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CONCRETE COMPRESSIVE STRENGTH OF POST COMBUSTION WITH AND WITHOUT WATERING

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ABSTRACT

The strength of the building structure after a fire is determined by the length of time the fire takes place and the cooling process used. According to several previous studies, it is said that the longer the concrete burns, the lower the quality of the concrete will be. This study aims to observe the compressive strength of concrete after the combustion process by cooling through experimental trials on 21 samples of cube model concrete. The concrete sample consisted of three samples of normal concrete and 18 samples of concrete that would be given combustion treatment and the quality of the design concrete was K250. Three samples of normal concrete were tested at the age of 14 days, then 18 samples were prepared for the combustion process with normal fire. A total of nine samples of concrete were treated with combustion for one hour, two hours and three hours with normal cooling in the open air as many as three samples each. Meanwhile, nine other concrete samples that had undergone combustion were given cooling treatment by sprinkling with water. The average compressive strength of concrete with a duration of one hour, two hours and three hours without water cooling respectively is 320.05 kg/cm^2, 285.65 kg/cm^2 and 235.21 kg/cm^2, with the percentage of decrease in the quality of concrete to normal concrete respectively is 9%, 19%, and 33%. Meanwhile, the average compressive strength of concrete with water cooling for the same duration of combustion is 295.72 kg/cm^2, 245.34 kg/cm^2 and 210.17 kg/cm^2, with the percentage of decrease in the quality of concrete to normal concrete respectively is 16%, 30%, and 40%. Based on the results of this study, the duration of combustion and the cooling treatment used can reduce the quality of concrete compared to normal concrete.

Keywords: Combustion; Compressive Strength; Concrete; Cooling; Watering

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1. INTRODUCTION

Concrete technology is a material that has been widely used as a construction material in the world and a good constructional material as it posses enough compressive strength for structural purposes (Rosyidah et al., 2019); (Gökçe et al., 2019); (Askar et al., 2019); (Ariyo et al., 2020). However, erratic weather and temperature conditions often pose a threat to the durability and lifespan of concrete (Śliwiński et al., 2021). Erratic temperature changes easily cause fire events (Triastuti, 2019);(Ajagbe et al., 2018). The impact of this fire is often experienced by the structure of residential buildings and office buildings. The effects of high temperature exposure for long period of time can decrease strength of concrete (Bamigboye et al., 2015); (Al-Naffakh & Jafar, 2020). Generally, concrete is resistant to high temperatures, but should not exceed 250ºC, because it can reduce the bonding of the concrete constituent structures and change the physical properties of concrete, such as discoloration of the concrete (Prasetiya et al., 2017); (Alkhamuddin & Adiguna, 2019); (Zabihi & Eren, 2014).

Some of the damage experienced by concrete after the combustion process is; chipped concrete plaster, blackened surface, surface cracks, deep cracks in the concrete, and in more serious cases, can cause the concrete to crack or crumble (Garrabrants et al., 2014); (Nurhidayati et al., 2019); (Sulianti et al., 2018). To find out the effect of combustion on concrete, it is necessary to do research on testing the compressive strength of concrete after the combustion process (Nurhidayati et al., 2019). Several studies have been developed such as research by (Dharmawan et al., 2016); (Patah & Dasar, 2022); (Setiyarto & Fira, 2019).

Based on several studies that have been developed above, it can be concluded that the effect of the combustion process at low to moderate temperatures (200ºC-300ºC), can increase the quality of concrete compared to normal (concrete without the combustion process and watering cooling) (Bajare et al., 2013). But burning with concrete quality that exceeds the temperature 200ºC - 300ºC it can reduce the quality of concrete compared to normal concrete (without combustion and watering). In this study, the quality of concrete will be tested to normal concrete (without combustion) and concrete with a combustion process and cooling with watering and without watering (Shackelford, 2014):

$$f'c = \frac{P}{A} \tag{1}$$

where *f'c* is the compressive strength of concrete (MPa), *P* is the maximum load (kg) and A is the surface area of the tested sample (cm^2). Testing the compressive strength of concrete sample as shown in Figure 1.

