

Drying Shrinkage and Porosity of Polymer Modified Concrete Containing Vinyl Acetate Effluents

Ainul Haezah Noruzman^{1*}, Mohammad Ismail², Taliat Ola Yusuf³ and Parham Forouzani⁴

¹*Politekik Sultan Salahuddin Abdul Aziz Shah, 40150 Shah Alam, Selangor, Malaysia*

²*Faculty of Civil Engineering, Universiti Teknologi Malaysia, 81310 Skudai, Johor, Malaysia*

³*School of Environmental Studies, Federal Polytechnic, Ede. P.M.B. 231.Ede, Osun State, Nigeria*

⁴*Department of Structures and Material, Faculty of Civil Engineering, Universiti Teknologi Malaysia, 81310 Skudai, Johor, Malaysia*

ABSTRACT

The volume of waste generated from surface coating industries is of global concern. The disposal of this waste in the form of effluent has put enormous pressure on land and also poses as a health hazard when it leaches into soil and underground water. The study aims to examine the utilization of vinyl acetate effluents from water based paint factories as an admixture in concrete. Concrete specimens containing 0%, 2.5%, 5% and 10% of vinyl acetate effluents by weight of cement were prepared. The specimens were tested for drying shrinkage for 28 days and porosity was tested using mercury intrusion porosimetry. Findings show that concrete containing various proportions of vinyl acetate effluents manifests higher shrinkage behaviour compared to the control item. An investigation of pore size distribution reveals that polymer effluents have particles size larger than 50 nm which are categorize as macroporous in accordance to IUPAC classification. It can be concluded that adding polymer vinyl acetate effluents affects concrete deformation due to the condition of its pore structures. The utilization of this material may provide beneficial effect in terms of the durability performance of concrete and minimize environmental pollution.

Keywords: Drying shrinkage, polymer, pore size distribution, porosity, vinyl acetate effluents

INTRODUCTION

ARTICLE INFO

Article history:

Received: 29 September 2016

Accepted: 05 April 2017

E-mail addresses:

ladyahn75@gmail.com (Ainul Haezah Noruzman),
mohammad@utm.my (Mohammad Ismail),
taliatyusuf@yahoo.com (Taliat Ola Yusuf)

*Corresponding Author

There is a rapid growth in surface coating industries due to population growth and urbanization. The production of water based surface coating especially water based paint is likely to increase due to strict regulation aimed at lessening the effect of volatile substances in the environment. Excessive

waste disposal from these industries are sent to landfills where it is further segregated (Dursun & Sengul, 2006). Most of the wastes are in the form of solids and liquids as well as volatile organic compound (VOC) emission and must be taken into consideration before it is released into the environment. Research has shown that the use of low-solvent and solvent-free paints can minimize health risks (Harrington et al., 1994). Therefore, switching to water based paint has become pertinent. Apart from being a harmful waste generated by paint industries, there exists the potential of recycling the waste especially as waste polymer in concrete. Manufacturing of water based paint from vinyl acetate resin consumes a large amount of water, ammonia, dispersant, pigments, extenders, resins, preservatives, antifoaming agents and polyvinyl acetate emulsions. (Randall, 1992). The ensuing cleaning operations produces wastes (Lorton, 1988; Dey et al., 2004). Thus using these wastes in concrete production can be an effective recycling method.

Concrete made by combinations of cements and organics material is not new. The first patent of this modification was issued by Cresson 90 years back. Concrete and mortar made by mixing water with polymer is called polymer modified concrete (PMC) and polymer modified mortar (PMM) respectively. In general, PMC depends significantly on the polymer content rather than water content when assessing the normal concrete or mortar (Ohama, 1998). Recent research incorporating waste polymer in concrete and mortar showed promising results in terms of strength and durability. This utilization as an indirect way of its disposal, will furthermore reduce the potential environmental pollution of this waste. Additionally, it will reduce the cost encountered by its management. Previous researchers (Nehdi & Sumner, 2003; Mohammed et al., 2008) studied the potential use of waste latex paint as a partial replacement for virgin latex in latex modified concrete and as partial replacement of mixing water in municipal sidewalk. Other work (Ismail & Al-Hashmi, 2011) accomplished the study of assessing the recycle of polyvinyl acetate resin wastewater to replace fresh water in the concrete. Besides of these isolate remarks from the previous study, there is not much research effort utilizing of vinyl acetate effluents in concrete especially from strength and deformations aspect. This research aims to study the possible use of vinyl acetate effluents in concrete production as well as to minimize or to reduce the menace of the problem associated with the disposal of vinyl acetate effluents. More important the combinations of waste polymers with concrete could be useful in improving some of properties of concrete and constitute a sustainable construction material.

