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AWARENESS AMONG PROFESSIONALS IN MALAYSIAN CONSTRUCTION INDUSTRIES ON REINFORCEMENT CORROSION PREVENTION AND PROTECTION

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Abstract: Reinforced concrete structures are subjected to damage and deterioration during their service life because of exposure to many types of environmental influence. These damages or deterioration can reduce the performance and intended function of the structure. On several occasions structural failures are closely linked to the corrosion of steel reinforcement in concrete. Information about the current practice to prevent and protect corrosion of reinforcement in Malaysia is fragmented and hard to acquire. Local standard for corrosion treatment technique is not available. Each concrete repair organizations normally have their own approaches in solving corrosion problems. This has made it difficult for regulatory agencies to plan and implement an effective corrosion management system in the country. This paper presents the results of an industry survey concerning the awareness of local professionals toward reinforcement corrosion protection and prevention. The respondents were professionals working with consultants, contractors, suppliers and research institutions. The results indicate that common methods of corrosion prevention are surface treatment and improvement in concrete technology, while patch repair and chloride removal are frequently used for treating corrosion. In general, the level of awareness among professionals on common methods of corrosion protection and prevention is considered satisfactory. However the awareness on modern and high technology methods in treating corrosion are still weak and need to be enhanced. The solar energy approach in preventing and protecting reinforcement corrosion was not implemented in Malaysia.

Keywords: Corrosion protection, concrete repair, corrosion management

1.0 Introduction

Usage of concrete as construction material was traced back in the Roman era and will continue to remain popular till the next century. Being a versatile material and cost effective has made concrete a popular choice over a wide range of construction materials.

The high alkalinity environment provided by concrete is conducive towards reinforcement. A thin layer called passivative layer will remain on the steel reinforcement surface when concrete is under high alkalinity condition. A passive layer is a dense, and impenetrable film that prevent and stop corrosion of steel reinforcement. However, two processes can break down the passive layer of steel, one is chloride attack and the other one is carbonation (Wranglen, 1985; Sarja and Versikari, 1996; Broomfield, 1997).

The popular 'patch repair' technique for treating corrosion problems is not that effective especially if the corrosion is due to chloride. To remove all the penetrated chloride is difficult and costly. Chloride that remains on the adjacent side of the affected area will initiate new corrosion circuit popularly known as 'incipient' anode formation. As a remedy for a long lasting passivating environment in steel reinforcement, application of electrochemical repair techniques has been introduced.

Technically, there are two systems in cathodic protection viz. sacrificial anode and impressed current. The sacrificial anode system uses a sacrificial or galvanic anode such as zinc without a power supply. Meanwhile, the impressed current system works by passing a small direct current (DC) from a permanent anode fixed on to the surface or into the concrete to the reinforcement. Solar energy has been tried as an alternative replacement to direct current (DC) for cathodic protection hoping to minimize the maintenance cost and provide sustainable energy (Chew, 2005).

Information about the current practice to prevent and protect the corrosion of reinforcement bar that being applied in Malaysia is limited and fragmented. Clear information about standardization of corrosion treatment techniques in Malaysia is quite hard to acquire (Muhamad Abid, 2006). Each concrete repair organizations normally have their own approaches in solving corrosion problems.

Overall, the current scenario in Malaysia in dealing with corrosion problems is still unclear. The awareness on how important the knowledge of steel reinforcement corrosion prevention and protection is yet to be determined. Furthermore, the awareness of local professionals on current and new technology methods in treating corrosion is also unclear. In view of the lack of information the study highlighted in this paper focused on determining the current level of awareness of local engineers and other professionals on issues related reinforcement corrosion prevention and protection. This is an important step towards developing strategies to enhance knowledge and expertise in this area.

2.0 Corrosion Management

Effective management of corrosion is important for different benefits depending on types of facilities involved. Among the benefits are maintaining safety, health and environmental standard that fulfill the statutory or corporate requirements, reducing unplanned maintenance, and in the long run reducing the life-cycle cost of the facilities.

Effective management of corrosion also means safe working environment is ensured with no statement of uncertainty. Corrosion management system that combines both proactive and reactive management measures can reduce element of uncertainty with

regard to degradation of structure due to corrosion. Corrosion control and consequential input upon operations is very much related to cost. Some are direct such as inspection, monitoring and maintenance while others are indirect such as increased maintenance, deferred production and logistics. Thus, implementing appropriate corrosion management that result in the reduction or elimination of corrosion related damages of facilities not only assists in compliance with regulatory requirements but also has a direct effect on the facilities overall economic performance.