Figure 1. Testing The Compressive Strength of Concrete Samples

To calculate the percentage decrease in the compressive strength of post-combustion concrete with and without watering to the compressive strength of standard concrete, use the formula as follows (Cornelis et al., 2014):

$$BPB = \frac{BS - BPD}{BS} \times 100\% \quad (2)$$

$$BDP = \frac{BS - BDB}{BS} \times 100\% \quad (3)$$

where, *BS* is Standard Concrete, *BPB* is Post Burned Concrete, and *BDP* is Post Burned Concrete by Immersion. This study aims to observe the compressive strength of concrete after the combustion process by cooling through experimental trials on 21 samples of cube model concrete.

2. METHODS

This research is an experimental study in a laboratory to test the compressive strength of normal concrete with concrete that undergoes a combustion process with normal cooling and cooling by sprinkling water. This research was conducted at the Concrete Laboratory, Faculty of Engineering, Universitas Putra Indonesia "YPTK" Padang for one month. The research procedure begins with the preparation of materials and tools in the form of preparing the sample formula for the test object, making the sample of the test object and treating the sample of the test object. The more complete research procedures as shown in Figure 2.

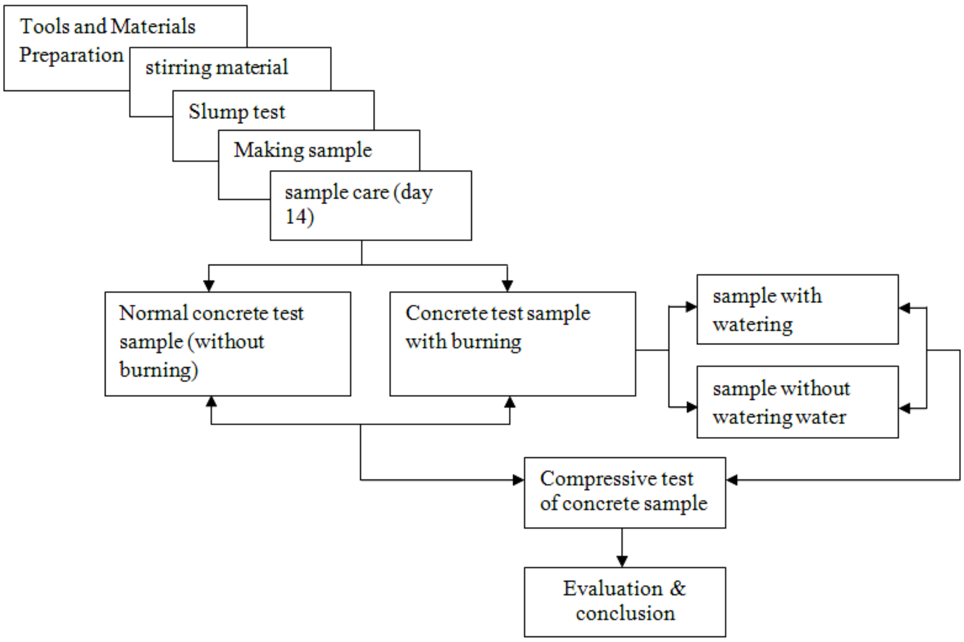

Figure 2. Flowchart of Research

The materials that will be used in this research are cement, coarse aggregate in the form of crushed stone, fine aggregate in the form of sand and water as needed. While the equipment used is a compactor rod, scales, cup, a set of sieves, oven, soaking tub, Los Angeles machine, cement spoon, concrete mixer, Abrams cone, concrete cube mold and compressive strength testing machine. Testing the specific gravity of cement using a 100 millimeter measuring cup and a container filled with water. The average density of cement used is 3.5 g/mm^3.

Material analysis was carried out on fine aggregate (sand) and coarse aggregate. Fine aggregate is checked for organic matter content, mud content inspection, water content inspection, gradation inspection, specific gravity and water absorption, volume weight inspection. For coarse aggregate, inspection of moisture content, examination of gradation, examination of specific gravity and water absorption, examination of volume weight is carried out, as shown in Table 1.

Table 1. Material Testing Result

Test	Result of Material Tessting	
	Coarse aggregate	**Fine aggregate**
Specific gravity	2,4 gr	1,91 gr
Sludge level	0,70%	0,4 gr
absorption	1,72 gr	11,1 gr
weight	1848,7 gr/l	1377,1 gr/l

Before the concrete is formed, it is necessary to carry out a mixing process for the concrete-forming materials and a slump test is carried out to see and determine the concrete viscosity which is stated by the magnitude of the decrease in the value of the concrete mix. The tool used for the slump test is called an Abrams Cone which is made of metal. A mixture of concrete that is too liquid causes the quality of the concrete to be low, whereas if the concrete mixture is too less water it makes the concrete mixture uneven and difficult to print(Karolina & Corsika, 2020); (Karolina & Malik, 2019).

