# EFFECTIVE LENGTH OF STEEL ELEMENT FOR TIME-DEPENDENT MACRO-CELL CORROSION

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## 1. Introduction

Time dependent variation of macro-cell corrosion or anodic-cathodic transformation generates active/neutral behavior of macro-cell corrosion activity [1]. This behavior of corrosion process produces maximum corrosion rates periodically depending on the transformation frequency. It is important to identify the anodic-cathodic transformation of steel bar when the measurements are taken as corrosion currents may be misinterpreted by the transformation.

According to Elsener [2], the characteristics of macro-cell corrosion is anodic and cathodic reactions spatially separated along the steel bar. And one of approaches to study the macro-cell corrosion introduced by Miyazato [3] is segmented steel bar.

This experimental study attempted to determine the effective length of steel element for time-dependency macro-cell corrosion research by electrochemical investigations, such as the macro-cell corrosion current densities.

## 2. Experimental program

### 2.1 Materials

Concrete specimens of 100×100×576 mm were cast in this experiment and the mixture proportion of concrete was shown in Table 1.

Table 1 Mixture proportion of concrete

| W/C | Weight per unit volume (kg/m$^3$) | | | | AE(C x weight %) |
|---|---|---|---|---|---|
| | W | C | S | G | |
| 0.55 | 190 | 345 | 770 | 966 | 0.008 |

A plain steel bar having a diameter of 10 mm was used. There were two types of segmented steel bars with different length of element as shown in Table 2 & Figure 1.

In order to accelerate the corrosion process, chloride ions (supplied by pure sodium chloride) were deliberately added during mixing the concrete.

Table 2 Segmented steel bars- Specimens

| | Specimen 1 | Specimen 2 |
|---|---|---|
| Element length (mm) | 15 | 60 |
| Number of element (n) | 28 | 8 |
| Average electrical resistance (Ω) | 0.8 | 0.1 |
| Chloride content (kg/m$^3$) | 1.2(side A) -9.6(side B) | |

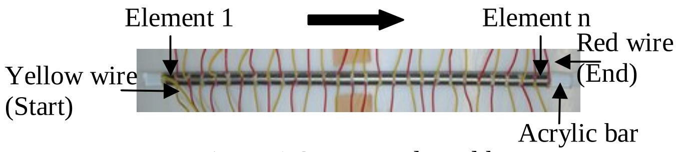


Figure 1 Segmented steel bar

### 2.2 Exposure conditions

After sealed curing (1 week, 20$^o$C), the specimens were covered by epoxy layer, to ensure that the penetration of moisture and oxygen through the bottom surface only. Then, all specimens were exposed to experimental conditions are controlled by a relative humidity of 60% and a temperature of 20$^o$C.

### 2.3 Measurement

Periodic macro-cell corrosion current measurement was carried out twice a week (Monday & Friday) by using a data logger. The current values were then converted to current densities of each steel element along the specimen by using formula suggested by Ominda [1].

## 3. Results and discussion

It was observed that the macro-cell corrosion density was drastically changed with the time exposure. This tendency possibly changes repeatedly until the destructive deterioration occurs. Furthermore since the length of steel element was not the same, even though the exposure conditions and concrete quality were constant, the time-dependent characteristics of macro-cell corrosion were different. These periodic corrosion current densities were shown in Figure 2 (Note: M-Monday, F-Friday & the number showed the week exposure) and the peak anodic current density in Table 3.

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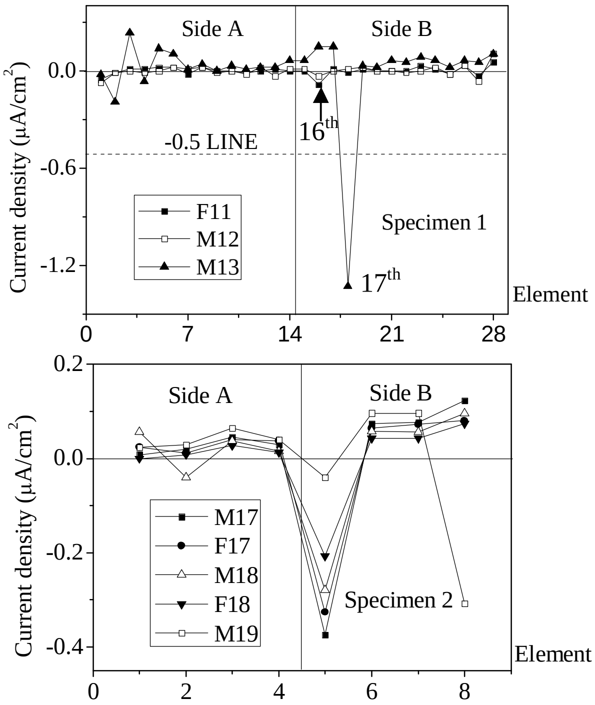

