Egypt. J. Chem. **Vol. 65**, No. 9 pp. 415 – 420 (2022)

Egyptian Journal of Chemistry

http://ejchem.journals.ekb.eg/

Using Lime Peels Powder to Eliminate Corrosion Rate and Improve Compressive Strength of Carbon Steel Mortar

Hyman Jafar Meerza Al-Jaaf,[a] Rand Salih Al-Jadiri,[a]* Lubna Ghalib[a]

[a]*Mustansiriyah University/ College of Engineering/ Materials Engineering Department Baghdad-Iraq.*

Abstract

This study aims to see how employing lime peel powder could reduce corrosion and increase compressive strength in carbon steel mortar. Mortar samples were prepared with the addition of the different weights of carbon steel fillings and 10, 20, and 30 gm lime peel powder as a sand substituent. The samples were conducted to compressive strength test and corrosion rate by weight loss method. pH and salt concentrations were also studied as varying factors. The first group mortar samples were immersed in water for 7, 14, and 28 days, while the second group were immersed for 90, 150, and 210 days. Furthermore, the samples were immersed in different pH solutions of 3, 5, 7, 9, and 11 and different salt concentrations of 5% and 10% calcium carbonate for the same periods. The first group were dried and conducted to the compressive strength test, and the second group were conducted to corrosion rate test. The results showed that the best weights used to eliminate corrosion rate and improve the compressive strength of mortar samples were 5 g carbon steel filings and 20 g lime peels powder addition. The findings show that the corrosion rate and compressive strength of mortar samples increase as they spend more time in the water. The corrosion rate was increased in acidic and alkaline solutions, but its value was higher in acidic than in alkaline solutions. The less corrosion rate for all mortar samples immersed in different pH solutions was at pH 7. In addition, the mortar samples corrosion rate increased with increasing the salt concentration. The best compressive strength and corrosion rate values of carbon steel filings mortar samples were at pH 7and 5% salt concentrations at 28 and 90 days, respectively. The reasons of using lime peels powder are: 1) it is used as recycled waste material, 2) the adsorption of lime peel powder extract on the surface of the steel filling leads to the formation of a protective layer that inhibits the action of the corrosive solutions and this layer develops in thickness and effectiveness with time. In conclusion, the inhibiting efficiency of lime peels powder is not due to the antioxidant activity of its compounds but also to the precipitation of a surface film, which prevents or eliminates corrosion rate and improves compressive strength.

Keywords: Lime peels; Carbon steel; mortar; Corrosion; compressive; pH; salt.

1. Introduction

Numerous scientists have suggested several protection measures over the last centuries to delay, slow, or stop corrosion, extending the life span of structural concrete. Silica fumes, glass fibers, and corrosion inhibitors have all been offered to prevent steel corrosion in concrete[1].

The aggressive ions reach the surface of the reinforcement in the mortar and reinforced concrete, causing corrosion to begin. These ions flow via the pore network's water, and their mobility is determined by the cement matrix's porosity and permeability. Because corrosion of reinforcement reduces the strength of mortar and concrete, it directly impacts mortar mass pore structure, porosity, and pore size distribution[2].

Corrosion of materials is one of the most serious issues in the industry, resulting in significant financial consequences. Industrial shutdowns, wasting of precious resources, product loss, reduced productivity, higher operational demands, and excessive overdesign are consequences of corrosion. Pickling carbon, alloy, and stainless steel with hydrochloric acid eliminates corrosion and scaling but is unpleasant. Protection methods, techniques, and treatments could control corrosion depending on the corrosion mechanism. Organic inhibitors dissolved in the corrosive solution are an efficient option for reducing the aggressiveness of acidic media in metals[3].

