Electrochemical Evaluation of AISI 304 SS and Galvanized Steel in Ternary Ecological Concrete based on Sugar Cane Bagasse Ash and Silica Fume (SCBA-SF) exposed to Na2SO4

Miguel Angel Baltazar-Zamora, Hilda Ariza-Figueroa, Laura Landa-Ruiz, and René Croche

Abstract—In the present research, was studied the electrochemical behavior of AISI 304 stainless steel and Galvanized Steel embedded in Ternary Ecological Concrete made with partial substitution of Portland Cement (PC) by combination of Sugar Cane Bagasse Ash and Silica Fume (SCBA-SF) in 10, 20 and 30% and exposed to a 3.5% solution of Na2SO4 as an aggressive medium. For the design of the concrete mixtures was used ACI 211.1 method. Quality control tests of fresh and hardened concrete were carried out in accordance with the ONNCCE and ASTM standards. The electrochemical evaluation was carried out for a period of 6 months, using the techniques of corrosion potential Ecorr (ASTM C-876-15) and Linear Polarization Resistance-LPR (ASTM G59) to determine the corrosion rate Icorr. The results indicate that AISI 304 SS has a high corrosion resistance from the curing stage to the end of monitoring, with values of Ecorr lower than -200 mV and negligible corrosion levels with values of Icorr below 0.1 µA/cm², greater protection is identified in the Ternary Ecological Concrete with replacement of 30% of PC by SCBA-SF.

Index Terms—Corrosion, Ecological Concrete AISI 304, Galvanized Steel, SCBA-SF, Sulfates.

I. INTRODUCTION

Corrosion is a phenomenon that destructively attacks reinforced concrete structures, being one of the main factors causing the reduction or shortening of their useful life, durability and operation [1-2]. This problem is due to the exposure of structures in environments where aggressive or deactivating ions such as sulfates and chlorides are found. [3-4]. It is known that the problem of corrosion in reinforced structures is for the community responsible for such civil works a problem of billions of dollars, however, in Mexico there are no data to give us an idea of the problem [5-6]. Among the causes causing the onset of corrosion are sulphates ions. The presence of sulphates in water that is in contact with a hardened cement paste, can considerably increase solubility of the components of such paste and cause, on the one hand, the development of the degradation of concrete by leaching and on the other hand the steel is left unprotected and that is where the corrosion process is triggered [7-8].

The objective of present research is to evaluate the corrosion behavior of bars of Galvanized Steel and AISI 304 stainless steel embedded in Conventional Concrete (CC) and Ecological Concrete (EC) made with partial substitution of Portland Cement (PC) by combinations of Sugar Cane Bagasse Ash (SCBA) and Silica Fume (SF) in different percentages (10%, 20% and 30%), agroindustrial and industrial waste of pozzolanic characteristics as indicated in various investigations [9-10].

All specimens of four concrete mixtures CC and TEC were exposed in sodium sulphates solution at 3.5%, as an aggressive medium.

II. MATERIALS AND METHODS

A. Materials

1) Materials used in the Dosage and proportion of Concrete Mixtures

| TABLE I | SUMMARY OF AGGREGATE CHARACTERIZATION RESULTS |
|---------|-----------------------------------------------|
| Physical properties of materials | Coarse aggregate | Fine aggregate |
| Specific Mass (MES) g/cm³ | 2.60 | 2.20 |
| Bulk Volumetric Mass (BVM) Kg / cm³ | 1332 | 1442 |
| Absorption (%) | 1.7 | 1.8 |
| Module of Fineness | - | 2.94 |
| Maximum Size Nominal (TMN) | ¾" | - |

The dosage of the concrete mixtures, Comun Concrete (CC) and Ternary Ecological Concrete (TEC) was carried out according to the ACI 211.1 [11], which is based on the physical characteristics of the aggregates fine and coarse. Table I shows the results of the physical characterization of the aggregates used in the present study, the tests were performed according to the ONNCCE standards.