3.0 Methodology

The study was conducted in two distinct phases. Generally phase I involved directory review to determine the complete concrete repair organization attributes. Most of the concrete repair organizations attributes were obtained through the 'Directory 2005' published by Construction Industry Development Board, Malaysia (CIDB) and internet surfing. To identify whether these attributes were applicable and suitable to our local concrete repair industry environment, a pilot study including a semi-structured questionnaire had been carried out to obtain the opinion from qualified respondents. Five pre-qualified respondents representing architectural firms, engineering consultants and construction companies were selected to answer the preliminary semi-structured questionnaire. In phase II a complete semi-structured questionnaire was created based on findings from phase I of the study and forwarded to qualified respondents selected randomly from the target population. The aim was determining the level of awareness of concrete repair industry professionals on matters related to reinforcement corrosion prevention and protection. The respondents were engineers and architects working with owners, consultants and contractors.

3.1 Design of questionnaire

According to Fellows and Liu (1997), questionnaire normally occurs in two primary forms: open or closed. Open questionnaire consists of questions that are designed to enable the respondents to answer in full, to reply in whatever form, with whatever contents and to whatever extent to the respondent wishes. In this study, however, a combination of open and closed questionnaire approach was adopted due to the fact that some questions allowed the respondent to answer in the format preferable by them. The semi-structured questionnaire consisted of six parts. Part A and B enabled general information about the respondent is gathered such as types of organization, experience, and, number of completed and ongoing projects. Part C was aimed at gathering opinion on the amount of money to be spent on repair works. In this part the cost of steel reinforcement is very much concerned. In Part D the awareness of the respondents on the current practice and methods in preventing and protecting steel reinforcement from corrosion were investigated. Part E was developed to gather information about the

experience and knowledge of personnel of the respondents. Finally Part F question allowed suggestions to be made by the respondents.

3.2 Data Collection

35 questionnaires were posted to randomly selected sample list. All selected respondents were given a period of four weeks to fill up the questionnaire which is deemed to be sufficient time for them to complete and return the questionnaire with the attached pre-stamped envelope. The survey exercise was mainly focused on Kuala Lumpur, Selangor and Johor areas.

3.2.1 Data Analysis

For the purposes of analysis of data collected through the questionnaire, the Statistical Package for Social Science (SPSS) was selected. The following statistical methods have been used for data analysis:

- Frequency Analysis
- Average Index

In analyzing the data on respondents' level of awareness or agreement of reinforcement corrosion prevention and protection, the following assumed values have been considered for responses based 5-point Likert Scales.

- Most Familiar/Agree = 1
- Familiar/Agree = 2
- Moderately Familiar/Agree = 3
- Less Familiar/Agree = 4
- Not Familiar/Agree = 5

3.2.2 Average Index

The data collected on the levels of awareness of reinforcement corrosion prevention and protection was tabulated based on the number of response for each category of degree of awareness or agreement. Based on the frequency analyses the average index was then calculated to determine the ranking of each factor being considered.

The average index is calculated as follow (Al-Hammad *et al.,* 1996):

$$\text{Average Index} = \frac{\sum a_i x_i}{\sum x_i}$$

Where, a_i = constant expressing the weight given to i, x = variable expressing the frequency of response for i = 1,2,3,4,5. Based on the assumed values stated earlier, x_1 = frequency of the "most familiar/agree" and corresponding to $a_1 = 1$, x_2 = frequency of the "familiar/agree" and corresponding to $a_2 = 2$, x_3 = frequency of the "moderately familiar/agree" and corresponding to $a_3 = 3$, x_4 = frequency of the "less familiar/agree" and corresponding to $a_4 = 4$, and x_5 = frequency of the "not familiar/agree" and corresponding to $a_5 = 5$.