Under typical circumstances, "mortars" and "concrete" including pozzolanic components have porosity values equivalent to or better than Ordinar

"*Corresponding author e-mail: randsalihfarhan@gmail.com
Received date 24 December 2021; revised date 10 January 2022; accepted date 02 February 2022
DOI: 10.21608/EJCHEM.2022.112803.5123

Portland Cement (OPC) Concrete. The features of pozzolanic materials, like fineness, ignition loss, metallurgy, chemical formula, and an essential element to highlight is the water/binder utilized, all influence the porosity progression. The pore size distribution, rather than overall porosity, is widely acknowledged as the most important component impacting the efficiency and durability of concrete structures. Microstructural, mechanical, and corrosion attitude investigations vary significantly due to the pore size variance. For varying weights of met kaolin, the outcomes of several experiments like “compressive strength”, “open circuit potential”, “resistivity”, “weight loss”, measurement of Ultra-Pulse Velocity (UPV), impressed voltage measurement, and water absorption investigations are listed[4].

Carbon steel is the primary prevalent engineering material used in pipes in the oil and gas sector. Even yet, throughout production operations like pickling, industrial cleaning, and descaling, it is targeted by the acid medium, which corrodes rapidly in the existence of acids. Acid media, particularly Hydrochloric Acid (HCl), are commonly employed to remove scale and salts from metal surfaces to clean containers and pipes in various industries. Coating, galvanizing, and painting processes may need this procedure. The acid solution might be treated by introducing certain organic inhibitors to limit metal dissolution and create physiochemical interaction at the metal surface by building a protecting film barrier[5].

Kathervel et al.[6] inspected the use of “Fly Ash”, “Rice Husk Ash (RHA)”, and “Limestone Powder” to substitute cement (LP). Many powders are gathered, and the usage of this by-product is a significant issue in terms of waste, environmental contamination, and health dangers. Binary blending (combining one Supplementary Cementitious Material “SCM” with cement) and ternary blending (utilizing two Supplementary Cementitious Materials “SCMs” with cement) have improved the efficiency of concrete. This study aims to find the best proportion of SCMs such as Fly Ash, RHA, and LP in a quaternary mix in respect of strength and durability. The quaternary combination enhances the compressive, tensile, and flexural strength, as well as the durability of the concrete, as expected.

El Hajjaji et al.[7] successfully prepared two “Pyridazine” derivatives, “1-Decylpyridazin-1-Ium iodide (DPI)” and “1-Tetradecylpyridazin-1-Ium iodide (TPI)”, and examined them as corrosion inhibitors for carbon steel in a 1 M Hydrochloric Acid (HCl) solution. Electrochemical impedance spectroscopy was used to assess the anticorrosion activity of these compounds at varying concentrations and temperatures (303–333K). At 10 3 M, the DPI and TPI both achieved 86.7 percent and 88.6 percent, respectively, according to the gathered data (303 K). The drop in TPI’s double-layer impedance has become more noticeable as the temperature rises. Both inhibitors followed the Langmuir adsorption isotherm when adsorbing to a mild steel surface. Following a 12-hour submersion duration, an inhibitory effect of 97.6% was found at the optimal concentration (103 M). The experimentally observed outcomes were validated by quantum chemical estimates depending on the DFT approach.

Lins et al.[8] studied the corrosion resistance of carbon and galvanized steel reinforcements when lime was incorporated into a cement mortar. Three different lime percentages were examined in mixed mortars. The preservation of water, the amount of absorbed air, and reinforced mortar compression strength were evaluated. The reinforced mortars were subjected to immersion testing that included 12 cycles of soaking in a 3.5 percent (wt/v) sodium chloride solution followed by drying in a 60oC stove. An electrochemical impedance spectroscopy was then used to assess reinforcement corrosion. They were repeated after 36 months of cyclic immersion testing. During cyclic immersion trials in saline solution, the polarization resistance of carbon and galvanized steel reinforcing increased with the amount of lime in mortar. Steels in mixed mortars with the greatest lime concentration had the least polarization resistance throughout 36 months. Following 36 months of cycle testing, the polarization resistance of carbon and galvanized steel in cement and blended mortars rose.