2) Dosage of Sustainable Concrete mixtures.

For the dosing of the four concrete mixtures (MC, M10, M20, M30), a ratio w/c = 0.65 was used. Table II shows the dosage for a 1m³ of concrete.

DOI: http://dx.doi.org/10.24018/ejers.2020.5.3.1852

Published on March 27, 2020.

M. A. Baltazar-Zamora is Research Professor of Universidad Veracruzana, Facultad de Ingeniería Civil – Xalapa, Xalapa, Veracruz, México (email: mbaltazar@uv.mx)

H. Ariza-Figueroa is a PhD student, Universidad Veracruzana, FIME, Xalapa, Veracruz, México (email: hilda_af@hotmail.com)

L. Landa-Ruiz is Academic Technician of Universidad Veracruzana, Facultad de Ingeniería Civil – Xalapa, Xalapa, Veracruz, México (email: lalanda@uv.mx)

R. Croche is Research Professor of Universidad Veracruzana, Facultad de Ingeniería Mecánica y Eléctrica – Xalapa, Xalapa, Veracruz, México (email: recroche@uv.mx)
TABLE II: DOSAGE OF CONCRETE MIXTURES IN KG FOR 1 m³

| Materials                  | MC | M10 | M20 | M30 |
|----------------------------|----|-----|-----|-----|
| Portland Cement            | 315| 283.5| 252 | 220.5|
| Sugar Cane Bagasse Ash     | -  | 15.75| 31.50| 47.25|
| Silica Fume                | -  | 15.75| 31.50| 47.25|
| Water                      | 205| 205 | 205 | 205 |
| Fine aggregate             | 746| 746 | 746 | 746 |
| Coarse aggregate           | 881| 881 | 881 | 881 |

B. Method

1) Characterization of Fresh and Hardened of Ternary Ecological Concretes

According to the ONNCCE and ASTM standards [12-15], the characteristics of the fresh state concrete and its mechanical strength (Hardened Concrete) were determined. See Table III.

TABLE III: PHYSICAL AND MECHANICAL PROPERTIES OF TERNARY ECOLOGICAL CONCRETES MIXTURES.

| TEST           | MC | M10 | M20 | M30 |
|----------------|----|-----|-----|-----|
| Slump (cm)     | 7  | 6   | 5.5 | 5   |
| Temperature (°C)| 24 | 23.5| 23.5| 22.5|
| Density (kg/m³)| 2345.83| 2307.29| 2301.04| 2296.04|
| F’c (Kg/cm²)   | 317.84| 291.84| 305.91| 245.44|

2) Characteristics of the reinforcement bars

AISI 304 SS and Galvanized steel bars were used as reinforcement in the study specimens made with Comun Concrete and Ternary Ecological Concretes. Each of the bars were placed 5 cm paint at the top and 5 cm at the bottom, in order to delimit the area of exposure to corrosion of steel in concrete with a length of 5 cm, see Fig. 1, as they have reported other researchers [16-18]. All specimens were made according to standard ASTM C 192 [19].

Fig. 1. Specifications bars of AISI 316 SS and Galvanized Steel

3) Nomenclature of study specimens

The nomenclature used to keep track of the electrochemical monitoring of $E_{corr}$ and $I_{corr}$ of and AISI 304 and Galvanized Steel as reinforcement in Ternary Ecological Concrete exposed to sodium sulfate as aggressive medium, is shown in Table IV.

