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# Practical Experiences with Corrosion Protection of Water Intake Gates in Mekong River

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Corrosion behaviour of water intake gate steel structures with different protective measures was investigated. Five material alternatives were taken for investigation, including: imported and recycled stainless steel, carbon steel with hot zinc spraying, painting and composite coatings. Results of corrosion rate for carbon steel, SUS 304, hot zinc spray coats in three water systems of Mekong river basin (saline, blackish and fresh) were also presented. Corrosion rate of carbon steel decreased with decreasing salinity in the investigated water environments. Meanwhile, these values for zinc coated steel, behaved by another way. Environmental data for these systems were filed and discussed in relation with corrosion characteristics.
Method of Life Cycle Assessment (LCA) was applied in materials selection for water intake gate construction. From point of Life Cycle Cost (LCA) the following ranking was obtained:

*Zinc sprayed steel < Recycled stainless steel < Composite coated steel < Painting steel < SUS 304*

From investigated results, hot zinc spray coating has been applied as protective measure for steel structures of water intake systems in Mekong river basin.

***Keywords** : steel, zinc spray, LCC/LCA method.*

## 1. Introduction

The Mekong river basin with total area of 93,781 $km^2$, occupying 12% of Vietnam territory, is one of the biggest plain in the world. Most of the Mekong delta is a low land with under +5.0 meters altitude, therefore, 40% of the delta territory is permanently influenced by severe salination regime of surrounding sea water. In other hand, due to its specific soil compositions, acidification process is occurred for some periods in the region. For these reasons, the delta water environment is very corrosive to metallic materials.[1),2)]

Different measures of corrosion protection have been applied for the water intake gates with moving steel parts freely opened for transport circulation in required periods of time. The gate is constructed by various grades of steels, changing from SUS 304, recycled stainless steel to carbon steel with protective coatings. Proposed coatings include: zinc spray, multi layer organic painting and polyester composite linings. Right choice of protective measures is a problem of great techno-economical importance for Mekong delta due to numerous irrigational steel structures operating and building in the area.

The paper is presenting practical results of materials selection suitable for water intake gates designing and constructing to operate in the Mekong river basin environments.

## 2. Experimental

### 2.1 Corrosion test

For right evaluation of corrosivity of water environmentsin the Mekong river basins, a long-term monitoring project has been implemented. Physico-chemical characteristics of the representative water samples taken from different regions are presented in Table 1. The samples were collected in the beginning of rainy season, usually lasting from May to November, when acidity in some areas was very high. pH values lowered below 5 and could reach 3-4 for some months.

A set of metallic specimens, including zinc sprayed steel, recycled stainless steel, composite coated steel, painting steel, imported SUS 304 stainless steel, was taken for corrosion testing in above mentioned water samples.

Corrosion rate is determined by mass loss method by immersion test in above mentioned media at room

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**Table 1. Physico-chemical characteristics of investigated water samples**

| No | Medium | Physico-chemical characteristics values | | | | |
|---|---|---|---|---|---|---|
| | | pH | Conductivity ($\mu Scm^{-1}$) | $Cl^-$ (mg/l) | $SO_4^{2-}$ (mg/l) | $Na^+$, $K^+$ (mg/l) |
| 1 | Saline water | 7.6 | 4100.0 | 19143.0 | 2594.1 | 11374.7 |
| 2 | Blackish water | 4.1 | 1100.3 | 83.5 | 149.2 | 6452.0 |
| 3 | Fresh water | 6.7 | 104.0 | 14.0 | < 5 | 6.3 |

temperature. All the specimens are characterized by initial parameters presented in Table 2.

Accelerated test by ASTM B 117 is also used for evaluation zinc coated steel specimens with different deposited thicknesses and post-treatment finishing.

