Corrosion Risk Assessment of Existing and New Reinforced Concrete Buildings after Six Years Tsunami Aceh 2004

M. Ridha[a,c], Syarizal Fonna[a,b], Syifaul Huzni[a], Israr[a], Zulfan Fauzi[a] and A. K. Ariffin[b]
[a] Department of Mechanical Engineering, Syiah Kuala University
Jl. Tgk Syech Abdurrauf No. 7, Darussalam, Banda Aceh 23111, Indonesia
[b] Department of Mechanical and Materials Engineering
Universiti Kebangsaan Malaysia, Bangi 43600 Selangor, Malaysia
[c]Tsunami & Disaster Mitigation Research Center (TDMRC), Syiah Kuala University
Jl. Tgk Syech Abdurrauf No. 8, Darussalam, Banda Aceh 23111, Indonesia
Email: ridha@tdmrc.org

Abstract - The corrosion of steels in concrete is majorly the main causes of failures of reinforced concrete structures. The penetration of ion chloride as present in seawater into the concrete will break down the passive layer of steel and thus, promote corrosion. Banda Aceh, a city located at the northwestern tip of Sumatra island, has coastal environment. When the tsunami struck Banda Aceh city on December 2004, many buildings were submerged by seawater and destroyed. Many reinforced concrete buildings were built at the tsunami affected area after that tragedy. Hence, the existing buildings and new buildings become susceptible to the corrosion. The aim of this study was to conduct a corrosion assessment for several existing and new reinforced concrete buildings in Banda Aceh's tsunami affected area. Haft-cell potential mapping technique that already well-known technique and has been widely used in the field for corrosion diagnosing of reinforced concrete was used for the assessment. The half-cell measured the potential value on the surface of reinforced concrete. The potential data was used to decide the corrosion level based on ASTM C867 criteria. Three existing and three new reinforced concrete buildings in Banda Aceh were chosen for corrosion assessment. The results show that the potential values on the reinforced concrete surface were varied between -200 mV to -350 mV (copper/copper sulphate reference electrode) for existing buildings. It means that the corrosion risk level of steel in concrete at certain part of building was already at intermediate corrosion risk after six years tsunami. While, the potential for new buildings was higher than -200 mV (low corrosion risk). Therefore, the further action is needed to be carried out for the existing building in order to prevent the failure of the building in the future.

Keywords: corrosion, reinforced concrete, half-cell, potential mapping, tsunami Aceh

I. INTRODUCTION

Aceh Province is the region whereas susceptible to earthquake because of its position nearby the fault between Eurasian plate and Indian-Australian plate. Also, Aceh is located in the Pacific Ring of Fire area. Banda Aceh is capital of Aceh Province that stricken by tsunami on December 2004. Some of the reinforced concrete buildings in this city still exist, but already cracked and submerged by seawater. Fig. 1 shows the tsunami affected area in Banda Aceh.

The effects of the submerged reinforced concrete buildings by seawater were ion chloride could be penetrated into the concrete and reached the steel surface. This ion would lowering the alkalinity of the concrete, hence destroyed the passive layer of steel. Therefore, the corrosion will initiate on the steel surface [1].

The problem surfaces cause these building were rebuilt which still using old structure during reconstruction and rehabilitation periods. The ion chloride remains in the concrete and thus, initiates corrosion on the reinforcement steel. During reconstruction and rehabilitation periods, many new reinforced concrete building were also built in tsunami affected areas. These new buildings might susceptible to corrosion too.

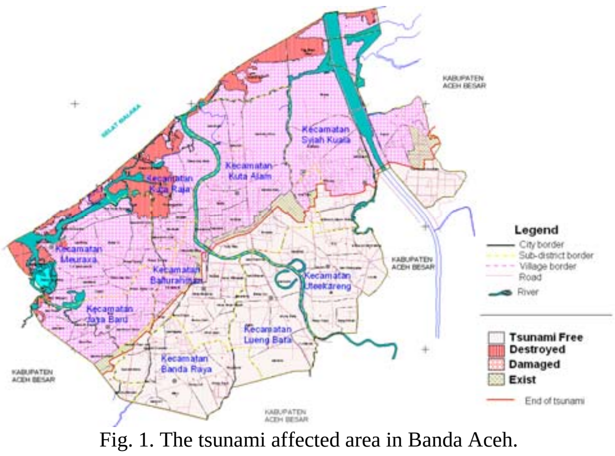

Fig. 1. The tsunami affected area in Banda Aceh.

