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Analysing the Corrosion Vulnerability of Stainless-Steel Bars in Accelerated Aggressive Environments

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Corrosion, Compressive Strength, Aggressive Environment, Cracking.

ABSTRACT:
Reinforced cement concrete, a widely utilized construction material, faces deterioration primarily because of the corrosion of the steel reinforcement embedded within the concrete matrix. To investigate the degradation rate of such structures, concrete specimens were cast both with and without embedded steel. The study employed accelerated corrosion techniques to expedite the assessment process. Even under accelerated conditions, stainless-steel rebar demonstrates remarkable resistance to corrosion. This discovery stemmed from a thorough investigation into cracking behaviour. During this examination, concrete structures containing TMT rebar exhibited cracks within just four days. Conversely, when stainless-steel rebar was employed, only superficial indications of cracking were observed in the concrete specimens. Multiple comprehensive corrosion studies further substantiate the notion that stainless-steel rebar exhibits outstanding resistance to corrosion even when subjected to harsh environmental conditions.

1. Introduction:

Concrete, the most widely utilized artificial construction material globally, is created by blending cementitious components, water, and aggregates in precise proportions. Presently, numerous civil engineering structures across the globe face significant deterioration issues stemming from factors such as carbonation and chloride attacks. Corrosion, which is the deterioration of materials due to chemical reactions with the environment, is responsible for the loss of steel through rust formation. The corrosion of steel reinforcement occurs when steel loses its protective passivation layer because of reduced alkalinity in the concrete due to processes like carbonation or chloride attack. This corrosion process is fundamentally electrochemical in nature and involves the movement of charges in the form of electrons and ions. Electrochemical corrosion emerges when different metals are present or when non-uniformities exist in the steel or the chemical and physical environment within the surrounding concrete. As the reaction products expand upon reacting further with dissolved oxygen, this expansion generates internal stress within the concrete. In some cases, this stress can be substantial enough to cause the concrete cover to crack and spall. The factors that typically affect the corrosion of reinforcement in concrete can be broadly categorized into two groups: environmental parameters and material parameters. Within the material parameters category, we consider those that are pertinent to the formation and development of corrosion. Concrete properties such as alkalinity, resistivity, permeability, and diffusion play a significant role in influencing the onset of corrosion and its progression, initially and up to the point where concrete begins to crack. These parameters are not static; they change over time. The ultimate outcome depends on both the future cement hydration within the concrete and the deterioration of the concrete itself. Once cracking occurs, the environment can be regarded as being in direct contact with the steel reinforcement.

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2. Literature Survey:

Abdul-Wahab. A studied about the effect of air pollution on atmospheric corrosion of engineering metals. Atmospheric corrosion is probably the most common form of corrosion by degradation of material exposed to air and its pollutants. This was the first ever corrosion study to be carried out in Oman concerning the influence of air pollution on atmospheric corrosion of metals. Common materials such as aluminium, brass, copper, epoxy, galvanized iron, mild steel, and stainless steel. The results are discussed as functions of the type of test material, test location, environmental pollution factors, and exposure time. The results indicate that copper and mild steel are the most corrosive metals, while stainless steel, aluminium and epoxy are the least corrosive. Furthermore, higher concentrations of chlorides were observed in the Airport and Sohar areas, which are close to the seacoast. The highest carbonate sites were in Al-Rusail and Sohar areas, these being more polluted industrial areas. Moreover, it was found that the atmosphere in the Al-Fahl area was polluted with sulphur compounds.

Abdulrahman Alhozaimy, et al investigated severe corrosion observed at intersection points of steel rebar mesh in reinforced concrete construction. Chloride-contaminated reinforced concrete panels were cast; laboratory measurements were conducted to determine the half-cell potential, corrosion current and concrete resistivity; and scanning electron microscopy and mercury intrusion porosimetry were performed. The experimental measurements at the intersection of steel rebars were found to be mostly higher than the areas between them. The high corrosion rate observed at steel intersection points appeared to be due to the coupled effects of the corrosive binding wire material, the electrical connectivity, the reduced centre-to-centre (c/c) steel bar spacing and poor concrete microstructure at the rebar intersection.

Apostolopoulos. C.A, V.G. Papadakis studied about consequences of steel corrosion on the ductility properties of reinforcement bars. In the present work, the main corrosion initiation mechanisms are shortly presented. Further, the propagation period and the main consequences on the mechanical properties of steel and concrete are analysed. The experimental results show that with increasing duration of exposure to a corrosive environment, the steel mass loss increases appreciably. This leads to a significant increase in the applied stress. In addition, a significant reduction of the tensile ductility of the material was observed. For laboratory salt spray exposure periods, some of the tensile properties of steel bars drop to values lying below the limits, which are set in the existing standards for using steel in reinforced concrete members. The experimental results from the accelerated corrosion tests on bare steel bars are in good qualitative agreement with results from steel bars embedded in aged concrete.

