Strength and Durability Characteristics of Polymer Modified Concrete Incorporating Vinyl Acetate Effluent

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Abstract. Waste generation from surface coating industries brings about worsening of the environmental scenery and human health in the world. The production of these wastes is detrimental to surrounding areas in landfill or dumping spaces, therefore necessary action is required to minimize the unpleasant situation. This research is aimed at using waste generated from the manufacture of paint known as vinyl acetate effluent as an admixture in concrete. The material is rinse water taken from the cleaning process reactor. Concrete of 0% vinyl acetate effluent cured in water with those of 2.5%, 5%, 10% and 20% by weight of cement were produced and cured using Japanese standard. The specimens were tested for compressive strength, splitting tensile strength and durability at 3, 7 and 28 days. Findings show that incorporating of 2.5% of Vinyl acetate effluent improves strength properties of concrete. Higher resistance of water absorption and sulfate conditions were observed in polymer modified concrete. The study has shown that incorporating vinyl acetate effluent in producing polymer modified concrete could bring lights of using the waste material for sustainable and environmental preservations.

Introduction

Solid waste management has become major challenges in many areas due to urbanization and industrialization. Rapid development in manufacturing sectors has resulted to the increasing amount of hazardous waste generation annually [1-3]. One of the manufacturing sectors progressively involved in waste generation is the surface coating industry. Paint consumption in Malaysia is expected to increase to about 166,000 tonnes by the year 2014 within Asia/Pacific region [4]. This may lead an increasing volume of waste generated by its production, which occupies several spaces and lands for recovery and disposal purposes. These volumes of waste generated enhance the necessity of utilization of waste material for environmental preservations.

Ordinary Portland Cement Concrete is the largest produced man-made material with global productions of about 3.8 billion m^3 annually [5]. Ease of application, low cost and strong compressive strength becomes the main reason for universal acceptance [6]. However, concrete suffer from some drawbacks such as poor durability, low tensile strength and higher drying shrinkage. These shorts coming properties of concrete can be solved by introducing polymers as modifiers [7]. The synergistic action between polymers and concrete gave better performance for durable and sustainable construction materials [8].

Previous studies conducted on the application of waste latex paint in concrete showed an encouraging result in terms of strength and durability [9-12]. However, there is no much information regarding to research utilizing of Vinyl acetate effluents as an addition in the concrete mixes. The material is in liquid form collected from the cleaning process equipment reactor in a plant paint factory. This utilization will further reduce the environmental pollution possess by this waste, which will form another way of its disposal. It will also reduce the cost usually encountered by its management.

Materials and Methods

Ordinary Portland cement (OPC) complying with BS EN 197-1:2011 [13] was used throughout the study. Chemical compositions of OPC are presented in Table 1. The aggregates used include crushed granite and naturally occurring river-washed quartz sand with a maximum nominal sizes 10 mm and 2.75 mm respectively. The sand has a fineness modulus of 2.57. Polymer used is typically waste generated from production of polymer dispersion factory in Johor, Malaysia. Vinyl acetate effluents or rinse water taken from the cleaning process reactor which is in liquid forms and milky white in color. The characteristics of the effluent is shown in Table 2 with p*H* value of the sample is 7.16 and the total solids content is 42 ±2%. Design mix is based on BS EN 206-1:2000 [14] and concrete mix proportions are tabulated in Table 3. Various percentages of specimens were prepared by varying the polymer cement ratio: 0%, 2.5%, 5%, 10% and 20% by weight of cement. Concrete containing vinyl acetate effluents was cured according to JIS A1171: 2000 [15] and control specimens as indicated in BS EN 12390-2: 2009 [16].

The compressive strength test was conducted in accordance with BS EN 12390-3:2009 [17]. Concrete was prepared by addition of vinyl acetate effluents as well as control specimens in 100 mm size cube. Average values of three specimen samples were tested at 3, 7, and 28 days for all the test. BS EN 12390-6:2009 [18] standard was used for the assessment of indirect tensile test, using 100 mm x 200 mm cylinder sizes tested at 28 days. BS 1881-122:2011 [19] standard was referred for water absorption test with latex addition of 0%, 2.5%, 5%, 7.5% and 10%. While that of chemical resistance test was based on latex addition of 0%, 1%, 3% and 10%.

