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EVALUATION OF THE CORROSION RESISTANCE OF LATEX MODIFIED CONCRETE (LMC)

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ABSTRACT

In recent years, various reinforced concrete structures worldwide have suffered rapid deterioration. Therefore, durability of concrete structures especially those exposed to aggressive environments is of great concern. Many deterioration causes and factors have been investigated. Corrosion of steel reinforcement was found to be one of the major deterioration problems. Penetration of chloride ions is one of the main causes which induces corrosion. The objective of this study is to evaluate the corrosion resistance of latex modified concrete (LMC) compared to conventional concrete using an accelerated corrosion cell.

The corrosion cell proved to be a good and simple method to evaluate the durability of concretes especially with respect to chloride ion penetration, and the protection of reinforcement against corrosion. The LMC proved to be superior in its corrosion resistance compared to conventional concrete, which recommends its use in structures exposed to severe aggressive environments.

Introduction

Corrosion of steel reinforcement in reinforced concrete structures represents one of the major deterioration problems of concrete structures, especially those which service in aggressive environment such as bridge decks due to the use of de-icing salts, and structures exposed to marine environment.

Recently, latex modified concrete (LMC) has been widely used in the construction industry due to its superior performance and suitability for various special applications, such as bridge overlays (1-4).

Penetration of chloride ions is one of the most important causes of initiating corrosion of steel reinforcement in concrete, if not the major cause of its premature corrosion (6,7,8). The destructive influence of chlorides in concrete, through chloride induced corrosion of embedded reinforcing steel has been of concern to engineers for many years. The ability of concrete to protect against the corrosion of reinforcing steel was evaluated by measuring the chloride permeability or chloride diffusion through the concrete. Even water or gas permeability were used to evaluate this property (1,3,4,5,6,8,9). The relation between the permeability or diffusivity of the concrete and its corrosion resistance was assumed to be directly proportional. Mehta 1991(10) concluded that the major concrete durability problems would be of no consequence to concrete that is relatively impermeable at the time of exposure to the environment and continues to remain impermeable through out the expected service life.

This paper is part of a larger research project on evaluating the various durability aspects of LMC. The objective of this study is to evaluate the protection against reinforcing steel corrosion of the latex modified concrete (LMC) compared to conventional concrete, using an accelerated corrosion cell.

Experimental Program

1. Materials and Mixture Proportions. The materials used in this work were; natural siliceous sand (Agour valley-Suez region), natural gravel (Katamya-Cairo), Ordinary Portland Cement Type I (Turah factory), and tap drinking water. Table 1 gives the main properties of the sand and gravel.

The polymer latex used was Styrene-Butadine Rubber (SBR) from Fosroc-Egypt. The SBR is in a liquid state of low viscosity having a solids content of 47%, pH value of 11.0, and specific weight of 1.0. A dosage of 15% solid latex material to cement by weight (P/C ratio) was used. The polymer latex used was added to the mixing water and added to the mixed dry concrete ingredients, then mixing was completed for about 5 minutes. Table 2 shows the mixture proportions (based on dry masses of aggregates) and the properties of the fresh and hardened concrete for the mixtures used.

2. Specimen Curing and Preparation. The conventional concrete specimens were covered with wet burlap after being casted for 1 day, then after being de-molded the specimens were cured by complete immersion in water until the test date. The LMC specimens were covered with wet burlap for 48 hours after being cast, then after being de-molded the specimens were air cured at 23°C and 50% R.H. until the test date. The air curing regime proved to be the most

TABLE 1

Main Properties of Used Sand and Gravel

Property	Sand	Gravel
Specific Gravity	2.50	2.50
Bulk Density (kg/m^3)	1600	1760
Fineness Modulus	2.30	---
Clay, Silt & Fine Dust (% by volume)	2.80	---
Nominal Max. Size	---	20

TABLE 2

Concrete Mixture Proportions and Properties

	Conventional Concrete	LMC
Mixture Proportions (kg/m³)		
Cement	400	400
Gravel	1150	1150
Sand	550	550
Water (W/C)	150 (0.42)	36 (0.09)
P/C ratio*	----	15%
Measured Slump (mm)	80 - 90	80 - 90
Density (kg/m³)	2480	2520
28 day Compressive Strength (MPa)**	38.7	40.8
28 day Indirect Tensile Strength (MPa)**	3.2	5.1

* P/C ratio represents the solid polymer to cement ratio by weight of the cement. The used polymer material constitutes 47% by weight of the used latex.