Binici[9] investigated how to make reinforced steel less corrosive. The research utilized Ordinar Portland Cement clinker, Ground Granulated Blast-Furnace Slag (GGBFS), and Powdered Basaltic Pumice to make the composite cement (GBP). Samples were weighted to measure the corrosion impacts in terms of weight loss. The sand was employed to create a 10 cm x 10 cm x 10 cm dimensions cubic construction. The structure was reinforced with four distorted and plain steel rounded bars. The concrete blocks were then immersed in natural saltwater. Concrete blocks were crushed after three years, and steel bars were removed. The bars’ surfaces are meticulously cleaned before being immersed in a 3 percent Hydrochloric Acid (HCl) solution. The corrosion rate was then calculated by weighing the reinforcement. When the rate of additives is raised, corrosion resistance improves. The corrosion of reinforcing steel is influenced by intergrading and separated grinding. Intergrading specimens show lesser corrosion than individual grinding samples. The fineness of cement and reinforcing corrosion have a tight connection. When the fineness of cement is increased, the rate of corrosion reduces.

In this article, I have summarized the current developments in organic and eco-friendly corrosion inhibitors utilized in acidic and salty environments, as well as potential future scope. Organic inhibitors that generate a hydrophobic coating on the metal surface protect it. The efficiency of these inhibitors is determined by their chemical composition, molecular structure, and surface affinity.

2. Experimental Methods

This section described the method of introducing the different weights of carbon steel fillings and Lime peels powder. The samples were tested by using the influence of adding carbon steel fillings and lime peels powder on mortar corrosion rate and compressive strength.

2.1. Chemicals and tools

The materials used in the current research are sand, cement, carbon steel, lime peels powder, “Hydrochloric Acid (HCl, 0.1 Molarity)”, “Sodium Hydroxide (NaOH, 0.1 Molarity)”, and “Calcium carbonate solution ($CaCO_3$)”. Mold and 1.20 mm size sieve were also used.

2.2. Mortar sample preparation

Samples are provided by mixing the materials cement, sand, carbon steel, and lime peels powder. Mortar and sand were mixed in a three to one ratio, and water was added to the mixture. Carbon steel and lime peels powder were added to the mortar in various weight percentages. Then the samples were submerged in water for some time. The immersion time for the first group was 7, 14, and 28 days, and for the second group was 90, 150, and 210 days. The samples were dried and to perform the compressive strength and corrosion rate tests, as shown in Figure 1.

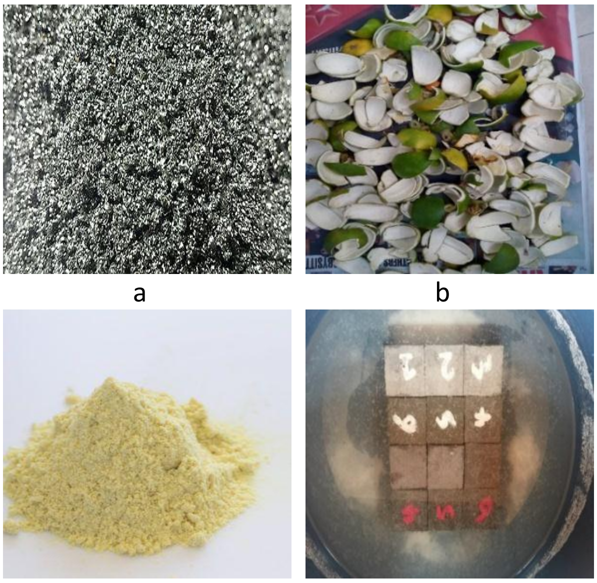

Figure 1. Materials used in the current research. a)- steel filling, b)- Lime peels, c) Lime peels powder, d) Mortar cubes

2.3. pH testing

The specimens were soaked in water with varying pH levels. The solutions were subjected to a pH measurement to assess the nature of every solution (“alkaline, neutral, or acidic”) and how every solution affects each sample’s corrosion rate and compressive strength.