TABLE IV: NOMENCLATURE CORROSION TEST.

| NOMENCLATURE | MC-GAL | MC-304 | M10-GAL | M10-304 | M20-GAL | M20-304 | M30-GAL | M30-304 |
|--------------|--------|--------|---------|---------|---------|---------|---------|---------|
| MC: Mixture Control made with 100% CP |
| M10: Mixture made with 90% CP, 10% SCBA-SF |
| M20: Mixture made with 80% CP, 20% SCBA-SF |
| M30: Mixture made with 70% CP, 30% SCBA-SF |
| GAL: Galvanized Steel |
| 304: AISI 304 Stainless Steel |

4) Electrochemical cell

For the evaluation of corrosion, galvanized steel bars and steel AISI 304 were embedded in each study specimen, these steel bars were used as working electrode (WE), a third bar of AISI 304 steel and 1/8” diameter, was also embedded as an auxiliary electrode (AE), and using a standar copper-copper sulfate (Cu/CuSO₄) as reference electrode (RE), this type of arrangement or electrochemical cell, allows to evaluate the corrosion current density ($I_{corr}$) by the technique of linear polarization resistance (LPR) as indicated by the ASTM-G59 standard [20], see Fig. 2. The tests were performed with equipment Gill AC Galvanostat/Potentiostat/ZRA from ACM Instruments, as they have done in different investigations [21-25].

Fig. 2. Electrochemical cell for the monitoring of Corrosion Current Density ($I_{corr}$).

III. RESULTS AND DISCUSSION

A. Corrosion potential ($E_{corr}$)

The standard ASTM C876-15 [26], considering a more interval according to the literature [27], was used to perform the monitoring of the corrosion potential ($E_{corr}$) and interpretation of the probability of corrosion (see Table V).

TABLE V: CORROSION POTENTIAL IN REINFORCED CONCRETE ($E_{corr}$).

| Corrosion potentials mV vs Cu/CuSO₄ | <= 500  | < -350 | -350 to -200 | > -200 |
|-----------------------------------|--------|--------|--------------|--------|
| Severe corrosion                   | 90% Probability of Corrosion |
| Uncertainty                        | 10% Probability of Corrosion |

1) $E_{corr}$ behavior AISI 304 SS and Galvanized Steel in control medium

The Fig. 3 present $E_{corr}$ values of galvanized steel and the AISI 304 Stainless steel embedded in the four concrete...
mixtures. In the curing stage all specimens with bars of AISI 304 present corrosion potential of -144 mV to -86 mV at 90 days, this values of $E_{corr}$ indicate 10% probability of corrosion, maintains a trend of values up to 180 days. In the case of specimens with galvanized steel, during the days of curing stage the MC-GAL, M20-GAL and M30-GAL presented $E_{corr}$ values from a range of -610 mV to -463 mV, however the MC-10 specimen presented $E_{corr}$ values in the curing stage of -765 mV a -755 mV. All the specimens after the curing stage presented $E_{corr}$ values with a tendency to more positive reaching values of -340 mV and 435 mV for day 90, to continue with the trend and end the monitoring period with $E_{corr}$ values between -290 mV and -340 mV, indicating according to ASTM C-876-15, uncertainty of the presence of corrosion.

2) $E_{corr}$ behavior AISI 304 SS and Galvanized Steel in $Na_2SO_4$

In Fig. 4 show the performance of galvanized steel and AISI 304 stainless steel 304 in the presence sodium sulphates. All the specimens with bars of AISI 304, MC-304, M10-304, M20-304 and M30-304, show the tendency from more negative to more positive values in the curing stage, going from -180 mV a -100 mV, to present during the entire period of exposure to sodium sulphates., $E_{corr}$ values more positive than -100 mV, indicating a 10% probability of corrosion or passivity of the steel, in agreement to ASTM C-876-15 standard. In the case of specimens with galvanized steel as reinforcement, MC-GAL, M10-GAL, M20-GAL and M30-GAL, they also have a tendency towards more positive corrosion potential values from the curing stage, going from values from -630 mV to -482 mV for day 28, continuing with a very homogeneous trend in all specimens, presenting throughout the period of exposure to sulfate of sodium, stable $E_{corr}$ values in a range of -360 to -380 mV, indicating according to ASTM C-876-15, 90% probability of corrosion, evidencing the sulfate attack when comparing the values of $E_{corr}$ reported in the control environment, see Fig. 3.

