STEEL CORROSION MAP OF VIETNAM

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ABSTRACT

In the framework of International cooperation program Australia-Asia, the atmospheric corrosion of metals in five nations located in tropical zone: Australia, Vietnam, Thailand, Philippines and Indonesia was carried out. In this program, mild steel, zinc, copper were tested on the set of sites, representative for different climatic conditions: severe marine, marine, industrial, urban and rural, simultaneously with the collection of climatic parameters and pollutants. In addition to weight loss method, after testing, surface morphology of the samples were studied by FTIR, FESEM and SEM. Based on the data obtained in the Program and referred the data bank collected in the Vietnam National Projects, the modeling model was created and corrosion map of steel for Vietnam was constructed. The variation of data from map, to that derived with those from National Project is very low, in most cases, less than 2-3%.

Keywords: Corrosion, natural testing, site, corrosion modeling, corrosion map.

1. INTRODUCTION

In humid tropical countries as Vietnam, the metal corrosion, particularly atmospheric corrosion causes a big loss for national economy. The Natural Institute of Vietnam was found on 1960; while in 1963 the first atmospheric corrosion study was undertaken in the North Vietnam. There followed several National and Ministerial Projects also focused on the metal corrosion investigation. The first attempt to consider the corrosion map construction for Vietnam was carried out in atmospheric corrosion group, at Institute for Tropical Technology. P. T. San, N. V. Hue and L. T. H. Lien were published first paper in this direction in APCCC-9 in Kaoshung, Taiwan, 1995. In this paper, based on the testing results obtained in the National Project numbered 48.08.01 and others, the mathematic term and corrosion modeling were developed and used to construct the corrosion map for North Vietnam. The map constructed corresponded adequately with the corrosion rates of mild steel in Vietnam atmosphere.

In the International Program Australia – Asia, atmospheric corrosion of mild steel, zinc, copper in the 20 sites of 5 Nationals: Australia, Vietnam, Thailand, Philippines and Indonesia was performed. The aim of Project was to develop the understanding on the fundamental mechanism of corrosion in tropics, to study the level and characteristics of common metals corrosion in the zone; to study the surface morphology of samples after testing in order to determine the relationship between chemistry of corrosion products and environmental factors, based on results obtained, to create the model of corrosion process for assessment of corrosion kinetics and construction of corrosion map.

2. EXPERIMENTAL PROCEDURE

2.1. Testing samples and testing procedure

To select the data for corrosion mapping, the mild steel (bellow – steel), zinc and copper, sized 10 × 16 × 1 (mm) were prepared at CSIRO. Testing period was 1, 3, 6, 9, 12, 24 and 36 months (3 samples/site/time/metal). Samples after testing were treated and analyzed at CSIRO. Data selected were subjected to computerization and modeling.

In addition to mass loss, the samples and corrosion products were investigated by Fourier Transform Infrared Spectroscopy – FTIR, Field Emission Scanning Electron Microscopy – FESEM and Scanning Electron Microscopy – SEM to study the structure, quantitative and qualitative analysis of corrosion products.

Atmosphere/surface temperature, humidity, rail fall, solar radiation, sunsight total time were recorded continuously by Datalogger and transformed to computer. Salinity and nitrogen compounds in atmosphere were detected by wet candle, sulfur by wet clothe, by the angle of 45^o, forward to the Sea. Sites in Vietnam were Hanoi (Phu Thuy), Do Son, Hue, Nha Trang and Ho Chi Minh city.

2.2. Basic disciplines for corrosion mapping

Corrosion maps are traditionally constructed using two basic methods. Both methods are based on the field observation from a set of sites distributed within the study area and located in such a way that they are representative of the variability of the corrosion rates within the study area.

