CORROSION RESISTANCE PROPERTY OF AN AQUEOUS EXTRACT OF ASAFOETIDA ON MILD STEEL IN SIMULATED CONCRETE PORE SOLUTION PREPARED IN WELL WATER

S. Shanmugapriya[1], S. Rajendran [2], P.Prabhakar [3], N. Karthiga[4]
[1] ,Department of Chemistry, Madha Engineering College, Kundrathur, Chennai, India.
[2] Corrosion Research Centre ,Department of Chemistry, St Antony's College of Arts and Sciences for Women, Dindigul – 624005,Tamil Nadu, India,
[3] Department of Chemistry, APA College of Arts and Culture, Palani, India
[4] Department of Chemistry, SBM college of Engineering and Technology, Dindigul, India

Abstract: Plant extracts have become significant environmentally suitable, readily available and renewable resource for extensive variety of inhibitors. In general, the plant extracts are inhibitors with elevated inhibition efficiency and of non-toxic eco friendly substance. Corrosion resistance property of mild steel immersed in simulated concrete pore solution (SCPS) prepared in well water has been evaluated by various studies, in the absence and presence of an aqueous extract of Asafoetida. The corrosion inhibition property is studied by weight loss method, UV spectra have been used to analyse the protective film. SEM and AFM studies have been employed to examine the surface morphology. Thus the corrosion resistance of mild steel incorporated in concrete structure can be improved by addition of an aqueous extract of Asafoetida. This green technology will be useful in construction technology.

Key words: *corrosion inhibition, mild steel, simulated concrete pore solution, Asafoetida extract, green inhibitors.*

1 INTRODUCTION

Corrosion is the damage or descent of metal surface by chemical interface with their surroundings in reinforced concrete structures. The most widely used metal is steel. Corrosion can cause terrible damage to metal and alloy structures causing economic loss in terms of repair, replacement, product losses, safety, and environmental pollution. Due to these harmful effects, corrosion is a disagreeable phenomenon [1]. The use of inhibitors for the control of corrosion of metals and alloys which are in contact with aggressive environment is one in the middle of the suitable practices used to reduce an/or avoid corrosion. A corrosion inhibitor is a substance which, when added in small concentration to an environment, effectively reduces the corrosion rate of a metal exposed to that environment. Corrosion inhibitors can be divided into two broad categories, namely, chemical and natural inhibitors Plants are sources of naturally occurring compounds [2-5], some with complex molecular structures and having different chemical, biological, and physical properties. The naturally occurring compounds are mostly used because they are eco-friendly, readily available, economical and readily available. These advantages are the reason for use of extracts of plants and their products as corrosion inhibitors for metals and alloys under different environment conditions. Different parts of plant extracts are used as corrosion inhibitors and they are commonly known as green corrosion inhibitors. Nowadays need for growing corrosion inhibitors becomes increasingly necessary to stop or delay the attack of a metal by corrosion. Substantial efforts are made to find appropriate compounds to be used as corrosion inhibitors in various corrosive media. Many works were conducted to examine extracts from naturally substances [6-10]. So in this work we have taken Asafoetida a natural product as our corrosion inhibitor.

METHODS AND RESULTS

2.1Analysis of results of the weight loss method

The rate of corrosion has been calculated by weight loss method.[11-14].The calculated inhibition efficiencies(IE) and corrosion rates(CR) of asafoetida extract in controlling corrosion of mild steel immersed in simulated concrete pore solution(SCPS) for a period of one day in aqueous extract of asafoetida is given in Table 1.

Table 1: **Inhibition Efficiency (IE%) and Corrosion rate (CR) obtained from asafoetida system in controlling corrosion of mild steel immersed in Simulated Concrete Pore Solution (SCPS) prepared in well water**

Corrosion rate in well water = 49.72 mdd

Asafoetida Extract in SCPS ml	Corrosion rate mdd	Inhibition Efficiency(IE) %
0	9.45	81
2	24.36	51
4	19.39	61
6	13.92	72
8	9.446	81
10	3.997	92

Various concentrations of the aqueous extract of asafoetida (2ml, 4ml, 6ml, 8ml, and 10ml) were added to the SCPS system. The corrosion inhibition effectiveness slowly increased. The maximum inhibition efficiency was found to be 92%.Thus it is observed that when 10 ml of asafoetida extract is added to SCPS, the inhibition efficiency increases from 81%to 92%.First the inhibition efficiency decreases and then it increases. This may be due to the fact that in the initial state the protective film formed is unstable and then in later cases the protective film formed is more stable.

