In Situ Electrosynthesis of Polymethyl Methacrylate within Ceramic Launch Pad Materials

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ABSTRACT

Electrokinetic deposition of methylmethacrylate is used to mitigate corrosion in reinforced concrete. The methylmethacrylate (MMA) monomer deposits in the pores in the concrete where it is converted into its polymer, polymethylmethacrylate, thus creating a barrier that also enhances the mechanical properties of the concrete. Previous to the MMA treatment an Electrokinetic deposition is used to transport calcium, sodium and potassium hydroxide particles through the capillary pores of concrete directly to the concrete reinforcement. The intent is to use these compounds as a sacrificial electrode layer during the electrokinetic deposition of methylmethacrylate monomer. Cylindrical reinforced concrete specimens were subjected to electrokinetic treatment and the specimens were tested to characterize porosity reduction and tensile splitting strength showing an increase in the tensile strength. In addition, nine specimens treated electro-kinetically and in long-term atmospheric exposure testing at NASA's Kennedy Space Center, seaside atmospheric exposure test site were tested to determine their corrosion rate.

RELEVANCE TO NASA RESEARCH

Launch pad facilities are subjected to fallout containing hydrochloric acid expelled from the solid rocket boosters. This acidic environment, combined with salt spray from the Atlantic ocean, heat, ultraviolet radiation, and high humidity makes the launch pad highly susceptible to corrosion and is one of the most corrosive environments in the US. Maintenance associated with corrosion of the infrastructure used by NASA's Kennedy Space Center to launch rockets represents a large expenditure of manpower and money.

PURPOSE

The purpose of this research is to study a novel way of treating concrete in NASA facilities to prevent its corrosion. In addition the electrokinetic treatment improves the mechanical strength of the concrete as an added benefit.

RESEARCH METHODS

Twenty five specimens of concrete, reinforced with a steel rod (Figure 1) were treated by electrophoresis. A dc electrical power supply was connected to the specimens with the positive (cathode) connected to the steel reinforcement bar and the anode to a metal mesh strip placed around the specimens (Figure 2).

Fig. 1 Specimen

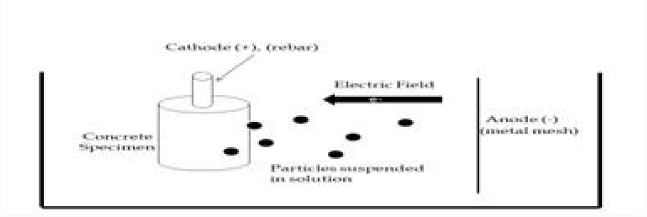

Fig. 2 Electroporesis

Fig.3 Experimental set up

The MMA electrodeposition process causes corrosion of the concrete reinforcement. To mitigate this corrosion, the reinforced concrete is treated electrophoretically with potassium hydroxide, sodium hydroxide and calcium hydroxide prior to the deposition of the methylmethacrylate.

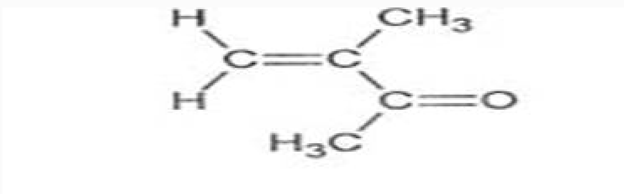

fig.4 Methylmethacrylate molecule

`Methylmethacrylate is a monomer that is soluble in water and can be driven electroporetically inside the concrete. Specimens 1 to 20 were treated; specimens 21 to 25 were kept untreated as control.

Additionally nine specimens had been in long-term environmental exposure at the NASA's Kennedy Space Center seaside atmospheric exposure test site. Specimens 1 to 6 were submerged in seawater for 1100 days, specimens 7 to 9 were exposed to the atmosphere at the test site for 1492 days.

RESULTS

Table 1 Porosity and Tensile Strength of treated specimens

Type of Treatment	Average Porosity (%)	Average Tensile Strength (psi)	Improvement in Tensile Strength Relative to Control (%)
Specimens 1-5 NaOH 2.25 M, KOH 2.25 M, $Ca(OH)_2$ 1.123 M+ MMA treatment	22.6±0.7	337	47
Specimens 6-10 NaOH 1.5M, KOH 1.5 M, $Ca(OH)_2$ 0.75M+ MMA treatment	21.9±0.4	366	60
Specimens 11-15 NaOH 1 M, KOH 1 M, $Ca(OH)_2$ 0.5M+ MMA treatment	21.9±0.7	260	14
MMA treatment (No hydroxides Treatment) specimens 16-20	23.1±0.3	213	-6
Control specimens 21-25	23.5±0.2	229	

Table 2 Tensile Strength and corrosion rate of exposed specimens

Specimen	Tensile Splitting Test (psi)	Corrosion Rate (mil per year)
1	421	0.1177
2	381	0.0477
3	419	0.0237
4	304	0.3956
5	387	0.4450
6	298	[illegible]
7	572	0.0473
8	732	0.0734
9	785	0.1709

DISCUSSION

The porosity of treated specimens did not vary much compared to the control specimens. This indicates that little methylmethacrylate (MMA) covered the concrete pores.

Even though little MMA entered the pores, it had a significant increase on the tensile strength of 60% and 47%.

CONCLUSION

The electrokinetic treatment has been shown as effective for strengthening the concrete even though the porosity has not changed much.

For the exposed specimens the steel reinforcement bars have visibly almost no signs of corrosion and the XPS results showed small peaks of iron, demonstrating the long term effectiveness of the corrosion prevention.

PROPOSED FUTURE WORK

It can be hypothesized that the hydroxides treatment had more to do with the strength increase than the MMA treatment. Further experimental work is needed to test this hypothesis. Also more work has to be done to achieve a better porosity reduction with MMA.

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