Anees U. Malik, Ismail Andijani, et al investigated migratory corrosion inhibitors (MCI) have been suggested as the possible chemicals for rehabilitating the damaged reinforced concrete structure. The inhibitor migrates through the concrete to the reinforcing steel and protects it from further corrosion by providing a thin, protective coating of MCI molecules on steel reinforcement. Studies have been carried out to investigate the performance of dimethyl ethanol amine-based MCI-A and triethanol amine-based MCI-B as surface coatings. Reinforced concrete specimens coated with MCI-A and MCI-B were subjected to exposure tests in salt solutions. The tests consisted of immersing the specimens in 5% NaCl solutions (laboratory tests) and open seawater or exposing the specimens to high tide (splash zone) for periods ranging from 6 to 12 months. The condition of the exposed specimens was evaluated by physical examination of the rebar and by carrying out electrochemical measurements. The electrochemical studies have consisted of open circuit potential and polarization measurements.

Castro. H, et al investigated the mechanical properties and corrosion behaviour of stainless-steel reinforcing bars. Austenitic stainless steels have recently been used as reinforcing bars in special civil constructions to increase their expected life in corrosion environments. The complete mechanical characterization of two kinds of austenitic stainless steel rebars, 304LN and 316LN grades, obtained after hot and cold rolling schedules, was performed. Their mechanical properties and their influence on this rib region were obtained, as well as determining the fracture behaviour of these bars by means of their *J–R* curves. The experimental work was completed with the study of the corrosion behaviour of all the bars in a saline environment. All the results have been justified considering the fabrication method employed in each case.

Deus J.M, L. Freire, et al studied the temperature dependence of the corrosion potential of passive stainless steel rebars embedded in the concrete or in alkaline media. The corrosion potential mirrored the temperature variations and the coefficient (mV/°C) increased as the average temperature range increased. These variations were observed in the long time-scale domain (several hours) and were interpreted based on temperature-induced changes in the chemistry of the passive layer. This behaviour and its interpretation have not been reported before and are of great importance from the point of view of understanding the electrochemical behaviour of stainless steel rebars and the inspection and durability of reinforced concrete structures.

Dimitri V. Val1 and Leonid Chernin studied about serviceability reliability of reinforced concrete beams with corroded reinforcement. However, cracking of the concrete cover and a reduction in the bond strength

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which may result in a slip between the corroding reinforcement and the concrete also decrease the stiffness of RC beams. The displacements of the RC beams increase and may exceed a limit value specified in a code, i.e., it has been noted that corrosion may also cause serviceability failure due to excessive displacements. The effect of corrosion on deflections of RC beams and, subsequently, on the probability of serviceability failure due to excessive deflection is considered. Results show that an increase in deflections due to corrosion has a lesser effect on the serviceability of RC beams than corrosion-induced cracking.

Garcia-Alonso M.C, et al studied the corrosion behaviour of new stainless steel reinforcing bars embedded in concrete. The evaluation, repair and restoration of structures are estimated to amount to 35% of the total volume of the work in the building sector and this continues to increase. The corrosion of rebars in reinforced concrete structures (RCS) is the main reason for their degradation, so the use of reinforcing stainless steel seems to be one of the possible solutions with the most probability of solving this problem. To demonstrate the advantages of using reinforcing stainless steels, the corrosion behaviour of AISI 304 and 316 reinforcements embedded in concrete slabs (C35/45 and C60/70 concrete) with two chloride contents are compared with three low-cost and low-Ni austenoferritic stainless steels and with the conventional carbon steel. The lower chloride contamination selected in this research, was enough to cause the corrosion in the active state of the carbon steel reinforcements, whereas the highest one exceeded the expected contamination in the natural environments, including sea media. The metallic materials remaining in the passive state can be considered, from the point of view of corrosion resistance, adequate as reinforcements in the RCS.

Peter J. Walker and Stephen Dobson investigated Stabilized rammed earth offers a low energy durable alternative to conventional building materials, such as masonry and processed timber, for low-rise residential projects. To date, rammed earth construction has mainly been used in the developing world, particularly in Africa and Asia. Despite recent applications in Australia and the United States, further development of rammed earth in these countries has been hindered by a lack of data on important aspects of material performance. In this paper, work undertaken to assess the bond of rebars embedded in rammed earth is described. A variety of cement-stabilized rammed earth pull-out test samples were fabricated with deformed, galvanized, plain, and stainless-steel rebar. Pull-out bond resistance is shown to be a function of rammed earth compressive strength, rebar type, embedment length, and the method of specimen preparation.