B. Corrosion Current Density ($I_{corr}$)

The criteria of the the DURAR Network Manual [28], were used to interpret the results of the Corrosion Current Density ($I_{corr}$), see Table VI.

| Corrosion rate ($I_{corr}$) µA / cm$^2$ | Level of Corrosion |
|----------------------------------------|--------------------|
| <0.1 µA/cm$^2$                        | Despicable         |
| 0.1 to 1 µA/cm$^2$                     | Moderate           |
| > 1 µA/cm$^2$                         | Very high          |

1) $I_{corr}$ behavior AISI 304 SS and Galvanized Steel in control medium

Table VII shows the corrosion rate of the study specimens with Galvanized Steel and AISI 304 Stainless Steel, embedded in Common Concrete and Ecological Concrete exposed for 180 days to the control medium.

| SPECIMEN      | ($I_{corr}$ µA/cm$^2$) | LEVEL OF CORROSION |
|---------------|------------------------|--------------------|
| MC-GAL        | 0.017                  | Despicable         |
| M10-GAL       | 0.023                  | Despicable         |
| M20-GAL       | 0.126                  | Moderate           |
| M30-GAL       | 0.104                  | Moderate           |
| MC-304        | 0.012                  | Despicable         |
| M10-304       | 0.014                  | Despicable         |
| M20-304       | 0.004                  | Despicable         |
| M30-304       | 0.003                  | Despicable         |

It can be seen that all specimens with AISI 304 stainless steel presented a $I_{corr}$ values under 0.1 µA/cm$^2$, what they indicate a negligible or despicable level of corrosion according to Table VI, presenting the smallest values of $I_{corr}$ the specimens of Ecological Concrete elaborated with 20 and 30% substitution of PC by SCBA-SF (M20-304 and M30-304), with values of 0.004 and 0.003 µA/cm$^2$, in the case of galvanized steel specimens, the MC-GAL and M10-Gal specimens have $I_{corr}$ values less than 0.1 µA/cm$^2$, indicating a negligible corrosion level or passivation, but the specimens with M20-GAL and M30-GAL have $I_{corr}$ values greater than 0.1 µA/cm$^2$, indicating a moderate level of corrosion. As the literature indicates, this behaviour of the $I_{corr}$ values of negligible levels of corrosion are expected in non-aggressive environments [29-30].

2) $I_{corr}$ behavior AISI 304 SS and Galvanized Steel in $Na_2SO_4$

Table VII shows the corrosion rate or $I_{corr}$ presented by the study specimens after 180 days of exposition to a 3.5% solution of $Na_2SO_4$, as an aggressive medium, all the specimens with AISI 304 SS, MC-304, M10-304, M20-304 and M30-304, have excellent corrosion performance with values between 0.005 to 0.015 µA/cm$^2$, $I_{corr}$ values indicating a negligible level of corrosion, presenting the specimens made with Ecological Concrete based on 20 and 30% of replacement of the PC by SCBA and SF, the benefit of the use of this residual agroindustrial, which is consistent with what was reported in other investigations [31].

In the case of specimens with galvanized steel and exposed to sodium sulphate, corrosion resistance or behavior in this aggressive environment is good in the MC-
GAL and M10-GAL specimens, with $I_{corr}$ values less than 0.1 $\mu$A/cm², indicating a negligible corrosion level or passivation, but the specimens with M20-GAL and M30-GAL sulphate attack is observed, as $I_{corr}$ values increase have to 0.209 and .207 $\mu$A/cm², twice what was reported in the control medium and indicating a moderate level of corrosion. The results of increased corrosion of galvanized steel are consistent with those reported in other investigations [32-34], which indicate a good protection of galvanized steel, but which depends a lot on the exposure conditions or the aggressiveness of the contact environment.

| SPECIMEN | $I_{corr}$ ($\mu$A/cm²) | LEVEL OF CORROSION |
|----------|-------------------------|--------------------|
| MC-GAL   | 0.021                   | Despicable         |
| M10-GAL  | 0.028                   | Despicable         |
| M20-GAL  | 0.209                   | Moderate           |
| M30-GAL  | 0.207                   | Moderate           |
| MC-304   | 0.015                   | Despicable         |
| M10-304  | 0.018                   | Despicable         |
| M20-304  | 0.006                   | Despicable         |
| M30-304  | 0.005                   | Despicable         |

### IV. CONCLUSION

Corrosion resistance in sulfate environments is good in the MC-GAL and M10-GAL specimens, with $I_{corr}$ values less than 0.1 $\mu$A/cm², indicating a negligible corrosion level or passivation.

