

Analysis of mechanical and physical behaviour of post-burn concrete

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Abstract. The occurrence of a high temperature change, such as in a fire incident will have an impact on the concrete structure, cracked surface structure, damage/collapse, and discoloration of the concrete. This research is conducted on K300 concrete with a sample of 15 cm x 15 cm x 15 cm cubes. Burning is carried out at temperatures of 250°C, 500°C, 750°C, and 1000°C with a containment time of 2, 4 and 6 hours. The cooling process is carried out by immersion then rested for 24 hours at room temperature. From the results of the research obtained at temperatures of 250°C, 500°C, 750°C, and 1000°C, the decrease in compressive strength are 4.44% -7.41%, 12.59% -22.96%, 56.44% -66.22%, and 76.74% - 100%. At the containment time for 2 hours, 4 hours and 6 hours, the decrease in compressive strength are w = 4.44% - 76.74%, 6.67% -93.70%, and 7.41% - 100%. At temperatures of 250 °C, 500°C, 750°C, and 1000°C, the increase in porosity are 8.09% - 9.57%, 11.79% - 15.50%, 16.98% - 18.46%, and 19.20% - 26.61%. At the containment time for 2 hours, 4 hours, and 6 hours, the increase in porosity are 8.09% - 19.20%, 8.83% - 22.16%, and 9.57% - 26.61%. From this research, it can be seen that the increase in temperature has a greater impact on the decrease in the compressive strength of concrete and the increase in the porosity of concrete compared to the increase in the combustion duration. Through this research, regression equations are generated which can be used to calculate the residual compressive strength at other combustion temperatures.

1. Introduction

The occurrence of high temperature changes, such as those that occur during fire incidents, will affect the structural elements. Because in this process there will be alternating heating and cooling cycle which will cause a complex physical and chemical phase change. This will affect the quality / strength of the concrete structure and will cause the concrete to become brittle (Wahyuni, E. and Anggraini, R., 2010).

The main problem faced in handling post-burn buildings is how to assess the residual strength of post-burning buildings. With the knowledge of residual strength, we can make the most efficient remedial actions to restore the condition as before. So that buildings that have experienced a fire can be used again. So far, post-burning buildings have been destroyed (demolished action) even though the burnt structural elements of the building may still have strength..

Based on the description above, it is necessary to do research to find out the relation between the increase in temperature height, burning time, and type of concrete forming material against the changes in the properties and characteristics of post-burn concrete on building structural elements so that the residual strength of concrete material can be identified

from the data. Thus, it can be determined worthy or not the structure of the building can be reused.

2. Scope of problem

1. Concrete that is processed, casted and treated until 28 days curing.
2. Materials used :
 - Type I Portland Cement
 - Patumbak Sand
 - Split
 - Water in the laboratory
3. Cubic samples with the size of 15 cm x 15 cm x 15 cm.
4. The quality of concrete used is K300 ($f'_c = 26,4 \text{ Mpa}$).
5. The temperatures used are at 250°C, 500°C, 750°C, dan 1000°C.
6. Burning time of concrete used are 2, 4, and 6 hours.
7. The cooling process of concrete after burning is done by immersion, then rested for 24 hours at room temperature.
8. Tests :
 - Mechanical properties (compressive strength)
 - Physical properties (porosity)

3. Objectives

1. To know the changes in mechanical properties of post-burn concrete at a certain temperature, concrete quality, and duration of burning.
2. To know the changes in physical properties of post-burn concrete at a certain temperature, concrete quality, and duration of burning.
3. To know the decrease in concrete quality or the measurement of residual strength of concrete material after experiencing a fire at a certain temperature, burning time, and quality of concrete to support detailed / planned structural elements in its repairs execution.

4. Research method

The method that is used in this research is experimental tests in the laboratory. Through this research, it will be known how far is the effect of variations in temperature and burning duration to the compressive strength and porosity of concrete on a certain concrete quality.

