An Experimental Work on Atmospheric Corrosion Formation over Metal Construction Material

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Abstract: Air pollution causes considerable harmful effects on construction materials and as a result of this considerable changes occur in construction materials. Pollutive materials such as SO₄ (sulphur oxide) and NOₓ (nitrogen oxide), that can be detected in very high level in atmospheric environments, form the atmospheric corrosion on metals located in those construction materials. Also in this study, the developments and effects of atmospheric corrosion on metal construction materials are aimed. In the experimental study, the corrosion effects of SO₂ (sulphur oxide) and NOₓ (nitrogen oxide) on steel sheets, being one of metal construction materials, are examined. At the end of the study, which pollutive materials cause the corrosion more and which type of steel sheets are more effected in this corrosion formation, are discovered.

Key words: Corrosion • Atmospheric Pollutives • Sulphur Oxide • Nitrogen Oxide • Metals

INTRODUCTION

The most important parameter in metals usage as construction materials, is that they are solid and long-lasting. However, metals howsoever solid and long-lasting may they be, undergo deformations, i.e. corrosion, as a result of various factors. Corrosion is the deformation of metals and alloys by being nibbled due to the electrochemical properties and environmental effects that they are present in [1].

Materials that corrode due to corrosion and that distort, become dysfunctional. Corroded metal materials, because they can not perform their function in their existing environment, cause awful negative situations about safety except their financial damages [2]. Corrosion has great risks in steel bridges and railways in terms of transportation and shipping safety and in building that are concrete reinforced and steel sheet-piling framework system, it has great risks in terms of earthquake safety. Moreover, corrosion is also a sincere danger and constraining source for old buildings, monuments and sculptures that are constructed from metal and that have historical and cultural property.

Corrosion occurs as a result of the fact that metal materials are affected by corrosive (corrosion instrumental) elements. Water, soil, concrete and various chemical elements all have corrosive effects [2]. Especially the atmospheric environments in which metals are present, is considerably important in corrosion formation. For the corrosion formation, that consists a oxidation stage, it is not necessary for the environment to contain atmospheric pollutives. However, provided that primary pollutives SO₂ (sulphur oxide) and NOₓ (nitrogen oxide), that can reach to high ratios in urban atmospheric environments, are present, these aforesaid pollutive elements accelerate the corrosion stage like a catalysis on metals as well as in all construction materials.

Particles found in the atmospherically polluted environments also has corrosive effects on metals. Metals that are resistant to particles in dry weather, do not have the same resistance power in humid conditions. Water vapor condensates around particles and corrosion process accelerates by means of the dissolution of SO₂ (sulphur oxide) and NOₓ (nitrogen oxide) gases among them. Therefore, corrosion is obverses more in industrial environments in which atmospheric pollution is in high ratios [3]. For example, while annual mass loss of iron in unindustrialized regions is between 16-1.39 grams, this ration can reach to 8.91-14.81 grams in industrialized regions [4]. Therefore, atmospheric environment that metals are present, is extremely important in terms of corrosion.

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Table 1: Corrosion losses in metal samples that are found in different atmospheric conditions

<table>
<thead>
<tr>
<th>Location</th>
<th>Atmospheric Condition</th>
<th>Annual/Mass Loss (gram)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sudan (Khartoum)</td>
<td>Dry (land)</td>
<td>0.16</td>
</tr>
<tr>
<td>Nigeria (Aki)</td>
<td>Tropical (land)</td>
<td>1.36</td>
</tr>
<tr>
<td>Singapore</td>
<td>Tropical (sea)</td>
<td>1.36</td>
</tr>
<tr>
<td>Iran (Babak)</td>
<td>Dry (land)</td>
<td>1.39</td>
</tr>
<tr>
<td>Germany (Berlin)</td>
<td>Semi-industrialized</td>
<td>4.17</td>
</tr>
<tr>
<td>England (Woolwich)</td>
<td>Industry</td>
<td>8.91</td>
</tr>
<tr>
<td>USA (Pittsburgh)</td>
<td>Industry</td>
<td>9.65</td>
</tr>
<tr>
<td>England (Sunderland)</td>
<td>Industry</td>
<td>14.81</td>
</tr>
</tbody>
</table>

The most important atmospheric factors that cause corrosion in metals by conjoining with preliminary pollutive materials such as $SO_2$ (sulphur oxide) and $NO_x$ (nitrogen oxide), are temperature and wetness period. High temperature and moisture increase the metal corrosion dramatically, especially if relative humidity rate outranges 75%, the corrosion formation accelerates [5]. Generally, reaction speed doubles with each $10^\circ C$ increase in temperature [6]. Moreover, factors such as dry period, rain, dew, fog, air circulation, pollution concentration, pollution concentration, sea salt aerosols and material surface, are extremely effective in the formation and development of corrosion [3].

