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The Effect of pH Water on the Concrete Mixtures and Curing Condition on the Compressive Strength of Concrete

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Abstract. This research examined the effect of acid water as a concrete mix material and as a curing system on the compressive strength of concrete. The effect of wet-dry curing conditions in normal and low pH water on the concrete compressive strength was also evaluated. The water pH of 3 and 7 was conducted in this research. Water pH of 3 was obtained by diluting the HCl solution with tap water. The result showed that the concrete compressive strengths with normal water were 26.23, 26.61, 28.31, and 28.31 MPa at 28, 56, 90, and 120 days, respectively. In comparison, concrete mixed with low pH water was 25.48, 26.04, 26.42, and 26.42 MPa at 28, 56, 90, and 120 days, respectively. The wet-dry curing system for normal water concrete mixed reduced the compressive strength at 28 days by 14.39%, 56 days by 18.44%, 90 days by 14.00%, and 120 days by 10.00%. The wet-dry curing with acidic water also decreased the concrete compressive strength. The wet-dry condition breaks the hydration process between concrete and acid water. Wet-dry curing decreased the compressive strength of concrete. The compressive strength at 28, 56, and 90days decreased 16.30, 12.32, and 7.86%, respectively. While at 120 days, the compressive strength on wet-dry curing slightly increased by 1.43% by 0.01%. Wet-dry curing breaks the concrete hydration process with acid water.

Keywords: acid water, concrete curing, pH water, wet-dry curing, compressive strength

1. Introduction

Cement, coarse aggregate, fine aggregate, and water are materials to produce concrete that the cement paste binds coarse aggregate and fine aggregate. Several factors influence the concrete performance, such as water and cement ratio, characteristics of aggregates, concrete curing system, and concrete mix water quality. Infrastructure development in aggressive acidic environments forces acid water to be used in the concrete mix or the curing treatment. So that the use of local water affects the results of the concrete obtained. This is because the area around the worksite, especially inland and swampy areas, contains a lot of acids to reduce the quality of the planned concrete [1].

As for the treatment of concrete, according to Sutandar et al. [2] that the quality control is essential. Concrete curing is a process after casting is done. This treatment is in immersion, which is often neglected during the concrete maintenance period. At the same time, this concrete treatment has a very big influence on the quality of the planned concrete. The strength of concrete depends on the binding of the concrete material in the form of coarse aggregate and fine aggregate by cement in the form of cement paste after being mixed with water. This is one of the factors to get the planned concrete strength apart from the selection of concrete materials in the form of coarse aggregate and fine aggregate [3].

2. Material and Method

Fine aggregate from Barito, coarse aggregate from Katunun, and Portland Composite Cement was used in this research. Normal water (pH of 7) was obtained from tap water, while acidic water pH of 3 was manufactured by diluting the HCl solution. Concrete test specimens were cylinders with a diameter of

15cm and a height of 30cm. The concrete composition was based on Indonesian Standard Code for compressive strength design of 25 MPa. The compressive strength was evaluated for 28, 56, 90, and 120 days. A total of 72 concrete cylinders were evaluated in this research. The mixed composition of concrete can be shown in table 1.

Table 1. The result of *Mix Design* 25 MPa

No	Material	Mix Design	Unit
1	Water	205	liter
2	Cement	519	Kg/m^3
3	Fine Aggregate	608	Kg/m^3
4	Coarse Aggregate	1.052	Kg/m^3

2.1. Manufacture of test objects

The specimens code was based on the curing system and pH of the water. The code of M indicated the concrete mixing water and followed by pH water, C represented the curing system, N expressed the full immersed curing, and WD referred to wet-dry curing. For example, M7C3WD was a concrete specimen representing mixing with water of pH of 7 and curing with pH of 3 with a wet-dry system. Specimen of M3C3N was a specimen with acid mixing water of pH of 3 and acid full immersed curing.

Before casting, the tools and materials to be used were prepared in advance. The formwork was cleaned, and the inner walls were coated with oil to remove the concrete mold easily. Then the prepared material is stirred using a mixer until evenly mixed. The concrete mixture is then inserted into the formwork and vibrated using a vibrator to remove trapped air bubbles when entering the concrete.

There were two types of curing conditions. The first was immersed continuously, and the second type was a cycle of wet-dry. One cycle means seven days immersed and seven days in ambient temperature in dry conditions. Two types of water pH were normal water pH (pH of 7) and acid water (pH of 3).

2.2. Concrete Compressive Strength Test

The compressive strength of concrete refers to ASTM C39/C39M. The specimens were removed from the tub and dried until a surface saturated dry condition one day before the test. The testing process was carried out by continuously adding a load on the test equipment until the specimens were destroyed and was recorded the maximum load on the dial. The compressive strength of concrete was calculated by using the equation as follow:

$$f_c' = \frac{P}{A} \tag{1}$$

Where:
f_c' = compressive strength of concrete (MPa)
P = maximum load (N)
A = cross-sectional area of concrete cylinder (mm^2)

3. Results And Discussion

The compressive strengths of the 72 cylinders test from the experimental test are listed in table 2. The following discussion evaluated these results based on variable research.