Corrosion of the reinforcement steel in concrete leads to formation of rust. As the steel corrodes, the volume of the rust also increases and at one stage the force induced by the corrosion products may exceed the strength of the concrete and because of this, cracking of concrete will occur. Then, the reinforced concrete buildings could be collapse suddenly caused of the corrosion when just relatively small earthquake happen. Hence, it is important to monitor and evaluate the corrosion risk level of the steels in concrete structure since the corrosion of steels in concrete is a major cause of premature deteriorations and failures of the reinforced concrete structures. Also the monitoring becomes important to maintain a long life of the structures and reduce the cost of maintenances [1-2].

Potential surveys are carried out on concrete structures to determine the corrosion risk level of the reinforcement steel. The potential on the concrete surface is used to evaluate the corrosion risk level on the steel surface in concrete structure that measured using haft-cell potential technique [3-6].

The purpose of this study is to apply haft-cell potential technique for evaluation corrosion risk level of some existing and new reinforced concrete buildings in Banda Aceh's tsunami affected area. The corrosion level was determined using ASTM C867.

II. HALF-CELL POTENTIAL TECHNIQUE

The half-cell is a simple device that a piece of metal in a solution of its own ions such as copper in copper sulphate and silver in silver chloride. The schematic of half-cell potential technique for measurement the potential in the concrete surface is shown in Fig. 2.

When the steel is in passive state, the potential measured by half-cell is small i.e. zero to -200 mV against a copper/copper sulphate standard electrode, or even a positive reading. The potential reading moves toward -350 mV when the passive layer is failing or the small areas are corroding. At more negative than -350 mV the steel is usually corroding actively [1].

The half cell potential measurement gives an indication of the corrosion risk level of the steel. ASTM C867 gives a way to interpret half cell potentials measurement data in the field as shown in Table 1 [1].

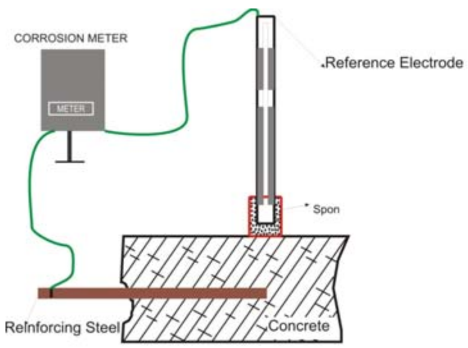

Fig. 2. Schematic of half-cell potential technique.

TABLE I
THE ASTM C867 CRITERIA FOR CORROSION RISK OF REINFORCED CONCRETE [1]

$Cu/CuSO_4$	Ag/AgCl	Hydrogen Standard	Calomel	Corrosion Risk
> -200 mV	> -106 mV	> +116 mV	> -126 mV	Low (10% risk of corrosion)
-200 s.d. - 350 mV	-106 s.d. - 256 mV	+116 s.d - 34 mV	-126 s.d. - 276 mV	Intermediate corrosion risk
< -350 mV	< -256 mV	< -34 mV	< -276 mV	High (<90% risk of corrosion)
< -500 mV	< -406 mV	< -184 mV	< -426 mV	Severe corrosion

III. CORROSION RISK ASSESSMENT SETUP

Three tsunami affected locations in Banda Aceh and were chosen. The locations are shown in Fig. 3. For each location, one existing and one new reinforced concrete were selected for monitoring of the corrosion risk. The existing building is the building that submerged by seawater and not destroyed by tsunami 2004. While, the new building is the building that built after tsunami 2004 stricken Banda Aceh.