MATERIALS AND METHODS

Materials

Ordinary Portland cement (OPC) complying with BS EN 197-1(2000) was used. Table 1 presents the chemical compositions and physical properties of the cement. Aggregates used are crushed granite gravel and natural-river washed quartz sand with minimum nominal sizes 10 mm and 2.75 mm respectively. The sand has a fineness modulus of 2.57.

Table 1
Chemical and physical properties of cement composition

Composition	%
Silicon dioxide (SiO_2)	20.1
Aluminium oxide (AlO_3)	4.9
Ferric oxide (Fe_2O_3)	2.4
Calcium oxide (CaO)	65.0
Sulphur oxide (SO_3)	2.3
Magnesium oxide (MgO)	3.1
Insoluble residue	1.9
Loss on ignition	2.0
Lime saturated factor	0.85

Vinyl acetate effluents used in this study, i.e. the waste latex was generated from production of polymer dispersion factory in southern of Malaysia. The effluents were collected from washing or cleaning tank before production of another batch of paint. The effluents are milky white in colour and have a viscosity of 12.5 cp with the total solids of the effluent at 42%. The physical and chemical properties of vinyl acetate effluents are shown in Table 2.

Table 2
Physico-chemical characteristics of the vinyl acetate effluents (All values in mg/L except for pH, turbidity and temperature value)

Parameter	Units	Parameter	Units
pH	7.12	Zinc (Zn)	1.0488
BOD	13363.00	Iron (Fe)	1.771
COD	77800.00	Calcium (Ca)	72.75
TSS	8200.00	Magnesium (Mg)	9.7165
TDS	5460.00	Sodium (Na)	1199.00
DO	2.72	Copper (Cu)	2.6921
Temperature, °C	19.91	Manganese (Mn)	0.9147
Turbidity, NTU	23.64	Nickel (ni)	0.0873
Tri-Chromium (Cr^{3+})	23.64	Mercury (Hg)	3.4998
Sulfate (SO_4^{2-})	0.1376	Cadmium (Cd)	0.0004
Chloride (Cl ⁻)	4514.00	Lead (Pb)	0.1302
Nitrate (NO_3^{-})	27.53	Phosphates (P_2O_5)	222.00
Sulphide (S ²⁻)	<0.002		

Mixture proportion and curing condition

Table 3 shows the design mix studied. The samples were prepared by varying the polymer cement ratio of 0%, 2.5%, 5% and 10% by weight of cement. The control samples are cured in accordance to BS 12390-2: 2009 while the vinyl acetate effluents samples are cured following JIS A1171: 2000.

Table 3
Mix proportion

Specimens	Vinyl acetate effluents (kg/m ³)	Cement (kg/m ³)	Fine aggregate (kg/m ³)	Coarse aggregate (kg/m ³)	Water (kg/m ³)
PMCVAW 0%	-	380	824	1009	209
PMCVAW 2.5%	9.5	380	824	1009	204
PMCVAW 5%	19	380	824	1009	198
PMCVAW 10%	38	380	824	1009	187

Drying Shrinkage

The drying shrinkage was measured in accordance to ASTM 596-09. The samples were casted in mortar specimen 25 mm x 25 mm x 250 mm. Each of the specimens were cured in 3 days and allowed to ambient curing for 28 days. Drying shrinkage is measured by using dial strain gauge between Demec points fixed at 100 mm from the central point on the top surface to the edge of specimens. The data is recorded every 24 hours until 28 days.

Porosity

This test was performed on Autopore IV 9500V1.09 Micrometrics Instrument high pressure mercury intrusion porosimeter with a pressure range for sub ambient to 33,000 Psi. The contact angle and the surface tension of mercury were 130° and 0.485 N/m respectively for oven dried samples (Laskar et al., 1997). Based on the assumption that pores are cylindrical and entirely and equally accessible to mercury, the applied pressure can be converted into the pore diameter by using the Washburn equation (Cook & Hover, 1993) where P is the applied pressure, γ is the mercury surface tension and D is the equivalent pore diameter.

$$D = \frac{-4\gamma \cos\theta}{P}$$

Samples obtained after drying are weighed and placed into a chamber. The chamber was subsequently evacuated to remove air from the sample after which mercury was released to fill up the chamber under high pressure. While applying pressure, mercury is forced to intrude into the samples gradually and the applied pressure was recorded. The resulting average pore size distribution curve is determined.

