Atmospheric corrosion map of structural steel in industrial area: a preliminary investigation

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Abstract. This paper explains the results of the initial stage of investigation of atmospheric corrosion on structural steel in industrial zones. Investigation is carried out on two shape profile of low carbon steel that is widely used for the construction of structures, namely sheet, and elbow. Corrosion rate measurement process and preparation were carried out based on ASTM G-50 and ASTM G-1 standards, with a total exposure time of six months in Medan Deli District, Medan, North Sumatra. The results of this initial stage of the investigation show that the average corrosion rate of low carbon steel for each profile is different, but overall it is still in the “good” category. This investigation will be continued for up to twelve months to obtain more complete data.

1. Introduction
Atmospheric corrosion is a type of corrosion that commonly attacks structural steel. Direct contact with the corrosive atmospheric environment due to loss of protection, such as paint or coating, causes atmospheric corrosion, which can reduce the quality of steel in carrying out its functions in a structure.

In a certain industrial area, where the investment that must be spent is so great as to build the structure of facilities and infrastructure, information regarding atmospheric corrosion becomes very important. The existence of this information can help develop good planning in building industry in the region.

Previous researchers have measured corrosion rates in a particular region and described them in steel atmospheric corrosion maps [1,2,3,4]. However, structural steel corrosion maps for industrial areas in Medan, North Sumatra are not yet available.

The objective of this investigation is to determine the corrosion rate of two shapes of structural carbon steel, namely sheet, and elbows, in industrial areas in the Deli Medan district for six months and map the results of these measurements into structural carbon steel structural corrosion maps. This initial investigation will be very useful and will be the basis for further investigation.

2. Method
2.1. Materials and procedure
The material used in this investigation is structural carbon steel, which is widely used in the construction of a structure in the test area. Two profiles or shapes, namely sheet, and elbows are chosen because they are widely used in construction. For the next designation, each form will be referred to as "Sheet type structural carbon steel" and "Elbow type structural carbon steel." The
dimensions and number of specimens used are based on the provisions set out in the ASTM G-50 standard, as shown in figure 1. The results of the material composition test of the structural carbon steel employed in this investigation are shown in table 1. Composition test of the material used was carried out using optical emission spectroscopy machines.

Table 1. Materials composition

| Specimens | C    | Si   | S    | P    | Mn   | Ni   | Cr   | Mo   | Cu   | Al   |
|-----------|------|------|------|------|------|------|------|------|------|------|
| Sheet     | 0.0454 | 0.007 | 0.0004 | 0.0042 | 0.2434 | 0.0043 | 0.0559 | 0.003 | 0.0056 | 0.0595 |
| Elbow     | 0.2648 | 0.3368 | 0.0017 | 0.0003 | 0.6113 | 0.0282 | 0.1191 | 0.011 | 0.0399 | 0.0078 |

2.2. Exposure
Specimen exposures were carried out in five selected points in the Medan Industrial Area located around Medan Deli district, Medan, North Sumatra. The location points that are the place of exposure can be seen in Figure 2. Five selected locations were given notations A, B, C, D, and E to facilitate the process of carrying out the investigation. Technical considerations and safety of equipment and materials exposed are one of the main considerations in selecting these locations.

Figure 1. Specimen

Figure 2. Map of research location
In this initial stage investigation, exposure is carried out for six months on the Exposure Racks. The racks are made based on ASTM G-50 standard, used as a place to put exposed specimens. Plastic holders are used to prevent contact between the specimens and the steel rack. The shape and geometry of the rack used in this investigation are shown in Figure 3.

![Figure 3. Exposure racks and frames (a. rear view, b. front view, c. top view)](image)

2.3. Corrosion rate calculation
Data collection is carried out every two weeks for six months for all locations. Each specimen is exposed and every two weeks period has been weighed (weight loss). Initially, the specimen was cleaned from corrosion products, by ASTM G-1 standards. Then the weight of the specimen at that time was weighed using a digital scale to ensure data accuracy. The next step is to do the calculation and data analysis after finishing weighing the specimen. The final stage is recapitulating all data that has been obtained to process data.

The formula used to calculate the corrosion rate is shown in equation (1).

\[
\text{Corrosion rate} = \frac{K \cdot W}{A \cdot T \cdot D} \tag{1}
\]

where:
- \(K\) = unit conversion constant, mpy \((3.45 \times 10^6)\)
- \(W\) = weight loss, gram
- \(A\) = coupon area, \(\text{cm}^2\)
- \(T\) = exposure time, jam
- \(D\) = metal density, g/cm\(^3\)

3. Results and discussion
3.1. Corrosion rate
The corrosion rate of sheet type and elbow type structural carbon steel are shown in figure 4 and figure 5 respectively. There is a significant difference in the value of the corrosion rate among the five selected exposure locations. The highest average corrosion rate occurred at location E, and the lowest was at location A. Possible causes were the condition of pollutants in the air not the same between one location and another. This requires further investigation to ascertain these causal factors. At this stage, weather factors and the location distance of the exposure from the coast are ignored.

Fontana [5] stated that the corrosion resistance of ferrous-based materials with corrosion rate 5-20 mpy \((0.1-0.5 \text{ mm/year})\) was included in the "good" category. If the corrosion rate at location E, the
highest compared to other locations, is averaged then the value obtained is 8.47 mpy, still in the range of "good" category.

Figure 4. The corrosion rate of sheet type structural carbon steel

Figure 5. The corrosion rate of elbow type structural carbon steel

3.2. Mapping
The average corrosion rate for six months was then plotted into structural steel atmospheric corrosion maps using Surfer® software. The kriging interpolation method is employed to extract additional data so that it can be made into a map. The mapping results for sheet type and elbow type structural carbon steel are shown in Figure 6 and Figure 7, respectively. Qualitatively, there is an influence of the
distance between locations on the pattern of distribution of the corrosion rate mapped. To improve this condition, it is necessary to add more measurement location points with a relatively uniform distance to produce a better distribution of corrosion rates, so that the corrosion rate map created can produce a map of conditions that are close to the actual situation.

4. **Conclusion**

Data from the initial atmospheric corrosion investigation in the Medan Deli industrial area against two types of structural steel, it was known that the corrosion rate that occurred was still in the "good" category. From the data of the corrosion rate measurement results, an atmospheric corrosion map has been made for two types of structural steel which can then be used as a basis for planning further investigations.

![Figure 6. Map of corrosion rate of sheet type structural carbon steel](image1)

![Figure 7. Map of corrosion rate of elbow type structural carbon steel](image2)
References

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