INFLUENCE OF WASTE LATEX AND ACRYLIC PAINT ON CONCRETE MASONRY BLOCKFILL RHEOLOGY AND STRUCTURAL PERFORMANCE

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SUMMARY

The viability of using waste latex and acrylic water based paint as an effective admixture to enhance the properties of blockfill grout was investigated. Various laboratory tests and field trials were undertaken, with the aim of developing a product to a state where it could be successfully released into the New Zealand market, with release into international markets in the future.

The end product will be an environmentally friendly blockfill grout, containing none of the existing chemical admixtures which are usually included in blockfill for grouting of reinforced concrete masonry walls. It complies with the requirements and specifications of the appropriate material design standards.

INTRODUCTION

A valuable resource exists in the waste stream of water based acrylic and latex paints that are currently ending up in landfills at a large economic and environmental cost. The supply within New Zealand currently stands at 70,000 litres of paint, and with a growing balance, the need for a successful solution grows proportionally.

Many of the exhibited properties of waste paint are similar to those of polymer admixtures, commonly used within concrete mix design. Polymeric admixtures increase the matrix bond between the cement and aggregate particles and increase the workability and flow of cementitious materials. Investigating the increased workability was the primary reason for application as a blockfill grout, although there were other contributing factors such as the low risk implications, and the reduced visibility of blockfill should colour tint be an issue. The ability of the material to flow effectively within the core of a masonry unit, and the resulting potential to remove mix-water and thus increase strength, is the motivation of the project.

PaintCrete, a consortium between a paint manufacturer (Resene); a specialist in product stewardship (3R Group); and a concrete and masonry manufacturer (Firth); has been established

to develop applications that utilize waste paint to enhance the properties of concrete. The use of PaintCrete as block-fill is the subject of this research project and is the first application to be tested: but depending on the quantities of water-based paint available, the PaintCrete partners expect to develop other concrete applications using waste paint.

This research seeks to validate PaintCrete as an efficient, safe, marketable blockfill grout. The success of PaintCrete will be gauged against appropriate material design standards and the assessment of experienced professionals within the industry.

PRINCIPLES OF POLYMER MODIFIED CONCRETE

Polymer based admixtures have been an active ingredient in the modification of cementations applications for well over 70 years. Ohama, (1998) reported a study on polymer-based admixtures which summarized the present knowledge of the field.

Although polymer-based admixtures in many forms are used in cementitious composites such as grout and concrete, it is important to ensure that both cement hydration and polymer film formation proceeds well in order to yield a monolithic matrix phase with a network structure in which the cement hydrate phase and polymer phase interpenetrate. It is in the formation of such a co-matrix phase that superior properties compared with conventional cementitious materials are achieved. The co-matrix phase is generally formed according to the simplified model (see Figure 1) and the inclusion of the aggregates within the matrix is shown.