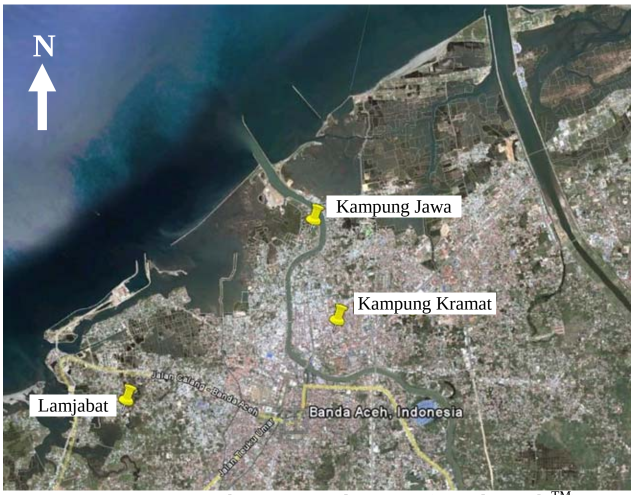

Fig. 3. Corrosion risk assessment locations (Google Earth TM)

Before the measurement of potential corrosion on the concrete surface, the location of reinforcement steels was mapped by using rebar locator. The potential corrosion measurement points would be located precisely above the reinforcement steels. Then, the potential corrosions on those points were measured by using half-cell meter. The equipments for locating the reinforcement steels and measuring potential corrosion were shown in Fig. 4. The potential corrosion measured by the half-cell device in Fig. 4 (a) is against copper/copper sulphate standard electrode.

(a) (b)

Fig. 4. (a) SCRIBE DHC Digital Half Cell Meter; (b) Rebar locator (profometer3)

IV. CORROSION RISK ASSESSMENT OF REINFORCED CONCRETE BUILDINGS IN TSUNAMI AFFECTED AREA

A. Location 1: Kampung Jawa

The assessment of corrosion for tsunami affected buildings was started for civilian reinforced concrete buildings at Kampung Jawa. The existing building is shown in Fig. 5 and three columns were selected for the assessment. This building located around 1.5 km from coastal line and submerged by seawater around 6 m high.

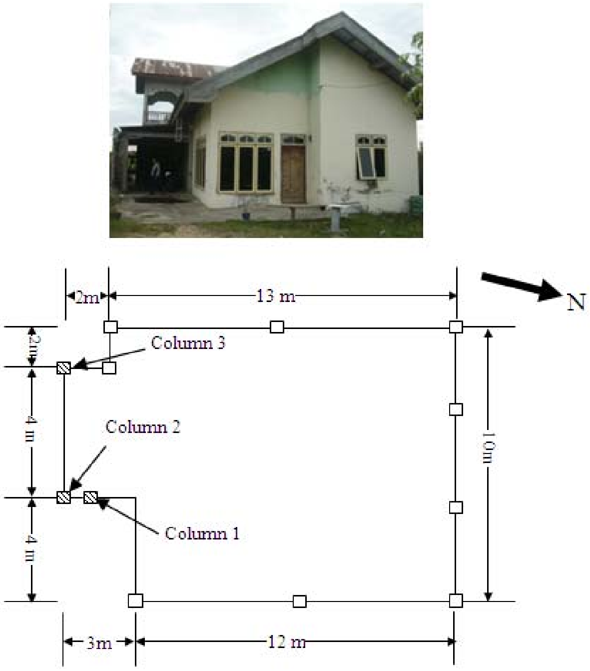

Fig. 5. The existing building in Kampung Jawa

The potential corrosion distribution for the existing building in Kampung Jawa is shown in Fig. 6. The figure shows that the potential corrosion distributions were varying between -200 mV to -350 mV. It indicates that the corrosion risk level is already at intermediate.

From these data, it can be decided that the corrosion of reinforcement steels might took place there for all columns. It needs to take preventive action before the corrosion worsening and early failure occurs.

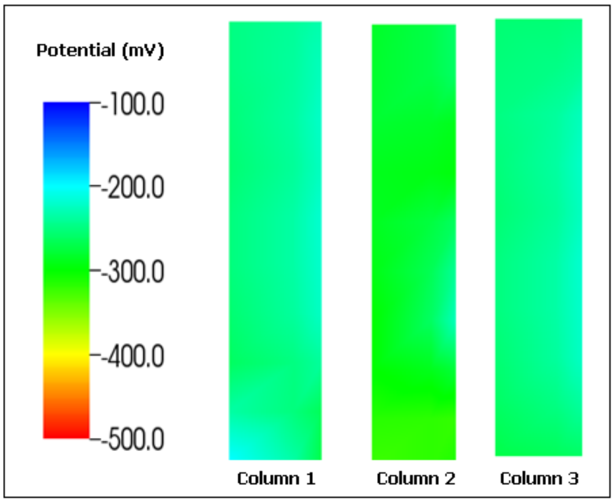

Fig. 6. Potential corrosion distribution for the existing building in Kampung Jawa

Fig. 7 shows the new reinforced concrete building in Kampung Jawa that built after tsunami 2004. This building also located around 1.5 km from coastal line.

