Study of mortar creep with additional polymer materials for concrete repair

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Abstract. The polymer is the type of additional material which has high adhesion and is deformable. This study aims to determine the effect of additional polymer against the value of the compressive creep, as well as to predict the long-term creep value based on existing short-term data and the possible error value. The method used in this research is to experiment in the laboratory. The object used in the study is a cylinder with a diameter of 75 mm and a height of 275 mm. The variations in polymer content that are used were 0%, 2%, 4%, and 6% of the cement weight. The data obtained on the creep values that occurred during the 84-day test data analysis showed that the addition of polymer content in the repair mortar tended to decrease the creep value. The greater the polymer content, the smaller the creep value that will decrease. In the calculation of the obtained creep prediction, it showed a difference when compared to direct measurement. As the predicted value obtained has a large error value, it is necessary to modify the formula to get a more precise prediction.

1. Introduction
Concrete repair process technology has developed a lot, one of which is the mortar with polymer as an added material, in this case, the admixture which can affect the chemical properties of the mortar itself. The function of this polymer is to provide flexible properties to the mortar so that the material produced after drying has better flexibility. In this case, fast setting polymeric mortar is used as the test object which will later be used for concrete repair materials.

The creep that occurs on the polymer motorbike has a certain mechanism that can cause the creeping phenomenon to slow down the cracks that occur in the concrete. With the polymer mortar which has better flexibility, this flexibility will be able to avoid problems that befall the building in the future such as cracks due to the possibility of creeping and shrinkage. In this case, because the material used is more flexible, when deformation occurs the mortar that binds it is also able to move flexibly so that there is no case of mortar release or peeling.

In this study, the effect of the proportion of the polymer mixture on the creep size of the mortar mixture was sought and how to predict and evaluate the long-term creep value based on short-term data obtained from the results of mortar experiments mixed with certain polymer proportions. The purpose of this study was to determine the effect of the proportion of polymer blends with high fast-setting on the creep size of the mortar mixture and also to predict and evaluate the long-term creep value based on short-term data obtained from the results of mortar experiments that have been mixed with a certain proportion of polymer.
2. Literature review

The polymer is a new additive that can produce mortar with very high compressive strength. The polymer provides additional strength to improve the quality of the mortar, making it superior to ordinary cement mixtures. The function of this polymer is to provide flexible properties to the mortar so that the material produced after drying has better flexibility compared to materials formed from ordinary cement mixtures. This flexibility will be able to avoid problems that befall the building in the future such as cracks (there is a possibility of expansion shrinkage due to the influence of temperature, minor earthquakes, etc.).

Creep is a property in which the concrete undergoes permanent deformation due to the constant load acting on it. Creeps appear with diminishing intensity over time and may end after several years. In general, high-strength concrete has a smaller creep rate compared to lower-quality concrete. The amount of creep deformation is proportional to the magnitude of the load held and the period of loading[1]. The creep value can be determined by subtracting the total deformation from the shrinkage. This is because the total deformation that occurs is a combination of creep and shrinkage values[2]. Concrete creeping continues for a very long time, which tends to reach a limit value after indefinite time under load[3].

In general, creeping does not cause a direct impact on the strength of the structure but results in a redistribution of stress on the workload and then results in an increase in deflection[4].

According to[5], the effects of creeping on structure include:

a. Creeping in the concrete will increase the deflection of the reinforced concrete beam, and in some cases, there may be critical considerations in the planning.

b. In reinforced concrete, creeping can result in load transfer from the concrete to the reinforcing bars.

c. In eccentric loads on very slender column structures, creeping can increase deflection, which can result in buckling of the column structure.

d. Creeping can relieve (with relaxation) the stress concentration caused by shrinkage, temperature changes, or displacement of supports.

e. Creeping can reduce internal stress due to unequal shrinkage or restraint, thereby reducing cracking.

f. In mass concrete, the creeping that occurs can cause cracking when the confined concrete changes temperature due to increased heat due to hydration.

g. There is a loss of prestress in the prestressed beam, therefore it is necessary to increase the initial prestress.

There are several methods for predicting creep, one of which is based on the ACI 209R - 82. In predicting long-term creep, it requires data or the value of the creep to be studied from the short-term (28 days) test used to estimate long-term creep.

