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Study on Effectiveness of Corrosion Preventing Materials for Exposed Steel in Construction Projects

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Abstract: ***Corrosion is a natural process that converts cast metal into chemically stable oxide, hydroxide, or sulfide. It chemically and electrochemically reacts with the environment. In the presence of moist air, the iron Fe2+ or Fe3+ process oxidizes to corrode, becoming Fe (OH) 2. Further, react moist with air it becomes Fe2O3.H2O is called brown rust. That is called corrosion. The strength of steel is decreased due to this process. The corrosion of steel is a major problem for construction projects. The corrosion of steel leads to the crack of concrete elements, reducing the bond energy and cross-section of steel. To prevent this, it is important to follow proper precautions. So far there are a very limited amount of research has been done on the effectiveness of these chemicals. Hence this research has identified the effectiveness of several chemicals currently used in construction projects. This research mainly focuses to identify the most effective material for applying exposed steel on concrete elements in projects in different locations. Ferrorep, ZRC, Q/D metal primer Zinc phosphate, SAFE CORE R were selected, which is the most commonly used corrosion-preventing materials on the sites. Selected four materials were applied on steel pieces and kept in different 4 locations, Sooriyawewa, Bandarawela, Galle, and Matara (Coastal Area). Image Comparative method was used in analyzing the collected data which were taken every week at the above-mentioned locations. Image J software was used to analyze the obtained image. As per the analysis, ZRC and Q/D metal primer zinc phosphate can be applied to protect the steel from exposure to the environment in any area. Further SAFE CORE can be used for shorter period protection. Q/D metal primer zinc phosphate can be recommended in any type of environmental conditions and its cost is also lower than the other three selected materials.***

Keywords: Corrosion; Construction project; Effectiveness; Reinforcement; Steel

1. Introduction

The reinforced concrete structure has so many members and it is used for all structural members subjected to bending, such as Beam, Columns, Slabs, Shear walls and Foundations to heavy structures, etc. It consists of concrete and steel bars.

The most critical contribution to steel corrosion and deterioration of the concrete structures is the environmental and geomorphological conditions, to which they are exposed during their lifetime. (Jeremy Lewis, 2012).

The process of corrosion of steel is more critical and complex in behavior. The most common type of steel corrosion occurs when it is exposed to oxygen with the presence of water, which creates a red iron oxide commonly called rust. Steel is combining with moisture and oxygen as follows. First, the iron (Fe) that comprises steel loses some electrons and becomes positively charged.

Iron hydroxide continues to react with oxygen and water, yielding Fe2O3.H2O - also known as hydrated iron oxide or brown rust. Corrosion of Steel can lead to cracking of concrete elements, reduction of bond strength, reduction of effective steel cross-section of structural components, and loss of them. Also, this will reduce the axial, and flexural strength of elements, and makes them structurally weak. Even if corroded elements look stable, it does not mean they are safe in fact, the corroded structures become vulnerable for design loads. Corrosion can also reduce the shear strength of the slab close to the columns, and increasing the chance of punching shear failure. In footings, the corrosion can result in shear failure of the footing, anchorage failure, or flexural yielding of steel reinforcement. (FPrimeC, 2016)

For this reason, building owners, architects, and builders must take proper precautions to prevent corrosion in the exposed reinforcement. There are intended starter bars in the concrete structures as exposed steel. These starter bars are exposed to the environment for few days or sometimes months due to the shutdown and temporary closure of construction sites due to reasons like payment delays or pandemic diseases like a covid 19. Then the starter bar can be exposed to the environment and exposure to the water (moisture) and oxygen for a longer duration leads to the corrosion process in steel. It would be an extra cost to remove the corrosion in the steel. It wastes both time and money and the main problem is that this corroded steel can be reusable? Then if corrosion preventing material had been applied before the site was shut down, this corrosion problem would have not been raised. Therefore it is necessary to find materials that can minimize and prevent corrosion for a few days or months without corrosion. There are several techniques to prevent corrosion, but this research finds out only use a coating or barrier material for preventing corrosion in the exposed steel in the construction projects. The protective coating should have excellent corrosion-resisting properties. The coating should not affect the bond strength of steel to concrete and also other properties. There are verities of materials that are used to prevent corrosion in projects, but all the materials are not suitable for every environmental condition such as the location of the project (a coastal area or not.), climatic

condition, etc. therefore it is necessary to identify the most suitable materials for different environmental conditions for preventing corrosion in the exposed steel. Then it's better to identify the effectiveness of corrosion-preventing material for exposed steel that is currently used in construction sites**.** This research mainly focuses to identify the most suitable material for applying exposed steel on concrete elements in the construction projects' different locations. The main objectives of the research are to identify corrosion-preventing materials in exposed steel used in construction projects and analyzing the effectiveness of the identified corrosion-preventing materials in exposed steel in different locations around Srilanka.