The potential corrosion data that measured on the three columns surface of the new building in Kampung Jawa are shown in Fig. 8. The potential values on the surface of concrete are ranged between -100 mV to -200 mV. It means that the corrosion level is low, only 10% corrosion risk.

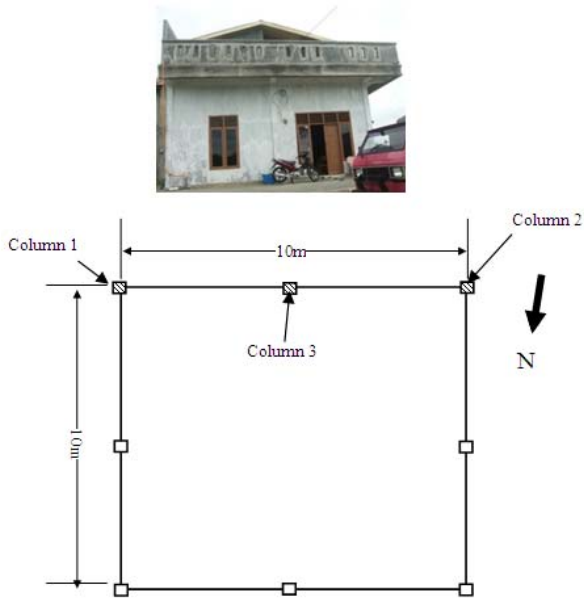

Fig. 7. The new building in Kampung Jawa

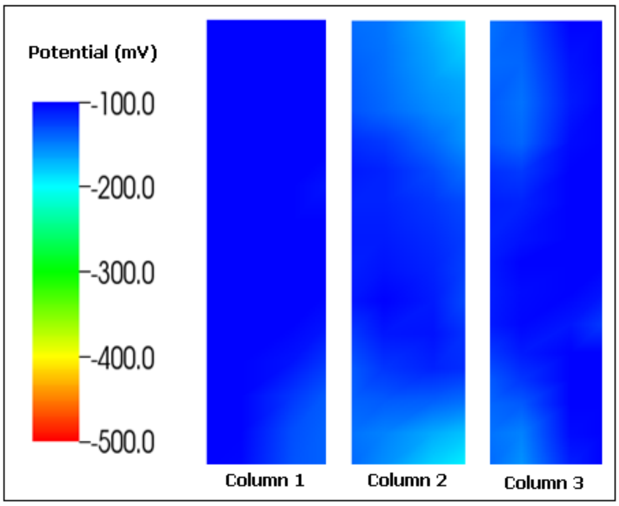

Fig. 8. Potential corrosion distribution for the new building in Kampung Jawa

B. Location 2: Kampung Kramat

The corrosion assessment continued for the buildings in Kampung Kramat (Fig. 3). One of existing civilian buildings was chosen and three columns were selected. Fig. 9 shows the existing civilian building in Kampung Kramat. This building is located around 3.6 km from coastal line and during tsunami 2004 was submerged around 3 m high by seawater.

Fig. 10 show the potential corrosion distribution for each column of existing civilian building in Kampung Kramat. Majorly, all column are already at intermediate corrosion risk level (-200 mV to -350 mV), although, some part at column 1 is still at low corrosion risk. Hence, the corrosion might already occur at all columns.

The new building in Kampung Kramat that becomes the object of the assessment is shown in Fig. 11 and also located around 3.6 km from coastal line.

