Effect of Steam Curing Treatment and Cement Addition on Flexural and Compressive Strength of Premixed Mortar For Ferrocement Material

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Abstract. *Premixed mortar which has been implemented for several civil works is also possible to be used in ferrocement structures. The requirement of compressive strength for ferrocement mortar is 30 MPa, meanwhile premixed mortar is commonly lower than that. The objective of this study is to evaluate the effect of steam curing and cement addition on the flexural and compressive strength of premixed mortar regarding to ferrocement requirement. Specimens were made from premixed mortar of SIKA with ratio of 1:0,35 of water by volume. The variables were ages of samples (1, 3, 7, 14, 21, and 28 days), percentages of cements addition (0%, 10%, 20%, 30% and 40%) and admixture used. All specimens were cured with steam of boiled water in a tank. The flexure test used three points loading method on a mortar prism of 40x40x160mm and compressive testing was on a broken part of prism with surface area of 40x40mm. The results showed that steam curing increased flexural strength of premixed mortar very sligtly and increased gradually the compressive strength in line with the ages. The addition of cement also increased gradually both flexural and compressive strength in line with the increase of cement adition. The requirement of compressive strength for ferrocement mortar was reached with 40% of cement addition in the premixed mortar. The use of admixtures had no effect on both flexural and compressive strength.*

Keywords: premixed mortar, steam curing, admixture, flexural, compressive strength.

INTRODUCTION

Ferrocement is a thin reinforced concrete structure made from a mixture of sand and hydraulic cement (mortars) with small diameter wire mesh reinforcement in layers and continuously throughout the structure [1]. The properties of ferrocement structures are affected by the size of reinforcement, strength of the mortar, stiffness of structure, method of production, and construction process. In addition, ferrocement structures can be formed in any shape of structures [2]. Mortar plays an important role as a matrix in ferrocement works and other finishing works, because it must not only meet the technical requirements, but also have a high decorative value. However, the requirement for the mortar to be used for ferrocement buildings is a compressive strength of 30 MPa [3].

Nowdays, the mortar has been developed with industrialised process by mixing of cement and sand in dry condition, called ready mixed or premixed mortar which can be used on site with the water addition only. The use of premixed mortar has some benefits due to simplifying the construction process and waste reductions [4]. Premixed mortar is a mixture of dry ingredients consisting of cementitious materials and fine aggregates for mortar, packed in an airtight bag to protect it from the weather. In Indonesia, the commercially available premixed mortar (MSP) has a compressive strength of 2.4 - 17.2 MPa [5].

Some researches have studied on the treatment to obtain a better quality of concrete or mortar by applying some treatments, such as sinking in water tank, heating in an oven, and steam curing [6]. Steam curing is a method to accelarate the compressive strength and to develop the properties of concrete at early ages by implementing of hot water vapor at a temperature between 40 °C and 100 °C for a certain period. Zeyad et al [7] resumed that steam curing can speed up the process construction due to early superior mechanical properties. However steam curing also might reduce the volume of samples [8] and decrease the strength as long as the steam duration with temperature under 70°C [9].

Since there is a limit strength of premixed mortar which is lower than ferrocement requirements, this research needs to be carried out to evaluate the mechanical properties due to curing treatments and cement adition. The use admixture in premixed mortar perhaps increase the performance of premixed mortar as well.

MATERIAL AND METHOD

Material and Samples

Premixed mortar used in this study was pre-packed polymer modified mortar combining cement with selected grades of sand and several admixtures which was produced by SIKA in a bags of 40 kg. Portland Composite Cement (PCC) product of Baturaja was used as cement addition. Admixture of SikaCim was used in. The composition of premixed mortar approximately is about 2 (sand) : 1 (cement+pozzoland), as shown in its bag.

The samples were made by mixing water and premixed mortar with a ratio of 1 : 3,5 in volume. Firstly, some premixed mortar were put in a metal bowl, then switch on the mixer in about 5 minutes until mortar completely homogeneous. Furthermore, the mortar was poured in a metal mould with three gangs to form prism specimens with a dimension of of 160 mm x 40 mm x 40 mm. Fresh mortar then was compacted by a rubber hammer to reduce some voids in the samples. Fresh samples with its mould then were put in a tank to get steam curing treatment. The number and variables of samples are shown in Table 1 and Table 2.