Pedro Albrecht, and Terry T. Hall Jr. studied the Corrosion environments including rural, industrial, and marine, becoming increasingly severe in that order. The steels under consideration are A242, A588, copper, and carbon steels, with their corrosion resistance decreasing in that order. Comparisons of the data with the medium corrosivity bands for weathering and carbon steels help to determine the severity of environments and the corrosion resistance of steel compositions. For bare exposed structures, a corrosion allowance should be added to all member thicknesses arrived at by stress calculations can be estimated by extrapolating an applicable thickness loss curve to the end of the service life of the structure. The corrosion allowance thickness loss data obtained from simple test specimens, mostly of the 1503100 mm size of an index card, must be applied carefully to complex structures such as a bridge, which has a variety of details with different exposure conditions. When portions of a bare, exposed structure remain damp or wet for long periods of time, thickness losses can be much higher than those reported for test specimens exposed at 30° facing south. Good structural detailing that prevents moisture accumulation is of utmost importance.

Robert E. Melchers studied coastal infrastructure the long-term durability of new steel structures and the remaining life of existing steel structures is of central interest to their proper maintenance and asset management. This is particularly the case where protective measures such as paint coatings, galvanizing, or cathodic protection will become or are already ineffective or non-existent. Guidelines currently available for new design and for assessment are largely empirical and have a high degree of uncertainty. To address this recent research has produced better quality models for the progression of corrosion with time. These employ fundamental characteristics of steel corrosion as obtained from actual field observations and from laboratory-based electrochemical and other observations. The models are reviewed herein and an illustrative application to a typical infrastructure component is presented. It is shown that seawater temperature has an important influence on the rate of early corrosion and has longer-term effects not predicted by short-term observations. Also, the influence on corrosion of small changes in metal composition and in water velocity, salinity, and pollution are described.

Roberto Capozucca , M. Nilde Cerri investigated the influence of damage due to corrosion of reinforcement in the compressive zone of RC beams. In the damaged RC beams, the corrosion of reinforcement, because of an electrochemical process, produces an increase in the diameter of bars due to rust products that give rise to a micro-cracking of the concrete around the bars. In the compressive zone, the micro-cracking of concrete creates a loss of strength of concrete. A theoretical model to analyse the influence of reinforcement corrosion in the compressive zone of RC beams is

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described considering a modified law for concrete. The theoretical results are compared with the experimental data obtained from bending tests on undamaged and damaged RC beam models.

Siebren J. DeJong, Patrick J. Heffernan and Colin MacDougall undergone research on the fatigue of reinforcing bars has been based on constant amplitude fatigue tests performed in a noncorrosive environment. Fatigue in a corrosive environment, known as corrosion fatigue, can result in a synergistic damage mechanism that is worse than the combined damage of corrosion and fatigue acting separately. The periodic overload and corrosion-fatigue resistance of machined specimens is made from two corrosion-resistant reinforcing steels: MMFX micro composite and 316LN stainless steel. A series of constant amplitude and periodic overload tests were performed in both laboratory air and in an aqueous 3.5% by-weight NaCl solution to compare the fatigue resistance of these materials with conventional reinforcing steel. MMFX had reduced constant amplitude performance in the corrosive environment, whereas 316LN stainless steel showed no environmental reduction under constant amplitude loading except at high loads. Periodic overload fatigue results in laboratory air were like that found with conventional reinforcing steel, with much shorter periodic overload lifespans compared to constant amplitude loading. Corrosion fatigue reduced the periodic overload performance of both materials, although both materials retained their intrinsic fatigue limit 250 MPa stress range in the corrosive environment, a drastic improvement over the periodic overload corrosion-fatigue performance of conventional reinforcing steel.

Seneviratne. A.M.G, G. Sergi, C.Lin studied three elastomeric surface coatings that were applied to naturally carbonated concrete components obtained from buildings that were suffering from reinforcement corrosion. Dynamic mechanical thermal analysis suggested that the most successful coating was able to maintain its elastomeric properties over the required period of exposure and over a wide range of operational temperatures. It also had a relatively low but uniform bond strength to the concrete, and this appeared to have a beneficial effect on its ability to accommodate the movements of the substrate. Such coatings are considered capable of extending the service lifetimes of carbonated reinforced concrete structures in cases where significant chloride contamination does not exist and where the only substantive route for moisture ingress is via the coating.