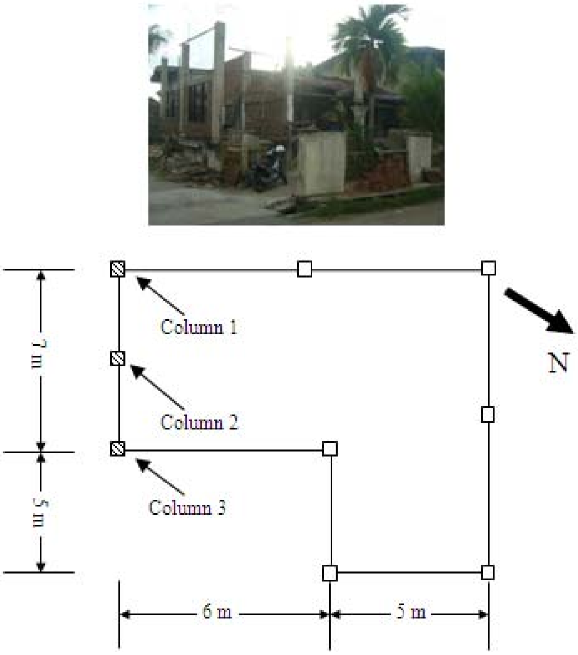

Fig.9. The existing building in Kampung Kramat

The potential corrosion measured on the three columns surface of the new building in Kampung Kramat are shown in Fig. 12. The potential values are ranged between -100 mV to -200 mV and means that the corrosion level is low, only 10% corrosion risk. It can be decided that there was no corrosion occur in these column.

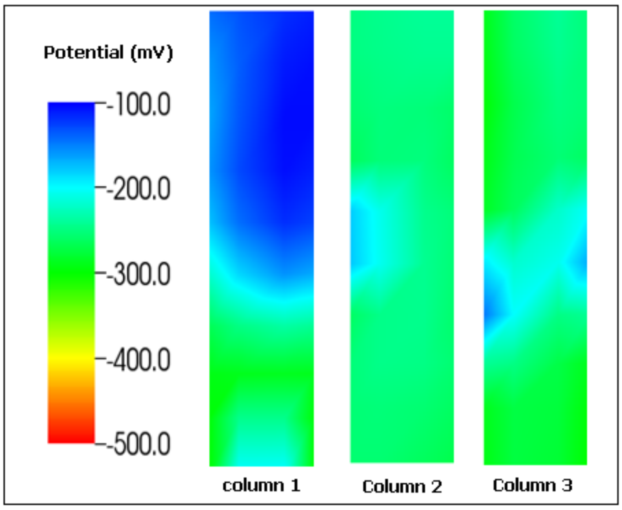

Fig. 10. Potential corrosion distribution for the existing building in Kampung Kramat

