Comparison of types of grouting to guarantee zero tendon slip with post-tension system prestressed concrete bridge anchors

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Abstract. Prestressed concrete is internal stresses of appropriate magnitude and distribution are given in such a way that the stresses caused by external loads are resisted to a desired level. The use of prestressed concrete is mostly applied in bridge construction, especially in the bridge girders. During the stressing girder process, grouting is carried out to prevent the anchor from slipping. The strength of the adhesion of the grouting material used determines the homogeneous nature and whether the prestressed concrete section next to it can meet the anchor load. If the bond strength does not meet the requirements, it will cause slippage in the anchors which will ultimately affect the strength of the prestressed concrete structure due to quite large prestress losses due to slippage. The method used is to test the adhesive strength of the strands that have been grouted with f.a.s. 1:3 using each grouting material such as PCC (Portland Composite Cement), PPC (Portland Pozzoland Cement), OPC (Ordinary Portland Cement) and Sika Grout 215 which is then compared with the grouting material that adheres best. The results obtained were Sika Grout 215 bond strength of 3.6629 MPa, PCC bond strength of 3.2986 MPa, PPC bond strength of 2.5743 MPa and OPC bond strength of 2.307 MPa.

1 Introduction

Concrete construction is commonly used, especially in the construction of roads and bridges. On Concrete highways are used to replace flexible pavement. Meanwhile on Concrete bridges are used for the lower structure to the upper structure. The concrete used is conventional concrete and prestressed concrete. Concrete Conventional is normal concrete that does not experience pre-service stress. Concrete Conventional does not have prestressed wire, only a mixture of concrete and reinforcing steel.

According to Raju [1], prestressed concrete is concrete in which the internal stresses with appropriate magnitude and distribution is given in such a way that the stress stresses caused by external loads are resisted to a certain degree desired. Prestressed concrete is divided into

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two stretching systems, namely the stretching system pretensioned (pretensioned prestressed concrete) and posttensioned systems (posttensioned prestressed concrete).

According to Sudarmono [2], the concrete pre-tensioning system is first pulled with a support rigid anchor beams printed on the ground or in the form of columns embedded in the ground, then the mold is installed, then the concrete is cast and compacted according to required shape and size. During the hardening process, the concrete is maintained and cared for either by wetting or by chemicals. After reaching design strength, the tendons are cut and prestressing forces begin to act on the concrete.

The concrete post-tensioning system is first cast, before that a channel (sheath) is installed for it placing tendons. If the concrete is strong enough then the wire is high quality inserted into the channel and then withdrawn using hydraulic jack bearing on the end surface of the rod and then the tendon is anchored either with pegs or nuts. In this system the prestressing force is transmitted to the concrete by end anchor, and if the anchor is curved then radial pressure is distributed through the cables and channels. The space between the tendon and the duct is then removed grouting to distribute stress and prevent slip on anchors.

The bond strength of the grouting material determines whether or not the cross-sectional properties of the concrete are homogeneous prestressing in addition to meeting the anchor load. If the adhesive strength is not sufficient requirements will then cause slippage in the anchor which will ultimately affect strength of prestressed concrete structures due to sufficient prestress loss large due to slip.

2 Background

This research was carried out independently of the results of previous studies has been carried out as a comparison and study material. As for the results. The research used as a comparison cannot be separated from the research topic. Research conducted by Rizkia [3], regarding the influence of stressing methods one-way and two-way against loss of prestress. Analysis carried out namely calculating prestressing forces, determining the number and trajectory of tendons, calculate prestress loss due to one-way and two-way stressing methods direction, as well as control of tension and deflection in girders. Equation with Rizkia's research [3], which examines prestress loss. The difference, in Rizkia's [3] research, is that the testing was carried out using analyze prestressing forces. Research conducted by Brian et al [4], determined the relationship between strong concrete compression of 40 MPa with bond stress between steel and concrete.