The following is the formula used in ACI 209R - 82 to estimate the long-term creep of concrete from short-term data obtained from the research results:

\[ \Phi \infty(t_0) = \left( \frac{(t-t_0)^{0.6}}{10 + (t-t_0)^{0.6}} \right) \times \Phi \infty(t_0) \]

Where:

- \( \Phi(t,t_0) \) = The size of the age \( t \) with current loading \( t_0 \)

- \( \Phi \infty(t_0) \) = The ultimate creep value

- \( t-t_0 \) = Loading time

3. Research Methods

The preparation stage is carried out, there is this stage, all the materials, and equipment needed in the research are prepared in advance so that the research runs smoothly. Materials and equipment that
need to be prepared include cement, water, fine aggregates, accelerators, superplasticizers, polymers, test object formwork, and other supporting equipment.

The polymer-added mortar mixture used is:

1. Cement
2. Fine Aggregate
3. Water
4. Accelerator
5. Super Plasticizer
6. Polymer

The specimens used mortar with added polymer with a predetermined composition and proportion, ordinary mortar plus superplasticizer, ordinary mortar plus superplasticizer and accelerator, and repair-mortar from the manufacturer. The creep specimen is cylindrical with a diameter of 75 mm and a height of 275 mm. On the body of the test object, a demec point is installed which functions as a point to determine the level of damage caused by loading when tested later. The total number of scrambled specimens was 12 in which each variation amounted to 2 specimens. The following are variations of the types of test objects:

a. 0% polymer-added mortar
b. 2% polymer-added mortar
c. 4% polymer-added mortar
d. 6% polymer-added mortar
e. Ordinary mortar is added with a superplasticizer
f. One of the repair-mortar products from the manufacturer

![Cylindrical Mortar Creep Test Objects 75x275 mm](image)

**Figure 1.** Cylindrical Mortar Creep Test Objects 75x275 mm

Before testing the test object, a test aid in the form of an iron cylinder (Load Dynamometer) with a diameter of 7.5 cm and a height of 27.5 cm must be prepared first.

The steps for preparation and installation are as follows:

1. Prepare an iron pipe with a diameter of 7.5 cm and a height of 27.5 cm.
2. Flatten the top and bottom surfaces of the iron pipe.
3. Take the center point of the iron pipe, then smooth the part using a grinder.
4. Clean the point with alcohol.
5. Attach the head of the strain gauge which has been lightly glued to the point. After that, connect the leg of the strain gauge with the prepared wire. Take care that the two feet of the strain gauge does not touch and also do not touch the metal pipe.
6. Cover the head of the strain gauge with silicone plastic.
7. Repeats steps 3 to 6 for the adjacent point that is 180° from the first point.

The following are the steps for creep testing:
1. Remove the creep specimen from the mold or formwork for 24 hours.
2. Before loading the test object, the initial length measurement is carried out.
3. Setting up the Demountable Mechanical Strain Gauge, which includes:
   a. Set the dial gauge contained in the demountable mechanical strain gauge and the needle is set to the zero position.
   b. Set the value of the reference bar where a value of 200 mm is used.
4. Attach the test object to the Creep Loading Frame and place the Load Dynamometer on the top.
5. Attach the cable from the Load Dynamometer to the strain indicator.
6. Apply load by tightening the string at the top until the value of the strain is read on the strain indicator.
7. Measure the creep value by reading and recording the needle change in the number indicated by the dial gauge after the needle has stopped or is stable.
8. Repeating the measurement for each damage point 5 times.
9. Calculating the creep value of the test object.

4. Results and Discussion
In this study, a cylindrical specimen was used with a diameter of 75 mm and a height of 275 mm. The creep test on mortar was started when the mortar was 1 day old, except for the 6% polymer test stains tested when the mortar was 7 days old. Mortar testing was carried out at mortar ages reaching 1, 2, 3, 7, 10, 14, 21, 28, 35, 42, 49, 56, 70, and 84 days. The creep value is obtained from the calculation between the difference in length change divided by the initial length which is then reduced by the amount of creep value obtained previously. The following is a graph of the relationship between creep and mortar age:

![Figure 2. Creep Loading Frame](image)

![Figure 3. Creep repair mortar chart](image)
Each polymer specimen with different levels can reduce the creep value which is different according to the equation generated by the regression line. The resulting numbers indicate that the greater the proportion of polymers added to the mixture, the smaller the effect of decreasing the creep value on the MSA mixture.

