The Attack of Alkali Silica Reaction on The Strength of Sea Water Resistance Concrete Pavement

A Sumarsono¹, NM Labib², Suryoto¹, A Setyawan¹, Zulfadli³

¹Roadmate Research Group, Civil Engineering Department, Sebelas Maret University
²Civil Engineering Department, Sebelas Maret University Jalan Ir.Sutami No.36A Surakarta 57126.
³Staff at Indonesian Ministry of Public Work

E-mail: arysetyawan@staff.uns.ac.id

Abstract. Aggregate is the main material in concrete slab for rigid pavement. Quality of the aggregate should be eligible for the rigid pavement. Roads with rigid pavement structure can be damaged by non-technical factors including the effect of tidal flood. That damage due to the attack of alkali silica reaction in concrete. So, it required a research to select the type of aggregate that is more resistant to alkali silica reaction that will produce concrete more resistant to sea water. The method used is this research is experimental one, some sample in alkali silica reaction test using mortar bar of (25x25x285) mm dimensions. For the testing compressive strength and flexural strength of concrete using a cube-shaped test specimens of 150mm x 150 mm and a beam shape (150x160x600)mm. For testing performed after the age of concrete 28 days for normal conditions and after a concrete immersed fresh water 28 days, then soaked in seawater 13 days, and 26 days for testing the effect of sea water on the concrete strength. The test was performed using aggregates from PT. Armada Hada Graha, Magelang and PT. Pancadharma Puspawira, Surakarta. The conclusion at this experiment is aggregate basalt (Surakarta) is more resistant to alkali silica reaction that caused by sea water than the aggregate andesite (Magelang).

1. Introduction

Today the use of concrete as one of the construction options in road pavement is commonly called rigid pavement. In concrete mixes, the aggregate proportion is 70% - 75% of the total volume of the concrete plate. Aggregate quality and quality must meet the requirements for road pavement. If the aggregate quality does not meet the specified requirements, then the level of durability and durability of construction becomes low. In addition, there are non-technical problems including the effects of rob floods. Rob floods often occur in the northern coastal areas, one of them is Semarang City or other areas located on the coast of the North Coast. One of the causes of floods is caused by a decrease in land surface so that the sea level becomes higher [1]. Rob floods caused some damage to existing infrastructure, especially on roads using rigid pavement. This damage can be caused by an alkali silica reaction.

Alkali silica reaction is a reaction between silica content (SiO₂) in aggregate and alkali in cement. Silica-containing aggregates can be reactive or non-reactive to alkaline elements in cement. This reaction causes expansion in concrete. This expansion can cause cracking, porous and spalling surfaces. Alkali silica reactions usually occur in near-shore construction that experience direct contact...
with sea water or those affected by rob flooding. Seawater has sodium content which is an alkaline element which can cause alkali silica reactions in concrete

Because the alkali silica reaction can occur at any time, the selection of the aggregate to be used needs to be selected first so that it will not cause a decrease in performance and damage to rigid pavement. Including aggregate use from the Asphalt Mixing Plant (AMP) in Magelang Regency and Surakarta City. The aggregates from AMP PT. Panca Dharma Puspawira in Surakarta City is basalt and aggregate rock originating from AMP PT. Hada Graha Fleet in Magelang Regency is andesite rock.

Alkali silica reaction is a chemical reaction in concrete and mortar between hydroxyl ions (OH⁻) from alkali (Na⁺ and K⁺) from cement, and certain silica-containing rocks and minerals found in some aggregates. This reaction and the gel resulting from the alkali silica reaction under certain conditions can cause abnormal expansion and cracks in the concrete [2]. Identifying the vulnerability of aggregates to alkali-silica reactions before using them in concrete is one of the most efficient attempts to prevent damage caused by alkali-silica reactions. [3]

The presence of sea water can accelerate the damage to concrete, because sea water contains a lot of salt solution, around 78% is sodium chloride (NaCl) and 15% is magnesium sulfate (MgSO₄). The presence of salts in seawater can also reduce the strength of concrete up to 20% and decrease the strength and durability of the construction that was built [4].

This study aims to determine the effect of aggregate types namely basalt and andesite rocks which are aggregates of the Asphalt Mixing Plant (AMP) at PT. Fleet of Hada Graha, Magelang and PT. Panca Dharma Puspawira, Surakarta for the alkali silica reaction that occurs and determine the effect of sea water immersion on alkali silica reaction in terms of compressive strength and concrete flexural strength. So that it will be known which mixtures use which aggregates are more reactive and which have higher durability to the alkali silica reaction.