Yingang Dua, Martin Cullen b, Cankang Li carried out research on the structural performance of RC beams under simultaneous loading and reinforcement corrosion. Five reinforced concrete beams were first loaded to 60% of their strength and then subjected to sustained load and reinforcement corrosion simultaneously until they collapsed either due to corrosion development or further loading. The experimental results indicate that, under the same loads, the time-dependent deflections of corroded beams increased more rapidly than those of non-corroded beams and reached their limiting deflections prematurely. A local corrosion of a shorter length of tensile bars decreased beam strength and ductility more greatly than an extensive corrosion of a longer length of bars. Simultaneous loading and corrosion impair beam strength and ductility more significantly than separate ones. Either further corrosion or an occasional over-loading or both are likely to cause concrete structures under service loads to collapse suddenly without significant deflection.

3. Scope and Objectives

The objective is to investigate the corrosion performance of alloyed reinforced bars incorporated within concrete structures when subjected to harsh environmental conditions. Within the concrete material, various assessments were conducted, including evaluations of compressive strength, time-to-cracking, macrocell corrosion, and potential-time studies. In solution-based investigations, a range of electrochemical methods, including the linear polarization technique, TAFEL extrapolation, potential-time analysis, and gravimetric assessments, were conducted both in the presence and absence of chloride ions. Additionally, an accelerated test known as anodic polarization was employed to determine the acceptable threshold for chloride concentration. Furthermore, chemical analyses were carried out to estimate alkalinity levels and the concentration of free chloride ions. The corrosion behaviour of alloyed steel, specifically stainless steel rebars, was thoroughly examined and compared to conventional TMT rebars. The corrosion performance of stainless steel and TMT rebars was assessed within a simulated concrete environment, considering the presence or absence of chloride. Various electrochemical methods were employed to study their corrosion performance comprehensively.

4. Materials and Methods:

Cement used for RCC, PCC test specimens and cement extract for solution study was Portland pozzolana cement (PPC) - 53 grades confirming to IS 12269: 1987. Natural river sand confirming Zone III was used as fine aggregate for casting RCC and PCC test specimens. Natural blue metal obtained from local quarries was used as coarse aggregate for casting RCC and PCC test specimens. The maximum size of coarse aggregate used was 20mm. Distilled water was used for casting and curing of the RCC and PCC test specimens. Double distilled water was used for the preparation of cement extract. The stainless steel rebars were

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purchased from a special agency available at Chennai, because of their non-availability in the regular market. Most of the dealers are ready to supply in bulk quantities. However, we required fewer amounts according to the experiments. At last, we purchased from special dealers in stainless steel rebars located in Chennai. In this study, stainless steel rebars (316) of 8mm diameter were used in both concrete and solution studies. The composition of stainless-steel rebar is given below in Table 4.1. TMT rebars (Fe415) of 8mm diameter were used in both concrete and solution studies. The composition of TMT rebar is given below in Table 4.2. Sodium chloride NaCl of different percentages depends upon the types of tests used in the various performance investigation studies of SS / TMT rebars. Sodium hydroxide of 0.04N concentration was used in this study for measuring potential. Cement extract (CE) prepared with PPC with a water-cement ratio of 2:1 was used for electrochemical studies. This acted as a control without the addition of any chloride for various experiments. It is used as an indicator in the chloride estimation test. Silver Nitrate ($AgNO_3$) of 0.1N was used as a burette solution in the chloride estimation test.

Table 4.1 Composition of Stainless Steel Rebars

CHEMICAL ELEMENTS	COMPOSITION
Carbon (C)	0.08
Chromium (Cr)	16.5
Nickel (Ni)	10
Silicon (Si)	1
Phosphorous (P)	0.05
Sulphur (S)	0.02
Molybdenum (Mo)	2

Table 4.2 Composition of TMT rebars

CHEMICAL ELEMENTS	COMPOSITION
Carbon (C)	0.25
Manganese (Mn)	0.55
Silicon (Si)	0.30
Sulphur (S)	0.055
Phosphorous (P)	0.055

5. Result and Discussion

5.1 Electrochemical Studies in Solutions

5.1.1 Potential time study

The potential time behaviour of SS / TMT rebars exposed in CE is shown in Fig 5.1. It can be seen from the figure that the potential of SS rebars initially shows -200 mV. Later, it moves towards a positive direction and reaches around -20mV at the end of the 15^{th} day. Thereafter potential lies between -20 to -50Mv throughout the study period of 90 days. This clearly shows the superior performance of SS in normal environmental conditions. From the figure, it can also be seen that potential variation of TMT rebar under normal environment. Here the potential goes on increasing with time and reaches -700mV at the end of the 15^{th} day. Thereafter the potential slightly fluctuates with time. From the 15^{th} day to the 90^{th} day, the potential lies between -700 to -600mV.