2.2 UV-visible absorption spectra

UV-visible absorption study has been widely used in corrosion inhibition studies. [15-19]. The UV-visible absorption spectrum of an aqueous extract of asafoetida is shown in Fig 1(a). A peak appears at 380.0nm. The UV-visible absorption spectrum of an aqueous solution containing extract of asafoetida in SCPS and Fe^{2+} ($FeSO_4.7H_2O$ solution freshly prepared) is shown in Fig 1(b). Peaks appear at 276.0 nm and 372nm. There is shift in the position of the peak. There is change in absorbance value also. This confirms the formation of complex in the solution. This probably consists of Fe^{2+}- umbelliferone complex in solution.

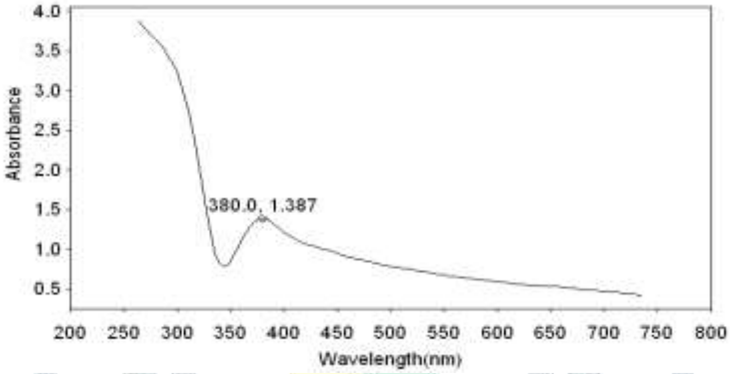


Fig 1(a): uv-visible spectrum of asafoetida extract

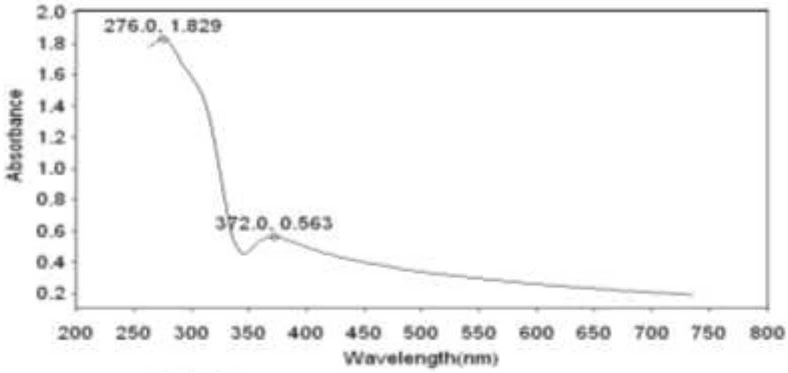


Fig 1(b) uv-visible spectrum of Fe^{2+} **- asafoetida extract in SCPS**

2.3. Fluorescence spectra:

Fluorescence spectra have been used in corrosion inhibition study by many researchers [20–25].The fluorescence spectrum (λ_{ex} = 300 nm) of a solution containing Fe^{2+} and aqueous extract of asafoetida is shown in Fig 2(a). A peak appears at 374 nm. This peak corresponds to Fe^{2+}- asafoetida complex in solution. There is UV emission. The fluorescence spectrum (λ_{ex} =300 nm) of the film formed on the metal surface after immersion in the solution consisting of SCPS and asafoetida extract is shown in Fig 2(b). A peak appears at 374 nm. This peak matches with the peak of Fe^{2+}- umbelliferone complex. Thus it is confirmed that the protective film consists of Fe^{2+}- umbelliferone complex is formed on the metal surface. It is observed that the intensity of the fluorescence spectrum in metal is higher (8080.396) than the intensity of the fluorescence spectrum formed in solution (3492.415).This can be explained by the fact that in the solid state (protective film) the electronic transition is restricted than in solution. So the intensity of fluorescence spectrum of the protective film decreases.

