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Latex-modified concrete overlays using waste paint

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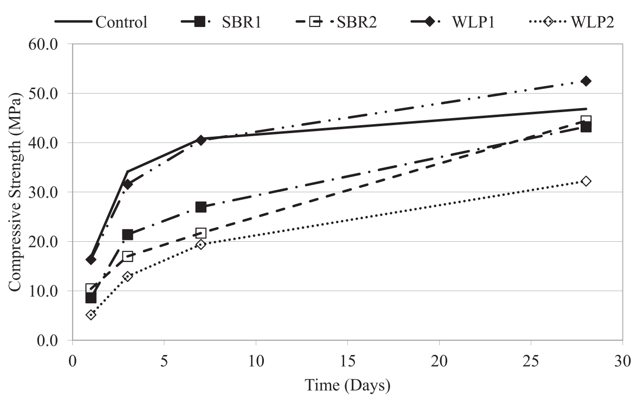
HIGHLIGHTS

- Latex paint is a major source of waste that is typically destined for landfills.
- It can be used to produce economic latex-modified concrete.
- The produced concrete has superior properties to normal concrete.
- It also has comparable properties to LMC produced using commercial additives.

GRAPHICAL ABSTRACT



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ABSTRACT

The U.S. generates over 35 million gallons of waste latex paint annually, which is difficult to recycle as it contains volatile organic compounds. However, waste latex paint can be used to produce an economic latex-modified concrete used for whitetopping, wearing surfaces in parking garages, and overlays, instead of commercial products resulting in significant cost savings. This study compares the use of waste latex paint to commercially available styrene-butadiene rubber latex in concrete for overlays, and evaluates concrete fresh and hardened properties as well as transport properties. Waste latex paint added to concrete results in characteristics comparable to polymer-modified concrete made with commercial latex products.

1. Introduction

Concrete is the world's most used man-made material and the construction industry's most used material. Portland cement is the essential binder in concrete, and makes the paste that binds all of the aggregates. However, production of portland cement requires a high amount of energy and reports estimate that it is responsible for up to 5% of the world's annual CO_2 emissions [1]. In addition, portland cement concrete is weak in tension, susceptible to chemical attack, and has a low strength-to-weight ratio. In order to overcome its vulnerabilities, several polymer-based admixtures and techniques have been constantly investigated and adopted in practice [2,3].

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Polymer-modified concrete (PMC) is a special concrete developed in an attempt to improve some of normal concrete drawbacks. Natural rubber was one of the first used polymers in concrete [3]; however, due to cost limitations, the use of PMC decreased. The use of synthetic polymers became widely accepted in the 1960 s [3]. After a study by the Dow Chemical Company and the Michigan Highway Department, styrene-butadiene rubber latex (SBR) became widely used in bridge deck overlays. The study found that SBR concrete had significantly lower chloride permeability than ordinary concrete, which can help protect the superstructure from corrosion-causing chloride ions [2,4].

Unused latex paint is a hazardous waste as it contains volatile organic compounds. In the United States, an estimated 16–35 million gallons of paint remain unused each year [5]. Without proper disposal, latex paint can pollute groundwater and harm wildlife. One solution to this problem would be to reuse the paint by taking advantage of the acrylic within the paint as an additive in concrete. Since polymers improve the properties of concrete, waste latex paint (WLP) has the potential to improve the properties of concrete as well.

Several studies have investigated the ability of WLP to simulate the properties of SBR. Nehdi and Sumner [6] completed one of the first studies on recycling waste latex paint in concrete by investigating the partial replacement of SBR with WLP. This study also examined the potential use of WLP in ordinary concrete for sidewalks. The investigation found that WLP concrete displayed similar characteristics as latex-modified concrete (LMC). A separate study by Mohammed et al. [7] examined the properties of concrete with incremental increases of WLP content. The investigation found several advantages to using WLP, including enhanced workability and improved flexural strength. In a more recent study, Almesfer et al. [8] investigated the use of WLP in concrete. The study examined various ratios of WLP addition in concrete to assess the optimum dosage. The study considered WLP as water replacement (0–20% replacement) and its impact on compressive strength, workability, tensile strength, elastic modulus of elasticity.

The present study compares the capacity of using WLP to produce concrete for overlays with similar properties to polymer-modified concrete incorporating SBR through five mixtures. The five mixtures consisted of one normal concrete (NC) mixture, two SBR mixtures made from different commercial manufacturers, and two WLP mixtures containing paint from two different sources. One paint product, WLP1, was acquired in a sealed container and the second paint, WLP2, was obtained in a previously open container, with no telling of any extent of drying. Although WLP1 and WLP2 both contained acrylic latex, SBR was used in testing due to its common commercial use in overlays.

