Corrosion potential of reinforced steel in reinforced concrete in Kabupaten Bireun: Analysis of groundwater content used as a concrete mixture

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Abstract. The use of groundwater as a mixture in making reinforced concrete is common in Bireun District, Aceh. This research is the initial stage of investigating the relationship between the quality of concrete and water resistance as a mixture in Bireun Regency. At this stage, the research focus is directed to find out what elements are contained in groundwater in five locations in Kabupaten Bireun, namely Gampong Paya, Gampong Teupok Teungoh, Gampong Pulo Lawang, Gampong Lhok Awe Baroh and Gampong Lhok Awe. Water content testing is carried out by referring to SNI 06-6989.14-2004 and SNI 06.6989.19: 2009. The results analyzed and compared with the reference of ASTM C 1602 M-04 standard. Laboratory test results show that chloride, sodium, sulfate and dissolved oxygen differ from location to location. Chloride content in two locations, Gampong Paya and Tumpok Teungoh, is far above the standard content set in the ASTM C 1602 M-04 standard. While at three other locations, chloride content was below the limit of ASTM C 1602 M-04. Investigation of the potential for corrosion of reinforcing steel in reinforced concrete using groundwater as a mixture in five locations will provide further information.

1. Introduction
Kabupaten Bireuen is part of the Aceh region located in the coastal area. Various potentials and attractiveness in the field of marine cause this region to continue to grow and develop rapidly. Construction of structures and infrastructure is carried out in line with regional development and population growth. Various facilities and infrastructure are built such as residential buildings, places of worship, office buildings, bridges, and various other public facilities. The quality of the facilities and infrastructure built, especially reinforced concrete, will be strongly influenced by the mixture used. One of the main ingredients in making concrete is water. High chloride content in concrete mixed water can trigger the corrosion process in steel reinforcement in concrete [1, 2]

The use of groundwater as a concrete mixture is very common in Kabupaten Bireun. The chemical content of groundwater and its influence on the quality of buildings in Kabupaten Bireun is not yet understood. There have been no previous studies examining the effect of groundwater content on the corrosion potential of reinforcement in reinforced concrete in the region.
This research is a preliminary step in investigating the influence of groundwater as a concrete mixture on the corrosion phenomenon of reinforced concrete. The main focus of the study at this stage is to examine the content of chloride, sodium, sulfate and dissolved oxygen (DO) in groundwater in five selected locations in the Bireun region.

2. Method

2.1. Sampling location

The groundwater investigated in this study came from five locations in Kabupaten Bireun, namely Gampong Paya, Gampong Teupok Teungoh, Gampong Pulo Lawang, Gampong Lhok Awe Baroh and Gampong Lhok Awe Gampong (figure 1). The main consideration in determining the location is the level of development and population density. Also, the location can represent the overall condition of Kabupaten Bireun.

2.2. Chemical composition test

Testing the chemical composition of groundwater samples taken from five locations in Kabupaten Bireun was conducted at the Laboratorium Penguji BARISTAND Industri Banda Aceh (LABBA). Test parameters and methods used are shown in Table 1.

| No. | Test Parameter     | Test Method                                           |
|-----|--------------------|-------------------------------------------------------|
| 1   | Chloride (Cl-)     | SNI 06.6989.19.2009                                    |
| 2   | Natrium (Na)       | Atomic absorption spectroscopy (AAS)                   |
| 3   | Sulfate (SO₄)      | IK.5.04.01.31                                          |
| 4   | Dissolve Oxygen (DO)| SNI 06-6989.14.2004                                    |

3. Results and discussion

The test results of the chemical content of Cl, Na, SO4 and DO for each location are shown in figure 2 through figure 6. High chloride content was found in two locations, namely Gampong Paya and Gampong Teupok Teungoh. The magnitude of chloride is far above the standard specification for mixing water as shown in table 2. The high content of chloride ions in concrete mixed water can trigger the corrosion process in steel reinforcement in concrete [2, 3]. However, its influence in the Kabupaten Bireun area still needs further investigation.
Figure 2. The chemical content of groundwater from Gampong Paya (in mg/L)

Figure 3. The chemical content of groundwater from Gampong Teupok Teungoh (in mg/L)

Figure 4. The chemical content of groundwater from Pulo Lawang (in mg/L)
Sodium and oxygen-dissolved elements are found in groundwater tested with very small amounts. The effect of these two elements on the process of corrosion initiation is very small compared to chloride ions. Another element found in groundwater in Bireuen Regency is sulfate (SO₄). The presence of sulfate elements in concrete mixed water can inhibit the process of cement hydration reactions. Sulfate attacks cause a decrease in strength in cement paste. Sulfate will react with the composition of the concrete matrix and cause a complex reaction [4].
Magnesium sulfate (MgSO₄) reacts with calcium hydroxide Ca (OH) produces calcium sulfate or gypsum (CaSO₄²⁻). Furthermore, gypsum reacts with calcium alumina hydrate (CaO.Al₂O₃) to produce calcium sulfoaluminate (3CaOAl₂O₃ 3CaSO₄). The resulting calcium sulfoaluminate is found between cement aggregate and paste. The calcium sulfoaluminate volume is produced three times the volume of calcium aluminate (the original ingredient). This inflating nature of calcium sulfoaluminate causes loss of cement and aggregate paste bonds, which ultimately causes cracks in the concrete [4].

Nevertheless, sulfate content in all locations in Kabupaten Bireun is far below the standard specification for mixing water, so theoretically, the effect of sulfate on reducing the quality of reinforced concrete is minimal.

4. Conclusion
The results obtained from testing, will then be analyzed and compared with the reference of ASTM C 1602 M-04 standard. Laboratory test results show that chloride, sodium, sulfate and dissolved oxygen differ from location to location. Chloride content in two locations, Gampong Paya and Tumpok Teungoh, is far above the standard content set in the ASTM C 1602 M-04 standard. While three other locations, Gampong Pulo Lawang, Gampong Lhok Awe Baroh and Gampong Lhok Awe, chloride content was below the limit of ASTM C 1602 M-04, next step of this work is to investigate the corrosion potential of reinforcing steel in reinforced concrete using groundwater as a mixture in five locations in Kabupaten Bireun to provide further information.

References
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