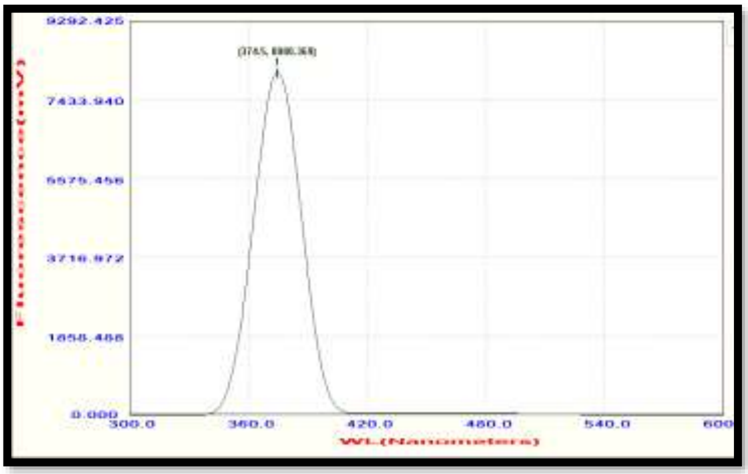


Fig 2 (a): Fluorescence spectra λ ex =300 nm (a) Fe^{2+} + asafoetida extract

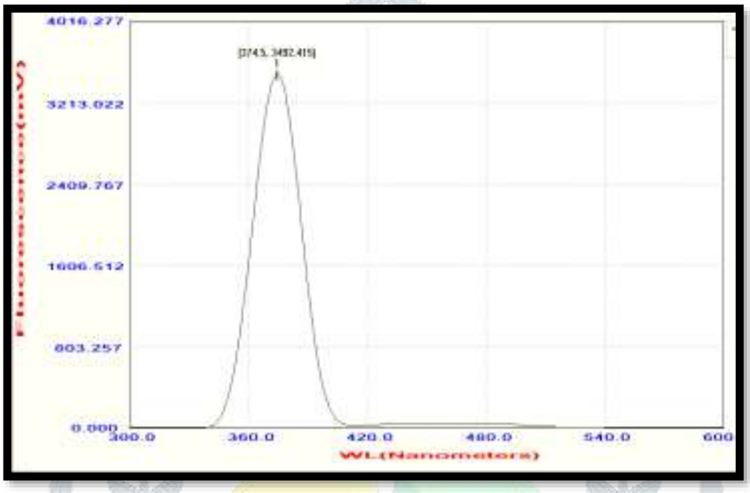
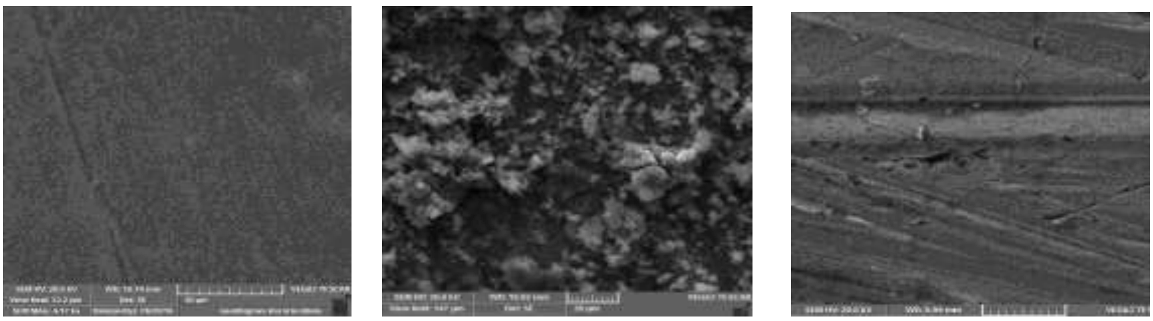


Fig 2(b); Film formed on metal surface after immersion in the SCPS solution containing 10 ml of asafoetida extract

2.4 Scanning Electron Microscopic Studies (SEM) analysis of Metal Surface

The SEM images of various surfaces are shown in Fig:3. The SEM image of polished metal is shown in Fig 3(a). The SEM image of polished metal immersed in well water is shown in Fig: 3 (b). The SEM image of the metal immersed in SCPS and inhibitor system is shown in Fig: 3 (c). The SEM image of polished metal is smooth. The SEM image of the metal in well water is found to be rough and the pits are visible on the metal surface. The SEM image of the metal in SCPS and inhibitor system is smooth due to the formation of protective film. Thus SEM study is useful to know the smoothness of the protective film. [26-28].



(a) (b) (c)

Fig 3: SEM micrographs of (a) Polished mild steel, (b) Mild steel in well water (c) Mild steel in SCPS+10 ml inhibitor system

2.5 AFM studies

The AFM image of mild steel immersed in SCPS and Asafoetida extract is shown in Fig 4. The 2D AFM images of polished metal surface, corroded surface (immersed in SCPS prepared in well water) and the film protected metal(SCPS +inhibitor solution) are shown in Fig 5. The AFM parameters RMS (Rq) roughness (nm), Average (Ra) roughness (nm) and maximum peak to valley height (nm) were calculated.[29-30] These values are given in Table for polished mild steel, mild steel immersed in SCPS and mild steel in SCPS+ Asafoetida extract.