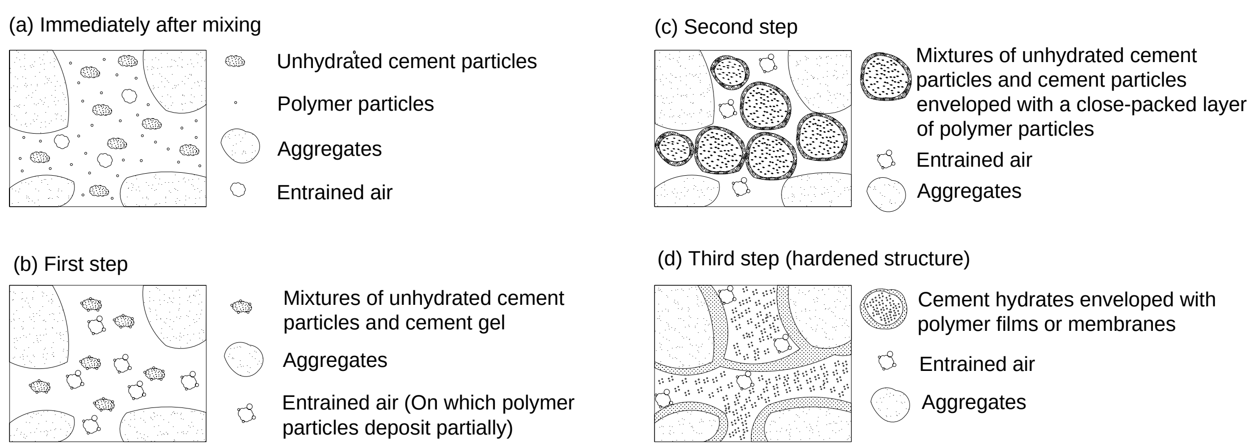

Figure 1. Simplified model of polymer-cement co-matrix formation (Ohama, 1998)

PROPERTIES OF POLYMER MODIFIED CEMENTITIOUS MATERIALS

Ohama described the properties of polymer modified grout and concrete as being markedly improved over those found when using conventional mix designs. The properties of the fresh and hardened concrete are affected by a range of factors such as polymer type, polymer-cement ratio, water-cement ratio, air content and curing conditions. However these can all be controlled to create the desired properties, outlined below. It follows that given the highly variable ingredients

of paint across the many types and brands included in the waste stream, the resulting properties of the cementitious material will be difficult to accurately predict and harder to control during manufacture.

Workability

The increased workability of polymer-modified cementitous materials is one of the primary advantages observed in this study. The workability is mainly interpreted in terms of the improved consistency due to the 'ball bearing' action of the polymer particles and fine mineral fillers in the paint: the entrained air and the dispersing effect of surfactants, which act as emulsifiers; and paint stabilizers, by lowering the surface tension of a liquid allowing easier spreading in the polymer latexes. It is expected that the concentration of surfactant in any given paint is likely to result in higher concentrations of surfactant than is commonly included via chemical admixtures in conventional blockfill grout (Aggarwal, 2007).

Air entrainment

In most latex-modified mortars and concretes, the amount of air entrained is slightly more than that of an ordinary concrete mix. This is because of the action of the surfactants in the polymer latex, which have a foaming effect. Specifically in the case of waste paint and the multitude of paint types/brands contained, there are many different ingredients and additives which can affect the material's air entraining qualities. The net effect of these was identified within the laboratory phase.

Strength

Polymer modified concretes and cements show a noticeable increase in tensile or flexural strength but no improvement in compressive strength compared with ordinary cement mortar and concrete. This can be explained by the high tensile strength of the polymers themselves and an overall improvement in cement hydrate-aggregate bond.

PRIOR APPLICATIONS OF PAINT IN CONCRETE

Nehdi and Sumner (2003) reported upon on the application of recycling waste latex paint (WLP) in concrete with a focus on its use for urban concrete sidewalks in Ontario, Canada. They found that WLP contributes in a similar form to virgin latex by exhibiting the same advantages in cementitious materials, such as increasing flexural strength and decreasing chloride ion penetrability. A field demonstration sidewalk modified with WLP exhibited enhanced workability and finishing, and better durability to surface scaling and aggregate pop outs. They concluded that more research was required to investigate the effect of WLP on the stability and spacing factor of air bubbles in air-entrained concrete, the effect of WLP on expansion due to alkali-silica reaction, the variability of WLP over time, its effect on industrial concreting

equipment, and the stability of contaminants that may be present in recycled paint (Nehdi & Sumner, 2003).

LABORATORY TESTING

Laboratory testing was completed for the purpose of determining an initial approximation of the optimal paint dosage to achieve the desired properties. The results reported below on the various fresh and hardened properties of Paintcrete verify the potential of waste paint as a successful cementitious admixture. This ensured that the later phases of larger scale tests are undertaken with an enhanced knowledge of the optimal paint dosage, giving results comparable to that expected to occur when it is applied at industry level.