** The average of three test results.

suitable regime for LMC(1,11,12). The specimens were tested after 28, 56 and 90 days of age. The experiment was conducted on three replicates and the average of the three results is reported and used in the discussion of test results.

The specimens consisted of concrete cylinders (10 × 20 cm) in which a steel reinforcing bar (10 mm in diameter and about 25 cm in length) was embedded (the specimen is usually referred to as Lollipop specimen). The steel bar was embedded into the concrete cylinder such that its end is at least at 5 cm from the bottom of the cylinder, Figure 1 shows a schematic diagram of the specimen.

3. Accelerated Corrosion Cell. An accelerated corrosion cell was used to compare between the rate of corrosion of both the conventional concrete and the latex modified concrete (LMC). Similar cells were reported by several researchers (13,14,15). In this cell the specimen was immersed to its half height into a 15% sodium chloride (NaCl) solution at room temperature, and connected to a constant 12 volt D.C. power supply such that the steel bar acts as the anode. A steel plate electrode was used as the cathode. The steel plate was cleaned periodically to prevent the deposition of calcium on the surface. Figure 2 shows a schematic diagram of the corrosion cell.

The specimens were monitored periodically by visual inspection to record how long it takes to crack due to the corrosion of the reinforcing bar. Also, the intensity of the electric current was recorded at different time intervals.

Test Results and Discussions

The corrosion current versus time relation had a steady low rate of increase in the current with time. The current intensity showed a sudden rise which coincides with the cracking of the

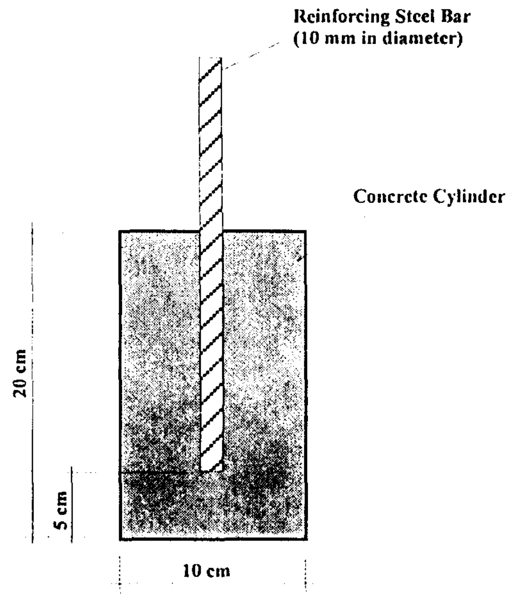

FIG. 1.
Schematic diagram of the lollipop specimen.

specimen recorded visually. The curve between the corrosion current intensity (mA) and time (hours) was plotted in order to determine the corrosion time of the specimen. at which the specimen cracked by corrosion. Therefore, the corrosion time can be defined as the time from the start of the experiment to the instant when a sudden rise of the current (cracking of the specimen) is observed. Figures 3 and 4 show typical curves of corrosion current versus time at different test ages for conventional concrete and latex modified concrete (LMC) respectively.

The latex modified concrete (LMC) showed a longer time to corrosion at all test ages compared to the conventional concrete, which indicates that LMC offers better protection to steel reinforcement against corrosion, Table 3 gives the average corrosion time (hours) for conventional concrete and latex modified concrete (LMC) at different test ages.

The increase in the corrosion time with test age was only about 4.2% for the conventional concrete, while it was about 23.9% for the latex modified concrete. This increase in the corrosion time with test age indicates a superior performance of latex modified concrete over conventional concrete, and that superior performance is enhanced as age increases.