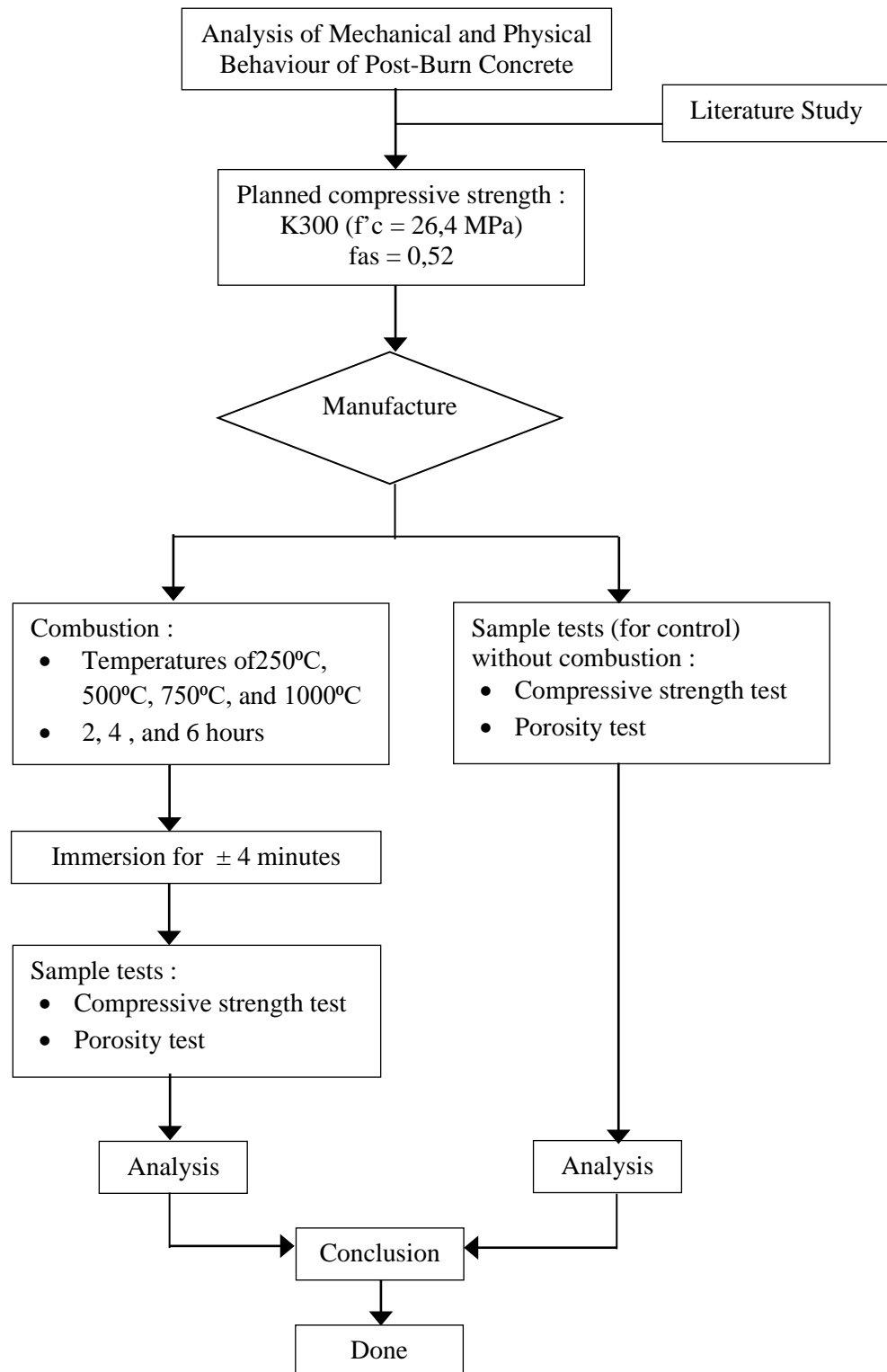


Figure 1. Research flowchart

4.1. Samples

The following is a table of plans for the number of samples for compressive strength and porosity test:

Table 1. Number of samples

Temperature containment time (hours)	Compressive strength and porosity test				
	Without combusti on	Combusti on			
		250°C	500°C	750°C	1000°C
0	2				
2		2	2	2	2
4		2	2	2	2
6		2	2	2	2
Total		26 pieces			

4.2. Concrete combustion

The combustion of the sample is done by using a furnace. The combustion is carried out at temperatures of 250°C, 500°C, 750°C, and 1000°C with variations of temperature containment time for 2 hours, 4 hours and 6 hours. After that, the combustion process is stopped then soaked in a drum filled with water and rested for 24 hours at room temperature.