RESULTS AND DISCUSSION

Drying Shrinkages of Polymer Modified Mortar

The measured values of shrinkage over a period of 28 days are plotted in Figure 1. It shows that the shrinkage strain of mortar containing vinyl acetate effluents was higher than control mortar. The greater the amount of the polymer in mortar tends to lead to increases in drying shrinkage created by the possible evaporation of water due to the lower water resistant of polymer vinyl acetate and concrete composite (Ramakrishnan, 1992). According to Lenart (2015), shrinkage values are mainly affected by temperature, environmental humidity and the wind speed as well as pore structure. Moisture easily evaporates from large capillary pores and the volume depends on the water-cement ratio. The greater the ratio, the greater the drying shrinkage (Aitcin, 2003). In the study however, higher shrinkages with increases in vinyl acetate effluents was observed may be due to the microstructure and pore size distribution created by the polymer film formation observed by Capener and Tang (2007). Shrinkage under practical conditions depends on loss of water from the mesopores and also the size of the macropores (Collins & Sanjayan, 2000).

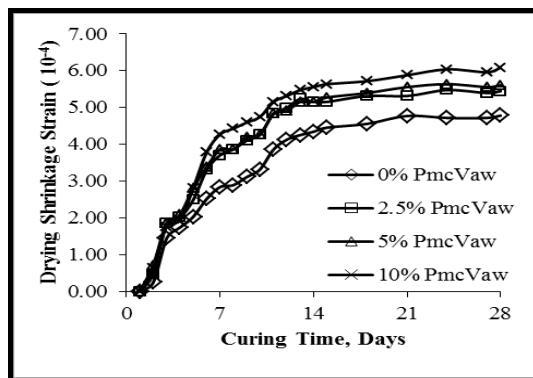


Figure 1. Drying shrinkage at 28 days

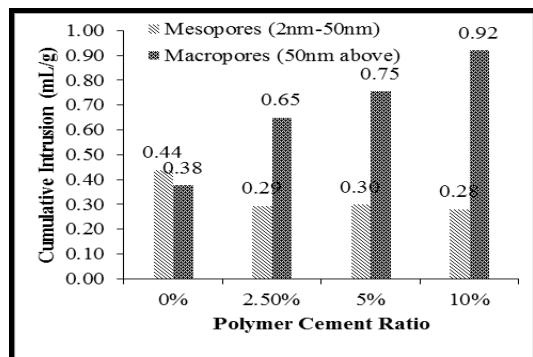


Figure 2. Characterization of pore size distribution among the samples

Pore Structure Condition of Vinyl Acetate Effluents in Mortar

Results from MIP are used to characterize pore size distribution. Pore sizes can be classified according to the International Union of Pure and Applied Chemistry system (IUPAC, 1972). The capillary pores are made up of both the mesopores and macropores, and are the water filled spaces existing within the original cement grains, while the micropores are part of the calcium silicate hydrate gel component (Collins & Sanjayan, 2000). As shown in Figure 2, samples containing vinyl acetate effluents have higher macropores compared to the control specimen. This is probably due to the presence of surfactants that are present in the effluents. These indicate that the vinyl acetate effluent samples are porous material.

CONCLUSION

Based on experimental findings, it can be concluded that drying shrinkage increased with vinyl acetate effluents in mortar due to moisture being absorbed by the polymer mortar matrix as a result of its lower resistance. The loss of water from the matrix is the reason for the increased shrinkage. Since the capillary pores of vinyl acetate effluents are made of mesopores and macropores they have the effect of increasing macropores making mortar made from the waste porous.

ACKNOWLEDGEMENTS

The authors wish to thank the cooperation and financial support of RMC, GUP grant No 03H35 as well as technical support of the Faculty of Civil Engineering, Universiti Teknologi Malaysia.