An obvious decrease in the initial current intensity was observed for the latex modified concrete (LMC) compared to that of the conventional concrete, which indicates a higher electric resisitivity for the latex modified concrete (LMC). Also, fluctuation in the corrosion current intensity was observed during the first 100 hours of the test for all the latex modified concrete specimens. This fluctuation was not observed for the conventional concrete specimens. Figure 5 shows the corrosion current during the first 100 hours for the latex modified concrete. The dense microstructure of the latex modified concrete (LMC) (6,7), and its smaller pores which are partially filled with the polymer film reducing its permeability and absorption (1,6) are responsible for the fluctuation observed in the corrosion current.

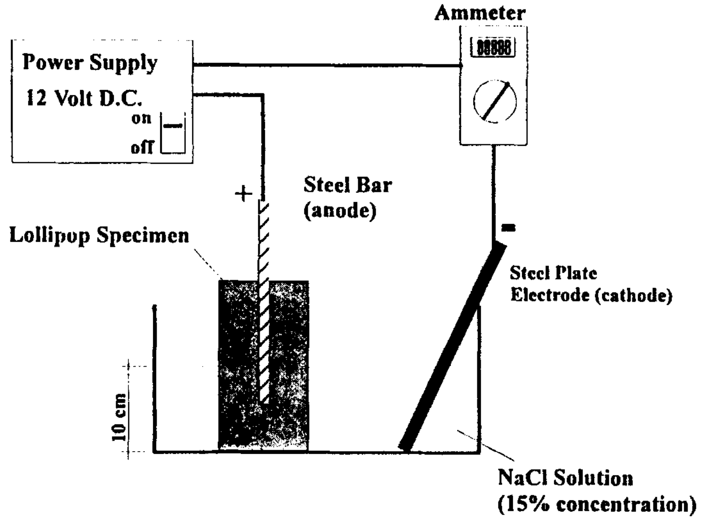

FIG. 2.
Schematic diagram of the accelerated corrosion cell.

Also, it was noted that wetting of the upper portion of the specimen, above the solution level in the cell, occurred about 12 hours after setting the experiment for the conventional concrete specimens. However, for the latex modified concrete (LMC) only the lower portion of the specimens was wetted until the cracking of the specimens. This could be attributed to the water blocking property, and consequently blocking of moisture movement in the latex modified concrete (LMC).

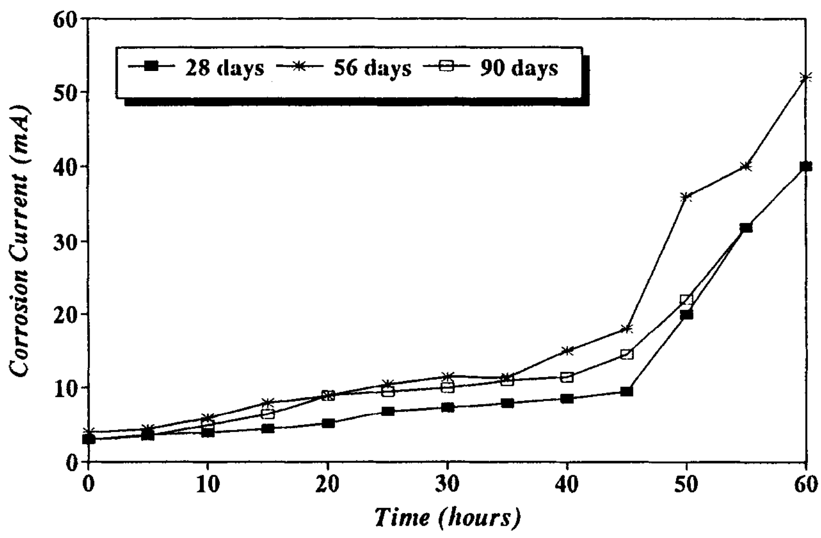

FIG. 3.
Typical curve of corrosion current with time for conventional concrete at different test ages.