2. Methodology

In this research, a quantitative approach was selected with a practical experiment; the quantitative approach is the most suitable method by which data can be easily presented. The primary data were collected from construction professionals and practical experiments.

2.1 Data collecting for the first objective

Data were collected using interviews with the technical staff in the construction projects for this interview questions were prepared. The interview questions were divided into main two sections. One has consisted of demographic data for a respondent profile including the total year of experience, education level, and occupation level of the respondents. Other sections include the 7 questions used to identify the corrosion-preventing materials of the reinforcement. The interview was conducted among engineers, assistant engineers, and technical officers. The first pilot survey was conducted to see if the interview questions were clearly understood. Here participants were selected by non probability purposive sampling. Because the research topic is not familiar with the common public and data were collected from the professionals (Site engineers, site managers, technical assistants. etc) who are frequently using corrosion prevention materials. The respondents should have sound technical knowledge about the research topic. Therefore for the research sample has to be selected purposively. Further reliability of the data of the purposive sample is higher than the random sampling in this type of research.

2.2 Data collecting for the second objective

The data was collected from the interview were incorporated to achieve the second objective. Samples of four materials that are most commonly used in the construction project were found through the interviews conducted. Preparing of four steel sample

Figure 1.1: Selected materials from interview

2.2.1 Selection diameter and length of the steel pieces

First, a pilot survey was performed to select the bar diameter for the application of the material sample. The bars of different diameters exposed to the environment but all bars were corroded at the same rates. Hence for the experiment 10 mm, diameter bars were used since there is no relationship between the rate of corrosion and the bar diameter. The starter bar is placed as lap length (50 d, d-diameter of the bar) of exposure, so 500 mm length was chosen as sample pieces of PVC pipe (40mm) filled with cement sand to hold the pieces of steel bar. The total length of 525 mm steel bars 20 pieces of steel with 500mm exposure length were used for this experiment.

2.2.2 Selection of the location

The samples were placed in 4 selected locations. Sooriyawewa, Bandarawela, Galle (Neluwa), Matara coastal area were selected to represent all the possible climate conditions.

2.2.3 Application of the selected material on steel

Ferrorep: water (100g: 35g) added and mixed well for at least 3 minutes until a lump-free mass was obtained. The can should be left open for 5 minutes before application. Ferrorep was applied by using a brush in two layers. Each layer was applied once the previous one had dried as the specification. SAFE CORE R was supplied in power with liquid. Those two components were mixed until a homogenous color was achieved. The mixed SAFE CORE R was applied by brush in one coat on the surface as a specification.Q / D Metal Primer Zinc Phosphate was applied directly on the steel without mixing anything else. ZRC must shake well before spraying to the container for two minutes. Then ZRC was sprayed on the steel well as an indication in this sample.

Those five samples were applied to four materials types and the other one was kept without any application as a control sample. Those five sample sets were placed in four places as mentioned in the methodology.

Most commonly used corrosion prevention materials found from the interview were applied to pieces of prepared steel and sent to relevant locations. Photographs were taken weekly in each sample. Meanwhile, each of those samples was visually observed and recorded. To ensure the consistency of photographs, photographs were taken by the same person with the same camera to minimize human errors. This was done for six weeks of duration. The comparative analysis method was used to analyze the data.

The color variation in the photographs of the steel bars was taken to the analysis.