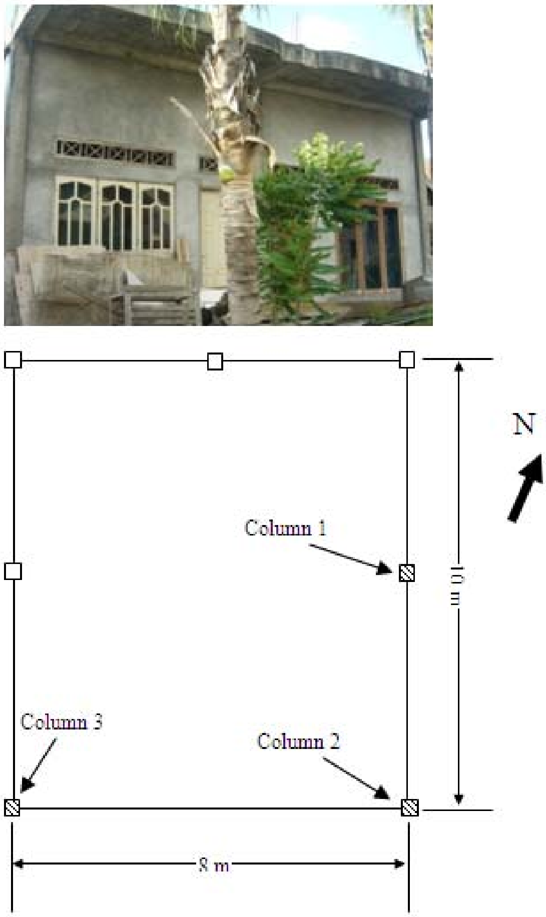

Fig. 11. The new building in Kampung Kramat

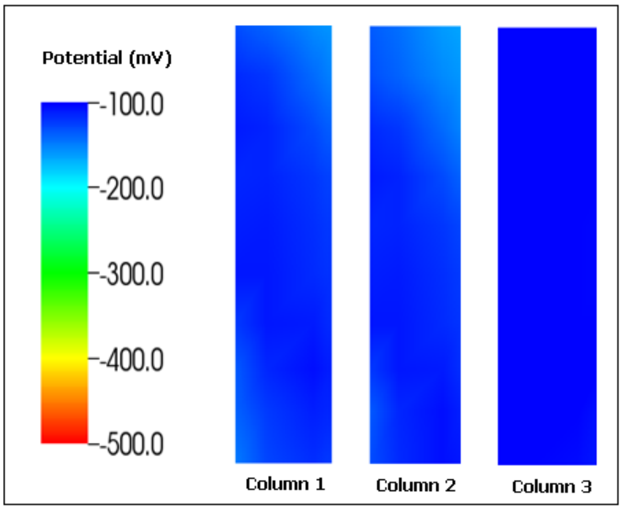

Fig. 12. Potential corrosion distribution for the new building in Kampung Kramat

C. Location 3: Lamjabat

The assessment continued for the existing building in Lamjabat that also struck by tsunami Aceh 2004. Same as before, three columns were selected. Fig. 13 shows the existing building in Lamjabat. The building is located around 1.5 km from the sea and submerged by sweater around 7 m during tsunami 2004.

The potential corrosion distribution for each column of existing building in Lamjabat is shown in Fig. 14. The corrosion risk level for column 2 and 3 was intermediate corrosion risk that indicated by the potential corrosion ranged between -200 to -350 mV. It was almost the same as previous results. The corrosion might already occur in those columns. Thus, it needs to take preventive action before the corrosion worsening and early failure occurs.

However, the corrosion level for column 1 was low risk (10% corrosion risk). It might due to the recasting of the column after tsunami 2004. Hence, there is no corrosion or the corrosion already stop.

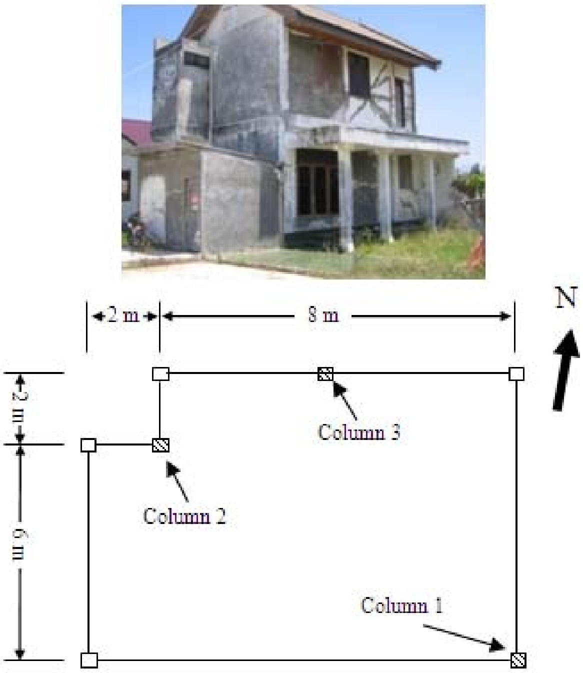

Fig. 13. The existing building in Lamjabat

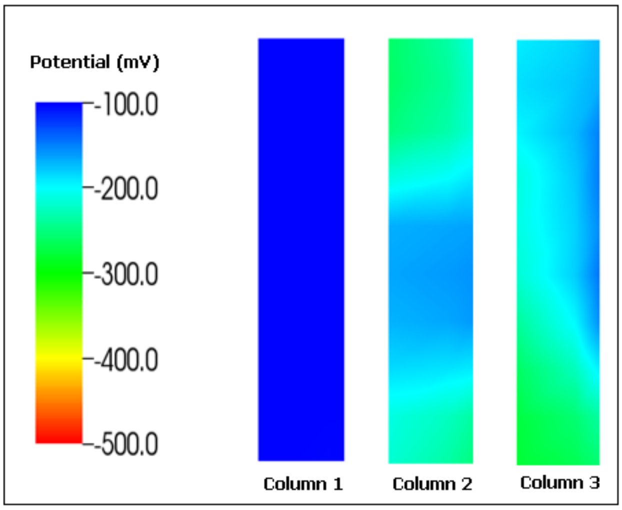

Fig. 14. Potential corrosion distribution for the existing building in Lamjabat

The new building in Lamjabat is shown in Fig. 15 and also located around 1.5 km from the sea. Three columns were selected for the assessment as seen in the figure.