TABLE 1. Variable of of plain premixed mortar samples with ages

Samples ages (days)	Number of samples for flexure test	Number of samples for compressive test
1	3	6
3	3	6
7	3	6
14	3	6
21	3	6
28	3	6
Total	18	36

TABLE 2. Variable of samples with cement and admixture addition

% Cement addition	Admixture use	Number of samples for flexure test	Number of samples for
0	With (A)	3	6
	Without (B)	3	6
10	With (A)	3	6
	Without (B)	3	6
20	With (A)	3	6
	Without (B)	3	6
30	With (A)	3	6
	Without (B)	3	6
40	With (A)	3	6
	Without (B)	3	6
	Total	30	60

Steam Curing Treatment

Steam curing treatment was implemented on samples in a boiled water tank (shown in Figure 1) after 2 hours of pouring in three steps and different duration. First, samples were placed in a curing tank with initial warm water vapour with a temperature about 40°C and then boiled the water to reach a temperature of 100°C for 30 minutes. Second, samples were cured in temperature of 100°-120°C for 120 minutes. Last was cooling process by opening tank cover to decrease the temperature of samples untill 30°C for 30 minutes. Therefore steam curing treatment was finished in 5 hours after pouring. Samples were demoulding after 24 hours and curing continuosly in water with normal temperature until testing.

FIGURE 1. Curing treatment by boiled water steam in a tank

Flexural Strength

The flexural strength test was implemented on prism samples with three points loading and 100 mm of span as shown in Fig. 2. The flexural test results a maximum load which is used to calculate the flexural strength by equation 1.

$$\sigma = \frac{3PL}{2bh^2} \quad \text{.....} \quad (1)$$

with :
σ = Flexural strength (MPa).
P = Maximum load (N)
L = Length of the span (mm)
b = The average width of the specimen in the collapsed area (mm)
h = The average height of the specimen in the collapsed area (mm).

FIGURE 2. Flexural test with three poins loading on a prism

Compressive Strength

The compressive strength test was implemented on broken part of prism samples with a compression area of 40 mm x 40 mm by steel plat on both bottom and top samples as shown in Fig. 3. The maximum load was used to calculate compressive strength by equation 2.

$$f'_c = \frac{P}{A} \quad \text{.....} \quad \text{…….(2)}$$

With:
f'_c = Compressive strength of concrete (MPa).
P = Maximum compressive force (N)
A = Cross-sectional area of the test object (mm2)

FIGURE 3. Compression test on part of prism

RESULTS AND DISCUSSION

Effect of Steam Curing on Flexural Strength of Plain Premixed Mortar

Prisms of plain premixed mortar treated by the steam curing were tested in bending test in different ages. The flexural strength of samples in different ages were almost similar as shown in Figure 4. The flexural strength of samples in one day was 5,0 MPa and increased slightly in line with ages. At 28 days, the flexural strength increased to 5,9 MPa which is 17,2% higher than one in 1 day. In other words, by steam curing flexural strength at 1 day can reach 82,8% compared to 28 days. It perhaps due to the effect of high temperature may increase rate of cement hydration [7]. However, the standar deviation bars showed overlapping for all days which might indicate that the steam curing have no significant effect on the flexural strength of the premixed mortar.