Figure 1.2: Selected materials applied on steel

3. Findings/ Analysis

3.1 Data analysis of first objective

Simple statistical techniques were used to analyse data. Microsoft Excel software used to tabulate the results. The unit rates of the selected materials were collected from several companies and an average unit rate for the relevant material was obtained from them

Table 6.1: The most widely used 4 material selected from the interview and their cost

Selected material	Description	Rate per $1m^2$(Rs)
Ferrorep	• R / F protects against corrosion and strengthens concrete intended to withstand high humidity conditions. • Cement based material	112.50
ZRC	• ZRC is 95% metallic zinc • Zinc based material	805.00
Q/D metal primer zinc phosphate	• Zinc phosphate is high • Protects metal surfaces from rust • Zinc based material	107.00
SAFECORE R	• It ensures excellent corrosion resistance Protect from sulphide and chlorides • Cement based material	289.90

3.2 Data analysis of second objective

Image comparative method was used for analyzing this data. Image J software was used to analyze the obtained image. Image J software is a Java-based program with large developers and many resources. It offers many advantages over other image analysis software, including the availability and ease of use of custom-designed plugins for various image analysis software. However, Image J only works as an analytics package and it cannot capture images. Image J software can be used for any image analysis application, including documentation, photo analysis, aerial photo analysis, microscope, and medical imaging. Objects can be selected, measured for several parameters and data can be exported to a spreadsheet file. (Papadopulos, 2007)

Pixel is one of the small dots or squares that make up an image on the computer screen. The grey value indicates the brightness of the pixel. Mean is the sum of the grey value of all the pixels in the selection divided by the no of pixels. (Anon., 2021)

Obtained photos were analyzed by using this image J software and those images were created as an above graph and mention mean values are shown as follows. The graphs' mean values can be summarized as follows.

After observing the photographs taken from the samples in these areas, it appears that the mean values of the samples have changed slightly, which means that the samples have been corroded. The following shows the difference in the mean values. The following equation was used to obtain the mean value changes

M = Mo – Mn

M – Each week mean values, Mo –Mean value of Initial sample

Mn –Mean values of Initial sample, 1st-week sample, 2nd-week sample, 3rd-week sample ….. (Six weeks should be considered separately)

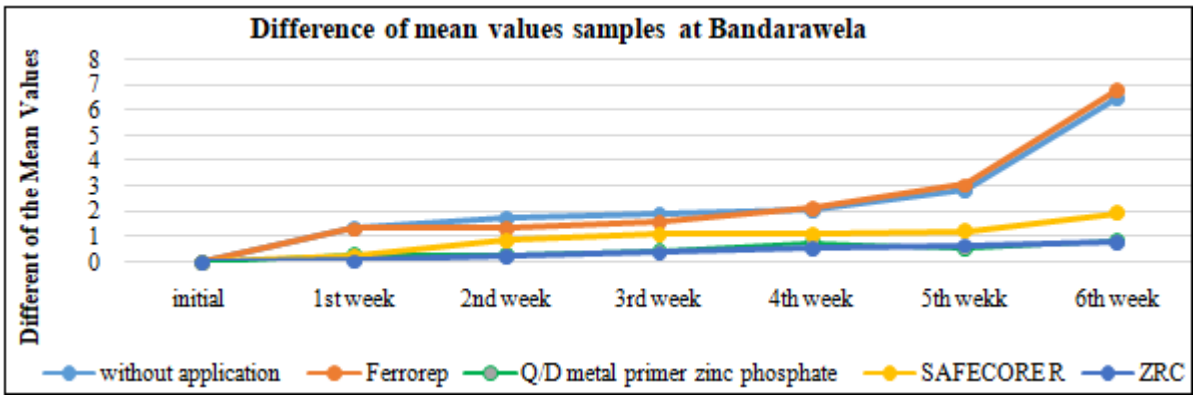

Figure 6.1: Different of mean values of samples at Bandarawela

This area has a high moisture content (humidity) in the air and a lower temperature than other selected locations. Considering the visual analysis, one difference of the mean values of the photograph is ignored as the deviation of the photos. As figure 6.2, steel has corroded within a week without any application. Ferrorep also cannot be used within one week to protect the exposure steel and SAFE CORE R can be used for up to two weeks to protect steel from corrosion. As shown in Figure 6.2, Q / D Metal Primer Zinc Phosphate and ZRC are similar in exposure conditions and can protect steel from corrosion up to six weeks from the date of use.