The specimens with M20-GAL and M30-GAL present $I_{corr}$ values increase have to 0.209 and .207 $\mu$A/cm², twice what was reported in the control medium and indicating a moderate level of corrosion and signs of sulfate attack after 180 days of exposure.

The results of increased corrosion of galvanized steel are consistent with those reported in the literature, which indicate a good protection of galvanized steel, but which depends a lot on the exposure conditions or the aggressiveness of the contact environment.

All the specimens with AISI 304 stainless steel, MC-304, M10-304, M20-304 and M30-304, have excellent corrosion performance with values between 0.005 to 0.015 $\mu$A/cm², $I_{corr}$ values indicating a negligible level of corrosion.

The specimens made with Ecological Concrete based on 20 and 30% of replacement of the PC by SCBA-SF presented the highest resistance, this indicates a contribution to the sulfate corrosion resistance of SCBA and SF, agroindustrial and industrial wastes, in addition to contributing to a reduction of CO₂ emissions, derived from the manufacture of Portland cement and which are responsible for 7% of total emissions worldwide.

It can be concluded by last, that it is feasible to use Sugarcane Bagasse Ash in combination with Silica Fume for the manufacture of Ternary Ecological Concrete resistant to sulphates corrosion.

## ACKNOWLEDGMENT

MA Baltazar-Zamora, et. al., thank PRODEP for the support granted by the SEP, the Academicians UV-CA-458 "Sustainability and Durability of Materials for Civil Infrastructure" under the Call 2018 for Strengthening Academic Bodies with IDCA 28593.

