

2.2.4 The coarse aggregate volume

The volume of the coarse aggregate depends on the fineness modulus of the sand and the maximum size of the coarse aggregate. The weight of the coarse aggregate calculated equal to the volume ratio of the coarse aggregate multiplied by the unit weight of the coarse aggregate in the dry state and in a firm pan. In general construction, the concrete collapse was set in range of 7.5 ± 2.5 cm. The calculation methodology of concrete admixtures complied with ACI standard (18).

2.2.5 The testing concrete sampling and concrete curing in the operational room under material control process and condition of standard testing

ASTM C 129 begin at mixing the ingredients together and put into the mold divided equally for four layers, uses the tamping steel twenty-five time in each layers, smoothen a surface, soak for twenty-four and release the mold to curing in water and air until the testing period as shown in Figure 1 (19).

Figure 1 The process of concrete curing

2.2.6 The compressive strength testing

This process had complied with the standard ASTM C 192. The samples of a cylinder had a diameter 10 cm, height 20 cm. The concrete samples reached the required time for measurement and weighing [20], coated the area with Sulphur. Then put in the compressive testing machine until the sample breaks and calculate the compressive strength of the compacted concrete as shown in the equation below;

$$Compressive\ Strength(fc') = \frac{P}{A} \quad (2.1)$$

Where P was Maximum Pressure (kg)
A was Net Area (cm^2)

The process of compressive strength testing as shown in Figure 2

Figure 2 The testing of concrete compressive strength

3. Result discussions

3.1 Compressive strength development of concrete

The development of compressive strength of 350 kg/cm^2 in accordance with ASTM C192 (20) found the water immersion causes the compressive strength of the concrete increasing as fluctuates from further time period of 1–28 days. The compressive strength of concrete was the highest at the water immersion curing method at 359.26 kg/cm^2 and air curing at 311.46 kg/cm^2 significantly lower as shown in the Figure 3 and Table 1.

Table 1 The comparison of compressive strength between wet and air curing at the curing ages

Compressive Strength (kg/cm^2, ksc)		
Day	Wet Curing	Air Curing
3	173.83±5.18	167.68±5.56
5	213.63±5.85	201.08±6.93
7	243.49±5.99	224.28±7.46
14	301.63±8.83	267.11±6.83
21	336.73±7.22	295.70±6.14
28	359.26±6.95	311.46±9.99

Note ± Standard Deviation

3.2 Compressive strength development rate of concrete

The development rate of compressive strength varies due to the age and curing method, all curing methods at 7 days had similar strength development rates at 28 days.

The compressive strength development rate of the curing methods by water immersion was the highest at 28 days of wet and air curing as 102.65% and 88.99% respectively, the compressive strength was developed during the increasing of curing time. The experimental results indicated the need of concrete moisture for the hydration and curing (harden). Being dried, it actually stops getting stronger. The compressive strength concrete of air curing would be less than a wet curing method. The reaction of water with the cement in concrete is extremely important to its properties and reactions (21). The compressive strength of wet and air curing concretes as shown in Figure 3.

3.3 Analysis of the strength test results of concrete samples

As a result of the hydration reaction, the compressive strength of the concrete was increased with rising curing times at 28 days, the compressive strength of the soaked samples was similar to the designed samples was cured by water immersion. As a result of immersion in water, the hydration of cement can be continuous and complete. The air cycle drying in the air causes the compressive strength lower than designed. There was easily expected that when water was added to cement, each of the compounds undergoes hydration and contributes to the final concrete product. The water can be reacted with calcium silicates, Tri-calcium silicate and di-calcium silicate that is contribute to compressive strength. The hydration reaction itself consumes a specific amount of water. Therefore, concrete was actually mixed with more water than it was needed for the hydration reactions. This extra water was added to give concrete sufficient workability. Flowing concrete was desired to achieve proper filling and composition of the forms. The water was not consumed in the hydration reaction. It will be remained in the microstructure pore space. These pores made the concrete weaker due to the lack of strength-forming calcium silicate hydrate bonds (22).