The two groups of samples were cured in two salt concentrations ($CaCO_3$) solutions for 7, 14, and 28 days and 90, 150, and 210 days, respectively. Later, the samples were dried and weighted to find the corrosion rate values and evaluated by a compressive strength machine to know how they could be affected[10].

2.4. Corrosion Rate

The corrosion rate was estimated based on the weight difference before and after residence in water and the impact of the additive materials. The corrosion rate was calculated by the equation (1):

$$Corrosion\ rate\ \left(\frac{mm}{yr}\right) = \frac{W \times K}{\rho \times A \times T} \qquad (1)[11]$$

Where:

W = Weight loss (g),

K = A constant, it has no units and equals “8.76x104”.

ρ = Carbon steel density = (7.85 g/cm^3)

A= Cross-sectional area = (“5 cm x 5 cm = 25 cm^2 ”)

T = Time = (90, 150and 210 days).

2.5. Compressive Strength Test

The compressive strength of the different samples was estimated utilizing. The device capacity is 100KN.

The mortar samples were dried to perform the compressive strength experiment. Each sample was placed in the device to obtain the maximum load values for each group. Equation 2 shows the equation for calculating the compressive strength value.

$$Compressive\ strength\ (MPa) = \frac{Ultimate\ load\ (N)}{cross\ sectional\ area\ (mm2)} \qquad (2)\ [10]$$

3. Results

3.1. Impact of carbon steel filling and lime peel powder

The impact of adding the carbon steel fillings on the resulting compressive strength is illustrated in Figure 2. The figure shows the results of the first group of specimens immersed in water for 7, 14, and 28 days. The results show that the compressive strength increased when the placements spent more time immersed in water. This is attributed to the increase in the bonding forces of the cement mortar. In addition, the results show that the maximum compressive strength value was obtained when the carbon steel filling was 5 g for all immersion periods. Increasing the carbon steel fillings lead to decreased compressive strength. This decrease in the compressive strength is attributed to the caron steel fillings acting as inners that reduce the mortar bonding.

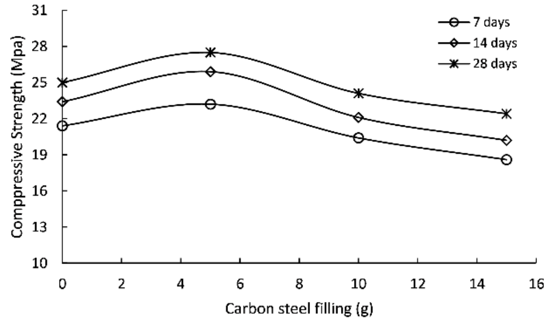

Figure 2. Impact of carbon steel filling on the compressive strength.

The corrosion rate study was performed for the second group of samples, which was immersed for 90, 150, and 210 days, and the results are provided in Figure 3. The outcomes revealed that increasing the steel carbon content led to an increase in the corrosion rate of the samples for all immersion periods. The results are expected as increasing the steel content lead to an increased corrosion rate. Because of this behavior, a corrosion impedance is needed. The lime peels powder is studied extensively in the current research for this purpose.

Different lime peel powders of 10, 20, and 30 g were added to the carbon steel mortar samples with the highest value of compressing strength value (5 g). the results show that the addition of the lime peel powder has a beneficial impact on the compressive strength of the samples. The compressive strength has an average increase of about 16%. Further, the results show that adding more than 20 g of lime peel powder decreased the compressive strength.

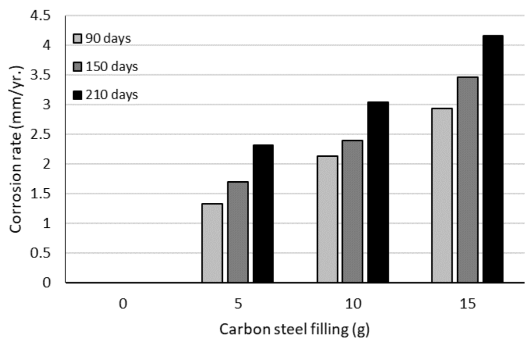

Figure 3. Impact of carbon steel filling on the corrosion rate.