The predicted value of the mortar creep coefficient will be reviewed in the long term until the age of 1000 days, where the long term will be predicted using the ACI 209.R-82 method with short-term data of 84 days. The following is a graph of the calculated results of the creep coefficient prediction.

![Graph showing comparison of creep coefficient predictions with ACI 209.R-82](image)

**Figure 4.** Comparison of the MS observed Creep Coefficient Graph with the Prediction Results of AC1209.R82.

Based on the graph, it shows that the mortar with the added material of superplasticizer and accelerator has a higher creep value than the mortar repair manufacturer or mortar with the addition of superplasticizer alone. In the graph, it is also known that the mortar with polymer added material 2% has the smallest creep value among polymer specimens and all test specimens.

After comparing the creep value with the stress unit of each specimen, it can be seen that the amount of creep reduction is due to the effect of adding polymer. The 2% polymer content has the best results among other polymer specimens. The greater the level of addition of polymer, the smaller the effect of creeping reduction on the MSA mixture.

Predicting creep value is different from predicting shrinkage value. However, what can be predicted from the creep value is the coefficient of the creep value of the specimen itself. This is because the different loading of each specimen causes the elastic strain value of the test object to have a different value. From the data analysis, it shows that the mortar with added material of superplasticizer and accelerator has a smaller creep coefficient value when compared to other specimens. This is because MSA has a very large elastic strain value at the beginning of the loading period. If you pay attention to the creep coefficient prediction graph for each variation sample tends to be uniform, that is, the longer the loading occurs, the less likely the creep occurs when compared to the initial loading period.

The error value of the prediction of the creep coefficient of each variation of the test object shows that a large number of data or the length of the short-term data will reduce the error rate. For example, it can be seen that with 14 days of short-term data the prediction value of the MS% creep coefficient is around 88.73%, of course far away when compared to the 84-day short-term data which has an error value of 37.45%. Even with the short-term 84-day data, the error value that appears is still considered...
too large, it is necessary to make adjustments to the optimal half-time of the creep value coefficient for each variation of the test object.

From the optimal half-life adjustment of the creep value coefficient of polymer and non-polymer specimens, different half-lives are obtained. Polymer specimens have an optimal half-life on day 17, while non-polymer specimens have an optimal half-life on day 4 and for manufacturer's repair on day 6. And it can be concluded that short-term data 56 days is stable enough to determine a prediction.

The deviation value generated from the short-term prediction of 84 days data is very small, on average less than 5% of the predicted 84-day creep coefficient. From the deviation value of the six variations, it shows that the prediction is under-estimate, that is, the predicted value that appears is less than the value from direct observation.

5. Conclusion
From all the testing, data analysis, and discussion carried out in the study, can be conclude that: The addition of polymer content with a certain percentage in the repair mortar will affect the creep value. Where the greater the level of addition of polymer, the greater the creep value that occurs. The best level of polymer addition to reducing the creep value was 2% MSAP which could reduce the creep value by 38% of the MSA mixture, while for MSAP 4% and 6% MSAP specimens it could reduce the creep values by 25.3% and 9.3%. Long-term creep prediction using the ACI 209R-82 method cannot be applied to the test object because it has a large error value beyond the normal limit (30%).

Modification of the ACI 209R-82 formula, namely by replacing the estimated half-life of achieving ultimate creep on the test object with an estimated half-life of 2, 3, 5, 7, 9, 11, 14, 17 and 20 days, resulting in a polymer test object having a value The optimum error is at 17 days, while the non-polymer specimens have the optimum error value at 4 days and for BASF products at 6 days.

References
[1] Dipohusodo, Istimawan. 1999. Struktur Beton Bertulang. Gramedia Pustaka Utama: Jakarta
[2] Kristiawan, S. (2002). Restrained Shrinkage Cracking of Concrete. Inggris: School of Civil Engineering PhD.
[3] N. Krisna Raju, 1989, "BETON PRATEGANG", Edisi kedua, Erlangga, Jakarta.
[4] Dipohusodo, Istimawan. 1999. Struktur Beton Bertulang. Gramedia Pustaka Utama: Jakarta
[5] Neville, A.M, and Brooks, J.J, 1997, Concrete Technology, London.