The quality of concrete is determined by the magnitude of the compressive strength of the concrete obtained. Similarities with research by Brian et al [4], studying about adhesive strength. The difference, in research by Brian et al. [4], namely Bond strength testing is carried out between steel and concrete with compressive strength concrete 40 MPa while in this study bond strength testing was carried out between grouting materials and the tensile strength of prestressed concrete.

Research conducted by Peera et al., examined concrete design prestressing using the Mourice Method. Similarities with Peera's research et al, namely studying prestressed concrete in girders. Difference with research by Peera et al, namely research using analytical methods Maurice [5].

Research conducted by Pratama et al., examined the influence long term creep and shrinkage which causes concrete to lose prestressing. The similarity with Pratama et al.'s research is that it examines concrete prestress loss. Differences with research by Pratama et al., is the method used by ACI 209R, CEB-FIP 1990, and AS 3600-2016 [6].

Research conducted by Adewuyi et al, examined analysis investigation of prestressed concrete structures by connecting combinations pre-tensioned and post-tensioned concrete reinforcement. Similarities with Adewuyi's research et al., namely, studying prestressed
concrete. Difference with research by Adewuyi et al., testing to determine grouting materials the most closely related, while in Adewuyi's research it is a combination of post-tension and post-compression reinforcement [7].

Research conducted by Arusmalem et al. determined adhesive strength reinforcement in various variations of normal concrete quality. Analyzing concrete structures reinforced when working to withstand loads that will cause adhesive stress to the tangential surface between reinforcing bars and concrete. Factors that The quality of the concrete that influences the bond strength is the quality of the concrete. Equality with research by Arusmalem et al, namely studying bond strength on concrete. The difference, in Arusmalem et al's research, was testing the bond strength carried out on reinforced concrete type while in this research. The bond strength test was carried out on concrete with prestressed concrete type [8].

3 Methods

![Workflow diagram](image)

Fig. 1. Workflow diagram.

3.1 Materials

In the initial stage of making samples, the things that need to be done are: prepare materials for making test objects. In this research it will be Three test objects were made for each grouting material. So that the total test objects made are 12 test objects. The following are the materials needed for this test:

a. 1 zak of OPC cement
b. 1 zak of PPC cement
c. 1 zak of PCC cement

d. Sika Grout 215 as much as 1 zak

e. Black iron pipe with a diameter of 1.25 inches (long required for one test object pipe 48 cm)

f. Strand of 12 sticks with a length of 150 cm

3.2 Cut 1¼” diameter black iron pipe (as a replacement for the sleeve)

After all the materials are available, cut the black iron pipe with a diameter of 1¼” with a cut length of 48 cm. To cover the pipe, use multiplex each 1 cm thick. Figure 2 will explain the pipe cross-section.

![Fig. 2. Sketch of pipe cross section.](image)

3.3 Assemble strand and pipe

Prepare strands each 50 cm long and 100 cm long then put them together with the help of a connecting pipe to straighten the strand to prevent overlap. Then insert the strand into the pipe at the intersection position strand in the middle of the pipe.

3.4 Making grouting mixture

The next step is to make a mixture of each grouting ingredient with fas 1:3. For 4 kg of cement mixed with 1 liter of cement using mixer.

3.5 Insert grouting on the black iron pipe

Enter the grouting that has been made using a mixer into the pipe that has been made assembled previously until full grouting. The outside of the pipe. The iron is beaten so that the grouting inside is solid and not hollow. Contents grouting until full.

3.6 Dry the grouting for a minimum of 3 x 24 hours

Dry the test object for a minimum of 3 x 24 hours. At least 3 times 24 hours the test object must not be disturbed or moved. Because time is minimal for grouting drying is 3 x 24 hours for the grouting to harden properly perfect without causing cracks in it.

3.7 Welding strand ends

Weld at both ends of the strand so that when it is pulled the iron bond is attached the strand is not separated. Welding is carried out using electric welding. In process welding sparks must not touch the strand rod because of this. This can reduce the strength of the strand.
3.8 Perform a tensile test with a steel tensile testing machine

After 3 days of grouting, a tensile test was carried out using a powerful machine steel pull. The strand is pulled until the strand is released from the grouting which will then the tensile strength value is obtained.