**Experimental Study:** In this study, the effects of $SO_2$ (sulphur oxides) and $NO_x$ (nitrogen oxides) on steel sheets that are used densely in construction sector as construction materials on atmospheric corrosion are examined. In reality, we need much more time so as to occur various atmospheric pollutive impacts on metal construction materials especially as a result of a study conducted in an environment in which atmospheric pollution is present. Because in this experimental study, conducted in atmospheric environment, any intervention in the accelerator of these pollutives impacts, is not in question. Moreover, the measurement of pollutive elements that are present in atmospheric environment is not practically possible. However, in the studies conducted in lab environment, there is an opportunity both to shorten experiment period by accelerating it and to determine and measure the pollutive element amounts used in the experiment. Therefore, also in this study, in order to minimize the experiment period, the usage of sulphur oxide and nitrogen oxide ratios that may be present in atmospheric environments in high ratios, is found appropriate. For this reason, in sulphur oxide and nitrogen oxide detection, Short Term Air Quality Limit Values that are determined for general atmospheric environment according to international standards, are accepted. Short Term Limit Values (STLV) are the arithmetical average of all measurement results that should be exceed In one month. The maximum $SO_2$ (sulphur dioxide) amount is 400 $\mu g/m^3$, $NO_x$ (nitrogen dioxide) amount 300 $\mu g/m^3$ and $NO$ (nitrogen monoxide) amount is 600 $\mu g/m^3$ that STLV should contain.

In the experiment, in order that pollutive elements impacts on steel sheets occur in equal ratios, a single STLV value is taken both for $SO_2$ (sulphur oxide) and $NO_x$ (nitrogen oxide) and according to this, STLV value is accepted 400 $\mu g/m^3$ for both. In the experiment, 695-98 of purity $H_2SO_4$ (sulphuric acid) is used for $SO_2$ (sulphur oxide)-containing humid environment formation and 665 of purity $HNO_3$ (nitric acid) is used for $NO_x$ (nitrogen oxide)-containing humid environment formation. In the experiment, by using STLV value as the basis, $H_2SO_4$ (sulphuric acid) and $HNO_3$ (nitric acid) ratios corresponding to 1 liter pure water are calculated and (400 $\mu g/m^3$) solutions are prepared. For this mean, 2 glass desiccator of 30 cm diameter are used. In the below part of the first desiccator, sulphuric acid solutions (400 $\mu g/m^3$) in the below part of the other desiccator nitric acid solution (400 $\mu g/m^3$) are put. A total of 8 steel sheets are placed in both of these desiccators, compromising 2 steel sheets of 1 mm thickness and 2 steel sheets of 5 mm thickness on porcelain disc in each desiccator.

Therefore, it is accepted that acidic solution in both of two desiccators affects on steel sheet samples by evaporation in close environments and due to this effect the corrosion will occur and will develop with time. Experimental study lasted 4 months. During this period, steel sheet samples in desiccators were weighted on 0.001 gr. precised digital scale once in every 15 days and whether there is a weight increase due to corrosion or not, was tried to be detected. Data obtained from the measurement are recorded and at the end of the experiment graphics are prepared by using these data.

Table 2: Air quality limit values [7], [8]

<table>
<thead>
<tr>
<th>Pollutant Substance</th>
<th>Short-term Limit Value (Monthly)</th>
<th>Long-term Limit Value (Annual)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$SO_2$ (micrograms/m3)</td>
<td>400</td>
<td>150</td>
</tr>
<tr>
<td>$NO_x$ (micrograms/m3)</td>
<td>300</td>
<td>100</td>
</tr>
<tr>
<td>$NO$ (micrograms/m3)</td>
<td>600</td>
<td>200</td>
</tr>
</tbody>
</table>
Fig. 1: Photograph showing experiment apparatus

Fig. 2: Schematic cut-view belonging to experiment desiccators

Fig. 3: The impact of sulphuric acid solution on weight increase over thin steel sheets due to corrosion

Fig. 4: The impact of nitric acid solution on weight increase over thin steel sheets due to corrosion

Fig. 5: The impact of sulphuric acid solution on weight increase over thick steel sheets due to corrosion

Fig. 6: The impact of nitric acid solution on weight increase over thick steel sheets due to corrosion

Findings: According to prepared graphics and the informations gathered from graphics;

When the impact of sulphuric acid solution on thin steel sheet is examined, it is detected that it causes corrosion in a short time and in a fast way both on A and B samples (% 0.13-% 0.19).

When the impact of nitric acid solution on thin steel sheet is examined, it is detected that during the first two months, there are not any weight increase on samples, however, after the first two-month period, the nitric acid solution causes weight increase due to corrosion both on A and B sample (% 0.08-% 0.12).

Weight increase values of nitric acid solution over thin steel sheet samples (% 0.08-% 0.12), remain far below that the weight increase values of sulphuric acid solution over thin steel sheet samples (% 0.13-% 0.19).
Corrosion formation, corrosion speed and weight increase due to corrosion are in direct relationship with metal cross-sectional thicknesses. According to this, weight increase in metals (% 0.19) that have thinner cross-sections (steel sheets) is recognized in higher rated compared to weight increase (% 0.05) in metals that have thicker cross-sections. Therefore, this situation makes construction material cross-section choices that will be used in environments in which SO₂ (sulphur oxide) and NOₓ (nitrogen oxide) are in high ratios, much more important.

In the beginning of corrosion formation, weight increase occurs in all metals. It is possible to say that as occurring in most corrosion reactions, atmospheric corrosion that develops in the form of weight increases, may develop as weight decrease at the latter stages due to time.

Therefore, pollutive elements such as SO₂ (sulphur oxide) and NOₓ (nitrogen oxide) that can may be found in high rates in urban and industrial environments, cause atmospheric corrosion on metals. In corrosion, metal material cross-sectional thickness plays a more important role than pollutive element type. So that, metal material cross-sectional thickness causes that corrosion formations occur in slow or fast way and that weight increase is kept in low ratios or reaches to high ratios related to this.

REFERENCES