### 2.2 LCC/LCA evaluation

LCC/LCA method was used for evaluation life cycle cost of water intake gates with different protection measures (see Table 2). The gates have been designed for functioning in Mekong delta environments for at least 20 years. Designed gates with wall thickness 5 mm and general monetary unit (MU) have been taken for calculation. Inflation rate has proposed to be 5% a year.[3)]

**Table 2. Characterization of the specimens with different protective measures**

| No | Specimen | Dimension (mm) | Type of coating | Coating thickness (µm) |
|---|---|---|---|---|
| 1 | Mild steel | 150x100x5 | - | |
| 2 | Mild steel | 150x100x5 | Polymastic 2000 Grey | 500 |
| 3 | Mild steel | 150x100x5 | Polyester composite | 5,000 |
| 4 | Mild steel | 150x100x5 | Zinc spray | 100 |
| 5 | SUS 304 | 150x100x5 | - | |
| 6 | Recycled stainless steel | 150x100x5 | - | |

## 3. Results and discussion

### 3.1 Comparison of corrosion rates

Results of corrosion rates are presented in the Table 3. It is clear that corrosion rates of carbon steel are decreased in the order: saline water > blackish water > fresh water. Meanwhile, corrosion rates of zinc sprayed specimens were little changed during testing. Regarding materials, the corrosion rates follow the ranking (the painted and composite coated specimens were not taken for comparison):

**Table 3. Corrosion rate of various materials in different water media**

| No | Material | Corrosion rate (mpy) in water | | | Remark |
|---|---|---|---|---|---|
| | | Saline | Blackish | Fresh | |
| 1 | Carbon steel | 0.0969 | 0.0809 | 0.0706 | Even surface |
| 2 | Zinc sprayed steel | 0.0174 | 0.0135 | 0.0147 | Even surface |
| 3 | Recycled stainless steel | 0 | 0 | 0 | No sign of corrosion |
| 4 | SUS 304 | 0 | 0 | 0 | No sign of corrosion |
| 5 | Painted steel | - | - | - | N/A |
| 6 | Composite coated steel | - | - | - | N/A |

Carbon steel > zinc sprayed steel > recycled stainless steel ~SUS 304

In all investigated media, mild steel and zinc coated steel underwent uniform corrosion. Its surfaces seemed quite flat with fine grains under corrosion products.

The steel specimens under composite and paint coating were generally uncorroded during testing. However, it is rarely used in practice due to defects, very frequently occurred in process of gate operation. The operation needed for transport circulation or for water level regulation of the gate systems. The defects usually caused coating blistering, resulting steel substrate corrosion.

Among the other investigated systems, only stainless steel specimens were resistant to water environments regardless saline or weak acidic characters. Due to low corrosion rate, a set of zinc sprayed specimens with different deposited thicknesses (from 50 to 100 µm) and post-treat-

**Table 4. Comparative results of corrosion behaviour for zinc coatings**

| No | Specimen Thickness | Treatment method | White rust (*mm*) from edges after (*hours*) | | | |
|---|---|---|---|---|---|---|
| | | | 100 | 200 | 250 | 300 |
| 1 | 100 | Sealing | 0 | 0 | 5 | 10 |
| 2 | 100 | | 30 | 30 | 30 | 30 |
| 3 | 70 | Sealing | 0 | 0 | 0 | 15 |
| 4 | 70 | | 10 | 30 | 30 | 30 |
| 5 | 50 | Sealing | 0 | 0 | 5 | 15 |
| 6 | 50 | | 0 | 20 | 30 | 30 |

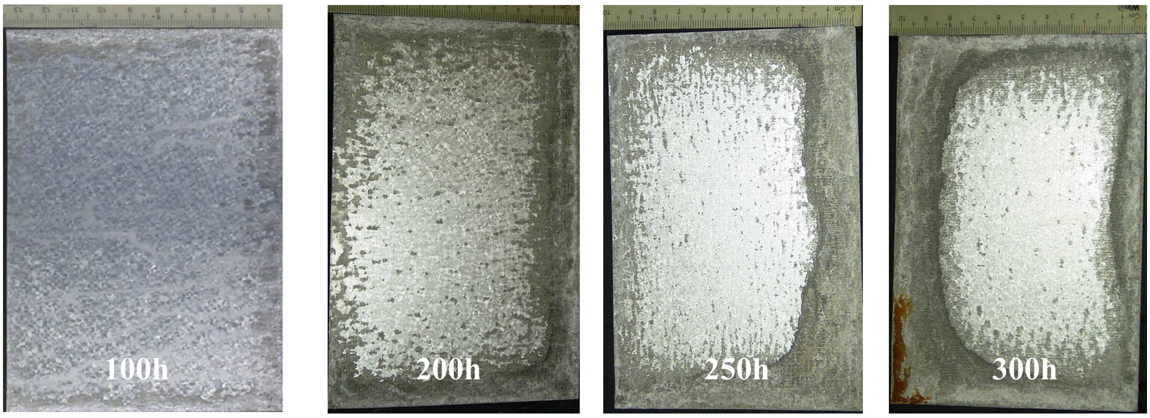


**Fig. 1.** Corrosion behaviour of zinc coated specimens with different salt spray time

ment finishing methods (with and without sealers) was taken for further accelerated testing by ASTM B 117.