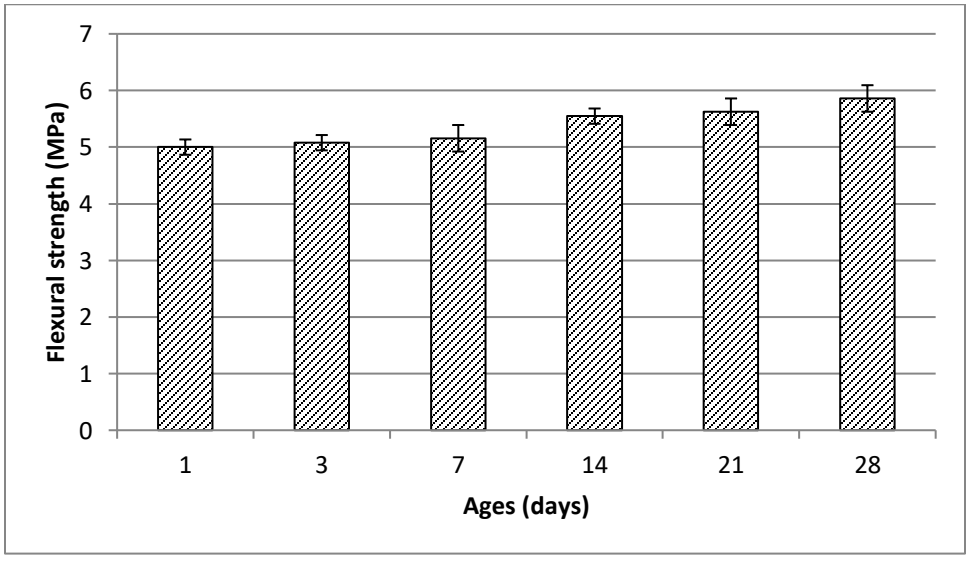

FIGURE 4. Steam curing effects on flexural strength of plain premixed mortar

Effect of Steam Curing on Compressive Strength of Plain Premixed Mortar

Regarding compressive strength results in Figure 5, the diagram shows different trend with the flexural strength's diagram. The compressive strength increased slightly in low ages, from 2,0 MPa at 1 day to 2,5 Mpa at 7 days. Then, it increased gradually to 3,1 - 3,2 MPa at 14 -21 days and to 4,7 MPa at 28 days. Comparing at 28 days, the compressive strength at 1 day and 7 days were 43% and 52% only. It indicated that the steam curing decreased the compressive strength of the premixed mortar at low ages. It perhaps due to microcracks appearence in samples during steam curing process [6,9] which need a long time to recovery itself during cement hydration.

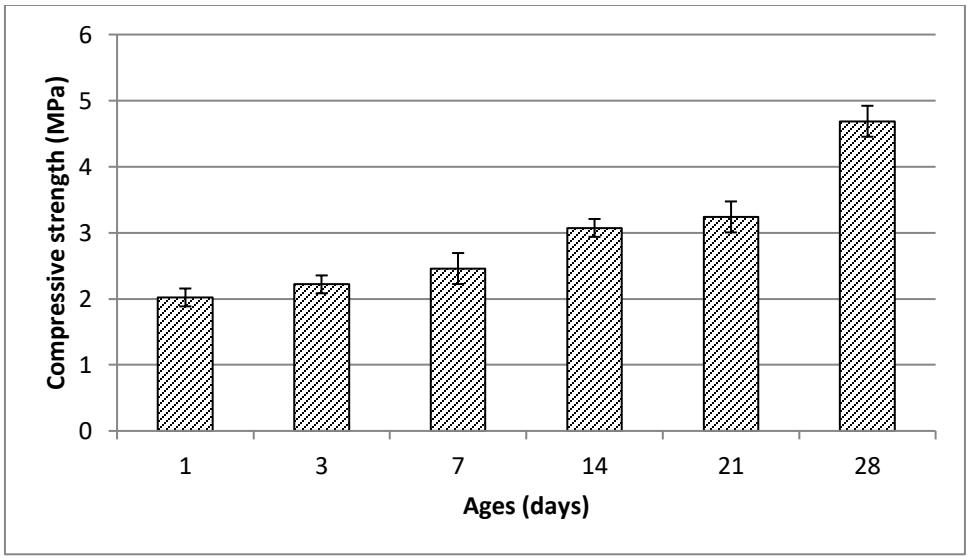

FIGURE 5. Steam curing effects on the compressive strength of the plain premixed mortar

Effect of Cement and Admixture Addition on Flexural Strength

The prism samples were made with variables of cement addition of 10%, 20%, 30%, 40% and admixture use. The results were then compared with the plain premixed mortar. All prism samples were tested with three points loading at 28 days. The flexural strength for all samples are presented in Figure 6. The diagram shows that flexural strength increased in line with cement addition but it was not affected by the presence of admixture. Flexural strength of samples with cement addition and admixture increased to 15%, 26% and 67% for cement addition of 20%, 30% and 40% respectively. In general, the increase of cement amount also can increase the flexural strength [10]. It is believed due to the number of CSH formed also increase. However, the standar deviation bars shows overlapping at samples with cement addition up to 30%, means that the cement additional might have no significant effect on the flexural strength.

