International Journal of Psychosocial Rehabilitation, Conference Special Issue
ISSN: 1475-7192

Corrosion Risk of Steel used as reinforcement in a Reinforced Concrete within Kabupaten Bireuen: Analysis of groundwater content used as a concrete mixture

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ABSTRACT-- *Corrosion is one of the main causes of reinforced concrete (RC) failures. The use of ground water which does not meet the standard as mixed water triggers degradation of concrete and corrosion. The main focus of this research is to examine the corrosion risk affected by groundwater content used as a concrete mixture. An experimental study was carried out on conventional reinforce concrete beam (RCB) with 2,5 cm concrete cover and 10 mm of steel reinforcement diameter. The groundwater used as a concrete mixture selected from three locations in Kabupaten Bireuen. The selected locations are Gampong Lhok Awe (A), Gampong Krueng Juli Timu (B) and Gampong Paya (C). The specimens were set in a wet-dry cycle and immersed in an artificial seawater of 3.5% NaCl solution. The measurement was performed by using half-cell potential mapping technique. The experimental results show that the corrosion risk to RCB specimens were at intermediate to severe level, just in five week of wet-dry cycle immersed. In addition, the corrosion risk of RCB A were at severe corrotion level, while RCB B at high (>90% risk of corrotion) and RCB A still at intermediate levels. If expressed as a percentage, the potential values of RCB C and B are 34.9% and 16.0% more negative than RCB A. Laboratory test results of groundwater chemical content show that corrosion risk of RCB spesimens will be strongly influenced, especially by chloride content. Chloride content at Gampong Paya is far above the standard content set in the ASTM C 1602 M-04 standard. While at two other locations Gampong Lhok Awe and Gampong Krueng Juli Timu, the chloride content was below the standard limit. Differences in the amount of chloride contained in groundwater causes the level of risk of corrosion imposed also different*

Keywords-- *Corrosion risk; reinforced concrete beam; groundwater content; half-cell potential mapping; Kabupaten Bireuen.*

I. INTRODUCTION

Various facilities and infrastructure in Kabupaten Bireuen are built using RC as a structure material, such as residential buildings, office buildings, bridges and other public facilities. Four main materials used in making RC are cement, aggregate, water and steel reinforcement. The quality and characteristic of forming materials will significantly affect the quality and characteristics of RC produced. Water that contains dangerous compounds such

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Received: 02 Jan 2020 | Revised: 12 Feb 2020 | Accepted: 17 Mar 2020

ISSN: 1475-7192

as salt if used in concrete mixture, will affect and even can change concrete features and characteristics. The use of groundwater which does not meet the standard as mixed water triggers degradation of concrete and corrosion. There have been no previous studies examining the effect of groundwater content on the corrosion potential of steel reinforcement in reinforced concrete in Kabupaten Bireuen. The main focus of this study is to examine the corrosion risk affected by groundwater content used as a concrete mixture[1,2,3].

II. EXPERIMENTAL PROCEDURES AND METHOD

2.1 Sampling location

The groundwater used as a concrete mixture came from three locations in Kabupaten Bireuen, namely Gampong Lhok Awe (A), Gampong Krueng Juli Timu (B) and Gampong Paya (C) (Figure 1).

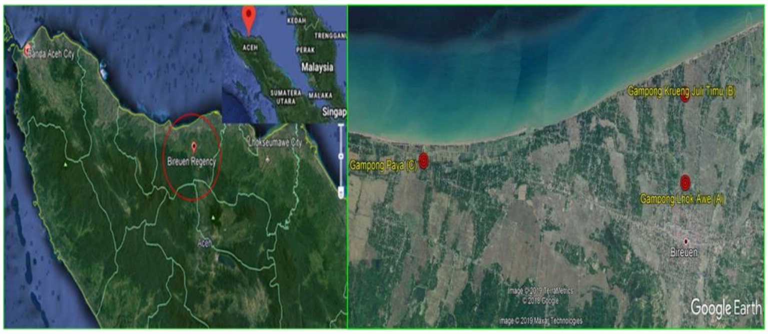

Figure 1: Sampling locations in Kabupaten Bireuen

2.2 Groundwater chemical content test

Groundwater samples taken from three locations in Kabupaten Bireuen. Testing the chemical content of Groundwater was conducted at the Laboratorium BARISTAND Banda Aceh (LABBA). Test parameters and methods used are shown in Table 1.

Table 1: Test parameters and methods

No.	Test Parameter	Test Method
1	Chloride (Cl^-)	Tritrimeter (SNI 06.6989.19.2009)
2	Natrium (Na)	Atomic absorption spectroscopy *(*AAS*)*
3	Sulphate (SO_4)	Spektrofotometer

2.3 Specimens

An experimental study was carried out on conventional reinforce concrete beam (RCB) with 2,5 cm concrete cover and 10 mm of steel reinforcement diameter. For measurement purpose, the surface of all RCB specimens was mesh and numbered as as shown in Figure 2. The mesh represents steel reinforcement inside the concrete. In this study, the specimens were set in a wet-dry cycle and immersed in an artificial seawater. The specimens would be treated by immersing it into corrosive environment. The immersion medium was artificial seawater that contains 3.5% NaCl.

