TESTING OF MASONRY BLOCKS WITH WASTE POWDER PAINT (WPP)

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Research

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ABSTRACT

Every year several million pounds of powder paint is discarded as waste from automotive and furniture manufacturing industries. The degradation of re-processed polymer in powder paint and the high volume challenge the recycling process, restricting to dispose the waste powder paint (WPP) in landfills. Therefore, there is an interest to use WPP in other industries. To supplement this interest, this research project was initiated with the objective of evaluating the potential of using WPP to control efflorescence in masonry blocks. Further, testing was performed to evaluate the absorption property of the masonry blocks with different WPP percentages.

Two mixes were used in preparation of masonry blocks, namely (i) light, and (ii) heavy. A total of 24 masonry block specimens were used in the test, out of which 18 had WPP. The specimens with WPP included specimens (i) without WPP (benchmark specimens) and (ii) with low, medium, and high amounts of WPP. These specimens were provided to the research team by a masonry block manufacturer, who did not reveal the respective mix composition of the specimens. Out of 18 blocks with WPP, 12 of them were used for evaluating the efflorescence potential and the rest were used for the absorption test. Out of 6 benchmark specimens, 4 of them were used for evaluating the efflorescence potential and rest were used for the absorption test. The efflorescence and absorption testing were performed following the procedure outlined in ASTM C67-12 and ASTM C140, respectively.

With the limited investigations of this research project, it was observed that all the specimens with light mix developed efflorescence, and the light mix specimens with medium amount of WPP had the highest efflorescence. However, the specimens with heavy mix did not produce any efflorescence. In regard to the absorption test, it was observed that absorption of the light mix specimens was about 3.5% greater than that of the heavy mix specimens, irrespective of the amount of WPP. However, from the research project it became apparent that the light mix specimens developed efflorescence irrespective of the WPP amounts. In order to derive firm conclusions, mix composition of the specimens should be known, and additional investigation for other properties is essential.

Keywords: Absorption, efflorescence, concrete, leaching, masonry, waste powder paint

Definitions:

- *Leachant* - the initial solution with which a solid is contacted and into which the solid dissolves or is leached.
- *Leachate* - the final solution resulting from a test in which a solid is contacted by a solution and leaches or dissolves.
- *Leaching* - the preferential loss of components from a solid material into solution leaving a residual phase that is depleted in those components, but structurally unchanged.

OVERVIEW

Powder paint is used in many industries including automotive and furniture manufacturing. When the powder paint is sprayed on to the components, a significant amount is wasted. As per a survey of six companies carried out by the Green Manufacturing Initiative (GMI) at Western Michigan University, waste powder paint (WPP) amounts to 1.5 million pounds per year. In general, WPP needs to be discarded into landfills. There is an interest to use WPP in other industries as a recycled material. However, the degradation of re-processed polymer and the high volume of waste exceeding the capacity of the outlets challenge the recycling process. Due to these recycling challenges and the significance of the monetary expenses involved in using WPP as a landfill material, there is an interest of exploring the use of WPP in other industries, without further processing, to promote sustainability. One such potential application is the use of WPP in masonry or concrete products. One of the greatest challenges faced by the masonry block industry is the leaching that causes discoloration of the surface of the structures. The most common effect is the development of efflorescence (mostly a white color deposit). Leaching is a process of extracting minerals from a solid by dissolving them in a liquid. Other words, any material that will get in contact with water will leach components from its surface or its interior, depending on the porosity, water repellency, and other properties of the material. The soluble salts in efflorescence may be any of the following or a combination thereof.

Sodium sulphate - Na_2SO_4
Potassium sulphate - K_2SO_4
Sodium carbonate - Na_2CO_3
Sodium bicarbonate - $NaHCO_3$
Calcium carbonate - $CaCO_3$
Magnesium sulphate - $MgSO_4$
Sodium silicate - Na_2O_3Si

The process of leaching is controlled by the release mechanisms of cations and anions, and many factors such as, (1) physical properties of cement matrix (permeability, absorption, porosity, tortuosity, etc.); (2) chemical factors such as pH-value, incorporation of soluble salts in mineral and glassy phases, and redox-potential; and (3) release mechanisms such as dissolution, “wash-off”, and diffusion. The porosity and pore structure depends on composition, age and degree of hydration, carbonation (affects pH), w/c ratio, curing, type of cement, grain size of the materials used, and temperature, and permeability. Wash-off is defined as the dissolving of absorbed soluble salts for a short period. Continuous dissolution is the dominant mechanism for leaching of concrete if aggressive leachates are in use. Dissolution occurs from the surface to the inside of the matrix. Diffusion depends on the concentration of elements in the pores and in the contact solution. Diffusion mainly occurs in the capillary pores.