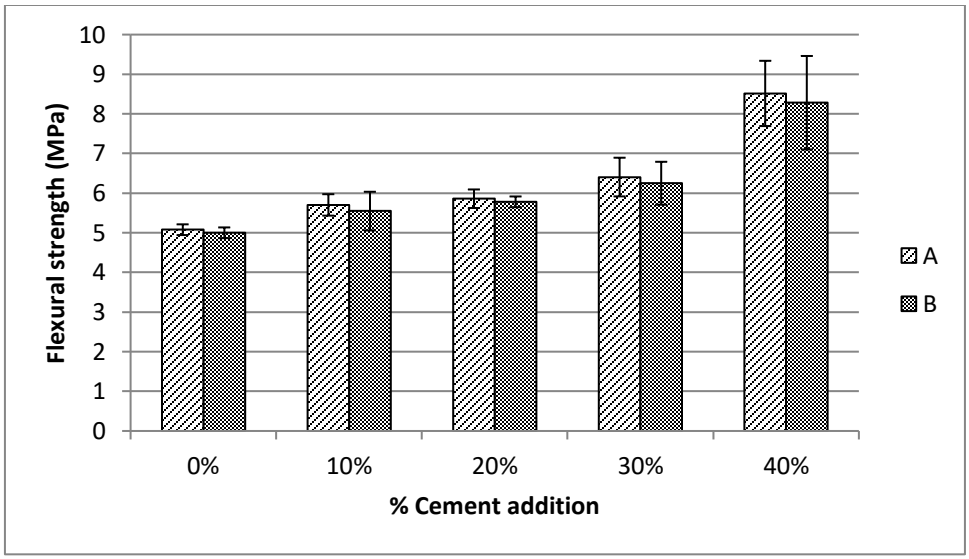

FIGURE 6. Effect of cement and admixture addition on the flexural strength.

Effect of Cement and Admixture Addition on Compressive Strength

The results of the compression test on broken part of prisms are shown in Figure 7. An overall trend of compressive strength increased due to cement addition and it was less affected by admixture. Comparing the plain premixed mortar, additional cement increased the compressive strength gradually 1.5 times at 20% , 5 times at 30% and 5.5 times at 40%. The reason of this is similar with previous that it is due to the increase of CSH formed in samples. Compressive strength at 40% cement addition reached to 30,39 MPa which confirm to mortar strength requirements for ferrrocement. Adding cement into premixed mortar have changed initial ratio of 2 sand : 1 (binder + pozzoland). By 40% cement addition the ratio becomes around 1 sand : 1 (binder + pozzoland). Although this composition has enough compressive strength to be used as mortar in ferrocement structures, however, the cost of material becomes more expensive compared to the ferrocement materials in general. Therefore the use of the premixed mortar is not suitable for ferrocement structure.