It was decided that information would be collected on blockfill compressive strength, tensile flexural strength and spread (workability). The spread information was recorded as the blockfill was batched, while the flexural strength data was recorded after 28 days. The compressive strength as well as the development of strength was required and hence cylinders were tested after 7 days, 28 days and 56 days.

The testing consisted of nine concrete cylinder samples, three flexural beams and three spread tests completed at 0%, 4%, 8%, 12%, 16% and 20% paint replacement of water by mass.

MATERIALS USED IN TESTING

Cementitious Materials

All materials used in the laboratory testing were identical to those found in the blockfill grout produced by a local ready-mix concrete plant. The mix design contained a water/cement ratio of 0.7 and a maximum aggregate size of 7 mm.

Chemical Admixtures

The following are the standard chemical admixtures as used and supplied by the blockfill supply company.

Micro Air 940 is an ultra stable air-entraining admixture for use in all types of concrete. Micro-Air is particularly recommended for use in concrete in which it has previously been difficult to maintain the desired air content. Micro-Air is supplied as a ready-to-use aqueous solution, free of added chloride. It improves durability, resistance to freeze/thaw cycles, workability and reduces permeability (BASF, 2006a).

Pozzolith 370C is a ready to use liquid admixture formulated to improve the performance of concrete in both the plastic and hardened states. Pozzolith 370C is a non-retarding, water reducing, strength enhancing admixture which does not contain added chloride (BASF, 2006b).

Waste Paint

The waste paint used in testing was sourced directly from the Resene Paintwise program, which recovers paint and packaging back from the community for useful application, rather that bulk disposal. The paint is collected in large storage tanks, which results in a consistent end product with little variation in properties ensuring a stable national average in material quality, given the variety of paints collected.

The paint was supplied for this testing program in 10 litre pails, and was subjected to approximately one minute of agitation by hand prior to testing. Based on visual inspection this returned the paint to a uniform state, ready for use within the blockfill mix. The colour of the paint was an “off grey”, slightly lighter, but not unlike the colour of typical concrete.

The paint was sampled and tested at the paint collection factory to determine the variability, with water content, pigment percentage and polymer percentage recorded. Twenty samples were taken across four drums of paint, with the drum average results below.

Table 2. Variability of paint samples obtained from the Resene Paintwise Program

Drum	**% Water**	**% Pigment**	**% Polymer**
1	46.6	28.9	24.5
2	47.9	22.5	29.6
3	48.7	26.9	24.4
4	47.1	28.8	24.1
Average	**47.6**	**26.8**	**25.6**

The data shown above (see Table 2) indicates that paint is made up of approximately 50% water, and thus the amount of water removed for replacement by paint is not as substantial as perceived. The other parts which make up the paint are where the variability is derived, as paint manufacturers use a broad range of pigments and polymers in their products. These ingredients contain an even greater number of additives present to keep the paint stable and as required to serve its original purpose. Along with the polymers, it is these ingredients which will create changes in the way concrete is expected to behave with possibly drastic changes to air content, workability, setting times, and concrete density.

TEST PROCEDURE

Testing was undertaken in accordance with the relevant standard NZS 3112:1986 (SNZ, 1986).

CYLINDER TEST RESULTS

Three cylinders were tested for each paint dosage and time period. The three cylinders were averaged and the data in the graphs (see Figure 2) shows this average value.

The 7 day results indicated peak strength at 12% water replacement for paint (see Figure 2). Data accuracy was ±0.5 MPa and with the spread of the data points with the addition of waste paint being around 2 MPa the trend does not yet hold substantial evidence to be considered valid. Also, the control test had a stronger compressive strength than the samples containing waste paint, suggesting that the paint had either reduced the cement matrix strength or simply retarded the mix, slowing down the speed at which the strength is developed.