Fig 5.2 shows the potential time variation of SS / TMT rebars exposed in CE and mixed with 3% NaCl. Here again, the potential time behaviour was almost similar for SS / TMT rebars as obtained in normal conditions. However, the SS rebar potential reaches a more positive value at the end of the 10^{th} day and fluctuates with progressive time. But all the potential values are less than -150mV clearly indicates the corrosion-resistant property of SS rebar even under very severe environmental like 3% NaCl. In the case of TMT rebar, the trend was almost a mirror reflection of normal environmental conditions. However, there is a very wide potential difference between SS / TMT rebars.

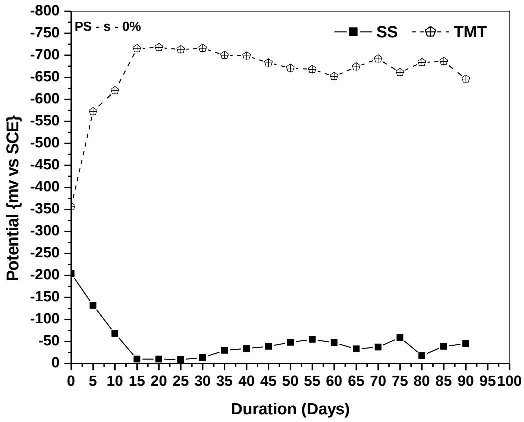

Fig 5.1 Potential time behaviour of rebars in cement extracts (CE)

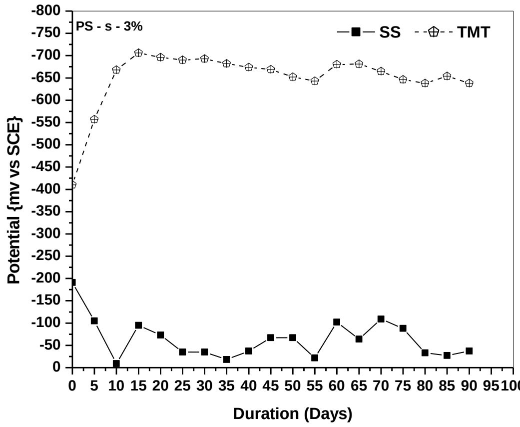

Fig 5.2 Potential time behaviour of rebars in cement extract and chloride (CE+CL)

5.1.2 Anodic Polarization Technique

The anodic polarization behaviour of SS / TMT rebars is shown in Table 5.1. It can be seen from the table that, in normal CE conditions both the rebars behave in a similar fashion i.e., in the normal concrete environment both rebars are quite safe even under accelerated conditions. In the case of CE + 1000ppm of chloride condition, the potential of SS rebar was almost steady state throughout the test period indicating its resistivity ability against chloride attack whereas the TMT rebar exhibits pitting corrosion within in short span of 200secs indicating its inability against chloride attack.

Table 5.1 Anodic polarization behaviour of SS / TMT rebars

SL.NO	MEDIUM	OCP mV		VOLTAGE AT 5sec mV		VOLTAGE AT 300sec mV	
		SS	MS	SS	MS	SS	MS
1	CE	-311	-360	+737	+675	+757	+695
2	CE+1000ppm	-311	-331	+748	+582	+667	-326

5.1.3 Linear polarization technique

The corrosion data obtained from the linear polarisation-resistant technique is given in Table 5.2. From the table under 0 to 5000ppm chloride levels the polarisation resistance of SS / TMT rebars was around 8500Ω/cm^2. In the case of TMT rebar, the obtained RP value is half of SS rebar. In the case of 5000ppm chloride level, TMT rebar shows a very low RP value i.e., more than 30 times lesser resistance value than the SS rebar. The corrosion current also shows the mirror reflection of RP data.

Table 5.2 Linear polarization behaviour of SS / TMT rebars

MATERIAL	MEDIUM	0CP	RP Ω/cm^2	Io A/cm^2
SS	CE	-264	8491	3.0722 E^{-6}
TMT		-190	3945	6.6123 E^{-6}
SS	CE + CL 5000ppm	-305	8749	2.9816 E^{-6}
TMT		-416	255	102.12 E^{-6}

5.1.4 TAFEL extrapolation technique

The corrosion data collected from the TAFEL technique is shown in Table 5.3. From the table, the TMT rebar exhibits a corrosion current of 8.593 E^{-6} A/cm^2 whereas SS rebar shows 2.229 E^{-7}A/cm2 only. This clearly shows that SS rebar exhibits around 40 times lower corrosion current in normal environmental conditions. In the case of CE + 5000ppm condition also behaviour of SS / TMT rebars is like a normal environment. Here SS rebar shows 32 times lower corrosion current than TMT rebar in very high chloride level of 5000ppm.

Table 5.3 Results of SS / TMT rebars obtained from TAFEL technique.