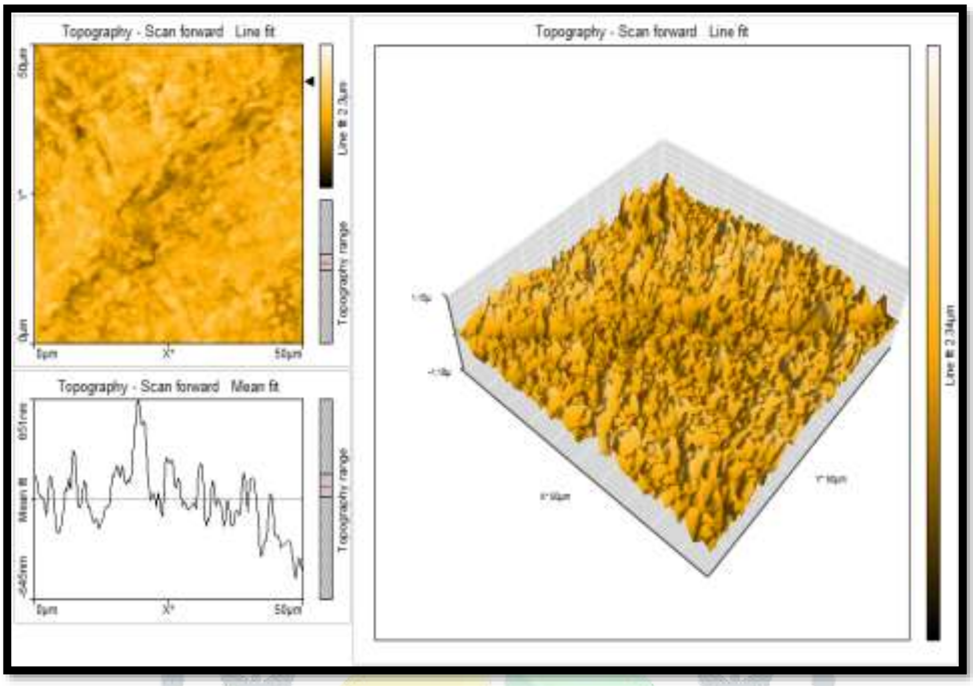


Fig 4: AFM images of of mild steel in SCPS and Asafoetida extract

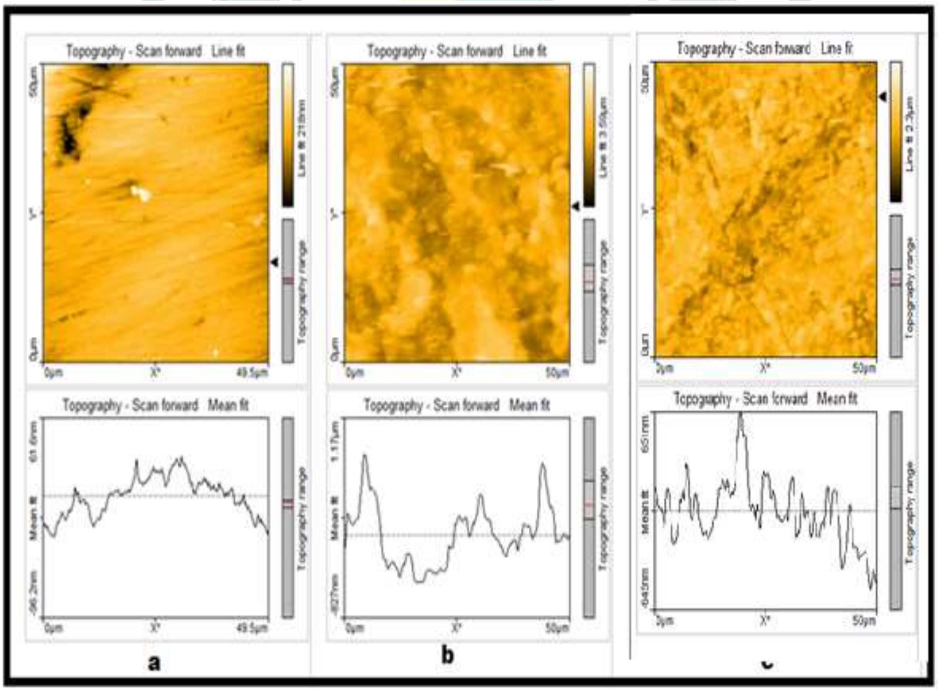


Fig 5: **Two dimensional AFM images of (a) polished metal surface (b) metal immersed in SCPS (c) metal surface immersed in SCPS and Asafoetida extract**