The potential corrosion of the new building in Lamjabat is shown in Fig. 16. The potential values on the concrete surface are higher than -200 mV and means that the corrosion level is low, only 10% corrosion risk. Hence, the building might be categorized as safe from the corrosion attack.

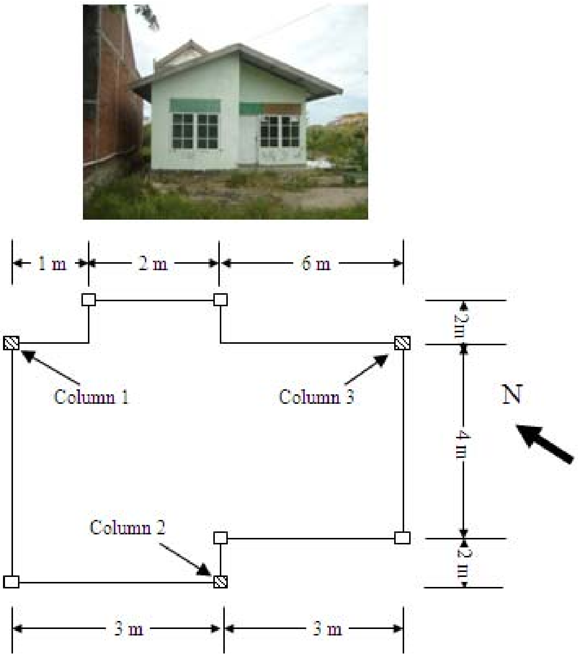

Fig. 15. The new building in Lamjabat

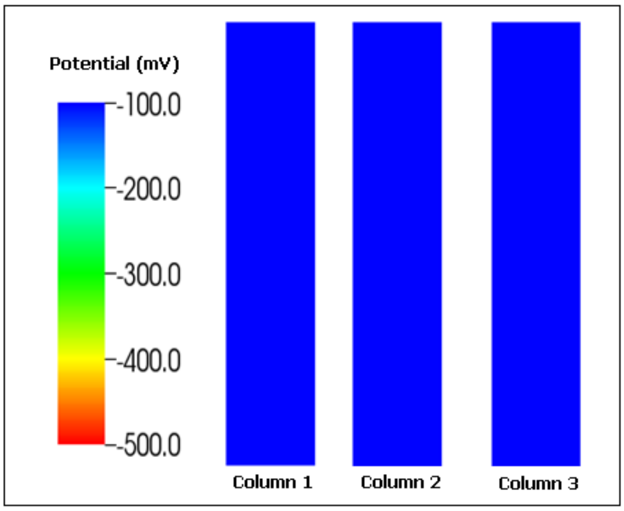

Fig. 16. Potential corrosion distribution for the new building in Lamjabat

V. CONCLUSIONS

The corrosion risk assessment for existing and new reinforced concrete buildings in Banda Aceh's tsunami affected area was already conducted by using haft-cell potential technique. The corrosion level was decided using ASTM C867. Three locations in Banda Aceh were chosen for the assessment. The results of assessment show that the corrosion risk level of reinforcement steel in concrete for existing building was already at intermediate corrosion risk after six years tsunami. It was indicated by the potential value on the surface of the structures ranged around -200 mV to -350 mV (copper/copper sulphate reference electrode). Therefore, the preventive action is needed to be done before the sudden failure of the building due to corrosion happen. However, the results of assessment also show that the corrosion risk level for new buildings in Banda Aceh's tsunami affected area was low (10% corrosion risk). The potential corrosion values for these buildings are higher than -200 mV. Hence, it might be categorized as safe from the corrosion attack.

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