Galle -Neluwa area has a normal condition than other selected locations. Considering the visual analysis, one difference of mean values of the photograph is ignored in this analysis as the deviation of the photos as well. As shown in figure 6.3, steel has corroded within a week without any applications. Q / D Metal Primer Zinc Phosphate, SAFE CORE R, and ZRC, all those three materials have a similar action in the exposure environment and those can be used to protect steel from corrosion up to six weeks from the date of use and Ferrorep can be used up to two weeks to protect steel from corrosion.

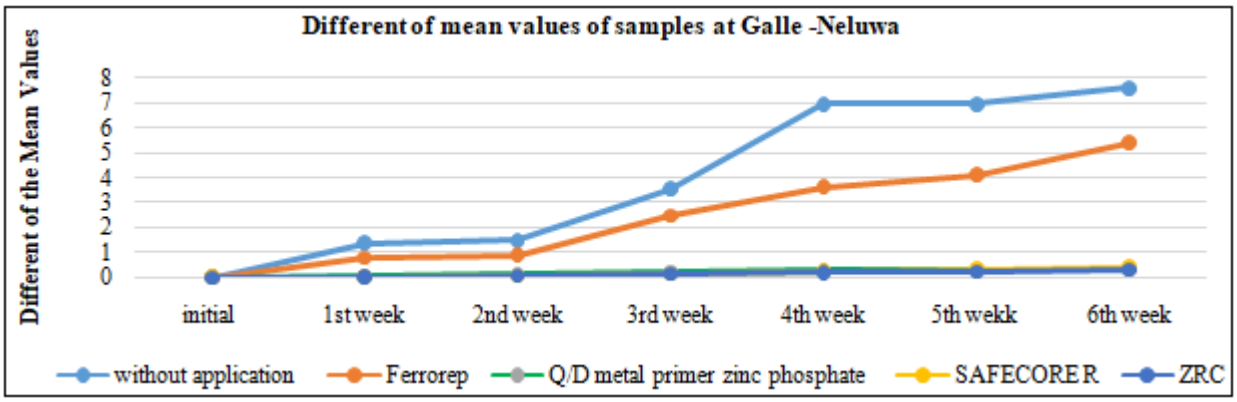

Figure 6.2: Different of mean values of samples at Galle –Neluwa

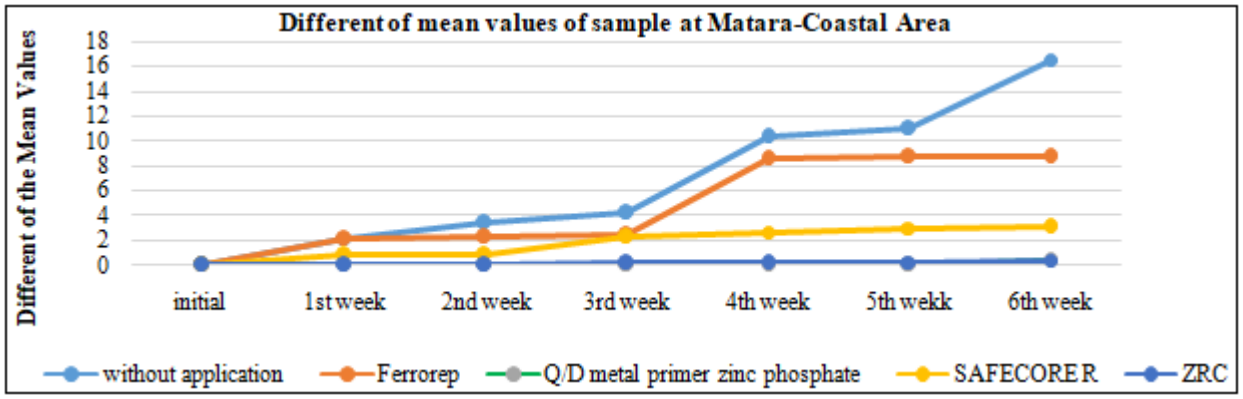

Figure 6.3: Different of mean values of sample at Matara-Coastal Area

The coastal area (Matara) has high humidity and a very high percentage of sodium chloride in the air. Considering the visual analysis, one difference of mean values of the photograph is ignored in this analysis as the deviation of the photos as well. As considering figure 6.4, steel is corrosive within a week without any applications even Ferrorep cannot be used in coastal areas to protect steel. As in other areas, Q / D metal primer zinc phosphate and ZRC can be used to protect steel from corrosion for up to six weeks from the date of applying material those two materials are almost the same in behaviour in the exposure condition, and SAFE CORE R can be used for up to two weeks to protect steel from corrosion.