REFERENCES

- Aitcin J. P. (2003). Portland cement hydration seen by a civil engineer. *Cement Lime Concrete*, 70, 115–130.
- Capener, J. C.-M., & Tang, L. (2007). Early Age properties of modern rendering systems based on mineral binders modified by admixtures. *12th International Congress on the Chemistry of Cement.*, 863–870.
- Collins, F., & Sanjayan, J. G. (2000). Effect of pore size distribution on drying shrinkage of alkali-activated slag concrete. *Cement and Concrete Research*, 30(9), 1401–1406. doi:10.1016/S0008-8846(00)00327-6
- Cook, R. A., & Hover, K. C. (1993). Mercury porosimetry of cement-based materials and associated correction factors. *Construction and Building Materials*, 7(4), 231-240.
- Dey, B., Hashim, M. , Hasan, S., & Sen Gupta, B. (2004). Microfiltration of water-based paint effluents. *Advances in Environmental Research*, 8(3-4), 455–466. doi:10.1016/S1093-0191(02)00122-3
- Dursun, D., & Sengul, F. (2006). Waste minimization study in a solvent-based paint manufacturing plant. *Resources, Conservation and Recycling*, 47(4), 316–331. doi:10.1016/j.resconrec.2005.12.004
- Harrington, J. M., Rose, F. G., & Koh, D. (1994). Paint -- Health and environmental risk management: Report of an international symposium held in Singapore: June 1-4, 1992. *Asia-Pacific Journal of Public Health*, 7(2), 115–118. doi:10.1177/101053959400700207

- International Union of Pure and Applied Chemistry (IUPAC). (1972). Manual of symbols and terminology, appendix 2, part 1, colloid and surface chemistry. *J Pure Appl Chem*, 31, 578.
- Ismail, Z. Z., & Al-Hashmi, E. A. (2011). Assessing the recycling potential of industrial wastewater to replace fresh water in concrete mixes: application of polyvinyl acetate resin wastewater. *Journal of Cleaner Production*, 19(2-3), 197–203. doi:10.1016/j.jclepro.2010.09.011
- Kardon, J. B. (1997). Polymer modified concrete: Review. *Journals of Materials in Civil Engineering*, 9(2), 85–92.
- Kim, J., Robertson, R. E., & Naaman, A. E. (1999). Structure and properties of poly (vinyl alcohol)-modified mortar and concrete 1, 29, 407–415.
- Laskar, M. A. I., Kumar, R., & Bhattacharjee, B. (1997). Some aspects of evaluation of concrete through mercury intrusion porosimetry. *Cement and Concrete Research*, 27(1), 93–105. doi:10.1016/S0008-8846(96)00192-5
- Lenart, M. (2015). Assessment of mortar shrinkage in aspect of organic and inorganic modifiers use. *Procedia Engineering*, 108, 309–315. doi:10.1016/j.proeng.2015.06.152
- Lewis, W. J., & Lewis, G. (1990). The influence of polymer latex modifiers on the properties of concrete. *Composites*, 21(6), 487–494. doi:10.1016/0010-4361(90)90421-R
- Lorton, G. A. (1988). Hazardous Waste minimization: Part III Waste minimization in the paint and allied products Industry. *Japca*, 38(4), 422–427. doi:10.1080/08940630.1988.10466394
- Mehta, P. K., & Monteiro, P. J. M. (2006). *Concrete Microstructure, properties, and materials* (Third Edi.). McGraw-Hill.
- Mohammed, A., Nehdi, M., & Adawi, A. (2008). Recycling Waste latex paint in concrete with added value. *ACI Materials Journal*, 105(4), 367–374.
- Nehdi, M., & Sumner, J. (2003). Recycling waste latex paint in concrete. *Cement and Concrete Research*, 33(6), 857–863. doi:10.1016/S0008-8846(02)01084-0
- Ohama, Y. (1998). Polymer-based admixtures. *Cement and Concrete Composites*, 20(2-3), 189–212. doi:10.1016/S0958-9465(97)00065-6
- Ramakrishnan, V. (1992). *Latex Modified concretes and mortars. A Synthesis of highway practice*. NCHRP Synthesis 179. Transportation Research Board, National Research council, Washington D.C.
- Randall, P. M. (1992). Pollution prevention methods in the surface coating industry. *Journal of Hazardous Materials*, 29(2), 275–295. doi:10.1016/0304-3894(92)85073-A

