Recovery compressive strength aluminum fiber lightweight concrete (with part of a roof tiles as coarse aggregate) after burning with a variation of water curing time

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Abstract. The research concerns the strength of lightweight concrete with aluminum fiber as micro-reinforcement by environmental load especially burning and water curing. In this cylindrical research concrete of 150 mm dia, 300 mm high for the compressive test. Fibre volume fraction are 0.75% of concrete. Aluminum fiber with aspect ratio 50, cement type I, sand, always, water, and discrete are used. Testing is based on SK SNI M 14 1989 F. The result shows that increasing self-recovery of the average compressive strength of cylindrical concrete is 121.30% and 109.55% on lightweight concrete and aluminum fiber lightweight concrete with water curing for 56 days. Water curing can self-healing lightweight concrete and aluminum fiber lightweight concrete after burning.

1. Introduction
An improvement lightweight aggregate performance is needed to compensate for the performance of the cement paste but remain light. The use of fiber as an added ingredient in lightweight concrete is a solution to the phenomenon that light concrete is more brittle than normal concrete, as reported that aluminum fiber has been able to increase the compressive strength, strength of splitting test, MOR by improving the quality of the matrix due to the bridging, dowel action, and composite action processes. Improve the performance of lightweight concrete beams in the form of increased bending capacity, the ductility, and shear capacity [1].

The subject of this research is oriented specifically on the possibility of improving the quality of lightweight concrete material by studying the phenomenon of temperature insulation, fiber bridging, and its composite action due to the addition of fiber, especially in pre-burn, post-burning conditions, and after water curing with various intensities for 28 days, 42 days and 56 days to obtain minimal time data for maximum recovery.

Given 28 days of water curing treatment on post-burn aluminum fiber of the metakaolin lightweight concrete, it can be increasing the average of the compressive strength, the average elastic modulus, the average strength of the splitting test, and the average mean rupture modulus of; 38.46%, 44.47%, 85.12%, and 25.21% respectively [2]. This means that the water curing efforts help the recovery of tobermorite (CSH) as the element that determines the strength of the concrete needs to be studied more in depth.
2. Literature review

Wetting post-burn concrete with water, restoring strength by building βCSH in its crystal [3]. The structure of CSH is amorph (without form) which consists of CaO, SiO₂, and H₂O with the ratio of C and S is 1.5, and the amount of H is highly dependent on the surrounding conditions; from 1 dry condition, up to 4 in saturation condition. The crystal of water released by the combustion temperature may still be able to return to its position if there is water entering around the CSH crystal. The presence of this crystalline water greatly affects the density of CSH, which ultimately affects the strength of its CSH.

The residual of the lightweight concrete stresses in % of the initial value due to the increase in temperature respectively; 200°C, 300°C, 400°C, 500°C, 600°C, 650°C, 700°C, 800°C, and 850°C are respectively; 95%, 92%, 90%, 85%, 90%, 95%, 75%, 60% and 50%.

The residual strength of the structures which has cooled down after it burns will depend on the highest temperatures during the fires, the mixtures used and the loading conditions during fires [3]. Also, due to the characteristics of heat transfer, only the temperature at the outer part increases dramatically while the inside of the concrete temperature depends on the depth of the outermost shell. For example, in research with 30 x, 40 x 1500 cm² column subjected to heating up to 1000 °C, in the surface of concrete where the temperature reached 835 °f [3]. However, the temperature inside the concrete is only 150 °C for 7.5 cm depth and 100 °C for 10 cm depth, although steel reinforcement is 2.5 cm depth high enough temperature 650 °C. This shows that the outside temperature of combustion can be much different from the temperature inside the concrete. This also makes this research very interesting, especially changes in the nature and strength of steel reinforcement in lightweight concrete with a variety of added materials in it.

The use of fiber in reinforced concrete can increase energy absorption, ductility, control cracks, and improve deformation properties [4].

A study conducted and proved that the weakness of the properties of concrete that is brittle is practically incapable of withstanding tensile stress and bending moments can be improved by adding local fibers made of pieces of wire to a concrete mortar. It also proved that the rate of improvement obtained by using local fiber is not inferior to results reported abroad using the original steel fiber [5].

3. Research methods

The materials used were water, cement type I, sand, coarse aggregate from roof tile fragments, and discrete. The equipment used were a set of scales and mixing of concrete, oven, cone abraum to measure slump, water bath for concrete treatment, and Compressing Testing Machine.