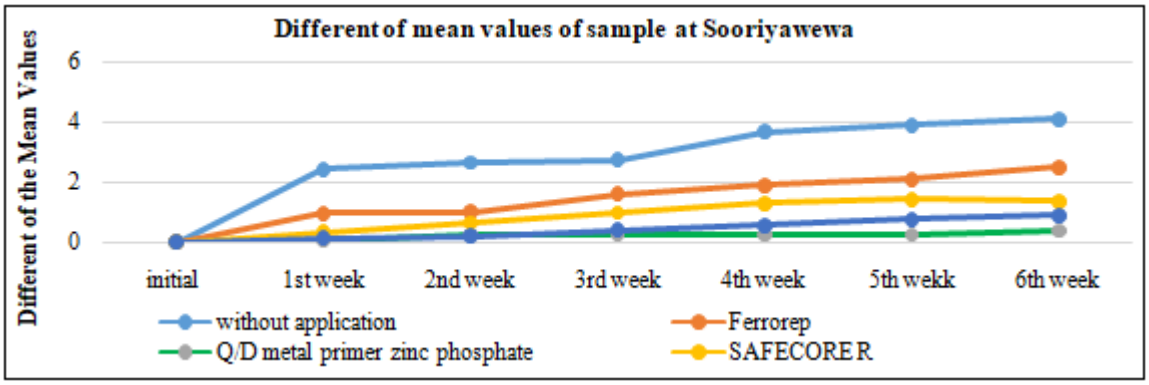

Figure 6.4: Different of mean values of sample at Sooriyawewa

This area has lower humidity and a high temperature. One difference of mean values of the photograph is ignored in this analysis as the deviation of the photos as well. According to figure 6.5, steel is corrosive within a week without any applications. Q / D metal primer zinc phosphate and ZRC are similar behaviour up to 3 weeks but after that, there appeared small changes even though those two materials can be used to protect steel from corrosion up to

six weeks from the date of applying materials, and SAFE CORE R can be used up to three weeks to protect steel from corrosion. Ferrorep can be used for up to one week to protect steel.

3.3 Limitation of the research

Some limitations had identified during the research. In this pandemic situation in the country (COVID 19), it had to be limited locations for sampling. These four locations with different environmental conditions were selected for the experiment but it would be better to cover at least different provinces Deviations can be occurred photographing samples. That is, the quality of the images depends on the lighting condition and climate of the locations. Uniformity is ensured by using the same person and the same camera photographing collecting photographs during the same time as well. The sample was also visually observed to minimize deviations. Every effort has been made to minimize the impact of these limitations on the study using these.

4. Conclusion

There are different environmental conditions in different localities in a tropical country like Sri Lanka. Therefore, some type of material cannot be used for every environmental condition to protect. From the findings of this study, in the coastal area and in Bandarawela, Ferrorep behaves as a sample without any application. Therefore Ferrorep cannot be used for the protection of exposed steel in coastal areas and high humidity areas. Ferrorep can be recommended to prevent corrosion of steel for short periods of time at selected locations. Safe CoreR can also be recommended to prevent corrosion of steel for short periods of time except for Galle and can be used very actively in the Galle area that means under normal conditions it can be used for up to 6 weeks. ZRC and Q/D behaved similarly in this research. Furthermore, those two materials can be used in any environmental condition for up to 6 weeks to protect the exposed steel. But ZRC has the highest rate among the materials selected for this study, so Q/D metal primer can be recommended as an effective material anywhere. Therefore, considering this research, Q/D metal primer zinc phosphate can be recommended as the cheapest and most durable material to protect the steel from corrosion. This material affects different environmental conditions in different ways. Therefore, suitable corrosion-preventing materials for the location were found in this study. The time consumed for corrosion also varies from material to material. Depending on the exposure time of the selected material, the appropriate material can be selected for the relevant purpose. This suitable material should be applied if the steel needs to be protected for longer to prevent corrosion of the exposed steel.

The corroded steel may be adversely affected the strength of reinforced concrete elements in the construction projects.

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