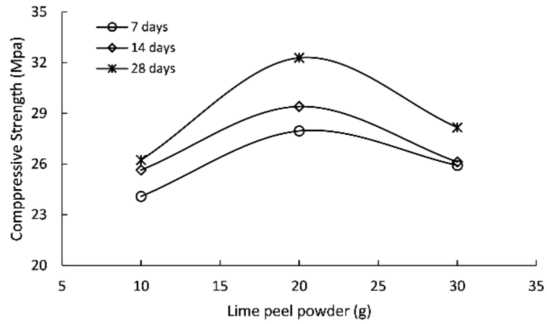

Figure 4. Impact of lime peel powder content on the compressive strength of carbon steel mortar.

The corrosion rate study was performed to investigate the impact of the lime peel powder on the samples immersed in water for 90, 150, and 210 days, as shown in Figure 3. The results show that the lime peel powder acts as a superior corrosion impedance. The corrosion rate was reduced by about 99% for the 20 g samples. The lime peel content of 10 and 30 g were also exhibited a reduction in corrosion rate.

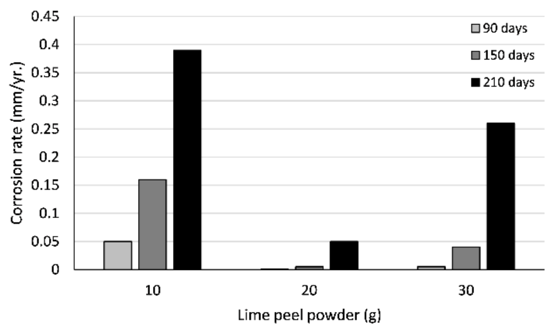

Figure 5. Impact of lime peel powder content on the corrosion rate of carbon steel mortar.

The above study revealed that the optimum improvement of the mortar was when adding 5 g carbon steel filling and 20 g lime peel powder. The current research would investigate the impact of pH and salt solution of this sample.

3.2. Impact of pH

The selected sample of 5 g carbon steel filling and 20 g of lime peels powder was further investigated for the pH test. The sample was immersed in different pH solutions of 3, 5, 7, 9 and 11. Each of these samples was left in water for “7, 14 and 28 days” and “90, 150 and 210 days”. Compressive strength and corrosion rate tests were tested for all samples to determine the optimal pH solution that provides the best carbon steel mortar properties. Figure 6 shows the impact of different pH solutions on the compressive strength. The neutral solution reveals the optimum compressive strength value for the three periods. The acidic and alkaline solutions reduce the compressive strength of the carbon steel mortar.

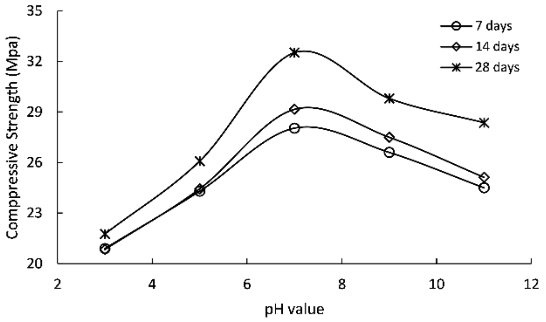

Figure 6.. Impact of pH value on the compressive strength of carbon steel mortar.

Alternatively, the corrosion rate test was performed for the samples immersed in the different pH solutions for 90, 150, and 210 days, as shown in Figure 7. The corrosion rate of the neutral solution shows the minimum corrosion rate of the carbon steel mortar. The mortar samples in the acidic and the alkaline solutions show a higher corrosion rate. In conclusion, the pH study reveals that the mortar sample of 5 g carbon steel filling and 20 g lime peel powder reveals the best compressive strength performance.