3.1. Effect of Curing System on Normal Water Mixed Concrete and Normal Water Curing

The comparison result of the compressive strength between M7C7N and M7C7WD was used to evaluate the effect of the curing system on normal water mixed concrete, as shown in figure 1. The immersed continuously was better than the wet-dry method of curing concrete. The compressive strength decreased respectively, 14.39%, 18.44%, 14.00%, and 10.00% at 28 days, 56 days, 90 days, and 120 days. The result was similar to the research results conducted by Simanjuntak *et al*.,[4]. The concrete

treatment that was soaked continuously for 28 days was better than other methods of concrete treatment, such as being wrapped for 28 days, cycles of immersed, and then drying for 14 days [4].

Table 2. The compressive strength of concrete specimens

Specimens code	The compressive strength (MPa)			
	28 days	56 days	90 days	120 days
M7C7N	26,23	26,61	28,31	28,31
M7C7WD	22,46	21,70	24,35	25,48
M7C3N	26,99	26,04	26,04	25,1
M7C3WD	25,29	23,02	24,35	25,1
M3C3N	25,48	26,04	26,42	26,42
M3C3WD	21,33	22,84	24,35	26,80

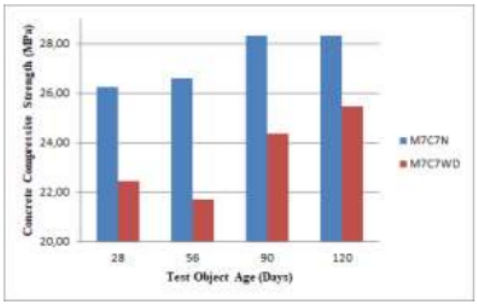

Figure 1. The concrete compressive strength of M7C7N and M7C7WD

3.2. Effect of Curing System on Normal Water Mixed Concrete and Acid Water Curing

The effect of the curing system on pH of 3 on normal water mixed concrete to compressive strength was evaluated using specimens of M7C3N and M7C3WD. The compressive strength of M7C3N decreased as the age of concrete. The same behavior also occurred for M7C3WD specimens. The compressive strength of M7C3WD at 56 days decreased significantly to 23.02MPa compared to 28 days. The acid water in mixing concrete reduced the strength of concrete. The result is shown in figure 2.

The curing of immersed continuously in acid water was a better performance than the wet-dry method of curing concrete. The compressive strength of concrete indicated that acid water affects the compressive strength for more than 28 days. This behavior occurred due to the corrosive nature of the acid. The compressive strength at 120 days of the M7C7N was 28.31 MPa, while the M7C3N was 25.48 MPa. This is the same as research that has been done that this decrease is the result of acid water enlarging the pores of the concrete, thereby reducing the strength of the concrete [5]-[7].

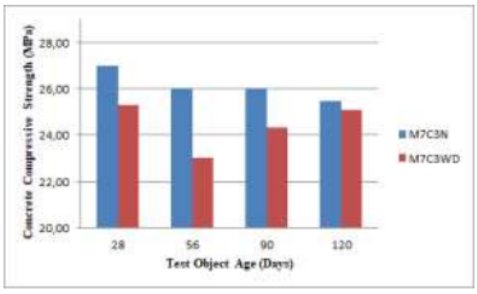

Figure 2. The concrete compressive strength of M7C3N and M7C3WD

3.3. Effect of pH Curing on Normal water mix concrete and Immersed Curing System

Comparing the results of the M7C7N test and the M7C3N test shows that curing concrete soaked in normal water continuously was better than curing concrete soaked continuously with acid water. At 56, 90, and 120 days, compressive strength in acid water decreased 2.13%, 8.00%, and 10.00%, respectively. However, at 28 days, the compressive strength in acid water increased 2.88% compared to normal water. The decrease is due to the damage to the concrete pores due to the reaction of concrete to acid. The results can be seen in figure 3.

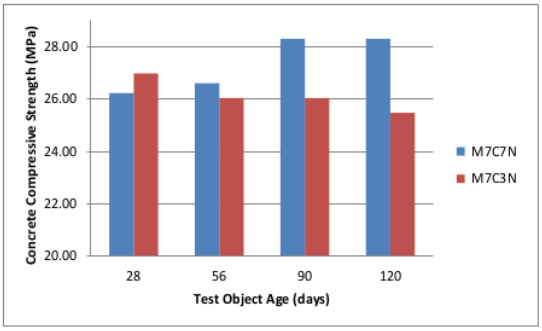

Figure 3. The concrete compressive strength of M7C7N and M7C3N

3.4. Effect of Curing System on Acid Water Mixed Concrete and Acid Water Curing

The effect of the curing method on acid water mixed concrete and on acid water curing, by comparison, an M3C3N specimen with the M3C3WD specimen. The concrete compressive strength of M3C3N was 25.48, 26.04, and 26.42MPa at 28, 56, and 90 days, respectively. In comparison, the compressive strength of M3C3WD dropped to 21.33, 22.84, and 24.35 MPa, respectively, as shown in figure 4. The concrete curing immersed continuously was better compressive strength than a cycle of wet-dry curing system. However, at 120 days, the wet-dry curing system was better than the fully immersed curing concrete. At the age of 120, the compressive strength of M3C3WD concrete was 26.80 MPa higher than M3C3N was 26.42 MPa. It happened because the wet-dry curing method breaks the hydration of concrete with acidic water.