MATERIAL	MEDIUM	0CP	BA	Io – A
SS	CE	-354	84.81	2.2297 E^{-7}
TMT		-261	245	8.5934 E^{-6}
SS	CE + CL 5000ppm	-383	-	5.3685 E^{-7}
TMT		-475	-	1.718 E^{-5}

5.1.5 Gravimetric study

The actual corrosion rate of SS / TMT rebars exposed in CE (with and without 1% chloride) is given in Table 5.4. It can be seen from the table that the TMT rebar shows a 17 times higher corrosion rate than SS rebars exposed in normal CE. In the presence of chloride, SS rebars show a very low corrosion rate of 3.251 E^{-7} mm/yr, whereas TMT rebar shows a higher corrosion rate of 2.6637 E^{-5} mm/yr under chloride conditions. The visual inspection of the exposed SS / TMT rebars clearly indicates that SS rebars have bright and corrosion-free surfaces even in the chloride environment. On TMT rebars severe corrosion was found on the entire surface of TMT rebar exposed in a chloride environment. A pitting type of corrosion was noticed on the TMT rebars exposed in normal CE. From the above results, it can be concluded that SS rebars displace a minimum durability of 15 times than TMT rebars in chloride as well as chloride-free conditions.

Table 5.4 Corrosion resistant of SS / TMT rebar in CE (with and without Cl)

Sl.no	Materials	System	Corrosion rate
1	SS	CE	0.5084 E^{-7}
2	TMT		8.6771 E^{-7}
3	SS	1%CECL	3.2513 E^{-7}
4	TMT		2.6637 E^{-5}

Table 5.5 Compressive strength data for different curing periods

Sl. NO.	Days	Compressive strength {σ}, N/mm²
1	7	16.5
2	28	25

5.2 Electrochemical and Accelerated Studies in Actual Concrete

5.2.1 Compressive strength test

The results of compressive strength for these curing periods are presented in Table 5.5. From the table, the 7 and 28-day compressive strength of the designed mix ratio. At the end of 28 days of curing, 25N/mm^2 strength was obtained, which was the targeted strength.

5.2.2 Potential time study in concrete medium

Fig 5.3 shows the potential time behaviour of SS / TMT rebars embedded in concrete exposed to distilled water conditions. The initial potential of -500mV tends to a positive direction and reaches -125mV at the end of the 5th day for TMT rebar. Where after potential fluctuates with time and increases with the exposure period. It reaches of maximum potential -550mV at the end of the 40th day of exposure under this normal exposure condition. In the case of SS rebar, most of the potential values are less than -150mV throughout the test period. Only two values exceed -200mV under this environmental condition. This clearly shows the SS rebars is highly corrosion-resistant in normal condition. Fig 5.4 shows the potential time behaviour of SS / TMT rebar embedded in concrete exposed highly aggressive environment of 3%NaCl. Here again, the potential of TMT rebars trends towards a positive direction for certain periods. Then it moves towards a more positive direction till the end of the experiment. The above trend clearly shows the active condition of TMT rebar. It can also be seen from the figure that SS rebar always shows lesser potential values throughout the test period even under this high chloride condition. Throughout the study, the potential of SS rebars was less than -200mV even under severe chloride conditions indicating their corrosion protection ability.

5.2.3 Macrocell study

The potential time behaviour of anode SS / TMT rebars is shown in Fig 5.5. From the figure the potential goes on increasing and reaches around -375mV at the end of the 3rd cycle. Later it fluctuates with time. But the SS rebar reaches a maximum potential of 250mV at the end of the maximum potential of 250mV at the end of the seventh cycle only. It is important to note that all the measured potential values are less than -250mV throughout the test period indicating the corrosion-resistant property of SS rebar even under severe chloride conditions. Fig 5.6 shows the potential time behaviour of SS / TMT cathode rebars. Here the trend was a mirror reflection of the anode rebar. The potential of SS rebar was always lesser than the potential of TMT rebar throughout the study period.