5. Results and discussion

5.1. Concrete compressive strength test

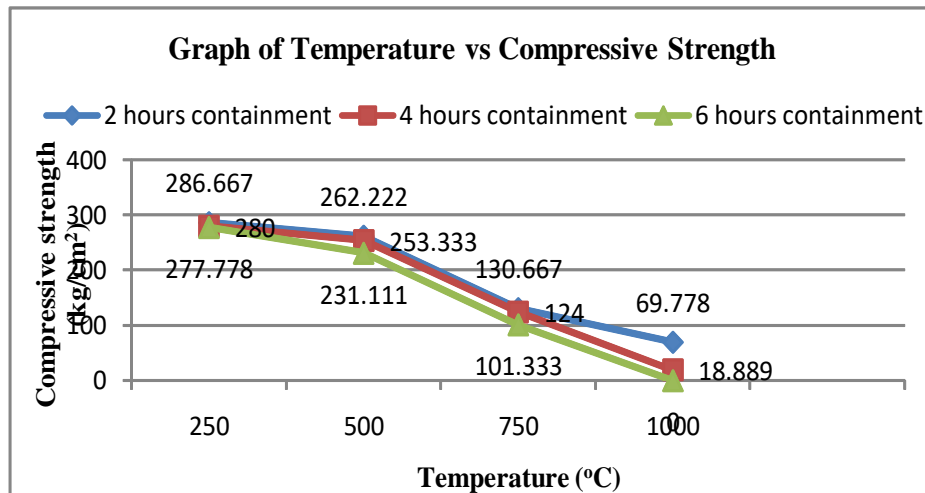


Figure 2. Graph of temperature (°C) –vs- compressive strength (kg/cm²)

At a temperature of 250 °C, decreases by 4.44% - 7.41%, at a temperature of 500°C, decreases by 12.59% - 22.96%, at a temperature of 750°C, decreases by 56.44% - 66.22%, and at a temperature of 1000°C, decreases by 76.74% -100%.

When the temperature is 500 oC the compressive strength decreases because the water absorbed in the aggregate starts to evaporate. When the temperature of 500 °C to 750 °C, there

is a significant decrease in compressive strength. This decrease in compressive strength is caused by the hydrated cement paste decomposes. $\text{Ca}(\text{OH})_2 \rightarrow \text{CaO} + \text{H}_2\text{O}$. CaO (lime) is hygroscopic (absorbs water), while H_2O begins to evaporate at a temperature of 10°C because of heat, causing a dry and brittle concrete (Febrina, F., 2010). At a temperature of 1000°C with of 6 hours containment, the physical surface of the concrete has been peeled off and the structure of the inside is very fragile so that the pointer on the compress machine does not move anymore when load is given.

Lime from the results of combustion, when added with water, will expand and crack. Cement and water function as an adhesive and reinforcing concrete. During the hydration process, the two most important components of the cement granules, C_2S and C_3S , will react with H_2O and produce CSH and $(\text{CaOH})_2$. C-S-H functions as a determinant of concrete hardness and aggregate binding. The hydration process is a process where the cement chemical composition, CaO , abbreviated as C, SiO_2 , abbreviated as S, Al_2O_3 , abbreviated as A, Fe_2O_3 , abbreviated as F, reacts with water, H_2O , abbreviated as (H). The effect of this hydration process causes micro and nano-sized crystals called gels and $\text{Ca}(\text{OH})_2$ which will continue to grow to fill the crystalline cavities where the cavities contain water and grow into solid crystals that along the time, growing crowded into crystal spaces that are still empty. Because the CSH element is the main element that supports the strength of the concrete, a significant reduction in CSH will greatly reduce the strength of the concrete.