If enough data points are available, the most straightforward approach is to conduct a contour consisting of lines of equal corrosion rate. In this approach, arranging the sites in some sort of grid pattern is desirable. This approach was used in producing corrosion maps for Australia and other countries (Span, Japan, Czech…). Unfortunately this approach is very costly both in terms of financial and time factor. In case there are not enough data points to adequately cover the spatial extent of study area, an alternative approach is to conduct a statistical or parametric model. Some examples of this approach include:

1. Corrosion as a hyperbolic function of distance from the coast (G. King)
2. Corrosion as a function of distance from the coast and level of sulfur dioxide (G. Trinidad)
3. Corrosion as a function of distance from the coast, climatic factors, level of salinity and geometrical parameters (P T San)
4. Corrosion as a function of distance from the coast, relative humidity and temperature (and salinity) (I. Cole [11]).

Selecting the set of variables to be considered is difficult and could very from one case to another.

To overcome these difficulties, a new approach to the construction of corrosion maps should be investigated.

2.2.1. Method based on the humidity temperature complex

Study on atmospheric corrosion showed that humidity, temperature, salinity, sulfur content have desirable effect on the metal corrosion, particularly steel. In the developing countries, sulfur dioxide content in the atmosphere is high, for example, at Prague (Czech) about 67 mg/m^3, whilst humidity and salinity is low, so the sulfur is main factor affected on the metal corrosion. The countries surrounding by sea (as Cuba) the salinity is very high (at Habana: 200 mg/m^2/day) and distributed far from coastline, so the salinity in the atmosphere is desirable factor for metal corrosion.

According to [2] and data obtained in the AusSEA Project, the salinity in Vietnam atmosphere is adequate low, about 10 mg/m^2/day in the North and 30 mg/m^2/day in the South, at the distance 1 - 2 km from coastline, the salinity is negligible (at Australia' coastline, about 110 $mgCl/m^2$.day). The highest sulfur dioxide at Hanoi is 7 mg/m^3 and Nha Trang: 0.3 mg/m^3. Based on these parameters, we suggested that the humidity and temperature complex and maybe salinity is main factors affected on the metal corrosion in Vietnam.

2.2.2. Method based on Holistic Model

To reduce the dependence on expensive and some times impractical field experiment, corrosion rates will be estimated by simulating the corrosion process itself.

In the first attempt, I. Cole and Colleagues [11-16] was suggested that the corrosion rate in a particular site is computed using the following steps:

1. The coastline is represented as a series of points (x, y).
2. Each point is associated with a particular coast type in order to reflect surf and ocean salt production [12].
3. The study area is partitioned into wind regions such that the wind pattern within a region is uniform.
4. Each region is associated with one or more wind rosettes.
5. A particular site is associated to the nearest wind rosette associated to wind region where the site belongs.
6. A particular site is associated to a set of coastline points by performing a radial each using a pre-determined threshold distance. For example, if the threshold distance is set to 1000 km, a circle with a 1000 km radius is drawn around the site and all coastline points within this circle are associated with the site.
7. Each of the coastline points associated with a site could possibly contribute to the amount of salt that can be transported from the coast to the site [11].
8. The amount of salt transported to the site is estimated using distribution pattern of both win direction and speed as derived from the selected wind rosette. The only other factor that is considered aside from the wind is distance. The form of topography is ignored (flat land assumption). The effect of topography and climate in salt transport will be considered in the next stage.

After estimating the amount of salt that is possibly transported to the site, the available moisture is estimated using relative humidity, temperature, wind speed and rainfall at the site [14, 15]. Note that relative humidity, temperature and rainfall are related to the amount of moisture while wind speed and temperature are related to the rate of drying [15]. Other factors such as condensation and cloud cover will be considered in next stage.

Based on these principles, the data were processed and steel corrosion map for Australia and Vietnam was constructed and showed on Fig. 1 and 3. Australia map is computed for steel in each of the 10,000 selected Australia towns. The resulting map compared with known data points (75 sites). The corrosion map for Vietnam was constructed from the same first principle approach and compared with the data selected from 8 sites.