Evaluation of the mechanism of leaching and the salts in the efflorescence requires extensive research. During this preliminary study masonry blocks with three different percentages of WPP (low, medium, and high) were used. Masonry blocks manufacturer gave two different masonry mixes, light and heavy. The exact composition of the mixes is unknown to the research team. The prime objective of the research was to evaluate leaching potential of these masonry blocks with 'mysterious' compositions.

SPECIMEN COMPOSITION AND LABELS

The two mixes that were used in preparation of masonry blocks were labeled as A (light) and B (heavy). The specimens with different WPP percentages were labeled with 0 (mix without WPP – benchmark specimens), 1 (low amount of WPP), 2 (medium amount of WPP), and 3 (high amount of WPP). Altogether, there were 24 masonry block specimens and 18 of them had WPP. Out of 18 blocks with WPP, 12 of them were used for evaluating the efflorescence potential and the rest were used for the absorption test. Out of 6 benchmark specimens, 4 of them were used for evaluating the efflorescence potential and rest were used for the absorption test.

ROOM CONDITION

Room conditions were set up as close to standard as possible. Davis weather station measured room temperature and humidity (Figure 1). Average temperature and humidity during the period were 70 ^{0}F and 26%, respectively. During leach testing, air circulation was maintained to facilitate water evaporation process by using a box fan (Figure 1).

(a) Weather station

(b) Box fan

Figure 1. Weather station and box-fan

LEACH TESTING

Objective

The objective was to evaluate the potential of using waste powder paint to control efflorescence in masonry blocks. Crystalline structures formed on the surfaces or in the sample containers were inspected for efflorescence indication.

Testing Procedure

There is no ASTM standard that directly addresses the evaluation of leaching potential of masonry blocks. Hence, ASTM C67-12 "Standard Test Methods for Sampling and Testing Brick and Structural Clay Tile" was used.

For these tests full size blocks were used. Blocks were brushed to remove loose material. Each block was labeled in accordance with its mix and compound type. The specimen weights were measured and recorded to the nearest 0.001 g. After that, each specimen was placed in a tray with de-ionized water. The water levels in the containers were marked. The specimens were dipped in the water, allowing part of the sample to remain above the water level (Figure 2). A box fan circulated air over the samples. The specimens were in this setup for seven days. During this time, a constant water level was maintained in each container by periodic inspection and filling with de-ionized water, as needed. During this time, periodic inspections were performed to document the level of efflorescence developed on the surface of specimens. The condition of specimens was digitally recorded by taking pictures in the order shown in Figure 3.