## REFERENCES

[1] M. Criado, D.M. Bastidas, S. Fajardo, A. Fernández-Jiménez, J.M. Bastidas. (2011). Corrosion behaviour of a new low-nickel stainless steel embedded in activated fly ash mortars. Cement and Concrete Composites, 33:6, pp. 644-652.
[2] Miguel Angel Baltazar-Zamora, Sabino Márquez-Montero, Laura Landa-Ruiz, René Croche, Oscar López-Yza. (2020). Effect of the type of curing on the corrosion behavior of concrete exposed to urban and marine environment. European Journal of Engineering Research and Science, 5:1, pp. 91-95.
[3] D.M. Bastidas, M. Criado, S. Fajardo, A. La Iglesia, J.M. Bastidas. (2015). Corrosion inhibition mechanism of phosphates for early-age reinforced mortar in the presence of chlorides. Cement and Concrete Composites, 61, pp. 1-6.
[4] M.A. Baltazar-Zamora, G. Santiago-Hurtado, C. Gaona-Tiburcio et. al. (2012). Evaluation of the corrosion at early age in reinforced concrete exposed to sulfates. International Journal of Electrochemical Science, 7:1, pp. 588-600.
[5] Maslehuddin, M., Al-Zaharni, M. M., Ibrahim, M., Al-Mehthel, M. H., and Al-Idi, S. H. (2007). Effect of chloride concentration in soil on reinforcement corrosion. Constr. Build. Mater. 21, 1825–1832.
[6] Melchers, R. E., and Li, C. Q. (2009). Reinforcement corrosion initiation and activation times in concrete structures exposed to severe marine environments. Cem. Conc. Res. 39, 1068–1076.
[7] M.A. Baltazar-Zamora et. al. (2012). Efficiency of Galvanized Steel Embedded in Concrete Previously Contaminated with 2, 3 and 4% of NaCl. International Journal of Electrochemical Science, 7:4, pp. 2997-3007.
[8] G. Santiago-Hurtado, M.A. Baltazar-Zamora, R. Galván-Martínez, L. D. López L., F. Zapata G., P. Zambrano, C. Gaona-Tiburcio, F. Almeraya-Calderón. (2016). Electrochemical Evaluation of Reinforcement Concrete Exposed to Soil Type SP Contaminated with Sulphates. International Journal of Electrochemical Science, 11:6, pp. 4850-4864.
[9] Miguel Angel Baltazar-Zamora, Abigail Landa-Sánchez, Laura Landa-Ruiz, Hilda Ariza-Figueroa, Pedro Gallego-Qintana, Aldo Ramírez-García, René Croche, Sabino Márquez-Montero. (2020). Corrosion of AISI 316 Stainless Steel Embedded in Sustainable Concrete made with Sugar Cane Bagasse Ash (SCBA) Exposed to Marine Environment. European Journal of Engineering Research and Science, 5:2, pp. 127-131.
[10] O. Ojeda-Farias, J.M. Mendoza-Rangel, M.A. Baltazar-Zamora. (2018). Influence of sugar cane bagasse ash inclusion on compacting, CBR and unconfined compressive strength of a subgrade granular material. Revista ALCIONAT, 8:2, pp. 194-208.
[11] ACI. Provision of mixes, normal concrete, heavy and massive ACI 211.1, p. 29. Ed. IMCYC, México (2004).
[12] NMX-C-156-ONNCC-2010: Determinación del reversible en el concreto fresco. ONNCCCE S.C., México, (2010).
[13] ASTM C 1064/C1064M-08—Standard Test Method for Temperature of Freshly Mixed Hydraulic–426 Cement Concrete; ASTM International, West Conshohocken, PA, 2008, www.astm.org
[14] NMX-C-162-ONNCC-2014: Determinación de la masa unitaria, cálculo del rendimiento y contenido de aire del concreto fresco por el método gravimétrico, ONNCCCE S.C., México, (2014).
[15] NCM-C-083-ONNCC-2014: Determinación de la resistencia a la compresión de especímenes — Método de prueba, ONNCCCE S.C., México, (2014).
[16] M.A. Baltazar-Zamora, G. Santiago-Hurtado, V.M. Moreno L., R. Croche B, M. de la Garza, F. Estupiñan L., P. Zambrano R., C. Gaona-Tiburcio. (2016). Electrochemical Behaviour of Galvanized Steel Embedded in Concrete Exposed to Sand Contaminated With NaCl. International Journal of Electrochemical Science, 11:12, pp. 10306-10319.
[17] G. Santiago-Hurtado, M.A. Baltazar-Zamora, A. Galindo D, J.A. Cabral M., F.H. Estupiñan L., P. Zambrano Robledo, C. Gaona-Tiburcio. (2013). Anticorrosive Efficiency of Primer Applied in Concrete Exposed to Soil Type SP Contaminated with Sulphates. International Journal of Electrochemical Science, 8:6, pp. 8490-8501.
[18] Miguel Angel Baltazar-Zamora, Laura Landa-Ruiz, Yazmin Rivera, René Croche. (2020). Electrochemical Evaluation of Galvanized Steel and AISI 1018 as Reinforcement in a Soil Type MH. European Journal of Engineering Research and Science, 5:3, pp. 259-263.
[19] ASTM C192/C192M–18–Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory, ASTM International, West Conshohocken, PA, 2016. www.astm.org

DOI: http://dx.doi.org/10.24018/ejers.2020.5.3.1852
[20] ASTM G 59-97 (2014) – Standard Test Method for Conducting Potentiodynamic Polarization Resistance Measurements, ASTM International, West Conshohocken, PA, 2014, www.astm.org

[21] G. Santiago-Hurtado, M.Á. Baltazar-Zamora, J. Olguín-Coca, L. D. López L, R. Galván-Martínez, A. Ríos-Juárez, C. Gaona-Tiburcio, F. Almeraya-Calderón. (2016). Electrochemical Evaluation of a Stainless Steel as Reinforcement in Sustainable Concrete Exposed to Chlorides. International Journal of Electrochemical Science, 11:4, pp. 2994-3006.