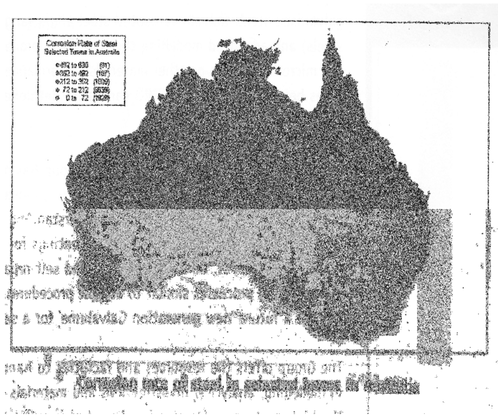

Figure 1. Corrosion map of Australia by statistic model

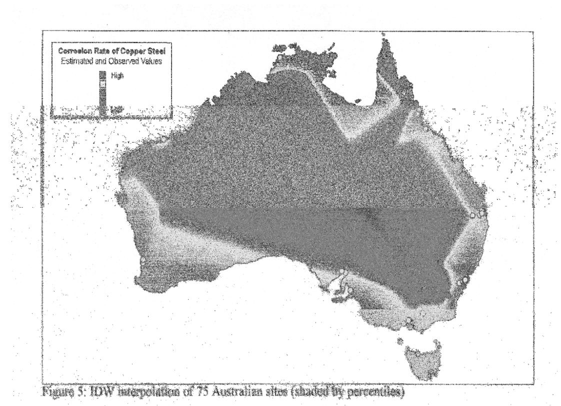

Figure 3. Corrosion map of Australia by IDW model

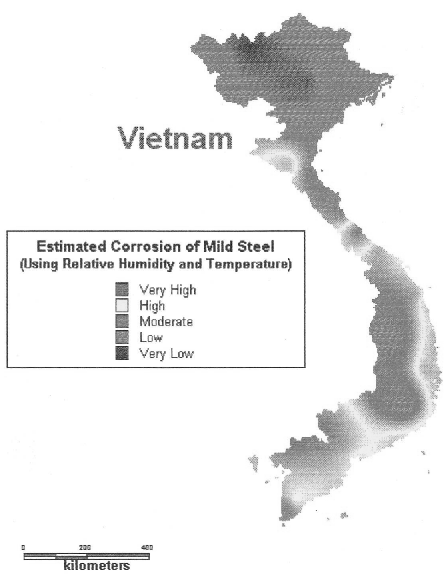

Figure 2. Corrosion map of Vietnam by Holistic Model

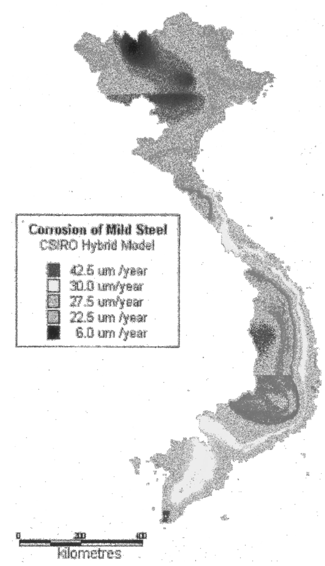

Figure 4. Corrosion map of Viet nam by IDW Model

Unfortunately the computing method creates anomalies in some areas due to scarcity of data such as in the Mekong Delta River, the corrosion belongs to very high category similar to that found along the shore whereas it would be expected to be much lower.

To improve the accuracy of map making, we were developed a new principle for corrosion mapping based on so called "Dimensional Spatial Interpolation for Corrosion"

It was also observed that a simple spatial interpolation technique could possibly approximate the result of the holistic model if there are enough available data points. The method is essentially "Inverse Distance Weighting – IDW" with boundary clipping.