Figure 2 Macro-cell current density

Table 3 Peak anodic values and positions of element ( μA/cm$^2$)

| Week | Specimen 1 | | Specimen 2 | |
|---|---|---|---|---|
| | Element | Density | Element | Density |
| 5 | 17 | -2.96(-3.03) | 5 | -0.74(-0.64) |
| 6 | 17 | -2.22(-1.3) | 5 | -1.1(-0.76) |
| 7 | 16 | -2.21(-3.44) | 5 | -0.65(-0.84) |
| 8 | 16 | -2.3(-2.3) | 5 | -0.72(-0.74) |
| 9 | 16 | -2.19(-0.57) | 5 | -0.65(-0.68) |
| 10 | 16 | -0.63(-1.17) | 5 | -0.86(-0.4) |
| 11 | 16 | -0.55(-0.09) | 5 | -0.43(-0.57) |
| 12 | 16 | -0.03 | 5 | -0.87(-0.72) |
| 13 | 18 | -1.33(-3.54) | 5 | (-0.85) |
| 14 | 18 | -2.21(-2.1) | 5 | -0.83 |
| 15 | 18 | -1.48(-1.31) | - | - |
| 16 | 18 | -1.31(-1.72) | 5 | -0.95 |
| 17 | 22 | (-0.31) | 5 | -0.37(-0.33) |
| 18 | 18 | -0.26 | 5 | -0.28(-0.21) |
| 19 | - | - | 8 | -0.31 |
| 20 | 18 | -0.09 | - | - |
| 21 | 20 | -0.92 | - | - |

(Note: the value in the bracket ( ) is the data measured on Friday)

From Table 3, it can be drawn the limit of density, as authorôs suggestion is -0.5μA/cm$^2$, that helps to identify the status of corrosion process. In other words, the density value, which is larger than -0.5μA/cm$^2$, the peak anodic current density has high possibility of changing into another element or the corrosion status is very small and not stable. For example, the Figure 2 showed that in specimen 1 when the density of element $16^{th}$ (week $11^{th}$) was larger than -0.5 μA/cm$^2$, then the peak value move onto 17th element (week $13^{th}$).

Based on the data analysis, the comparison of macro-cell corrosion behavior was conducted between specimens using different length of steel element as following criteria, such as the peak anodic current density and stable duration of peak value.

From the Table 3, it can be seen that the 15 mm-element specimen showed higher density values in the stable corrosion status in which macro-cell corrosion current density is smaller than -0.5 μA/cm$^2$. The results also coincide with practical thinking because the longer element it is, the chance of both anode and cathode occurring on the same element is expected as higher. As a result, the electrochemical values of steel element will neutralize or decrease in magnitude.

Also, it appears that the stable duration of density of peak anodic value in the case of 15mm element specimen is shorter than that of 60mm. For example, from Table 3, maximum density was found in element $16^{th}$ & $18^{th}$ of specimen 1stabled for 4 weeks but different periods (from $7^{th}$ to $10^{th}$ week, & $13^{th}$ to $16^{th}$ week, respectively), while it was found to be stabled for 5 weeks (from $5^{th}$ to $9^{th}$ week, & $12^{th}$ to $16^{th}$ week) in element $5^{th}$ of specimen 2. That meant the time-changeable current density of specimen of 15mm steel-elements was more often than that of 60mm. The reason, in authorôs opinion, is with the small steel element, for example 15mm, only anode or cathode exists on the element. As a result, in the case of anodic element, the supporting cathodic elements consumed much more oxygen to process the corrosion than longer steel element, in which both anode and cathode may appear on the same element. The potential imbalance becomes larger resulting in accelerating the macro-cell corrosion.

## 4. Conclusions

In the case of high non-uniform chloride content, segmented steel bar composed of the shorter length of steel elements presents the higher in magnitude as well as frequency of macro-cell current density during the experimental period. And on this basis, it can be concluded that 15 mm steel element was highly recommended for study the macro-cell corrosion.

## References

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