The basic material experiments were tested, including the test of mud content, sieve analysis, specific gravity, absorption, and organic content in the sand. Coarse aggregate from fractional roof tiles; abrasion test, sieve analysis, specific gravity, absorption, and mud content was performed. While cement and aluminum will be used data properties from the manufacturer. The calculation of lightweight concrete mix will be used mix design based on data obtained from the base material test with compressive strength (f’c) 25 MPa with a medium slump. The addition of aluminum fiber is 0.75% from the volume of concrete with a size of 2 mm x 50mm.

The test specimens were cylindrical diameter 150 mm height 300 mm, 30 pieces for the compressive strength test. The test samples were subsequently treated (curing) by immersion for 7 days and treated in an open and humid room until the test age of 28 days. Subsequently, the specimen is partially tested and partially burned at 500 °C. This temperature is proposed assuming that the melting point of aluminum is 660 °C (Callister [6]).

Some of the burned samples were treated with variation water curing after the combustion process is complete, and the sample is tested at 28 days, 42 days and 56 days from the curing process. Testing of research material, making of specimen, concrete weighing test, lightweight concrete compressive strength test, and elasticity modulus test were conducted in Civil Engineering Materials Laboratory of UNS. Combustion is done at Bayat Klaten Ceramics Lab.
4. Research Results and Discussion
The sand used is sand tested based on the ASTM standard with a mud content of 2.3%. The gradation table with a fineness modulus of sand of 2.55. The specific gravity in saturated surface dry conditions is 2.50. Coarse aggregate used in this study is the result of roof tile fragments. A mud content of is 0.5 %, abrasion is 47 %, fineness modulus is 5.66, the specific gravity in saturated surface dry conditions is 2.10. The aluminum fiber can improve the tensile strength of the concrete as it has a maximum tensile strength of 100 MPa and an 11% elongation. The aluminum fibers used in this study are small pieces measuring 2 mm x 50 mm on average. The material requirement for 1 m$^3$ of concrete is 400.00 kg of cement, 634.90 kg of sand, 644.10 kg of roof tile fragments, 160.00 liters of water, 15.75 kg of aluminum fiber, and 4.00 kg of discrete. The compressive strength is calculated from the load divided by the cross-sectional area. The compressive strength test can be seen as in figure 1.

![Figure 1](image1)

**Figure 1.** Set the compressive strength test

The result of the average compressive strength analysis in this research can be seen as in Figure 2 and is as follows:

For lightweight concrete, the average compressive strength is:
- Before Burning: 20.37 Mpa
- Burning 500° C: 19.05 Mpa
- Burning 500° C + Curing 28 days: 19.24 Mpa
- Burning 500° C + Curing 42 days: 21.31 Mpa
- Burning 500° C + Curing 56 days: 24.71 MPa

For aluminum fiber lightweight concrete the average strength value is:
- Before Burning: 23.76 Mpa
- Burning 500° C: 21.88 Mpa
- Burning 500° C + Curing 28 days: 25.08 Mpa
- Burning 500° C + Curing 42 days: 25.46 Mpa
- Burning 500° C + Curing 56 days: 26.03 MP

![Figure 2](image2)

**Figure 2.** Compressive strength vs. water curing time.
The process of water curing after the concrete is burned causes the water to absorb into the pores of the concrete and reacts with C2S and C3S compounds on cement granules yet to react as well as αCSH compounds in the concrete due to combustion temperature, the reaction product of the compound being CSH, and βCSH, able to restore the strength of concrete as before burning (Partowiyatmo and Sudarmadi,[3]). Additional hydration will fill the pore space left behind of vaporized pore water, increasing overall CSH density. βCSH formed by increasing the amount of H in the CSH crystal will return the density and strength of its CSH.

In this study, the recovery process was compressive at treatment 56 days after combustion of 121.30% for lightweight concrete, whereas for aluminum fiber lightweight concrete the value of compressive strength was 109.55%.

The CSH model before burning can be seen as shown in Figure 3 below. The H₂O attached to SiO₂ in the combustion process will loose, resulting in decreased CSH density. The CSH model after combustion can be seen as in Figure 4 below.

![Figure 3. The CSH model before burning](image1)

![Figure 4. The CSH model after burning](image2)

After treatment, the water permeates, enters and binds to the silicate again so that the CSH density increases. The CSH model after treatment with water as in Figure 5.

![Figure 5. The CSH model after treatment with water](image3)

5. Conclusion
From the discussion of the results of the study can be concluded:
Recovery of compressive strength on treatment 56 days after combustion of 121.30% for lightweight concrete, while for aluminum fiber lightweight concrete a change in compressive strength value of 109.55%.

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