The sample of the test object is then given heat treatment through normal combustion. After the combustion process, the test sample is given cooling. Samples of specimens were made as many as 21 samples, 3 samples for normal concrete, 9 samples for concrete post combustion without water cooling for the duration of combustion of one hour, two hours and three hours for each of the 3 samples. The other 9 samples were for the same burning duration and with water cooling. The age of the concrete used for testing is taken at the age of 14 days of concrete, then the compressive strength test is carried out, and the compressive strength test results are analyzed from the sample of the concrete specimen. Based on the results of the material test as shown in Table 1 below, the design for the concrete mix can be calculated. The standard used is (SNI 03-2834-2000, 2000), concerning the procedure for making standard concrete and the planned concrete quality is 20.75 MPa.

3. RESULTS AND DISCUSSION

3.1 Effect of Combustion on Physical Properties of Concrete

After the combustion process was carried out on the of the test object, concrete color looks brighter like gray-white (Figure 3). Changes in color in the concrete begin to appear at the combustion duration of 1 hour, which is yellowish gray, 2 hours of burning brownish gray, and 3 hours of burning reddish concrete, as shown in Table 2.

Figure 3. Concrete After Firing Process

Table 2. Material Testing Result

Combustion duration (Hrs)	Failure	Color
-	-	Gray-white
1	Smooth crack	Gray-yellowish
2	Large crack	Gray-brownish
3	Large crack- peel off	Reddish

There are also signage cracks, surface peeling/spalling on the concrete. Post-combustion concrete also becomes porous and very brittle, this is evidenced by the easy release of granules. Spalling is a symptom of peeling off part of the concrete surface in the form of a thin layer. Basically, concrete is not expected to be able to withstand heat above temperature 250°C, because the concrete will crack, peel and lose strength due to high temperature.

3.2 Concrete Compressive Strength

After the concrete has been treated for 14 days, the concrete will be tested for its compressive strength. The following is the result of the compressive strength of concrete that has been obtained, as shown in Table 3 and Figure 4.

Table 3. Comparison of The Compressive Strength of Concrete at The Age of 14 Days

Combustion duration (Hrs)	Compressive strength (kg/cm^2)	
	Sample with watering	Sample without watering
1	295.72	320.05
2	245.34	285.65
3	210.17	235.21

*Normal Concrete (Compressive strength = 355.43 kg/cm^2).

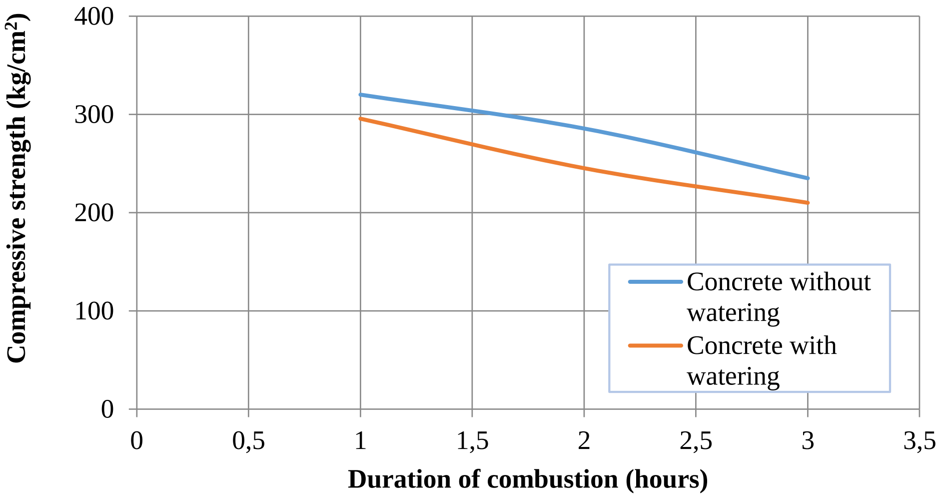

Figure 4. Plot of The Curve of the Compressive Strength of Concreteat the Age of 14 Days

Based on Figure 4, the compressive strength value of burning concrete at the age of 14 days with watering of 1 hour, 2 hours, 3 hours, respectively 295.72 kg/cm^2, 245.34 kg/cm^2, 210.17 kg/cm^2. Meanwhile, the compressive strength value of burning concrete at the age of 14 days without watering of 1 hour, 2 hours, 3 hours, respectively 320.05 kg/cm^2, 285.65 kg/cm^2, 235.21 kg/cm^2. The compressive strength will decrease if burned longer than normal concret, which is 355.43 kg/cm^2.