2. Recycle and reuse methods for waste latex paint

Other than recycling WLP in concrete, several methods and strategies exist to properly dispose of or use the WLP. With up to 35 million gallons of latex paint remaining unused every year, the need to dispose of or reuse the WLP in an environmentally safe manner is important. The most common method of disposing WLP is through solidification then disposal in a landfill. Other than being the most common method of disposal, it is also one of the most damaging to the environment. WLP disposal in a landfill has the potential to contaminate the groundwater. However, with decreasing budgets, a growing number of communities are allowing the solidification of paint, which is then taken to landfills [9].

Some communities attempt to use the waste latex paint for their own needs. For example, in Hernando County, Florida, a cover of WLP must be placed over any landfill in order to protect from odor, disease, and wind gusts. Therefore, the landfill sprays a WLP and water mixture onto the landfill as the daily cover. Additionally, WLP is used as fuel in incineration chambers; however, this is not an efficient use of the valuable materials found in latex paint. Other communities have allowed for neighborhood collection of paint, which is then stored in the neighborhood and made available to members of the community. Half of all paint collected in its original container is suitable for reuse. The disadvantages of this system include the work needed to collect the paint and the need for storage by the neighborhood. Paint consolidation combines paints with similar characteristics into one batch. This allows for recycling of collected paint into high quality paint that is comparable to unused paint. This method requires collecting, screening unusable paints, sorting paints by type, and mixing [10].

Segala [9] studied a technique to recycle paint known as processed latex pigment (PLP). Sources for PLP paint include automobile manufacturing plants, entertainment production, maintenance companies, and professional painters. PLP is a patented method for recycling industrial paint sludge, water-treatment sediment, and leftover latex paint. PLP is shipped to portland cement plants in order to use the PLP as an additive for special cements or use the PLP as a raw material for the kiln feedstock.

3. Materials and methods

3.1. Materials

Materials for this study included portland cement, coarse aggregate, fine aggregate, high-range water-reducing admixture, SBR from two commercial manufacturers, and WLP from two sources. The portland cement was locally available type II/V with a specific gravity of 3.15. No. 8 graded coarse aggregate (specific gravity of 2.79 and 0.60 absorption) and well-rounded fine aggregate sand was used for the study (fineness modulus of 3.00, specific gravity of 2.78, and absorption of 0.80). A commercially available high-range water-reducing admixture was used to increase the workability of the mixtures. SBR1 and SBR2 are commercially available with a density of 1010 kg/m^3 and a solid content of 0.48 and 0.47, respectively. WLP1 was received sealed from a known source and deemed by a paint professional as "middle-of the road" quality, whereas WLP2 was acquired from an unknown source in an opened container. WLP1 had a published density of 1330 kg/m^3 and a solid content of 54%. WLP2 had a published density of 1250 kg/m^3; however, the manufacture did not provide a solid content by weight.

3.2. Mixture proportions

The mixtures followed the Specification for Latex-Modified Concrete (LMC) Overlays, ACI 548.4 [11]. The tested mixtures followed the minimum cement requirement of 390 kg/m^3. The fine aggregate was proportioned to be 50–75% of the total aggregate by weight. The minimum latex and water were 121 L/m^3 and 94 L/m^3, respectively. The mixtures were covered for 24 h, and allowed to air cure in laboratory conditions. The mixture proportions are available in Table 1.

Table 1
Details of mixtures and their proportions.

	NC	SBR1	SBR2	WLP1	WLP2
Cement, kg/m^3	393	393	393	393	393
Water, kg/m^3	149	54	77	107	125
Polymer, kg/m^3	–	125	125	107	119
Coarse aggregate, kg/m^3	905	720	774	887	708
Fine aggregate, kg/m^3	1125	1125	1125	1125	1125
High-range water-reducing-admixture, mL/100 kg cement	780	32.5	0	325	260
Total Water, kg/m^3	149	119	143	149	185
Slump, mm	180	110	190	80	120
Air Content,%	2	4	2	1	1
Water-cement ratio (*w/c*)	0.38	0.30	0.36	0.38	0.47
Polymer-cement ratio (*p/c*)	–	0.15	0.15	0.15	0.15
Solid content by weight,%	–	48	47	54	50
Polymer density, kg/m^3	–	1010	1010	1330	1250

SSD Conditions.