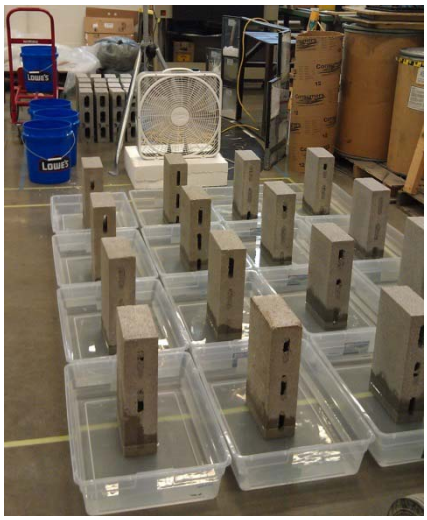

Figure 2. Masonry blocks in water

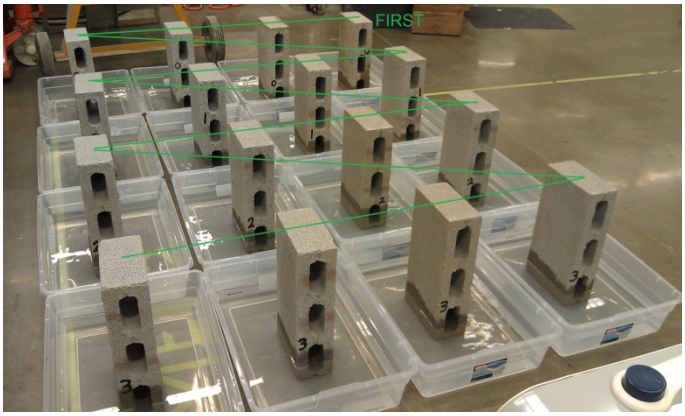

Figure 3. Order of picture documentation

Results

The two mixes that were used in preparation of masonry blocks were labeled as A (light) and B (heavy). The specimens with different WPP percentages were labeled with 0 (mix without WPP – benchmark specimens), 1 (low amount of WPP), 2 (medium amount of WPP), and 3 (high amount of WPP). Two specimens from each category were used in the test. Specimens were labeled in the format of xA-y (example: 0A-1; represents 1st specimen of light mix with no WPP).

One side of each specimen was immersed in 1 in. deep water. Water level was maintained at that level during the entire period. Specimens were observed daily for one week and the efflorescence status was documented as shown in Table 1 and Table 2. All the specimens with light mix developed efflorescence and the specimens with medium amount of WPP had the highest. None of the specimens with heavy mix had efflorescence. Without knowing the mix constituents, it is not possible to make any conclusions.

Table 1. Efflorescence Status

Duration	Light Mix				Heavy Mix			
	0A	1A	2A	3A	0B	1B	2B	3B
7 Days	Light	Light	Medium	Light	None	None	None	None

Table 2. Catalog of Efflorescence Status

None	Light	Medium
		

ABSORPTION TESTING

Objective

Objective of testing was to evaluate the absorption of specimens with different WPP percentages.

Testing Procedure

Testing was conducted following the procedure outlined in ASTM C140. Note that there are specific ASTMs to perform water repellency properties of masonry units. These tests were not considered at this time due to sample size and unknown mix composition. ASTM C140 is equally applicable for testing a complete block or samples derived from it.

Specimens for absorption test were prepared using the masonry blocks that were not used for leach testing. Each masonry block was cut into six pieces. Then the specimens were submerged in clean water for 24 hours. After that the specimens were removed and patted with damp burlap to bring the specimens to the saturated surface dry condition (SSD) and the SSD weight was recorded. Figure 4 shows the testing apparatus and the specimens in different moisture condition. After that, the specimens were placed in a ventilated oven to bring the specimens to the dry state. The specimens were dried in the ventilated oven at a temperature of 240 ^{0}F until the weight of specimens remained constant within the limits given in the ASTM. It is worth noting here that, after drying the blocks, they were allowed to remain in a ventilated oven using cooling mode at a temperature of 75 ^{0}F for about 2 hours to reach room temperature. After that the constant weight was recorded as the dry weight.

Electronic scale

Oven

Specimens in the oven

Specimen submerged in water

Saturated specimens on a burlap

Specimen in SSD condition

Figure 4. Apparatus and specimens in different moisture conditions

Results

Absorption (%) was calculated using the following equation and the results are depicted in Figure 5.

$$\text{Absorption (\%)} = (\text{SSD Weight} - \text{Dry Weight})/(\text{Dry Weight}) \times 100$$

Irrespective of the WPP content in the blocks, absorption of the light mix (mix A) was 3.5% greater than that of the heavy mix (mix B). It is clear from the results that the WPP content did not alter the amount of absorption. However, in order to derive firm conclusions, the mix composition of light and heavy mixes should be known. As well, additional testing on water repellency should be conducted.