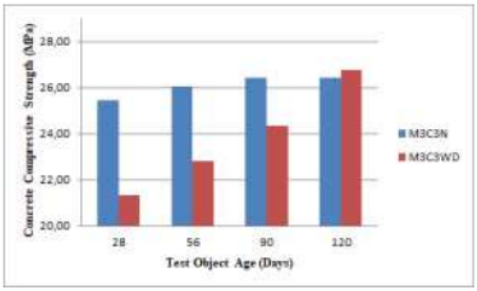

Figure 4. The concrete compressive strength of M3C3N and M3C3WD

3.5. Effect of Water Mixed Concrete on Acid Immersed Curing

The comparison between M7C3N and M3C3N evaluated the effect of water pH for mixing concrete submerged in acid water, as seen in figure 5. These specimens were the same curing system and pH of curing water but different water pH for mixing. At 28 days, the compressive strength of M7C3N was higher than M3C3N. At the age of concrete above 56 days, the compressive strength of M3C3N was better than M7C3N. The concrete with acid mixing water was higher compressive strength than concrete

with tap water. M3C3N were higher 1.45 and 3.70% than M7C3N at 90 and 120 days, respectively. The use of acid water in the concrete mixture does not significantly affect the strength of the concrete that was immersed in acid water continuously

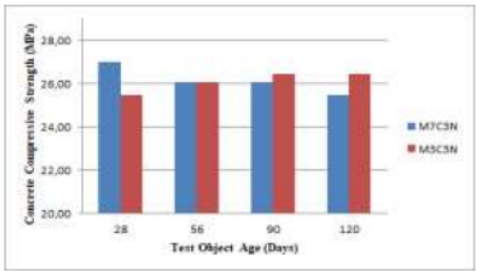

Figure 5. The concrete compressive strength of M7C3N and M3C3N

3.6. Effect of Water Mixed Concrete on Acid Wet-Dry Curing

The previous results showed that acid water mixing in concrete less significantly affected the concrete compressive strength kept submerged in acid water curing. Then the next evaluation compared M7C3WD and M3C3WD to evaluate the effect of acid water in the concrete mixture with wet-dry cycles. A significant effect of acid water mixing on concrete compressive strength occurred at 28 days, as shown in figure 6. The compressive strength of M3C3WD dropped to 21.33MPa while M7C3WD was 25.29MPa. The strength of M3C3WD increased as the age of the specimens increased and reached 26.80MPa at 120 days. Meanwhile, M7C3WD decreased at 56 days compared to 28 days of age but then continued to increase until 120 days which achieved 25.10 MPa. The compressive strength of 120 days was still lower than 28 days. The slight differences occurred at 56 and 90 days between these two pH of water mixings. At 120 days, acid water mixing concrete was higher than standard pH water mixing

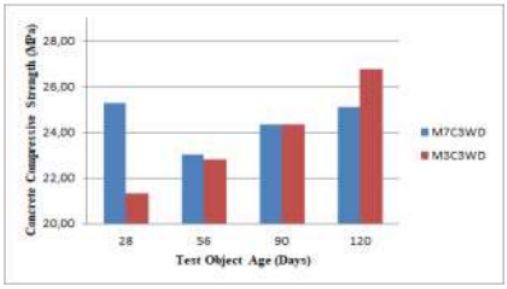

Figure 6. The concrete compressive strength of M7C3WD and M3C3WD

4. Conclusion

1. Results showed that the use of acid water as a concrete material affects the quality of the concrete. The use of water as a concrete material with a pH of 7 (M7C7N) resulted in compressive strength of concrete at 28, 56,90, and 120 days were 26.23, 26.61, 28.31, and 28.31 MPa, respectively. Slightly higher than using acid water (M3C3N) were 25.48, 26.04, 26.42, and 26.42 MPa, respectively.
2. The acid water was very influential when used as curing water of concrete. Normal water mixing and normal water curing in immersed curing (M7C7N) indicated a lower concrete quality than M7C3N by 2.88% at 28 days. However, acid water curing decreased the compressive strength of concrete at 56, 90, and 120 days by 2.13%, 8.00%, and 10.00%, respectively.
3. Wet-dry curing system on normal water mixing and curing reduced the concrete compressive strength. Wet-dry curing system reduced the compressive strength at 28, 56, 90, and 120 days of 14.39, 18.44, 14.0, and 10.0%, respectively. Similarities also occurred in an acid environment curing,

and acid water mixing. Wet-dry curing decreased the compressive strength of concrete. The compressive strength at 28, 56, and 90days decreased 16.30, 12.32, and 7.86%, respectively. While at 120 days, the compressive strength on wet-dry curing slightly increased by 1.43% by 0.01%. Wet-dry curing breaks the concrete hydration process with acid water.

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