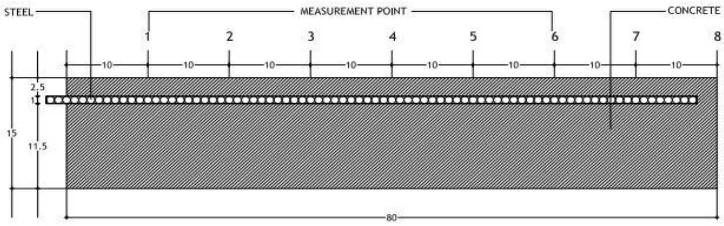

Figure 2: RCB specimen size and dimension

2.4 Half-cell potential technique

The measurement was performed by using half-cell potential technique with $Cu/CuSO_4$ as areference electrode. The half-cell potential technique for measuring the potential in the concrete surface is shown in Figure 3. Measurement of corrosion potential was conducted at every one-week interval in which the measurement was carried out until the fifth week.

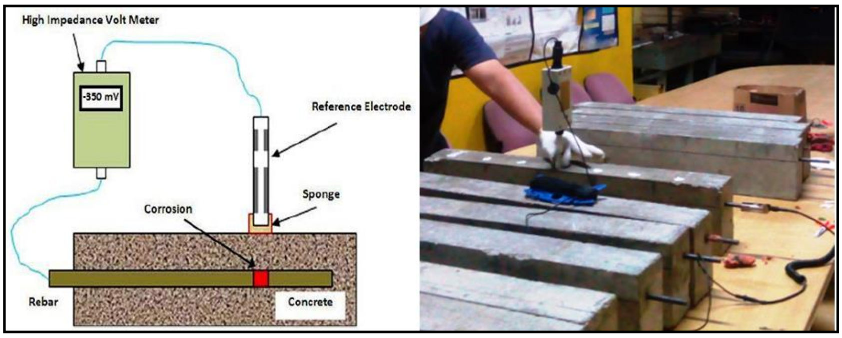

Figure 3: Schematic of the half-cell potential mapping technique

III. RESULT AND DISCUSSION

2.5 Groundwater chemical content

The groundwater used as a concrete mixture came from three locations in Kabupaten Bireuen, namely Gampong Lhok Awe (A), Gampong Krueng Juli Timu (B) and Gampong Paya (C) (Figure 1).

Table 2: Standard specification for mixing water [ASTM C 1602 M-04, 2004]

No.	Test Parameter	Limit (ppm)
1	Chloride (Cl^-)	500
2	Sulphate (SO_4)	3000
3	Alkalies as (Na_2O+K_2O)	600

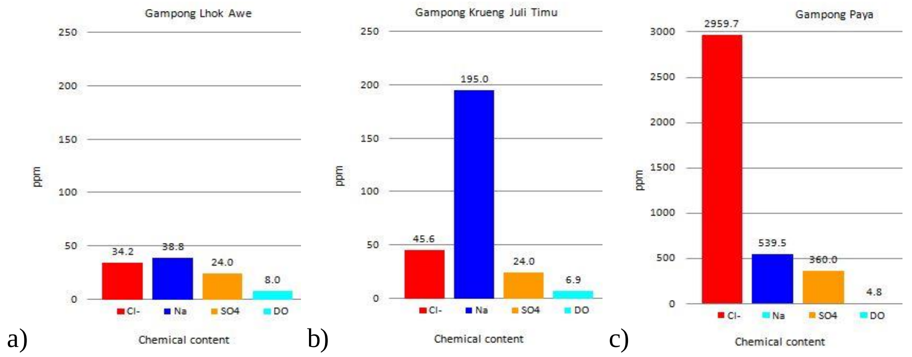

Figure 4: The chemical content of groundwater from Gampong Lhok Awe (a), Gampong Krueng Juli Timu (b), Gampong Paya (c)

The magnitude of chemical content standard specification for mixing water as shown in Table 2. Chloride (Cl^-) content of Gampong Paya groundwater is far above the standard limit set in the ASTM C 1602 M-04 standard. While at two other locations, Gampong Lhok Awe and Gampong Krueng Juli Timu, the chloride content was below the standard limit. The next element found in groundwater in Kabupaten Bireuen is sulphate (SO_4). Sulphate will react with the composition of the concrete matrix and lead the concrete cracks [5]. The sulphate elements are found in groundwater tested with very small amounts for all groundwater samples, so theoretically the effect of sulphate on reducing the quality of reinforced concrete is minimal. Another element found in groundwater samples is sodium (Na^+). The magnitude of sodium content of Gampong Paya groundwater is almost reached the standard set in the ASTM C 1602 M-04 standard. However, two other locations Gampong Lhok Awe and Gampong Krueng Juli Timu, have sodium content is far below the standard limit set in the ASTM C 1602 M-04 standard.