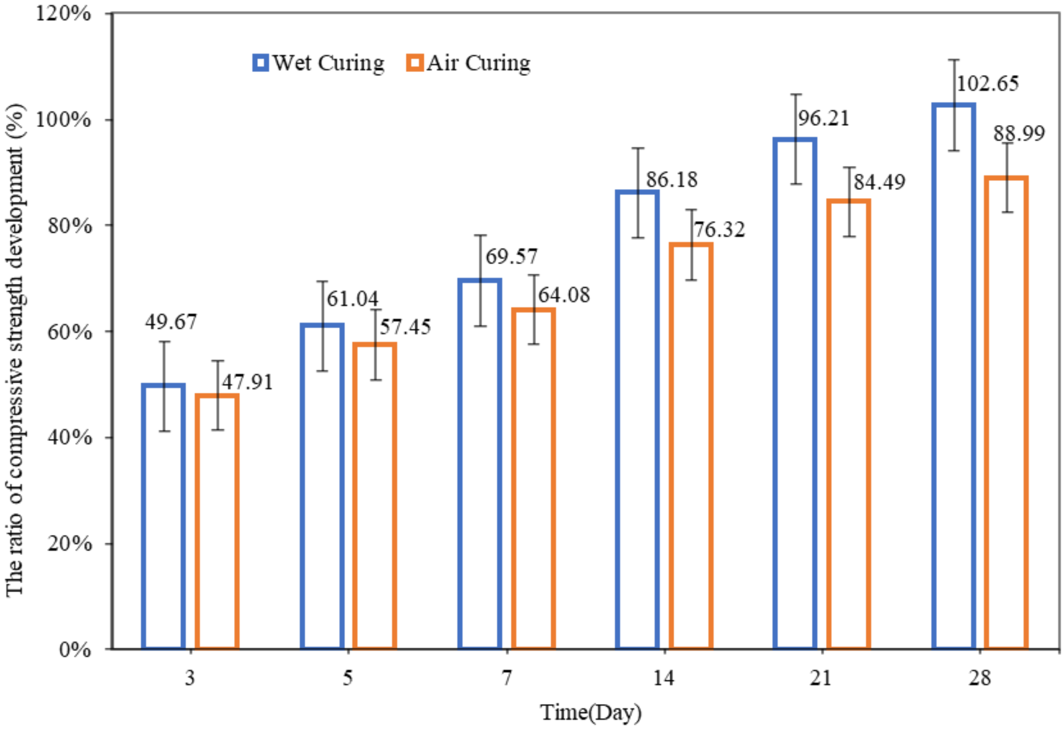

Figure 3 The comparison of concrete compressive strength development between wet and air curing

3.4 The rate of compressive strength loss due to curing

The development of compressive strength can be estimated as the rate of compressive strength loss due to incomplete hydration in the curing method. The air curing results in the highest rate of compressive strength loss at 13.30%. When the concrete was cured, the compressive strength of concrete will also increase with increasing curing time. During the initial period, concrete will develop strength quickly (The graph is very steep), 267.11% for air curing and 301.63% for wet curing at only 14 days. Then the concrete will develop its strength more slowly. (Graph started straight line) at 21 days of curing time and highest compressive strength was shown at 28 days of curing time. These results demonstrated that when water was added to cement, each compound undergoes hydration and contributes to the final concrete product. Calcium silicates contributed to strength at the first time. Tri-calcium Silicate is responsible for most of the early strength (first 7 days) as shown in Figure 4. Di-calcium silicate, which reacts more slowly, contributes only to the strength at later times. In addition, water and tri-calcium silicate were rapidly reacted to release calcium ions, hydroxide ions, and a large amount of heat. The pH quickly raised to over 12 because of alkaline hydroxide (OH-) ions release. The initial hydrolysis was rapidly slowed down after it starts resulting in a decrease in heat evolved (23-24).

4. Conclusion

The development of compressive strength of 350 kg/cm2 in accordance with ASTM C192 it was found water immersion causes the compressive strength of the concrete increasing as fluctuates from further time period of 1–28 days. During this period, the strength development was obviously increased by the higher curing time. due to the age and curing method, found all curing methods at 7 days had similar strength development rates at 28 days.