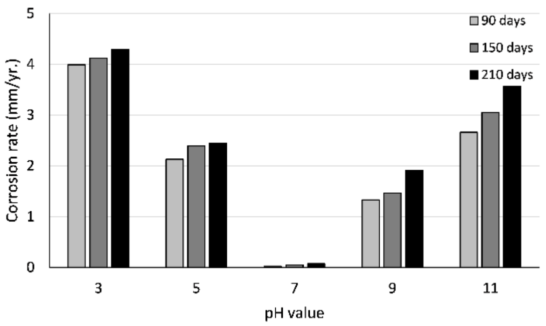

Figure 7. Impact of pH value on the corrosion rate of carbon steel mortar.

3.3. Impact of salt solution

The selected carbon steel mortar sample was tested in a 5% and 10% salt solution ($CaCO_3$) for the two immersion samples. The salty solution determined how the mortar sample could withstand the salt solution as some of the water used in construction in Iraq has salt content. The compressive strength test of the mortars is illustrated in Figure 8. The results show that the compressive strength increases with increasing immersion time (7, 14, and 28 days). This increase is attributed to the fact that spending more time in the water would increase the cement bonding of the mortar. However, increasing the salt concentration would decrease the compressive strength.

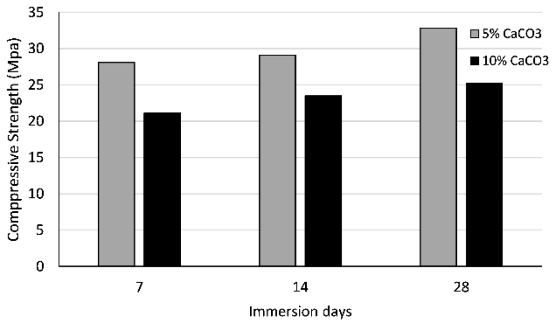

Figure 8. Impact of salt concentration on the compressive strength of carbon steel mortar.

Similar results were obtained for the corrosion rate of the samples immersed in longer time (90, 150, and 210 days) in the salty water. The corrosion rate increases with increasing the immersion days of the mortar samples. In addition, the corrosion rate increases obviously with increasing salt concentration from 5% to 10% as shown in Figure 9.

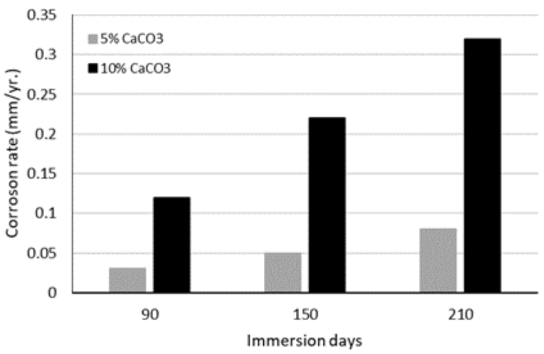

Figure 9. Impact of salt concentration on the corrosion rate of carbon steel mortar.

4. Conclusions

This study aims to research the effect of utilizing different weights of carbon steel fillers rather than sand and varied weights of lime peel powder on the corrosion rate and compressive strength of mortar. Two groups of mortar samples were prepared. The first group was immersed in water for 7, 14, and 28 days and subjected to compressive strength tests. The second group was submerged in water for 90, 150, and 210 days and was subject to a corrosion rate test. The sample had 5 g carbon steel filling and 20 g lime peel powder with the best compressive strength and corrosion rate properties. This sample was further tested for pH and salt concentration to investigate the optimum operating condition. The pH test reveals that the best compressive strength was at neutral pH (pH equal to 7), and the acidic and alkaline environments cause a reduction in compressive strength. Moreover, the rate of corrosion was reduced at neutral conditions. The samples were also tested in salt solutions of 5% and 10% of ($CaCO_3$). The results show that the corrosion rate increases with increasing the immersion days of the mortar samples, and the corrosion rate increases obviously with increasing salt concentration from 5% to 10%. In conclusion, the inhibiting efficiency of lime peels powder is not due to the antioxidant activity of its compounds but also to the precipitation of a surface film, which prevents or eliminates corrosion rate and improves compressive strength.