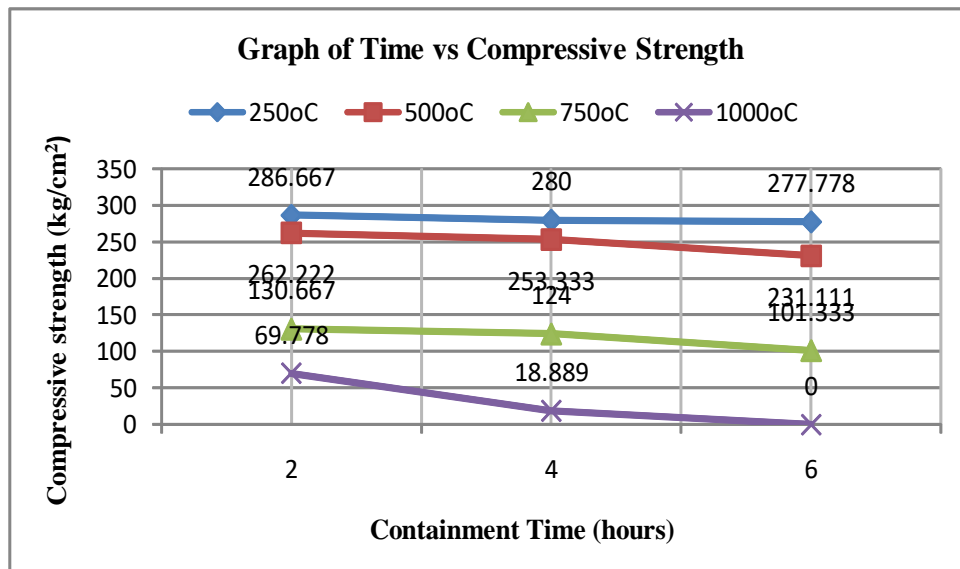


Figure 3. Graph of containment time (hours) –vs- compressive strength (kg/cm^2)

At 2 hours containment time, decreases by 4.44% -76.74%, at 4 hours containment time, decreases by 6.67% -93.70%, and 6 hours containment time, decreases by 7, 41% -100%.

5.2. Concrete porosity test

Concrete porosity can be obtained by using this formula :

$$\text{Porositas} = \frac{mb - mk}{Vb} \times \frac{1}{\rho_{air}} \times 100\% \quad (1)$$

With :

mb = wet mass of the sample before being burned (gram),

mk = dry mass of the sample before being burned(gram),

V_b = the volume of the cube sample (cm^3),

pair = water specific gravity (1 gr/cm^3).

- Normal concrete without combustion

From the test results, it is obtained that the average porosity for normal concrete without combustion is 3.02%.

- Concrete with combustion

The test results data of concrete compressive strength for each temperature and burning time are as follows:

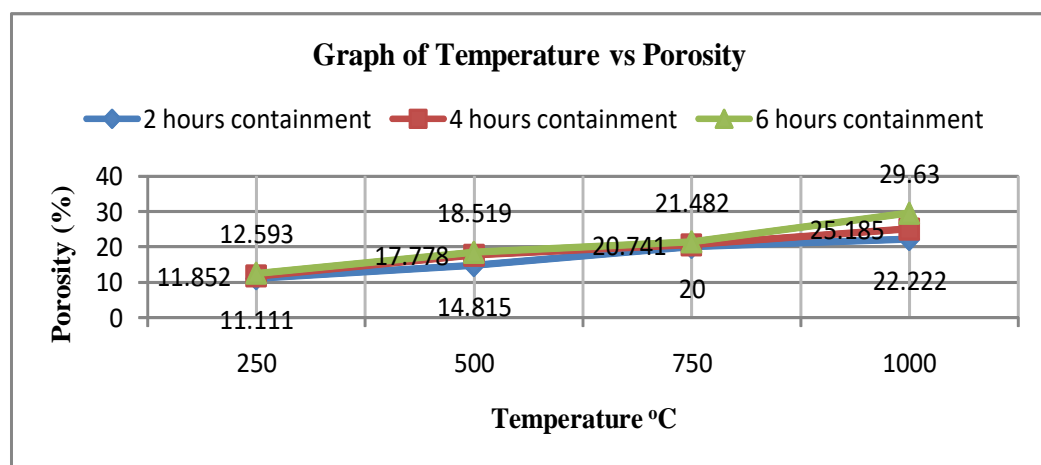


Figure 4. Graph of temperature (°C) -vs- porosity (%)