2.6 Corrosion risk

The complete half-cell potential test results on the concrete surface for all RCB specimens are given in Table 3. Table 3 show a comparison between the half-cell potential test results for all RCB specimens. If expressed as a percentage, the potential values of RCB C and RCB B are 34.9% and 16.0% more negative than RCB A.

Table 3: Half-cell potential test results for all RCB specimens

No	Groundwater Sources	Specimens Code	Potential Value (mV)			
			Week			
			0	1	3	5
1	Gampong Lhok Awe	RCB A	-70,68	-150,93	-276,82	-354,21
2	Gampong Krueng Juli Timu	RCB B	-104,82	-193,93	-319,86	-399,11
3	Gampong Paya	RCB C	-171,64	-256,68	-417,11	-499,88

ISSN: 1475-7192

The half-cell potential measurement on the concrete surface gives an indication of the corrosion risk level of the steel reinforcement. The corrosion risk level was determined using ASTM C867. ASTM C867 gives a way to interpret the corrosion risk level base on half-cell potential measurement data as shown in Table 4.

Table 4: The ASTM C867 criteria for corrosion risk of reinforced concrete

Reference electrode $Cu/CuSO_4$	Reference electrode Ag/AgCl	Corrosion risk
≥ 200 mV	≥ 106 mV	Low (10% risk of corrosion)
- 200 mV to - 350 mV	- 106 mV to - 256 mV	Intermediate corrosion risk
≤ 350 mV	≤ 256 mV	High (<90% risk of corrosion)
≤ 500 mV	≤ 406 mV	Severe corrosion

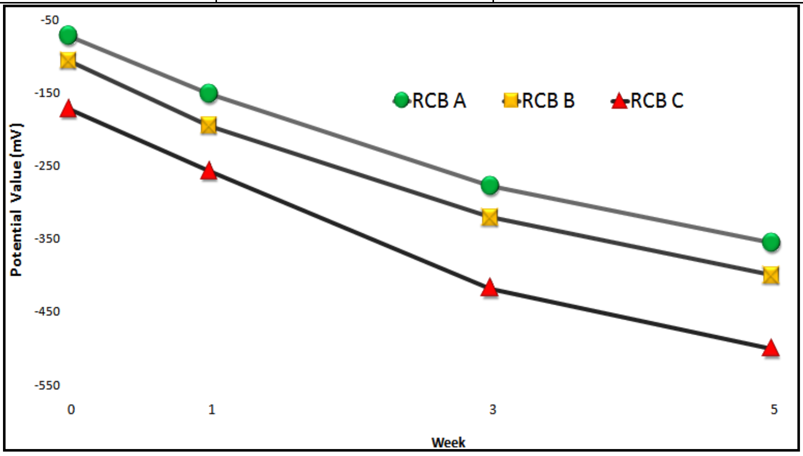

Figure 5: Steel reinforcement potential value vs measurement time

The half-cell potential measurement data (Table 3) indicated that the corrosion risk to RCB specimens were at intermediate to severe level, just in five week of wet-dry cycle treated. In addition, the corrosion risk of RCB C were at severe corrotion level, while RCB B at high (>90% risk of corrotion) and RCB A still at intermediate levels. If the steel is in passive state, the potential measured by the half-cell is relatively small, that is, 0 to −200mV ($Cu/CuSO_4$), or even positive. The potential reading moves toward the potential value of −350mV when the passive layer is failing or small areas are corroding. When the potential is more negative than −350mV the steel is usually corroding actively [4].

IV. CONCLUSIONS

According to ASTM C 1602 M-04 "Standard specification for mixing water used in the production of hydraulic cement concrete", the limit of chemicals content for water which will be used in concrete mix is as shown in Table 2. The test results of groundwater chemical content for each location are shown in figure 4 through Figure 6. The corrosion risk of steel reinforcement in reinforce concrete was investigated in this paper. The corrosion risk of steel reinforcement in reinforce concrete were determined by using half-cell potential technique. Laboratory groundwater chemical content test results show that chloride, sodium, and sulphate differ from location to location.

Received: 02 Jan 2020 | Revised: 12 Feb 2020 | Accepted: 17 Mar 2020

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The experimental results show that the groundwater chemical content such as chloride ions and sodium elements are affected the activity and the risk of steel reinforcement corrosion. Corrosion risk of RCB spesimens will be strongly influenced, especially by chloride content. The groundwater used as a concrete mixture with high content of chloride has higher corrosion risk. The corrosion risk of RCB A were at severe corrotion level, while RCB B at high (>90% risk of corrotion) and RCB A still at intermediate levels. If expressed as a percentage, the potential values of RCB C and B are 34.9% and 16.0% more negative than RCB A.

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