1. A set of 5 x 5 km grid is constructed (>80,000 grids are needed to cover Australia).
2. The value of each grad, Gi is computed as

$$G_i = \frac{\sum_{i=1}^{n} \frac{P_j}{(d_{i,j})^{\beta}}}{\sum_{j=1}^{n} \frac{P_j}{(d_{i,j})^{\beta}}}$$

   where P_j is the value at data point j, $d_{i,j}$ is the spherical distance between grid i and data point j, and β is the weighting power parameter.
3. A pruning strategy could also be included. For example, all data points that are father than some prescribed distance will be ignored.

The corrosion map derived using a pruning distance of 2,000 km and setting $\beta = 2$ for Australia is showed in Fig. 2 and for Vietnam – in Fig. 4.

2.2.3. A comparison between data from the map and from natural testing

For the evaluation of accuracy of corrosion mapping, some corrosion rates in Vietnam conditions are withdrawn from the map and from data indicated in the different National Projects as showed in Table 1.

Table 1. The comparison of data from map and other Projects

No	Site	Type of site	Corrosion rate of steel after 1 year testing (μm/year)		
			From Map	48.08.01[11]	KC-02[12]
1	Vinh Phu	Rural	22	21.8	-
2	Hanoi	Urban/Industry	26	25.3	-
3	Hai Phong	Urban/Marine	30	24.4	30
4	Vinh	Rural/marine	35	33.2	34
5	Da Lat	Rural	22	18.3	-
6	Ho Chi Minh city	Urban/Industry	40	40	42
7	Kien Giang	Marine	40	39.7	-
8	Quang Ning	Marine	29	-	24
9	Da Nang	Marine	37	-	34
10	Nha Trang	Marine	40	-	24

It is able to see that the data withdrawn from the map and selected from field tests are very similar, error of them within the range less than 2-3%. In many cases the corrosion rates cited from the map are coincided very well with the ones of field tests, as at Vinh Phu, Hanoi, Ho Chi Minh city, Kien giang… In the case of Nhatrang, high error is maybe concerning with the local of new and old sites.

3. CONCLUSION REMARKS

The first time, a corrosion map of steel in atmospheric conditions of Vietnam was constructed. The corrosion rates from the map are coincided well with the tested results in the field. Of course, its accuracy needs being improved, however, it is satisfied and is useful contribution to the development of Vietnam economy and technology.

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TÓM TẮT

Trong chương trình hợp tác quốc tế Australia –Asia, ăn mòn kim loại trên 5 Quốc gia thuôc vùng nhiệt đới: Australia, Việt Nam, Thái Lan, Philipin, Indonisia đã được thực hiện. Các kim loại kẽm, thép hợp kim thấp, đồng đã được thử nghiệm trên hàng loạt trạm, đại diện cho các điều kiện khí hậu: biển khắc nghiệt, biển, công nghiệp, thành thị và nông thôn, song song với việc thu thập các số liệu về khí hậu, độ ô nhiễm. Ngoài phương pháp đánh giá trọng lượng, mẫu sau khi thử nghiệm đã được nghiên cứu bề mặt bằng phổ phát xạ hồng ngoai (FTIR), kính hiển vi điện tử quét (SEM&FESEM). Trên cơ sở các số liệu thu thập được của Dự án, đối chiếu và tham khảo các số liệu thu được trong quá trình thử nghiệm ăn mòn kim loại ở Việt nam, dựa theo mô hình holistic và mô hình interpolation, cùng với bản đồ ăn mòn của 4 nước, bản đồ ăn mòn kim loại (cho thép hợp kim thấp) ở Việt Nam đã được xây dựng. Sai số của các số liệu suy ra từ bản đồ, so với các số liệu thu được từ các Chương trình Nhà nước rất thấp, đa số trường hợp nhỏ hơn 2-3%.

Từ khóa: ăn mòn, thử nghiệm tự nhiên, trạm, mô hình hóa quá trình ăn mòn, bản đồ ăn mòn.

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