3.9 Data analysis

After obtaining the maximum load value from the tensile test carried out on strand then this value is divided by the grouting surface area so that the bond strength value will be obtained and each test object will then be averaged for each sample, so that the average of the cement can be compared OPC, PPC cement, PCC cement, or Sika Grout 215 which have strong adhesion biggest.

4 Results and discussion

This research was carried out for 5 weeks due to limited testing time, so there were limitations to testing such as the age of the grouting material, variations in grouting material and the number of samples for each grouting material variable. Documentation of this research process will be displayed. This test is carried out using a tensile machine to obtain a bond strength value from which a comparison of each grouting material will later be made.

Due to the surface shape of the strand used consisting of several circles, then we take the effective diameter of the strand with the following calculation:

\[
\text{Nominal Cross-sectional Area} = \frac{\text{Nominal Cross-sectional Area} \times 4}{4 \pi} = \frac{98.71 \times 4}{3.14} = 11.2085 \text{ mm}
\]

From these calculations, the effective diameter value is 11.2085 mm.

4.1 Adhesion strength testing

From the tensile tests carried out we use the maximum load which can be seen in Appendix 1 Tensile Test Results. The maximum load is then transferred into the bond strength calculation. The following is a calculation of the adhesive strength of grouting after being drawn on each variable:

<table>
<thead>
<tr>
<th>Inspection</th>
<th>Symbol</th>
<th>Check up result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter (mm)</td>
<td>( \Theta )</td>
<td>11.2085, 11.2085, 11.2085</td>
</tr>
<tr>
<td>Blanket Area (mm²)</td>
<td>( A = \pi \cdot \Theta \cdot L )</td>
<td>7045.3511, 7045.3511, 7045.3511</td>
</tr>
<tr>
<td>Strand Length (mm)</td>
<td>( P )</td>
<td>200, 200, 200</td>
</tr>
<tr>
<td>Maximum Load (kg)</td>
<td></td>
<td>2927, 2206, 2609</td>
</tr>
<tr>
<td>Adhesive Strength (MPa)</td>
<td>Teka-P/A</td>
<td>4.154, 3.1311, 3.7031</td>
</tr>
</tbody>
</table>

Average: 3.6629

Fig. 3. Sika Grout 215.
From the testing of the four variables carried out, the average comparison was obtained as follows:

**Table 1.** Comparison of the Adhesion Strength of Grouting Materials for Each Variable.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Average Bond Strength (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sika Grout 215</td>
<td>3.6629</td>
</tr>
<tr>
<td>PCC</td>
<td>3.2986</td>
</tr>
<tr>
<td>OPC</td>
<td>2.3708</td>
</tr>
<tr>
<td>PPC</td>
<td>2.5743</td>
</tr>
</tbody>
</table>

From this comparison it can be seen that the highest bond strength is Sika Grout 215 of 3.6629 MPa, then followed by PCC of 3.2986 MPa, then PPC of 2.5743 MPa and the lowest is OPC of 2.3708 MPa.
5 Conclusion

From the bond strength tests carried out at the Semarang State Polytechnic Building Materials Laboratory, it can be concluded that:

1. The highest bond strength test is Sika Grout 215 amounting to 3.6629 MPa, then followed by PCC of 3.2986 MPa, then PPC of 2.5743 MPa and the lowest is OPC of 2.307 MPa.
2. The four grouting materials used by Sika Grout 215 have the highest bond strength compared to other grouting materials so they are very suitable for grouting prestressed concrete anchors. 
3. Judging from the grains, Sika Grout 215 has coarser grains compared to others and has a more pungent odor while on Other types of cement have relatively uniform granules (pass No. 200 sieve).
4. Density during grouting can affect the strength of the grouting. If the grouting is not dense enough and has voids, the strength of the grouting will not be optimal.

Recommendation

For next research, regarding f.a.s. which is ideal for each grouting material and its influence on the bond strength of the grouting. So that it can be determined which grouting material is most attached to the f.a.s. ideal.

References