Table 2: AFM STUDY VALUES

Sample	RMS Roughness (R_q) (nm)	Average Roughness (R_a)(nm)	Maximum peak-to- valley height (R_y) (nm)
Polished metal	13.833	11.485	72.147
Metal immersed in well water	541.76	406.56	2674
Mild steel immersed in SCPS	350.09	227.9	2113
Mild steel immersed in SCPS and 10 ml of Asafoetida extract	181.3	140.05	882.25

It is observed from the Table 2, for polished mild steel, the RMS roughness is 13.833 nm. The average roughness is 11.485 nm. The maximum peak-to-valley height is 72.147 nm. Analysis of Table5 reveals that the RMS roughness value for mild steel immersed in SCPS is higher than that of polished mild steel. This indicates that due to corrosion, thick nanofilm is formed on the metal surface. Similar is the case with average roughness and maximum peak -to-valley height.

For the metal immersed in inhibitor system, the RMS roughness 181.3 nm. This is higher than that of polished metal, but lower than that of metal immersed in corrosive medium. Similar is the case with average roughness value (140.05 nm) and maximum peak-to-valley height (882.25 nm). This indicates that a protective film of nanometer scale is formed on the metal surface. This film protects the metal from corrosion.

CONCLUSIONS

- Corrosion resistance of mild steel immersed in simulated concrete pore solution (SCPS) prepared in well water has been evaluated by weight loss method, in the absence and presence of an aqueous extract of asafoetida, a green corrosion inhibitor.
- The corrosion resistance property of asafoetida is also confirmed by uv and fluorescence spectral studies
- The smoothness of the surface is revealed by AFM and SEM studies.
- Thus it is observed that in the presence of a green inhibitor the corrosion resistance of mild steel incorporated in concrete structure increases.
- Thus the corrosion resistance of mild steel incorporated in concrete structure can be improved by addition of an aqueous extract of Asafoetida. This eco-friendly technology will be useful in construction technology.

ACKNOWLEDGMENT

The authors are thankful to their respective management for their help and support

REFERENCES

[1] Sivaraju, .P.K and Arulanantham.A (2010) "Inhibitive properties of plant extract (Acalypha indica L.)on mild steel corrosion in 1N phosphoric acid". International Journal of ChemTech Research 2(2),.

[2] Qurasishi M.A. (2004), "Naturally occurring products as corrosion inhibitors", NACE Meeting papers,.

[3] de Souza F.S., Spinelli A. (2009),, "Caffeic acid as a green corrosion inhibitor in mild steel", Corrosion science, Volume 51, issue 3, March pp.642-649.

[4] Sivaraju.M, Kannan.K, (2010) "Eco-friendly inhibitor (Tributes terrestris L) for mild steel corrosion in 1N Phosphoric acid". Asian Journal of Chemistry 22(1), , pp.233-244.

[5] Kasthuri P.K., Arulanantham A., (2010) "Eco-friendly extract of Euphorbia hirta as corrosion inhibitor on mild steel in sulphuric acid medium". Asian Journal of Chemistry 22(1), , pp.430-434.

[6] P.K.Sivaraju, A.Arulanantham, "Inhibitive properties of plant extract (Acalypha indica L.)on mild steel corrosion in 1N phosphoric acid". International Journal of ChemTech Research 2(2), (2010).

