Development of corrosion risk map for Peninsular Malaysia using climatic and air pollution data

Fathoni U, Zakaria C M and Rohayu C O
Centre for Forensic Engineering, College of Engineering, Universiti Tenaga Nasional, Selangor Malaysia
Email: fathoni@uniten.edu.my

Abstract. Malaysia has catapulted to an era of major transition. This rapid transition has also cause impact to the environment. The human activities contribute to pollutions. Buildings and it component's performances are affected directly or indirectly by air pollutions and climate factors. It has triggering and accelerating degradation processes. When deterioration start, service life of the buildings and its components will decrease. This paper presents initial development of corrosion risk map for Peninsular Malaysia using Geographical Information System (GIS). The air pollution and climate data obtained from Malaysia Meteorology Department (MMD). The air pollution data was the salt ion deposition of nitrate, chloride and sulphate in a form of wet fall out (WFO). The corrosion risk map generated using geographical information system (GIS) using inverse distance weighing (IDW) and weighted overlay method. It found that the corrosion risk map can be generated with further site verification and it can be used by engineers for further prediction of service life of building components in achieving sustainable construction design.

1. Introduction
The surrounding environment condition has influenced the deterioration process of building materials. Corrosion is one of the common deterioration resulted by this complex interaction of metallic materials and the nature. The environmental load is described as the deterioration agent from and its local. Those agents will accelerate the deterioration process. Degradation can be subjected by behavior or dreadful conditions but the terminology of deterioration is more on worsening or weakening of particular object. In this study the work deterioration will be used as an expression of a process to decline the performance or the aging process that lower the quality and performance of particular building components.

Deposition of pollutants on the building surface generally depends on atmospheric concentrations of the pollutants and the local climate. Once the pollutants are on the surface, interactions will vary depending on the amount of exposure, the reactivity and the amount of moisture present. The transformation reactions may take place both in gas phase and in aerosol phase. For most of the materials, SO₂ is the main corrosive agent in the air [1]. Research has discovered that when NO₂ is presented with SO₂, increased corrosion rate occur. The NO₂ oxidizes the SO₂ to sulphate thereby promoting further SO₂ absorption. As a result, SO₂ is considered as a major contributor to deterioration of metallic materials [1, 2].

Moisture conditions are strongly correlated with relative humidity and temperature in absorption process deep in to the exposed building components. The moisture or wetness of surface did not
depend only on relative humidity but also on other parameters such as salt deposition, sunlight radiation, wind, and absorption of ambient heat [3]. With the relative humidity greater than 50% for all regions in Malaysia and average temperature of 27°C, average yearly time of wetness (TOW) in Peninsular Malaysia is equal to 0.783 fractional hours. It is classified by ISO 9223 the level of corrosion as class 5 where the layer on the surface of the building components can reside slightly longer and deterioration process will become more effective [4].

The most understandable influence of temperature is on the rate of the chemical reaction resulting in deterioration. If their surface temperature falls below the dew point, the surface becomes moist and in the presence of corrosive pollutants whose concentrations are increasing under the stable influence of the temperature inversion, conducive to certain types of deterioration to materials.

A research study on concrete deterioration in the Malaysian environmental conditions has been embarked by Malaysia Public Work Department (PWD) [5]. Ten locations in the Peninsular were chosen consisting major towns near the coastal area. A building was selected at each site for the study to be carried out with a ranging between 18 years and 50 years of age. The Corrosive Risk Rating (CRR) was a measurement of concrete corrosion risk represented by a range of 1 to 5 numerical scales. The CRR value was dependent towards the sulphate content, chloride content at a depth of 20 mm and the carbonation depth on a concrete building. From the study Climatic Corrosive Index (CCI) was formulated based on the monthly mean temperature and the monthly mean Relative Humidity (RH). A formula was proposed corresponds to the Scheffers's index format.