2. Experimental
For testing the reaction of alkali silica aggregate to be carried out refers to ASTM C 1260: Standard Test Method for Potential Alkali Reactivity of Aggregates (Accelerated Mortar-Bar Method). The testing phase of the Aggregate Alkali Silica Reaction [5] is as follows:
- Printing mortar bars with sizes (25x25x285) mm with standard mix design ASTM C 1260
- After 24 hours the test object is removed from the mold
- then soaked in water with room temperature for 24 hours.
- The test object is then soaked in water with a temperature of 80 °C for 24 hours, after which it is recorded how much the size of the specimen.
- Transfer and soak the specimen into 1N NaOH solution at 80 °C
- Subsequent measurements were carried out on days 1, 4, 7, 11, and 14.
- After 14 days of immersion with a 1N solution of 80 °C NaOH, we can know the criteria of the aggregate clarification if the specimen increases in length:
  - <0.10% including non-reactive aggregates.
  - 0.10% to 0.20% including potentially reactive aggregates.
  - 0.20% including reactive aggregates.
- To determine the effect of seawater on the alkali silica reaction that occurs then the manufacture of test specimens and test steps as above is done, but in step 5 immersion is changed with the use of sea water at a temperature of 80 °C.

For compressive strength testing carried out refers to SNI 03-1974-1990 with a test object in the form of cubes measuring 15 cm x 15 cm x 15 cm and testing the concrete flexural strength carried out referring to SNI 03-4154-1996 with a test object shaped beam size 15 cm x 16 cm x 60cm with curing process using 3 types of immersion, including: a) 28 days fresh water bath, b) fresh water 28 days + 13 days soak using sea water, c) 28 days fresh water soak + 26 days soaking using sea water.
3. Results and Discussion

3.1. The Alkali Silica Reaction

Testing of alkali silica reactions to aggregates from PT. Fleet of Hada Graha, Magelang and PT. Panca Dharma Puspawira, Surakarta to find out the reactivity of both types of aggregates and compare which aggregates are more resistant to alkali silica reactions. Tests are carried out using the ASTM C 1260 (Accelerated Mortar Bar Method) method. The test results are presented at Table 1.

Table 1. Increase in length after immersion in NaOH 80° solution

| Type of Rock | Length Expansion (mm) |
|--------------|-----------------------|
|              | D+1 | D+4 | D+7 | D+11 | D+14 |
| Basalt (SKA) | 1   | 0.02| 0.05| 0.11 | 0.15 | 0.18 |
|              | 2   | 0.02| 0.08| 0.11 | 0.16 | 0.17 |
|              | 3   | 0   | 0.03| 0.08 | 0.15 | 0.17 |
| Andesit (MGL)| 4   | 0.24| 0.28| 0.34 | 0.36 | 0.41 |
|              | 5   | 0.15| 0.22| 0.29 | 0.31 | 0.33 |
|              | 6   | 0.02| 0.08| 0.19 | 0.21 | 0.23 |

From the results above it can be seen how the average length of increase of each specimen after the 14th day immersion with 80 °C sea water, and from the results of the study can be calculated how much the percentage of the increase in the second length of the aggregate. The results are presented at Table 2.

Table 2. Aggregate Reactivity Tests on Alkali Silica Reactions

| Aggregate Type | Initial Length (mm) | Average Expansion D+14 (mm) | % Expansion | Reaction         |
|----------------|---------------------|----------------------------|-------------|-----------------|
| Basalt (SKA)  | 286.50              | 0.173                      | 0.060       | Non Reactive    |
| Andesit (MGL) | 285.83              | 0.323                      | 0.113       | Potential Reactive |

The alkali silica reaction is then tested with ASTM C 1260 method, but the solution used to soak the specimens using seawater, the purpose of replacing the solution is to find out how the impact of sea water on the alkali silica reaction on the test object. And the results of this test are presented in Table 3.

Table 3. Increase in length after soaking with 80° Seawater

| Aggregate type | Length Expansion (mm) |
|----------------|-----------------------|
|                | D+1 | D+4 | D+7 | D+11 | D+14 |
| Basalt (SKA)   | 1   | 0.04| 0.09| 0.12 | 0.15 | 0.15 |
|                | 2   | 0.05| 0.13| 0.21 | 0.23 | 0.24 |
|                | 3   | 0.04| 0.06| 0.07 | 0.08 | 0.09 |
| Andesit (MGL)  | 4   | 0.01| 0.05| 0.11 | 0.12 | 0.15 |
|                | 5   | 0.12| 0.14| 0.16 | 0.18 | 0.19 |
|                | 6   | 0.07| 0.12| 0.18 | 0.2  | 0.22 |