[7] Al-Turkustani A.M., Arab S.T., (2010), “The use of Ruta chalepensias corrosion inhibitor for steel corrosion in 2M sulphuric acid solution”. Oriental Journal of Chemistry 26(2), pp.437-454.
[8] Satapathy A.K.,.Gunasekaran G ,(2009), “Corrosion inhibition by Justicia gendarussa plant extract in hydrochloric acid solution”. Corrosion Science 51(12), pp.2848-2856.
[9] Sivaraju V, Kannan K., (2010), “Eco-friendly inhibitor (Tributes terrestris L) for mild steel corrosion in 1N Phosphoric acid”. Asian Journal of Chemistry 22(1), pp.233-244.
[10] Kasthuri P.K., Arulanantham, A. (2010), “Eco-friendly extract of Euphorbia hirta as corrosion inhibitor on mild steel in sulphuric acid medium”. Asian Journal of Chemistry 22(1), pp.430-434.
[11] Sivaraju P.K.,.Arulanantham, A (2010) “Inhibitive properties of plant extract (Acalypha indica L.) on mild steel corrosion in 1N phosphoric acid”. International Journal of ChemTech Research 2(2),.
[12] Al-Turkustani,.Arab S.T, L.S.S.Al-Qarni, “The use of Ruta chalepensias corrosion inhibitor for steel corrosion in 2M sulphuric acid solution”. Oriental Journal of Chemistry 26(2), (2010), pp.437-454.
[13] Satapathy A.K.,.Gunasekaran G, (2009) “Corrosion inhibition by Justicia gendarussa plant extract in hydrochloric acid solution”. Corrosion Science 51(12), pp.2848-2856.
[14] Sethuram M.G. Raja ,P.B., (2005), “Corrosion inhibition of mild steel by Datura metal in acidic medium”. Pigment and Resin Technology 34(6), pp.347-352.
[15] Okafor P.C., U.J.Ekpe U.J., (2005), “Inhibition of mild steel corrosion in acidic medium by Allium sativum extracts”. Bulletin of Electrochemistry 21(8), pp.347-352.
[16] Rajenderan S.Shanmugapriya S., (2005), “Corrosion inhibition by an aqueous extract of rhizome powder”. Corrosion 61(7), pp.685-692.
[17] Priya S.L., Chitra A., (2005), “Corrosion behaviour of aluminium in rain water containing garlic extract”. Surface Engineering 21(3), pp.229-231.
[18] Ananda Louise Sathyanathan R., Essa M.M., (2005), “Corrosion inhibition of mild steel by ethanolic of Ricinus communis leaves”. Indian Journal of Chemical Technology 12(3), (2005), pp.356-360.
[19] Ananda Louise Sathyanathan R., Essa M.M., (2005), “Inhibitory effect of Ricinus communis (Castro-oil plant) leaf extract on corrosion of mild steel in low chloride medium”. Journal of the Indian Chemical Society 82(4), pp.357-395.
[20] El-Etre A.Y., Abdallah M., (2005), “Corrosion inhibition of some metals using lawsonia extract”. Corrosion Science 47(2), pp.385- 395.
[21] Jain T., Chowdhary R., (2005) “Corrosion inhibition of aluminum in hydrochloric acid solutions by peepal (Ficus Religeosa) extracts”. Bulletin of Electrochemistry 21(1), pp.23-27
[22].Buchweishaija I, Mhinzi G.S., (2008), “Natural products as a source of environmentally friendly corrosion inhibitors: The case of gum exudates from Acacia seyal var.Seyal”. Portugaliae Electrochimica Acta 26(3), pp.257-265.
[23] kaforP.C.O, Uwah O.O., (2009), “Combretum bracteosum extracts as eco-friendly corrosion inhibitor for mild steel in acidic medium”. Pigment and Resin Technology 38(4), pp.236-241.
[24] Obot I.B, Obi-Egbedi N.O., (2009), “A new efficient and effective eco-friendly corrosion inhibitor for aluminium alloy of type AA 1060 in hydrochloric acid solution”. International Journal of Electrochemical Science 4(9), pp.1277- 1288.
[25] Umoren S.A., Obot I.B., (2008), “Adsorption and corrosive inhibitive properties of Vigna unguiculata in alkaline and acidic media”. Pigment and Resin Technology 37(2), pp.98-105.
[26]. Wang, X.-P., Guan, Z.-C., Wang, X., Wang, H.-P., Du, R.-G.2017ECS Transactions80(10), pp. 655-661
[27]Bensabra, H., Franczak, A., Aaboubi, O., Azzouz, N., Chopart, J.-P.2017Metallurgical and Materials Transactions A: Physical Metallurgy and Materials Science48(1), pp. 412-424
[28].Verbruggen, H., Terryn, H., De Graeve, I.2016Construction and Building Materials124, pp. 887-896
[29]Yu, Q.-J., Fei, F.-L., Wei, J.-X., Hu, J., Ai, Z.-Y. 2012 Huanan Ligong Daxue Xuebao/Journal of South China University of Technology (Natural Science)40(10), pp. 134-141.
[30]Zhou, X., Yang, H.-Y., Wang, F.-H.2010Corrosion Science and Protection Technology22(4), pp. 343-347