In order to determine the degree of importance of the constructability principles considered in this study the classification of the rating scales proposed by Abd. Majid (1997) have been used. The classifications of the rating scales are as follows:

- Very familiar/Agree $1.00 \leq \text{Average Index} \leq 1.50$
- Familiar/Agree $1.50 < \text{Average Index} \leq 2.50$
- Moderately familiar/Agree $2.50 < \text{Average Index} \leq 3.50$
- Less familiar/Agree $3.50 < \text{Average Index} \leq 4.50$
- Not familiar/Agree $4.50 < \text{Average Index} \leq 5.00$

4.0 Results and Discussion

Out of thirty-five questionnaires, twenty were returned with complete answers giving a response rate of 57.1%. Majority of respondents (65%) are working with concrete repair companies while others with engineering consultants, material suppliers, contractors and research institutions. Most respondents have been actively involved in construction or structural maintenance projects with experience ranging from 3 to 30 years where the average is 13.2 years.

Based on the results of part C of the questionnaire it was found that majority of respondent were in the opinion that the total cost of steel reinforcement in project should be between 5-15 percent compared to the overall project cost. Within this range the amount of repair work needed due to corrosion in a worst case scenario will not be substantial. Table 1 below shows the respondent's opinion on the preferable total cost of steel reinforcement compared to overall project cost.

The average index calculations on the level of awareness of respondents with different types and sources of corrosion in Malaysia are shown in Tables 3 and 4 respectively. It is clear that most respondents were more familiar with general and pitting corrosion. The awareness on bacterial and dissimilar metal corrosion is considered to be at low level. The average index results also indicate that most respondents were familiar with corrosion due to carbonation and chloride attacks. However, the level of awareness of other sources of corrosion i.e. air salinity (Rank 3), air humidity (Rank 4)

and bacterial attack (Rank 5) is between moderate to less familiar indicating that the causing factors of rebar corrosion are not yet well understood by the respondents.

Table 1: Preferable total cost of steel reinforcement compared to overall project cost

Percentage of Reinforcement Cost Compared to Overall Construction Cost	Number of respondent	Percentage
< 5%	1	5%
5% - 15%	10	50%
15% - 25%	7	35%
> 25%	2	10%
Total	20	100%

Investigation on the sizes of reinforcement commonly used for structural members in projects that the respondents have handled, Table 2 shows the tabulation of the results of the survey. It is clear that the most common bar sizes were T12, T16 and T20.

Table 2: Amount of rebars in structural members

Rebar Size	≤T10	T12	T16	T20	≥T25
Structural Member	%	%	%	%	%
Pile Cap	30	65	5	0	0
Foundation	0	0	40	30	30
Beam	0	5	25	45	25
Column	0	5	15	40	40
Retaining Wall	5	25	15	45	10
Slab	0	0	10	55	35

Table 3: Awareness on different types of corrosion

Level of Awareness Types of Corrosion	1	2	3	4	5	Average Index	Rank
General Corrosion	15	5	0	0	0	1.25	1
Pitting Corrosion	7	6	5	1	1	2.15	2
Bacterial Corrosion	0	1	8	10	1	3.55	4
Dissimilar Metal Corrosion	0	2	10	5	3	3.45	3

Table 4: Awareness on common causes of reinforcement corrosion

Level of awareness Sources of Rebar Corrosion	1	2	3	4	5	Average Index	**Rank**
Carbonation	18	2	0	0	0	1.10	**1**
Chloride Attack	11	7	2	0	0	1.55	**2**
Bacterial attack	0	0	9	10	1	3.60	**5**
Air Humidity	1	2	5	11	1	3.45	**4**
Air Salinity	1	0	4	11	4	3.05	**3**

The analysis on the experience of respondents in applying corrosion prevention methods revealed that surface treatment was the most popular method (Table 5). Besides that, several respondents also mentioned other prevention methods that have been used for arresting corrosion problem such as applying protective coating on steel reinforcement and concrete surface, and providing suitable thickness to concrete cover. The result on the awareness of respondents on preventing corrosion by using solar energy system shows that only 4 out of 20 respondents are aware solar energy system application can be used for corrosion prevention. The average index of 4.4 indicates that the level of awareness with this method of corrosion prevention is low.

Table 5: Awareness on corrosion prevention methods for reinforced concrete structure

Level Of Awareness Corrosion Prevention Method	1	2	3	4	5	Average Index	Rank
Design for Durability	9	4	2	5	0	2.15	3
Improve Concrete Technology	11	5	4	0	0	1.65	2
Apply Surface Treatment	14	2	4	0	0	1.50	1
Use Corrosion-Resistant Rebars	0	1	7	11	1	3.35	4
Use Solar Energy Method	0	4	0	0	16	4.40	5

Looking at the corrosion repair methods, patch repair was found to be the most preferable and applied by respondents. The levels of awareness with other repair methods can be considered as towards the moderate to less familiar levels. Table 6 shows the overall results of respondents' awareness in applying different types of corrosion repair methods.