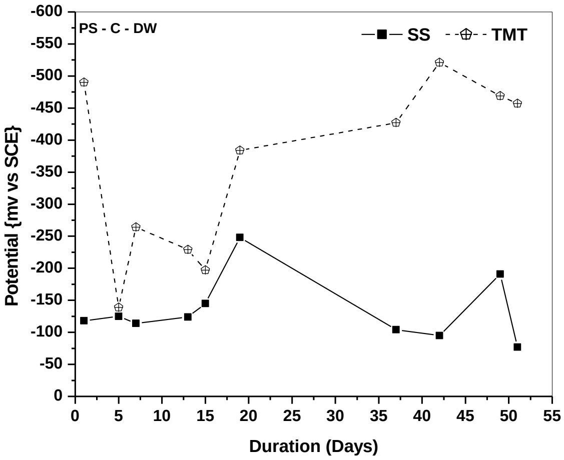

Fig 5.3 Potential time behaviour of rebars in distilled water

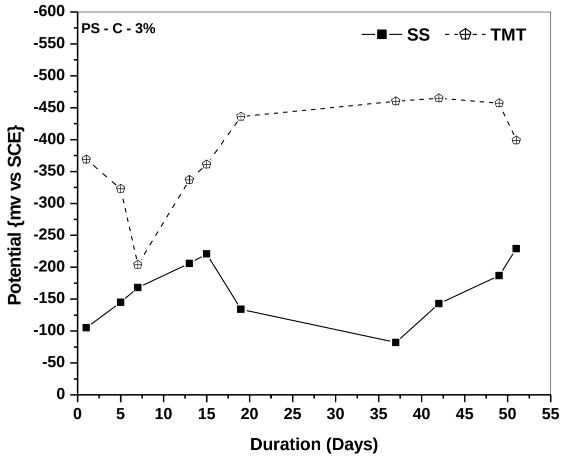

Fig 5.4 Potential time behaviour of rebars in 3%NaCl

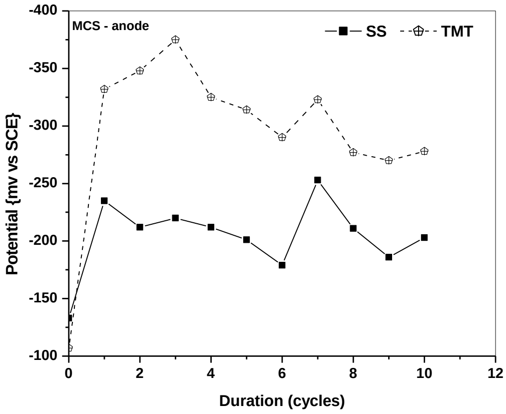

Fig 5.5 Potential time behaviour of anode rebars

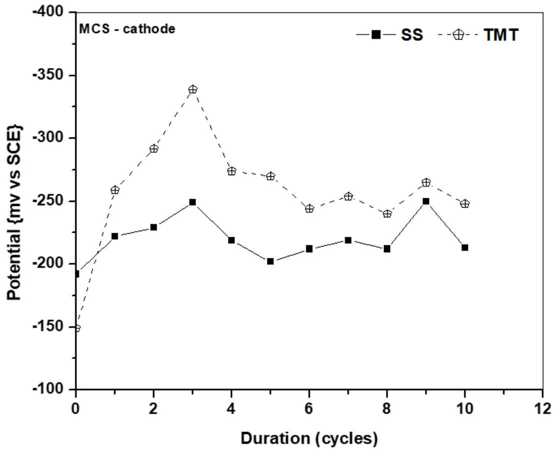

Fig 5.6 Potential time behaviour of cathode rebars

5.2.4 Time to Cracking Study

Fig 5.7 shows the corrosion current measured during the time-to-cracking study. It can be seen from the figure that the corrosion current was almost very close in SS / TMT rebars during the initial stage. Later, the corrosion goes on increasing and reaches a maximum of 180mA at the end of the experiment. In this rebar rusting and fine cracks were observed at the end of the fourth day. In the case of TMT rebar, the corrosion current increases with time at reaches a maximum of 107mA at the end of the fourth day. After the current decline with time here also rusting and cracking were observed from the fourth day onwards.

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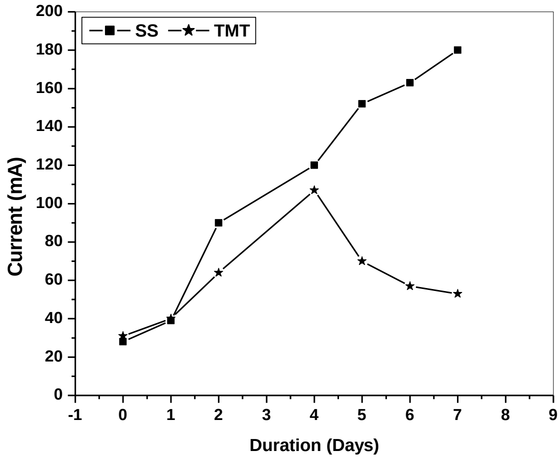