[22] S. Fajardo, D. M. Bastidas, M. Criado, J. M. Bastidas. (2014). Electrochemical study on the corrosion behavior of a new low-nickel stainless steel in carbonated alkaline solution in the presence of chlorides. Electrochimica Acta, 129, pp. 160-170.

[23] Miguel Angel Baltazar-Zamora, José Manuel Mendoza-Rangel, René Croche, Citlalli Gaona-Tiburcio, Cindy Hernández, Luis López, Francisco Olguín, Facundo Almeraya-Calderón. (2019). Corrosion Behavior of Galvanized Steel Embedded in Concrete Exposed to Soil Type MH Contaminated with Chlorides. Frontiers in Materials, 6, pp. 1-12.

[24] M. Criado, D. M. Bastidas, S. Fajardo, A. Fernández-Jiménez, J. M. Bastidas. (2011). Corrosion behaviour of a new low-nickel stainless steel embedded in activated fly ash mortars. Cement and Concrete Composites, 33, pp. 644-652.

[25] M. A. Baltazar-Zamora, D. M. Bastidas, G. Santiago-Hurtado, J. M. Mendoza-Rangel, C. Gaona-Tiburcio, J. M. Bastidas, F. Almeraya-Calderón. (2019). Effect of Silica Fume and Fly Ash Admixtures on the Corrosion Behavior of AISI 304 Embedded in Concrete Exposed in 3.5% NaCl Solution. Materials (Basel), 12:23, pp. 1-13.

[26] ASTM C 876-15 (2015) – Standard Test Method for Corrosion Potentials of Uncoated Reinforcing steel in Concrete, ASTM International, West Conshohocken, PA, 2015, www.astm.org

[27] H.W. Song, V. Saraswathy. (2007). Corrosion Monitoring of Reinforced Concrete Structures – A Review. International Journal of Electrochemical Science, 2:1, pp. 1-28.

[28] O. Troconis De Rincón et. al., Manual de Inspección, Evaluación y Diagnóstico de Corrosión en Estructuras de Hormigón Armado, p. 134. Red DURAR, CYTED, Venezuela (1997)

[29] M.A. Baltazar-Zamora et. al. (2012). Efficiency of Galvanized Steel Embedded in Concrete Previously Contaminated with 2, 3 and 4% of NaCl. International Journal of Electrochemical Science, 7:4, pp. 2997-3007.

[30] O. Troconis de Rincón et. al., (2016). Reinforced Concrete Durability in Marine Environments DURACON Project: Long-Term Exposure. Corrosion, 72:6, pp. 824-833.

[31] A. Landa-Gómez et.al., (2018). Corrosion Behavior 304 and 316 Stainless Steel as Reinforcement in Sustainable Concrete Based on Sugar Cane Bagasse Ash Exposed to Na2SO4. ECS Transactions. 84, pp. 179-188.

[32] F. Shaheen, B. Pradhan. (2017). Influence of sulfate ion and associated cation type on steel reinforcement corrosion in concrete powder aqueous solution in the presence of chloride ions. Cement and Concrete Research, 91, pp.73–86.

[33] T. Bellizze, M. Malavolta, A. Quaranta, N. Ruffini, G. Roventi. (2006). Corrosion behaviour in concrete of three differently galvanized steel bars. Cement and Concrete Composites. 28, pp. 246–255.

[34] P. Pokorny, P. Tej, M. Kouhl. (2017). Evaluation of the impact of corrosion of hot-dip galvanized reinforcement on bond strength with concrete—A review. Construction Building and Materials. 132, pp. 271–289.