5. Acknowledgment

The authors gratefully acknowledge support from Mustansiriyah University (www.uomustansiriyah.edu.iq). This work is supported by the Structure Laboratory, Automated Testing Laboratory and Chemistry Laboratory in College of engineering/ Mustansiriyah University-Baghdad-Iraq.

6. References

[1]. S. A. A. and Ismail M., Evaluation of corrosion inhibiting admixtures for steel reinforcement in concrete. *International Journal of the Physical Sciences*. **7**(1): p. 139-143(2012)

[2]. Pellegrini-Cervantes M. J., Almeraya-Calderon F., Borunda-Terrazas A., Bautista-Margulis R. G., Chacón-Nava J. G., Fajardo-San-Miguel G., Almaral-Sanchez J. L., Barrios-Durstewitz C. P., and Martinez-Villafañe A., Corrosion Resistance, Porosity and Strength of Blended Portland Cement Mortar Containing Rice Husk Ash And Nano SiO. *International Journal of Electrochem Science*. **8**: p. 10697-10710(2013)

[3]. Gutiérrez E., Rodríguez J. A., Cruz-Borbolla J., Alvarado-Rodríguez J. G., and Thangarasu P., Development of a predictive model for corrosion inhibition of carbon steel by imidazole and benzimidazole derivatives. *Corrosion Science*. **108**: p. 23-35(2016)

[4]. Parande A. K., Ramesh Babu B., Aswin Karthik M., Deepak Kumaar K. K., and Palaniswamy N., Study on strength and corrosion performance for steel embedded in metakaolin blended concrete/mortar. *Construction and Building Materials*. **22**(3): p. 127-134(2008)

[5]. Ghalib L., Al Jaaf H. J. M., and Abdulghani H. A., Temperature effect on the efficiency of Eucalyptus Camaldulensis leaves in the acid corrosion of carbon steel. *Materials Today: Proceedings*. **42**: p. 2475-2481(2021)

[6]. Kathirvel P., Saraswathy V., Karthik S., and Sekar A. S. S., Strength and Durability Properties of Quaternary Cement Concrete Made with Fly Ash, Rice Husk Ash and Limestone Powder. *Arabian Journal for Science and Engineering*. **38**: p. 589-598(2013)

[7]. El Hajjaji F., Salim R., Messali M., Hammouti B., Chauhan D. S., Almutairi S. M., and Quraishi M. A., Electrochemical Studies on New Pyridazinium Derivatives as Corrosion Inhibitors of Carbon Steel in Acidic Medium. *Journal of Bio- and Tribo-Corrosion*. **5**(1): p. 4(2018)

[8]. Lins V. d. F. C., Oliveira M. C. C. d., Costa C. G. F., and Araujo C. R., Lime Addition Effect on Corrosion of Reinforced Mortar. *revista Matéria*. **24**(3)(2019)

[9]. Binici H., The effect of cement type on corrosion resistance of reinforcement. *RCEE Research in Civil and Environmental Engineering* **2**(4): p. 181-189(2020)

[10]. Jafar Meerza Al Jaaf H., Abed Al-wahab Ali M., and Salih Al-Jadiri R., Effect of pH Solutions on Using Waste Marble powder to Enhance Mortar Compressive Strength. *IOP Conference Series: Materials Science and Engineering*. **561**(1): p. 012130(2019).

[11] Hashim, F., et al., Experimental and Theoretical Approach to the Corrosion Inhibition of Mild Steel in HCl Solution by a Newly Coumarin. Proceedings, 2019. 41(1).