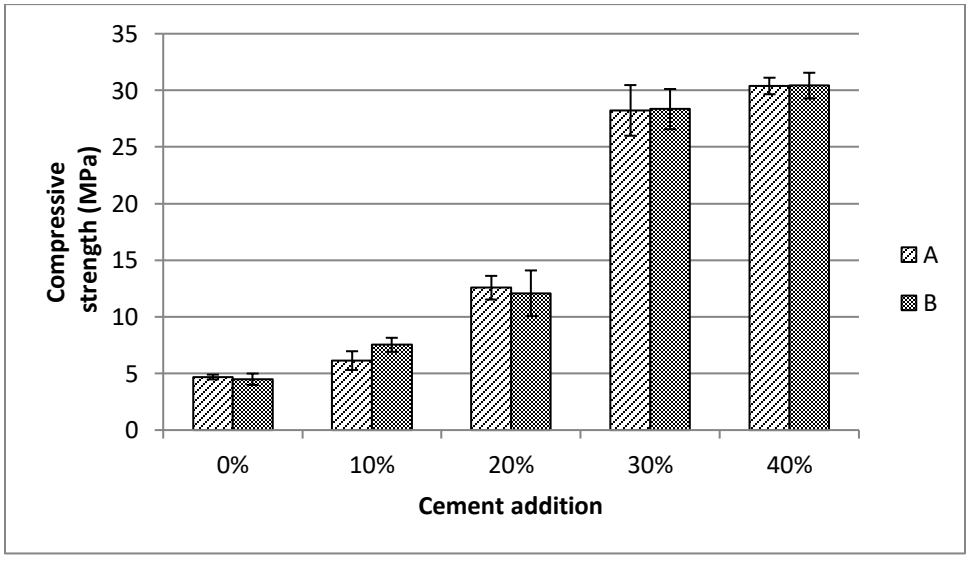

FIGURE 7. Effect of cement and admixture addition on the compressive strength.

Correlation between Flexural and Compressive Strength

The maksimum strength in this study was obtained at 40% of cement addition with 8,516 MPa for flexural strength and 30,34 MPa for compressive strength. The result of both test for all samples was presented in Figure 8. According to the European Concrete Committee (EEC) the flexural strength can be related to compressive strength by Equetion (3) [9] as follows:

$$f_t = 0{,}3 f_c'^{\frac{2}{3}} \quad \text{.....(3)}$$

With:

f_t = Flexural strength of concrete (MPa).

f'_c = Compressive strength of concrete (MPa).

The flexural strength of all mortars in this study ranged between 5 to 8 MPa. The correlation between compressive strength and flexural strength closely formed polynomial trendline in 5 level. It results very different trendline with the Eq. 3. Therefore, it needs a research further deeply to find this correlation for mortar.

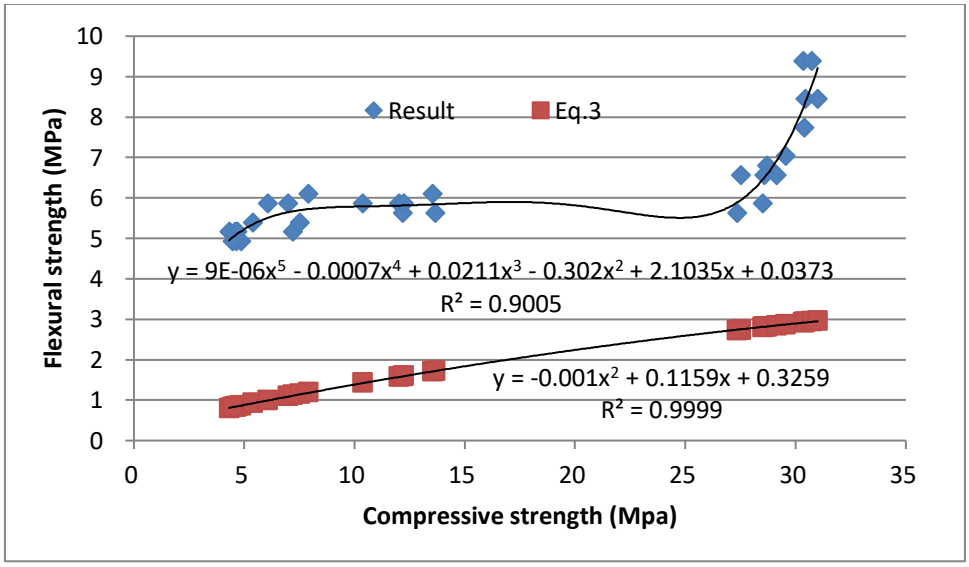

FIGURE 8. Diagram of correlation between compressive and flexural strength.

CONCLUSION

This study evaluated the mechanical properties of premixed mortar treated by the steam curing and correlated to cement and admixture addition. The following conclusions can be drawn**:**

- Curing treatment less affected the flexural strength of premixed mortar regarding the ages of samples, but it slightly affected the compressive strength at early ages and signicantly at 28 days.
- Cement addition affected both the flexural and compressive strength gradually in line with percentage of cement amount.
- Admixture addition has no effect on both the compressive and flexural strength of the premixed mortar.
- Premixed mortar can fulfill ferrocement requirement with 40% cement addition, but it is more expensive than common composition of mortar for ferrocement.

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