2. Methodology

In attempting to achieve the objective of this study, historical data have used. It consisted of air pollution data and climatic data. The data was recorded from 17 main measurement stations located in Peninsular Malaysia. The data from each measurement stations were recorded by Malaysia Meteorology Department (MMD). For the purpose of this study, data that extracted from the MMD data bank were the monthly weather report which record the received rainfall, temperature, humidity and air pollution data for 10 years from 1996 to 2005. The pollution data are in the form of wet fall out (WFO). Deposition of salt ion of chloride (Cl\(^{-}\)), sulphate (SO\(_{4}\)\(^{2-}\)) and nitrate (NO\(_{3}\)\(^{-}\)) were used. GIS maps have generated to determine data from the area which have no measurement stations. These maps are generated using inverse distance weighing (IDW) method. IDW method can efficiently apply and it has reliable computational process [6].

The process of development Corrosion Risk Map for Peninsular Malaysia was using ArcGIS 9.2. It was started with importing the data, generating the interpolation map using IDW method, reclassifying the IDW map into 5 levels scale and merge the generated map using weighted overlay method. Basically this study was producing initial map of corrosion risk map. The process of merging the generated IDW maps to produce the corrosion risk map was based on an assumption that the corrosion risk (CR) at a particular location is a function of environmental loads factors. It can be expressed in equation (1) where ion Chloride (C), ion Nitrate (N), ion Sulphate (S), received rainfall (Rain) and the time of wetness (TOW) are contributing to the level of corrosion risk.

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CR = f(N, C, S, Rain, TOW)
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3. Analysis and Discussion

The following Figures from Figure 1 to Figure 5 show the Chloride (C), Nitrate (N), Sulphate (S), received rainfall (Rain) and time of wetness (TOW) which has generated from respective average IDW map. The map also have classified to 5 different level from 1 to 5 where the class 1 represent lowest value and class 5 represent highest value of data.

It is very obvious for the area where it is more developed and have more industrial activities, these area is emitting high concentration of pollutant to the atmosphere. Those three areas are Klang Valley, southern part of Johor and Penang. The time of wetness for Peninsular Malaysia based on ISO 9223 is classified as class 5 but for the purpose of this study, it reclassified locally to a range of scale from 1 to
5. The purpose of reclassify the time of wetness IDW map is to distinguish locally which area having highest and lowest time of wetness as shown Figure 5.

![Figure 1. Classified of IDW Chloride Map](image1)

![Figure 2. Classified of IDW Nitrate Map](image2)

![Figure 3. Classified of IDW Sulphate Map](image3)

![Figure 4. Classified of IDW Rainfall Map](image4)

![Figure 5. Local Classified IDW time of wetness map for Peninsular Malaysia](image5)

Figure 6 shows the corrosion risk map for Peninsular Malaysia. By merging the five layers of environmental loads (i.e. N, C, S, Rain and TOW), a corrosion risk map generated. There are 5 different classes of corrosion risk that was represented in a scale from 1 to 5. Class 1 indicates the lowest corrosion risk and class 5 indicates the highest corrosion risk. From the generated corrosion risk map, Petaling Jaya has the highest rate of corrosion risk compared to other places. This is obvious, Petaling Jaya has the highest level of Nitrate and Sulphate. After Petaling Jaya, Kuantan and Kuala Terengganu are the area with level of corrosion risk 4. Although the concentration of Nitrate and Sulphate are low, the concentration of Chloride is very high compared to other areas. Kluang, Sitiawan and Alor Setar are the areas which have the lowest risk of corrosion. These areas are not much polluted by Chloride, Nitrate and Sulphate. The time of wetness at these areas are also low, therefore they fall under class 1, which is low corrosion risk. From this study, corrosion risk for Melaka is found slightly contradict with the ground condition. It was found from the previous study on building assessment, many building and infrastructure with metallic materials severely subjected to corrosion. Verification work is required to validate and improve the generated corrosion risk map [7].
4. Conclusion

Corrosion map have developed from this study. The result is based on the historical data from MMD for 10 years measured climatic and air pollution data from 17 measurement stations in Peninsular Malaysia. It shows that the generated corrosion map can be used for future study on corrosion cost to assist designer, engineer and maintenance officer also owner of building asset and infrastructure for estimating the maintenance cost. It also can be used in deciding alternative method of coating for corrosion prevention and using alternative technology and materials in construction. Site measurements are required to verify the result. So thus, its result can be reliable.

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