Fig 5.7 Corrosion current from time to cracking study

Conclusions

The above study clearly indicates that stainless steel rebars prolong the life of concrete structures, especially for structures present in marine and industrial environments. Even though subjected to aggressive environments such as chloride medium, stainless steel rebars show high resistance to corrosion. From the various studies, it was observed that stainless steel rebars exhibit superior corrosion-resistant properties than TMT rebars. The stainless-steel rebar shows very good corrosion resistance in an aggressive medium i.e., solution medium containing chloride and non-chloride. In a potential time study, the stainless-steel rebar shows very low negative potential compared to the TMT rebar even though placed in an aggressive environment for

90 days. In chloride and non-chloride environments, stainless steel rebar shows very good corrosion

resistance than TMT rebar. Even though some fluctuation in its potential it maintains its low negative potential compared to the high negative potential TMT rebar. It indicates its high corrosion resistance because of its alloyed properties. From various studies, SS rebar shows superior corrosion resistance in chloride medium. From the anodic polarization technique, the stainless-steel rebar maintains its high positive potential in CE + 1000ppm, but TMT rebar drops to a negative potential. From Linear polarization and TAFEL techniques, the stainless-steel rebar has a high resistant value compared to TMT rebar. Also, SS rebar maintains its low corrosion current compared to TMT rebar. Because of its low corrosion current, SS rebar shows superior corrosion resistance than TMT rebar. The SS rebar is also having excellent corrosion resistance when it is embedded in concrete. The studies performed in concrete i.e., potential and macrocell studies reveal that SS rebar shows very low negative potential compared to the high negative potential of TMT rebars. In an accelerated environment also, stainless-steel rebar shows high resistance to corrosion. This was found out from time to cracking study. In this study, TMT rebar embedded concrete cracks within 4 days. However, only symptoms of cracks were found on concrete specimens embedded with SS rebar. From the various extensive corrosion studies, it can be concluded that SS rebar displays excellent corrosion resistance against severe environmental conditions.

References:

1. Ben Young "Experimental and Numerical Investigation of High Strength Stainless Steel Structures" Journal of Constructional Steel Research 64 (2008) 1225–1230.
2. Baddoo. N.R "Stainless Steel in Construction: A Review Of Research, Applications, Challenges And Opportunities" Journal of Constructional Steel Research 64 (2008) 1199–1206.
3. Graham Gedge "Structural Uses Of Stainless Steel-Buildings And Civil Engineering" Journal of Constructional Steel Research 64 (2008) 1194–1198.
4. Gardnera. L, A. Taljab, N.R. Baddooc "Structural Design of High-Strength Austenitic Stainless Steel" Thin-Walled Structures 44 (2006) 517–528.
5. Gardner. L, D.A. Nethercot "Experiments on Stainless Steel Hollow Sections - Part 1: Material and Cross-Sectional Behaviour" Journal of Constructional Steel Research 60 (2004) 1291–1318.
6. Hirofumi Aoki "Establishment of Design Standards and Current Practice for Stainless Steel Structural Design In Japan" Journal of Constructional Steel Research 54 (2000) 191–210.
7. Insausti.G, M. Ashraf "Elevated Temperature Material Properties of Stainless-Steel Alloys"

Journal of Constructional Steel Research 66 (2010) 634-647.
8. Johansson.B, A. Olsson “Current Design Practice and Research on Stainless Steel Structures In Sweden” Journal of Constructional Steel Research 54 (2000) 3-29.
9. Ju Chen, Ben Young “Stress–Strain Curves for Stainless Steel at Elevated Temperatures” Engineering Structures 28 (2006) 229–239.
10. Kim J.R. Rasmussen “Recent research on stainless steel tubular Structures” Journal of Constructional Steel Research 54 (2000) 75-88.
11. Shek K.H. Lo C.H., J.K.L. Lai “Recent Developments in Stainless Steels” Materials Science and Engineering R 65 (2009) 39-104.
12. Theofanous. M, T.M.Chan, L.Gardner “Flexural Behaviour Of Stainless Steel Oval Hollow Sections” Thin-Walled Structures 47 (2009) 776-787.
13. Theofanou.M, T.M. Chan, L. Gardner “Structural Response of Stainless-Steel Oval Hollow Section Compression Members” Engineering Structures 31 (2009) 922-934.
14. Velasco.F, G. Blanco, A. Bautista, M.A. Martínez “Effect of Welding On Local Mechanical Properties Of Stainless Steels For Concrete Structures Using Universal Hardness Tests” Construction and Building Materials 23 (2009) 1883-1891.
15. Van den Berg G.J. “The Effect of The Non-Linear Stress-Strain
16. Behaviour Of Stainless Steels on Member Capacity” Journal of Constructional Steel Research 54 (2000) 135-160.
17. Wenjun Xi, Sheng Yin, Hoyi Lai “Microstructure and Mechanical Properties of Stainless Steel Produced by Centrifugal-SHS Process” Journal of Materials Processing Technology 137 (2003) 1-4.