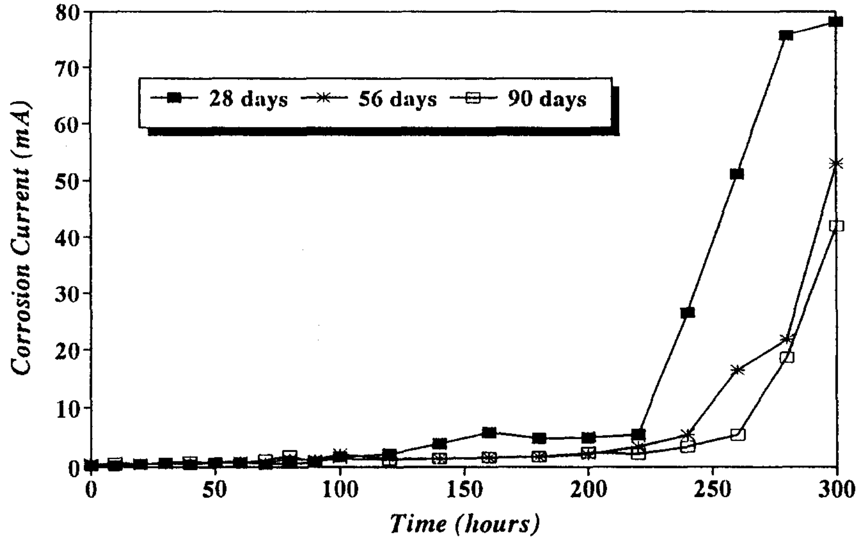

FIG. 4.
Typical curve of corrosion current with time for Latex Modified Concrete (LMC) at different test ages.

The crack propagation was as well different for both concretes. A fast longitudinal crack was observed for the conventional concrete, while a slow and a curved multi-directional crack was observed for the latex modified concrete (LMC). This could be attributed to the increase in the tensile strength (about 59.4%) of the latex modified concrete compared to that of the conventional concrete. This increase is due to the interlocking between the polymer network, the cement matrix, and the aggregates.

Conclusions

The accelerated corrosion cell proved to be a good and simple test to assess the durability of concretes especially with respect to chloride ion penetration, and steel reinforcement protection against corrosion.

TABLE 3

Average Corrosion Time (Hours) for Conventional Concrete and Latex Modified Concrete at Different Test Ages

Concrete Type	Test Age (days)		
	28	56	90
Conventional Concrete	48	48	50
Latex Modified Concrete	230	245	285

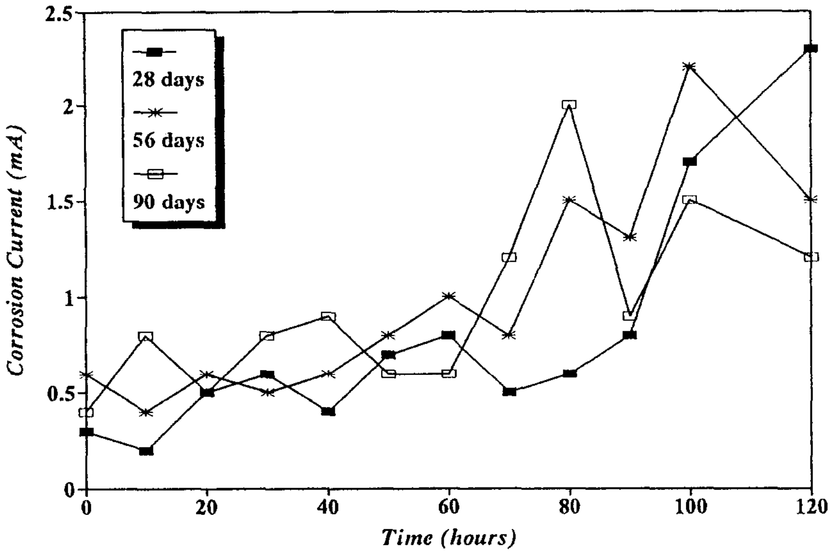

FIG. 5.
Corrosion current versus time for the first 100 hours for the latex modified concrete at different test ages.

The latex modified concrete (LMC) has a much better corrosion resistance compared to the conventional concrete of almost the same strength level. The corrosion resistance of the latex modified concrete increases significantly with age while that of the conventional concrete has a marginal increase. This higher resistance offers a better protection for the steel reinforcement against corrosion and especially that induced by the penetration of the chloride ions, which recommends the use of such concrete in structures exposed to severe environments such as bridge decks overlays, and marine structures.

Since the cost of production of latex modified concrete is higher compared to conventional concrete, the optimum latex modified concrete cover thickness for overlays should be investigated using the accelerated corrosion cell.

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