Table 4 shows the comparative results of corrosion behaviour for these specimens. It is clear that the specimens express very distinct corrosion behaviour to the accelerated conditions of ASTM B 117.

An example of corrosion behaviour for zinc coated specimen with sealing 100 µm thickness during salt spray testing is shown in Fig. 1. It can be seen very clear evidence of corrosion progress under impact of environmental conditions during testing.

### 3.2 LCC/LCA Evaluation

From the above investigated results of corrosion testing, some preliminary orientations can be drawn for practical application of suitable materials in water intake gate designing and installing. However, for such long operating structures as irrigational systems, LCC/LCA approach would be very useful tool in materials selection.

With estimated service time for water intake gates of 20 years, the LCC/LCA evaluation method is applied for calculation. All data for different measures of protection are given in Table 5. Repairing period for zinc sprayed steel gate is 10 years, meanwhile painted and composite coated steel gate require more frequent repair (1 or 2 years) resulting higher total cost.

From the Table 5 results, it is clear that present time value cost, id. total investment for the protection method with zinc sprayed coating is lowest among the calculated measures. This protective measure has been chosen for practical application in Mekong delta for last ten years.

Many projects have been implemented with of zinc spray application for water intake gates in Mekong delta. Some images of preparation and coating processes at the

**Table 5. Results of LCC/LCA calculation**

| Items | LCC cost (M.U) protection alternatives | | | | |
|---|---|---|---|---|---|
| | Zinc sprayed | SUS 304 | Painted steel | Composite coated steel | Recycled stainless steel |
| Material cost | 197,000 | 1,050,000 | 197,000 | 197,000 | 936,000 |
| Fabrication | 0 | 0 | 0 | 0 | 0 |
| Surface treatment | 240,000 | 0 | 130,000 | 110,000 | 0 |
| Total initial cost | 437,000 | 1,050,000 | 327,000 | 307,000 | 936,000 |
| Maintenance cost | 81,068 | 0 | 527,200 | 446,093 | 0 |
| Replacement cost | -13,511 | 0 | -20,267 | -6,756 | 0 |
| Value of lost production | 33,778 | 0 | 202,769 | 202,769 | 0 |
| Repairing | 0 | 0 | 0 | 0 | 0 |
| Operating cost | 101,335 | 0 | 709,702 | 642,106 | 0 |
| Total LCC | 538,335 | 1,050,000 | 1,036,702 | 949,106 | 936,000 |

**Fig. 2.** Some images of zinc spray application to water intake gates for Mekong water basin
Sand blast (left) and Zinc spray (right)

276 Mechanical & Construction Co. are illustrated in Picture 2.

The periodic inspections show that the first steel water intake gates with zinc spray coatings have been operated in irrigational systems of Mekong river basin since 1997 with very low corrosion rates and defects. Operation of the gates did not require frequent maintenance and repairing. In opposite, this is yearly work for the structures with painting or composite coatings. That would be an advantages for the application of zinc spray in Mekong water environment.

## 4. Conclusion

(1) Mekong basin water environment is very aggressive to steel structures under influence of salination and acidification process.

(2) Corrosion rates of metallic materials in Mekong basin water environments follow the ranking :

*Carbon steel > zinc sprayed steel > recycled stainless steel ~SUS 304*

(3) Method of Life Cycle Assessment (LCA) was applied in materials selection for water intake gate construction. the following ranking for Life Cycle Cost (LCA) was obtained:

*Zinc sprayed steel < Recycled stainless steel < Composite coated steel < Painting steel < SUS 304*

(4) Zinc spray coating on carbon steel is a good solution for water intake gates operating in different areas of Mekong river basin.

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