The trend witnessed after 28 days (see Figure 2) has developed further as expected however it has slightly left-skewed with the optimum value shifting towards 16% rather than the previously observed 12%. There still exists a drop off either side of this point suggesting that the addition of too little waste paint is as crucial as too much waste paint. It is also noted that the 16% data point has crossed the crucial 17.5 MPa barrier which is the standard required 28 day strength specified in NZS 4210, although it continues to lag behind the control test to a lesser degree than after 7 days.

The 56 day results (see Figure 2) have continued to follow the trend shown after 7 and 28 days, with a further increase in strength. The overall result is that at around 12%-16% an optimum strength occurs, with both points safely above the code specified 17.5 MPa minimum (SNZ, 2001).

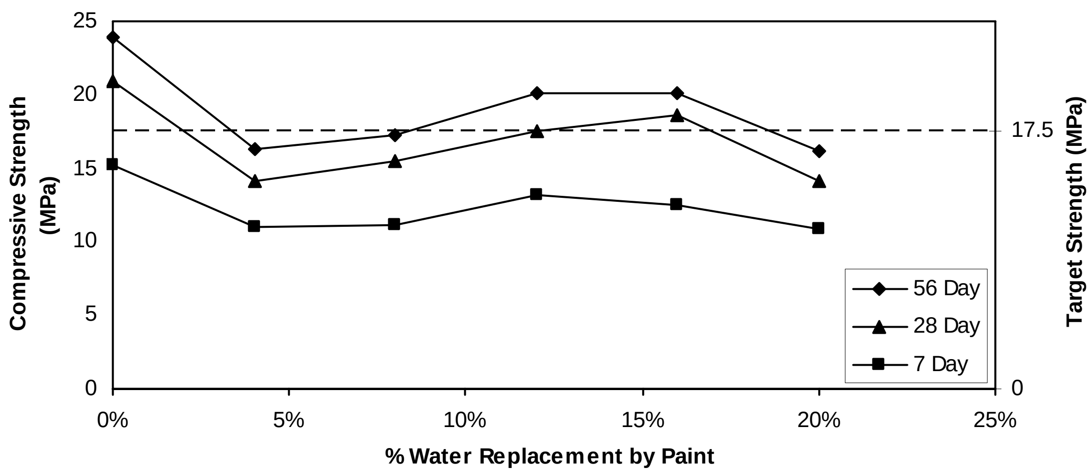

Figure 2. Compressive Strength Results

SPREAD TEST RESULTS

Spread tests were undertaken on the fresh concrete on each day prior to casting the cylinders and beams. As dictated by NZS 3112, the blockfill was allowed to flow through an inverted slump cone, onto a level low friction surface forming a circular mound. Two dimensions were measured at right angles to each other and averaged to obtain the spread data. Three tests were completed per batch and the variance observed between tests was found to be negligible.

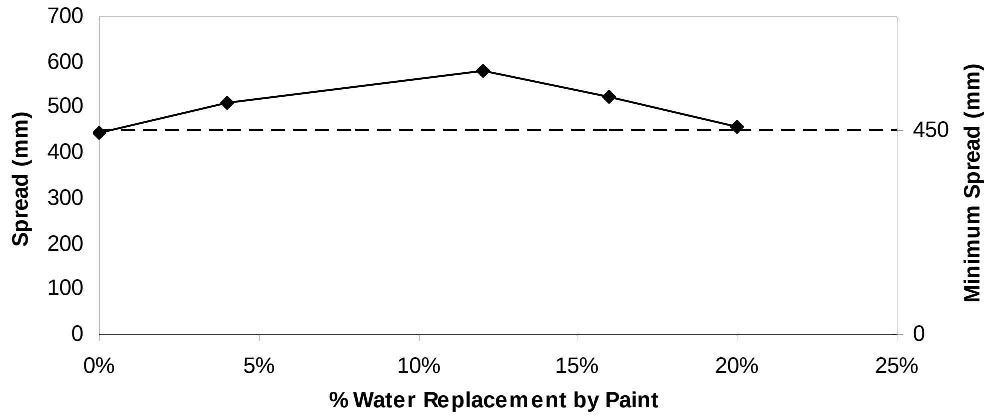

Figure 3. Average spread value

The trend observed within the compressive strength data is also apparent in the spread test results with a peak occurring at 12% paint replacement for water (see Figure 3). This optimum is 580 mm, which is well above the code specified minimum of 450 mm (SNZ, 2001).