From the results of the experiments of alkali silica reaction using sea water, the results are obtained as presented in Figure 1.
3.2. Concrete Compressive and Flexural Strength Test
Treatment with this condition is intended to find out how the characteristics of the test specimens in the seawater environment, and to determine the comparison of the durability of the specimens consisting of different aggregates.
Table 4. Concrete Strength Test Results

| No | Immersion Type | Aggregate Type | Code | Strength at 28 days (MPa) | Average Flexural Strength (MPa) | Condition |
|----|----------------|----------------|------|---------------------------|-------------------------------|-----------|
| 1  | Fresh Water 28 days | Basalt (SKA) | A    | 36.89                     |                               |           |
| 2  |                  |               | B    | 38.89                     | 36.52                         |            |
| 3  |                  |               | C    | 33.78                     |                               |            |
| 4  |                  | Andesit (MGL) | A    | 35.71                     |                               |            |
| 5  |                  |               | B    | 34.80                     | 36.21                         |            |
| 6  |                  |               | C    | 38.13                     |                               |            |
| 7  | Fresh Water 28 days + Sea Water 13 days | Basalt (SKA) | A    | 30.76                     |                               |            |
| 8  |                  |               | B    | 31.33                     | 31.48                         |            |
| 9  |                  |               | C    | 32.36                     |                               |            |
| 10 |                  | Andesit (MGL) | A    | 28.44                     |                               |            |
| 11 |                  |               | B    | 26.18                     | 30.27                         |            |
| 12 |                  |               | C    | 36.18                     |                               |            |
| 13 |                  | Basalt (SKA) | A    | 24.67                     |                               |            |
| 14 |                  |               | B    | 28.44                     | 25.70                         |            |
| 15 |                  |               | C    | 24.00                     |                               |            |
| 16 |                  | Andesit (MGL) | A    | 27.02                     |                               |            |
| 17 |                  |               | B    | 22.89                     | 24.96                         |            |

Figure 3. Flexural Strength of Concrete after immersion in sea water
Table 5. The Regression Line and R²

| No | Test                      | Aggregate Type | Regression Line                  | R²  |
|----|---------------------------|----------------|----------------------------------|-----|
| 1  | Alkali Silica Reaction    | Basalt (SKA)   | $y = 0.0293x + 0.0287$           | 0.9132 |
|    |                            | Andesit (MGL)  | $y = 0.0303x + 0.0437$           | 0.9616 |
| 2  | Compressive Strength      | Basalt (SKA)   | $y = -0.416x + 36.642$          | 0.9984  |
|    |                            | Andesit (MGL)  | $y = -0.4329x + 36.106$         | 0.9989  |
| 3  | Flexural Strength         | Basalt (SKA)   | $y = -0.0259x + 4.9854$         | 0.9700  |
|    |                            | Andesit (MGL)  | $y = -0.0262x + 4.6897$         | 0.9866  |

It can be seen in Table 5, the relationship between the line equation gradient on the alkali silica reaction test and the compressive strength testing and concrete flexural strength. In testing the alkali silica reaction, Basalt aggregate (Surakarta) shows a gradient or a ratio of length increase which is smaller than the Andesite aggregate (Magelang) and in testing the strength of the aggregate concrete Basalt (Surakarta) decreases the strength of concrete which is smaller than the Andesite aggregate (Magelang). From this relationship it can be concluded that the greater the length increase ratio in testing the alkali silica reaction will result in a greater decrease in compressive strength and flexural strength. The similar results as the research conducted by Ahmet et al [6].

4. Conclusion

Based on ASTM C 1260 Standard Test Method for Potential Alkali Reactivity of Aggregates (Accelerated Mortar-Bar Method), aggregates originating from PT. Panca Dharma, Surakarta (basalt) is not a reactive aggregate against attacks of alkali silica reactions, while aggregates from PT. Armada, Magelang (andesite) is potentially reactive to attacks of alkali silica reactions. That is, the aggregate from PT. Panca Dharma Puspawira, Surakarta is more resistant to attacks by alkaline silica reactions than aggregates from PT. Armada Hada Graha, Magelang.

Results of testing the compressive strength and flexural strength of concrete with variations in sea water immersion time, shows that concrete made from Basalt (Surakarta) aggregates is superior when used as material for rigid pavement compared to Andesite aggregates (Magelang), including for rigid pavement Basalt (Surakarta) aggregate seawater is more resistant and better in performance than the Andesite aggregate (Magelang).

Concrete strength performance made of Basalt (Surakarta) aggregates and Andesite aggregates (Magelang) can meet the value of compressive strength and concrete flexural strength required by SNI Pd T-14-2003 as road repair materials that are resistant to seawater.

References

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