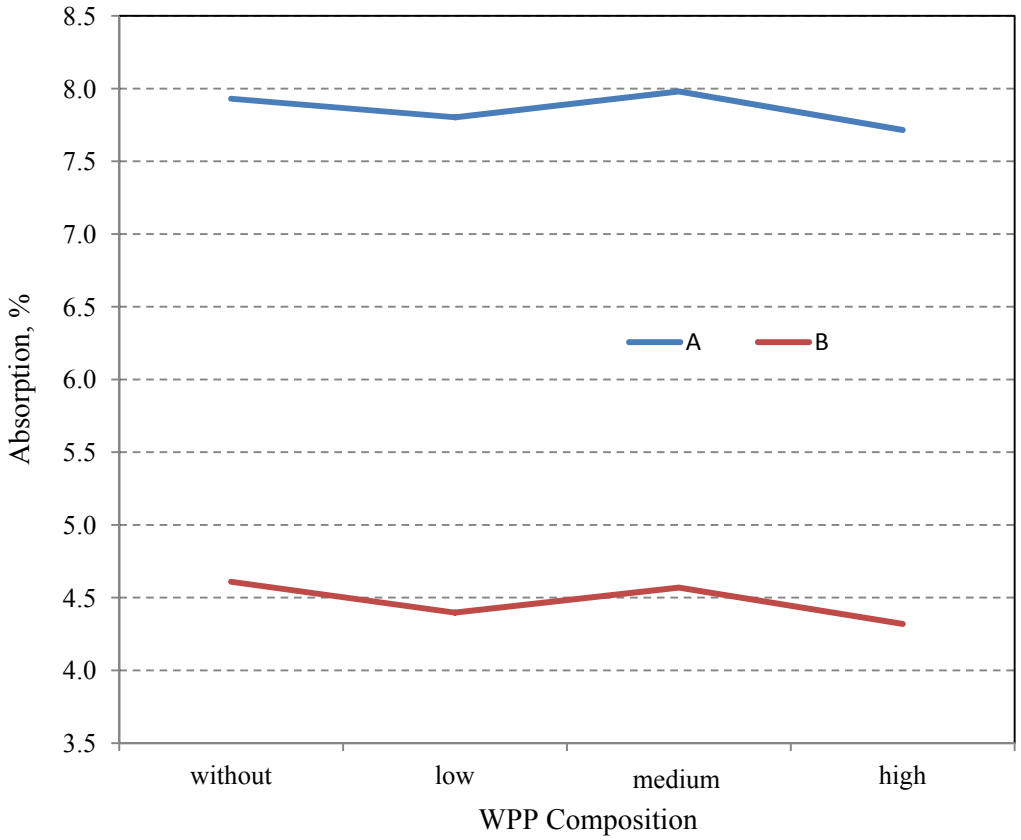

Figure 5. Absorption results of masonry units

SUMMARY AND CONCLUSIONS

The research team was provided with two *mysterious* mix compositions of masonry blocks, namely, (i) light (mix A), and (ii) heavy (mix B), to evaluate the potential of using waste powder paint (WPP) to control efflorescence in those blocks. A total of 24 masonry block specimens were provided with different percentages of WPP, labeled as (i) 0 (without WPP), (ii) 1 (with low amount of WPP), (iii) 2 (with medium amount of WPP), and (iv) 3 (with high amount of WPP). The efflorescence testing was performed for the 12 specimens with WPP and 4 without WPP, following the procedure outlined in ASTM C67-12. Further, absorption testing was performed for the remaining 6 specimens with WPP and 2 without WPP, following the procedure outlined in ASTM C140.

During the efflorescence testing, average temperature and humidity were 70 ^{0}F and 26%, respectively, and the air circulation was maintained to facilitate water evaporation process. The specimens were dipped in the water, allowing part of the sample to remain above the water level, for seven days. At conclusion of the test, it was observed that all the specimens with label A (i.e., light mix) developed efflorescence, specifically the specimens labeled 2A (i.e., light mix specimens with medium amount of WPP) had the highest efflorescence. However, the specimens with label B (i.e., heavy mix) did not produce any efflorescence.

During the absorption testing, each masonry block was cut into six pieces and then submerged in clean water for 24 hours. The specimens were then removed and patted with damp burlap to attain the saturated surface dry condition (SSD) and their weights were recorded. Afterwards, the specimens were placed in a ventilated oven at 240 ^{0}F to attain the dry state. The absorption was then calculated as the percentage of the dry weight for the specimens. At conclusion of the test, it was observed that absorption of the specimens with label A (i.e., light mix) was about 3.5% greater than that of the ones with label B (i.e., heavy mix), irrespective of the amount of WPP.

With the limited investigations of this research project, it became apparent that the light mix specimens developed efflorescence and had greater absorption, irrespective of the WPP amounts. In order to derive firm conclusions mix composition of the specimens should be known, and additional investigation for other properties, such as water repellency property, is essential.

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