This result is inversely proportional to research by (Tumingan et al., 2017), where in his research it was stated that concrete after burning at 400ºC and receiving cooling treatment with water had improved the quality of concrete compared to normal concrete. However, based on research by (Setiyarto & Fira, 2019), it is explained that the quality of concrete after burning and cooling with water has reduced the quality of concrete by up to 70%.

3.3 Effect of Cooling on Compressive Strength of Concrete

Concrete that has been cooled after burning either by watering or without watering has decreased compressive strength, as shown in Table 4 and Figure 5.

Table 4. Percentage Decrease in Compressive Strength of Post-Combustion Concrete with and without Watering

Duration of Combustion (hrs)	Cooling			
	Withaout watering		With Watering	
	Compressive strength (kg/cm^2)	decrease (%)	Compressive strength (kg/cm^2)	decrease (%)
1	320,05	9	295,72	16
2	285,65	19	245,34	30
3	235,21	33	210,17	40

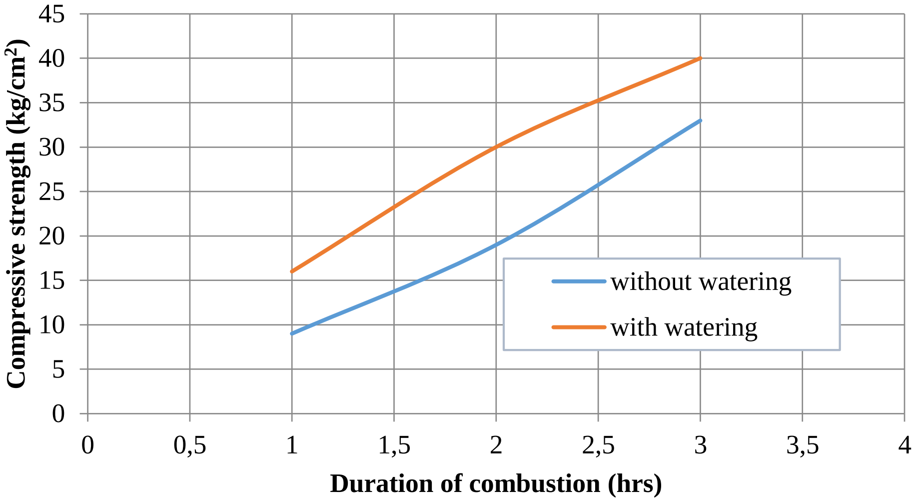

Figure 5. Plot of Percentage Decrease in Compressive Strength of Post-Combustion Concrete with and without Watering

Concrete without watering after combustion for 1 hour, 2 hours and 3 hours, decreased compressive strength by 9%, 19% and 33%, respectively. Meanwhile, for concrete with cooling water, the percentage reduction in concrete compressive strength for 1 hour, 2 hours and 3 hours of burning time reached 16%, 30% and 40% respectively. These results are also in line with research by (Dharmawan et al., 2016). Dharmawan et al (2016) stated that after burning the concrete decreased the quality of the concrete by up to 1.57%.

4. CONCLUSION

Based on the results of the research that has been carried out, it can be concluded that the compressive strength of concrete that was given regular cooling after the combustion process for 1 hour, two hours and three hours, was higher than the compressive strength of concrete that was given water with the same duration of combustion. The compressive strength of concrete without watering after combustion for 1 hour, 2 hours, 3 hours respectively is 320.05 kg/cm^2; 285.65 kg/cm^2; 235.21 kg/cm^2, it means that the quality of the concrete has decreased to 9%, 19%, 33%, for each duration of combustion. Meanwhile, the compressive strength of concrete with watering for the same duration of combustion was obtained at 295.72 kg/cm^2; 245.34 kg/cm^2; 210.17 kg/cm^2. it means that the quality of the concrete has decreased to 16%, 30%, and 40%, respectively. So, in general it can be concluded that the effect of watering on concrete after combustion, it can cause a decrease in the quality of concrete.

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