This trend is an ideal result, as when a higher workability occurs at the same time as higher compressive strength, it suggests that water can be removed from the mix and an even stronger hardened material can be achieved. This serves as potential to bring the compressive strength of the Paintcrete samples closer to, or greater than the control sample, while maintaining a superior workability.

The other notable point is that the addition of paint instantly increases the workability, rather than the sudden compressive strength drop, followed by a gradual increase, shown as soon as paint is present. The trend does suggest however that the inclusion of *too much* paint will cause the paste to seize up, and lose workability.

SPREAD VERSUS TIME RESULTS

Spread tests were conducted at a constant waste paint percentage of 12% based on the optimum suggested by earlier testing. Variation was introduced by removing the admixtures and introducing only waste paint with the mix-water, in an effort to perceive the best and worst case scenarios. The following mixes were tested, using the same 17.5 MPa blockfill quantities of cement, aggregate, sand and water as in previous tests.

Table 3. Spread vs. Time mix designs

MATERIAL	CEMENT	AGGREGATE	SAND	WATER	MICRO AIR	POZZOLITH	PAINT
Test One	*	*	*	*	*	*	
Test Two	*	*	*	*			
Test Three	*	*	*	*	*	*	*
Test Four	*	*	*	*			*

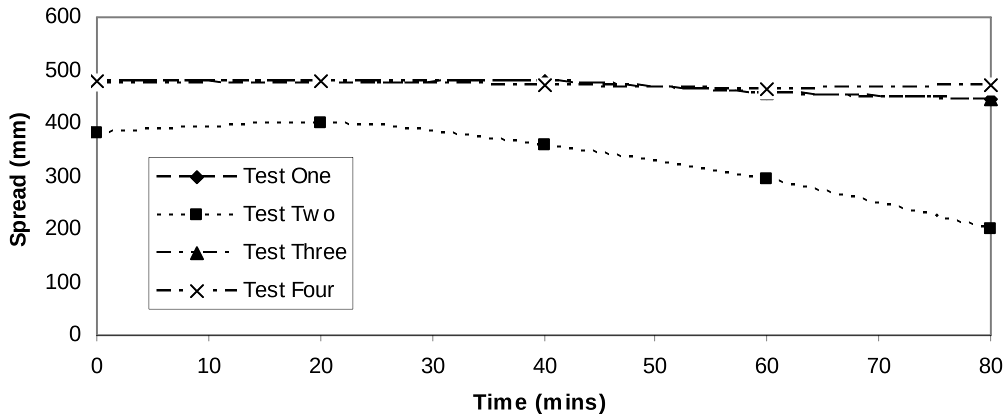

Figure 4. Spread vs. Time results

The results of this test were very positive as it is immediately noticeable that the only mix design that had undesirable properties was Test Two, which contained no additives (chemical or WLP) at all. The other three tests were almost inseparable and it can thus be concluded that waste paint on its own is equally as effective as the standard admixtures (Micro Air and Pozzolith 370C) at maintaining workability.

AIR CONTENT / YEILD POT RESULTS

The effectiveness of waste paint as an air entrainer is not known and can be excessive due to the level of surfactant potentially available. The following test was completed to investigate this property and determine if waste paint was a suitable replacement for the chemical admixtures currently used in conventional blockfill. The test was completed in conjunction with slump vs. time experiment (refer Table 3) and thus the identical mix design was utilised.