The curing methods by water immersion was the highest at 28 days of wet and air curing as 102.65% and 88.99% respectively. The air cycle drying causes the compressive strength to be lower than designed. There was easily expected that when water was added to cement, each of the compounds undergoes hydration and contributes to the final concrete product. The water can be reacted with calcium silicates, tri-calcium silicate and di-calcium silicate contributed to compressive strength. The hydration reaction itself consumes a specific amount of water. Therefore, concrete was actually mixed with more water than it was needed for the hydration reactions. This extra water was added to give concrete sufficient workability. Flowing concrete was desired to achieve proper filling and composition of the forms. The water was not consumed in the hydration reaction. It will be remained in the microstructure pore space. These pores made the concrete weaker due to the lack of strength-forming calcium silicate hydrate bonds.

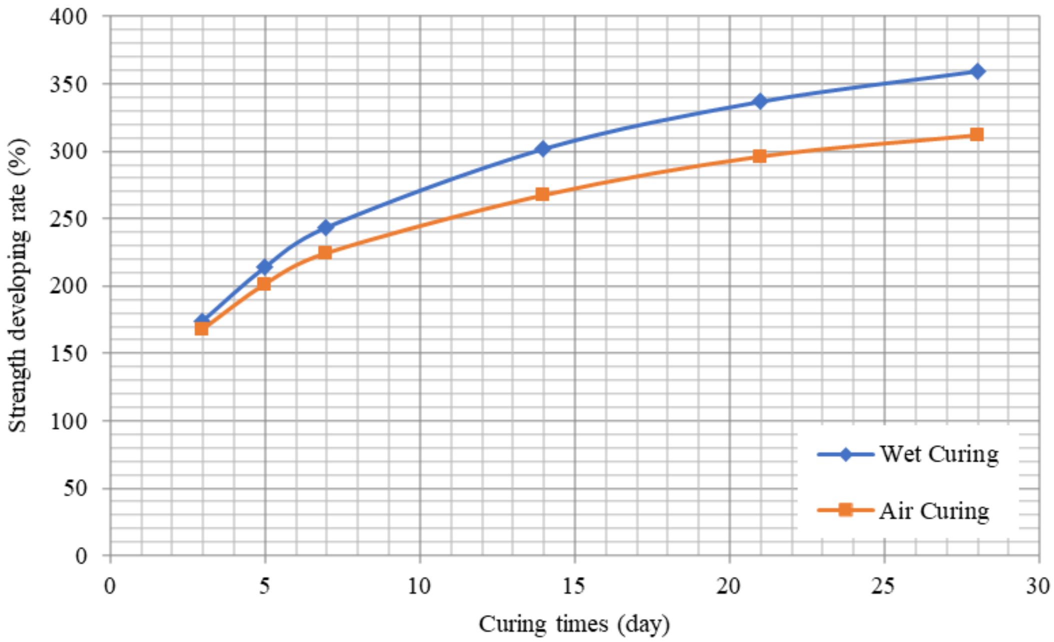

Figure 4 The comparison of compressive strength and curing

Tri-calcium Silicate is responsible for most of the early strength (first 7 days). Di-calcium silicate, which reacts more slowly, contributes only to the strength at later times. In addition, water and tri-calcium silicate were rapidly reacted to release calcium ions, hydroxide ions, and a large amount of heat. The pH quickly raised to over 12 because of alkaline hydroxide (OH-) ions release. The initial hydrolysis was rapidly slowed down after it starts resulting in a decrease in heat evolved. The reaction slowly produced calcium and hydroxide ions until the system became saturated. In this occurs, the calcium hydroxide was started to crystallize. Simultaneously, calcium silicate was hydrated begins to form. Ions precipitate out of solution was accelerated the reaction of tri-calcium silicate to calcium and hydroxide ions. (Le Chatlier's principle).

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Declaration of conflicting interests

The authors declared that they have no conflicts of interest in the research, authorship, and this article's publication.

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