The response to the question on other issues related to rebar corrosion that were encountered at the construction site shows that factors such poor concrete quality, insufficient design of concrete cover and deliver corroded steel reinforcement to the site were the common issues encountered at construction sites. Other issues identified from the study were lack of proper storage area, poor supervision, lack of knowledge on proper handling of corroded reinforcement, environmental effect and insufficient fund for corrosion prevention (see Table 7).

Table 6: Awareness with corrosion repair method available for reinforced concrete structure

Level Of Awareness Corrosion Repair Method	1	2	3	4	5	Average Index	Rank
Patch Repair Method	16	4	0	0	0	1.20	1
Cathodic Protection	0	1	10	8	1	3.45	3
Cathodic Prevention	0	1	6	9	4	3.80	4
Chloride Removal	0	1	3	13	3	3.40	2
Realkalization	1	0	1	9	9	4.25	5

Table 7: Main issues related to reinforcement corrosion at construction site

Level Of Agreement Issues	1	2	3	4	5	Average Index	Rank
Poor supervision	1	1	9	6	3	3.45	5
Poor concrete quality	11	4	2	2	1	1.90	1
Deliver corroded rebar to site	1	12	3	4	0	2.50	3
Insufficient design of concrete cover	7	7	4	4	0	2.45	2
Lack of proper storage area	2	8	3	4	3	2.90	4
Lack of knowledge on proper handling of corroded reinforcement	0	2	8	8	2	3.50	6
Insufficient fund for corrosion prevention	1	3	7	6	7	4.35	8
Environmental effect	1	3	4	4	8	3.75	7

In the study several suggestions to improve the effectiveness of existing steel reinforcement corrosion repair method in Malaysia were also given by the respondents. The most common suggestions are:

i. To focus on the thickness of the concrete cover.
ii. To increase the usage of corrosion resistance bars.
iii. To emphasize on the utilization of protective coatings of steel reinforcement and concrete.

5.0 Summary and Conclusion

In general, the awareness on how important the knowledge of steel reinforcement corrosion prevention and protection is still not up to the desired level. In fact, the awareness of corrosion protection and prevention method in Malaysia is considered low as far as this limited study is concerned. The results of the study indicate that local professionals are less familiar with modern and high technology methods in treating corrosion. This is an area that needs to be enhanced.

Based on the results of the questionnaire, there are two significant methods that usually applied for corrosion prevention: (1) surface treatment and (2) concrete technology improvement. Likewise, the common methods for corrosion repair that have been identified from the study were patch repair and chloride removal. Pertaining to solar energy application in preventing and protecting reinforcement corrosion, it can be said that the method has not been holistically implemented in Malaysia. Positive steps have to be taken in order to develop and publicise solar energy utilization for future used especially in steel reinforcement corrosion treatment.

Overall, the subject of corrosion remains an area to be further investigated especially in the context of Malaysia. The study has at least identified the current levels of awareness of local professionals toward corrosion prevention and protection. A detailed planning must be designed for applying the knowledge of corrosion prevention and protection in a proper manner. The outcome of current reinforcement corrosion treatment activities could be further improved by:

i. Enhancing the relationship between federal government and universities in disseminating the information to the public especially to repair's company on how important the issues of reinforcement corrosion awareness for Malaysian.

ii. Standardizing the approach in treating corrosion of reinforcement especially for designing the sufficient thickness and durability of concrete cover and protective coating.

iii. Carrying out a regular periodic and continuous observation for the reinforcement treatment process in detecting and analyzing the source of corrosion.

iv. Carrying out additional research on corrosion especially the research that relates to corrosion prevention and protection. Government and authorized body should support the effort of researchers in expanding, publishing and applying the accomplished research. Financial support is extremely important.

The importance of knowledge in corrosion prevention and protection is discussed. The results of the industry survey on corrosion prevention and protection is also discussed. The findings indicate that the common methods of corrosion prevention are surface treatment and improvement in concrete technology while patch repair and chloride removal are frequently used for treating corrosion. In general, the level of awareness of professionals on common methods of corrosion protection and prevention is considered to be satisfactory. However the level of awareness with modern and high technology methods is considered to be low.

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