At a temperature of 250°C, there is an increase in porosity by 8.09% - 9.57%, at a temperature of 500 °C, increases by 11.79% -15.50%, at a temperature of 750 °C, increases by 16.98% - 18.46%, and at a temperature of 1000 °C, increases by 19.20% - 26.61% of normal concrete porosity.

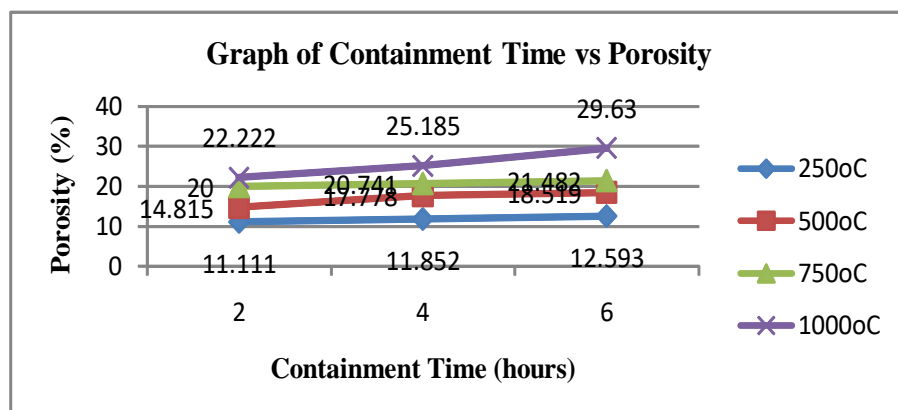


Figure 5. Graph of containment time (hours) -vs- Porosity (%)

At 2 hours containment time, there is an increase in porosity by 8.09% - 19.20%, At 4 hours containment time, increases by 8.83% - 22.16%, and at 6 hours containment time, increases by 9, 57% - 26.61% of normal concrete porosity.

From the test results above, it can be seen that the higher the combustion temperature, the greater the porosity of the concrete, this will cause concrete becoming porous. Similarly, the longer the containment time, the greater the porosity of the concrete. This is because (H₂O) contained in the concrete will mostly evaporate. The water molecules that will come out (migration) are blocked, then there is friction with the pores of the concrete which causes microcracks so that the porosity of the concrete increases. With increasing porosity, then the compressive strength of the concrete will decrease and cause damage to the concrete structure. (Ray, Norman, 2009).

5.3. Observation of the colors and visual conditions of concrete

The discoloration of the concrete starts to appear at 500°C which is greyish brown. This occurs because of the presence of an iron salt compound in aggregates or concrete sand which causes the concrete to change color. If the temperature reaches 750°C, there is a carbonization process which formed Calcium Carbonat (CaCO₃) that is whitish so it changes the color of the concrete to become brighter (Febrina, F., 2010).

6. Conclusions

1. Fire phenomena on concrete structures will cause changes in structure, including cracks, damage/collapse, and discoloration of the concrete surface. The color of the concrete will change with increasing temperature. The discoloration is caused by aggregates or sand which contains several iron compounds which can also cause corrosion.
2. Concrete will decrease in strength as the temperature rises.
3. Concrete will decrease in compressive strength along with the duration of combustion.
4. The higher the combustion temperature, the greater the porosity of the concrete.
5. The longer the duration of the fire causes the greater porosity of the concrete.

7. Suggestions

1. It is expected that further researchers can test the mechanical properties or physical properties of other post-burn concrete such as elasticity, tensile strength, or other post-burn concrete properties that have never been studied before..
2. For the development of further research, it can be tried on concrete with a mixture of additive materials, on concrete with different concrete quality, and on reinforced concrete by focusing on reinforcement test.
3. The next researcher can do the validation by examining post-burn concrete with variations in duration and temperature that have not been studied before.

8. Reference

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