	Test One	**Test Two**	**Test Three**	**Test Four**
Average Air %	6.4	3.4	12.2	12.6

Figure 5. Air content results

It is clear that waste latex paint was potentially too effective in entraining air, causing the air content to double from 6.4% to 12.6%. This was a similar result from the addition of waste paint, regardless of whether the chemical admixtures were present also. This suggests a possible upper limit or asymptote as air content increases. This test has highlighted the need to ensure that an excess dosage of paint is avoided, which would result in a density loss and resultantly a compressive strength reduction.

INITIAL INDUSTRY PAINTCRETE TRIAL

A wall with low risk implications (see Figure 6) was located at a processing factory and selected to be subject to the first full scale industry trial of blockfill grout containing latex and acrylic

water based paint. The test was planned to be purely qualitative in nature, with no physical data being collected. This step was required to establish that the masons involved in the construction phase were satisfied with the material.

The end result was a successful trial and the masons on site were pleased with the end product and had several positive things to say. They felt that it “flowed well, clearly with no need for re-vibration” and “Troweled a bit differently, smooth, like icing”.


Figure 6. The first full scale industry trial of Paintcrete

FURTHER PLANNED INVESTIGATION

The remaining laboratory tests planned will be investigation of the specific rheological properties of Paintcrete and will be verified with the assistance of a Rheometer, along with further tests to validate the complete removal of the standard chemical admixtures. Paint dosages will be varied and compared to that of standard blockfill grout. The rheometer data is expected to be more reliable than the trends obtained from spread tests.

The next step in the testing process involves larger scale testing to investigate the interaction between the blockfill and the masonry units under simulated seismic loading. The filled masonry units will be tested as prisms, and as full scale walls. These tests will examine the effects of water escaping the mix through the pores in the masonry units, as well as the overall construction benefits of Paintcrete.

The scope of study involving the chemistry of paint and it constituents is extensive, and possibly beyond the scale of this project. It will however be beneficial to look at the concept of the fine particles found in paint, working as fine fillers to pack around the aggregates, and potentially improve the rheology and strength when at the correct dosage. The use of an electron scanning microscope will also be employed to gain an understanding of how the polymers are interacting with the cement particles (Bache, 1981).

A full scale seismic in-plane test will complete the study with results compared to similar data on walls with standard blockfill (see Figure 7).

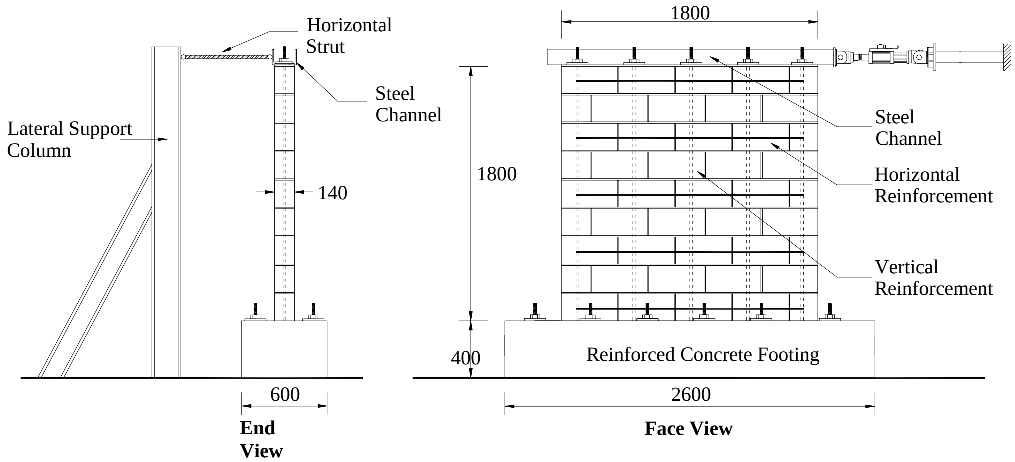

Figure 7. Full scale seismic in-plane Paintcrete test setup

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