Table 1. Chemical composition of cement

SiO_2	Al_2O_3	Fe_2O_3	CaO	SO_3	MgO	LOI
20.1%	4.9%	2.4%	65%	2.3%	3.1%	2%

Table 2. Characteristics of Vinyl acetate effluent

Fe [mg/l]	Ca [mg/l]	Mg [mg/l]	Mn [mg/l]	Cu [mg/l]	Turbidity [NTU]	Temp. [°C]
1.71	72.75	9.72	0.91	2.69	23.64	19.91

Table 3. Mix design of concrete

OPC [Kg/m^3]	Sand [Kg/m^3]	Gravel [Kg/m^3]	Water [Kg/m^3]	W/C	Slump [mm]
380	824	1006	209	0.55	75

Results and Discussion

Effects of concrete incorporating vinyl acetate effluents in strength. Figure 1 illustrates the compressive strength of concrete increased with the increase in polymer content. Specimens containing 2.5% of vinyl acetate effluents contributed to high strength compared to control specimen at 28 days. The increases are attributed to the lower water requirements and sufficient amount of polymer particles that filled up the capillary pores, forming a closed packed layer on gel product surfaces on the unhydrated cement grains and developing silicate layers over the aggregates. As the water withdrawn from hydration process or evaporates, the closed packed polymer particle coalescence into a continuous film to form a co-matrix intermingled with the hydrated cement paste and binding with the aggregates [7-8]. Results of tensile strength are shown in Figure 2. There was an increase in tensile strength at 1% addition of vinyl acetate effluent, in comparison to the normal concrete. This probably was achieved due to improvement in cement hydrate-aggregate bonding and high tensile strength of latex film. The quality of vinyl acetate effluents and curing method play an important role in tensile strength development [20-21].

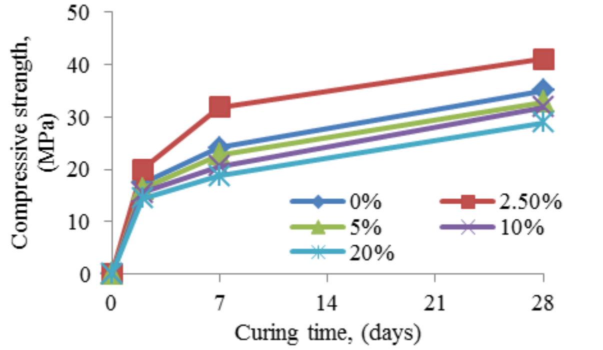

Figure 1. Effect of curing time on compressive strength of concrete mix incorporating vinyl acetate effluents

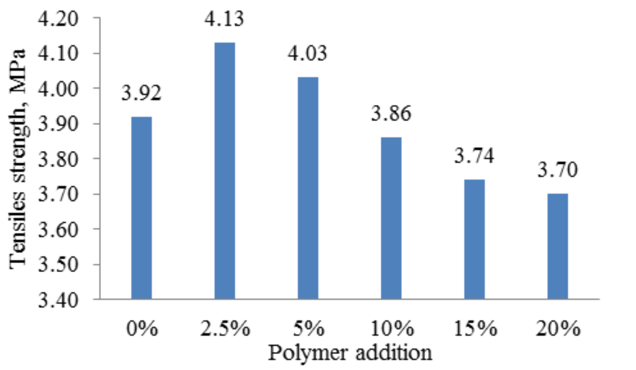

Figure 2. Results of tensile strength at 28 days

Effects of concrete incorporating vinyl acetate effluents in sulfate condition. Table 3 shows the results of water absorption in concrete. It was observed that concrete containing vinyl acetate effluents have high resistance of water absorption compared to control specimen. This is probably caused by the effect of the polymer film sealing the capillary pores and provides water-proofness in the concrete [21], and as the latex increases, water absorption decreases. Results of Sulphate action in concrete incorporating vinyl acetate effluents are illustrated in Figure 3 and Figure 4.

Table 3. Results of water absorption

Vinyl Acetate Effluent [%]	0	2.5	5	7.5	10
Water Absorption [%]	4.19	2.81	3.42	2.28	1.15

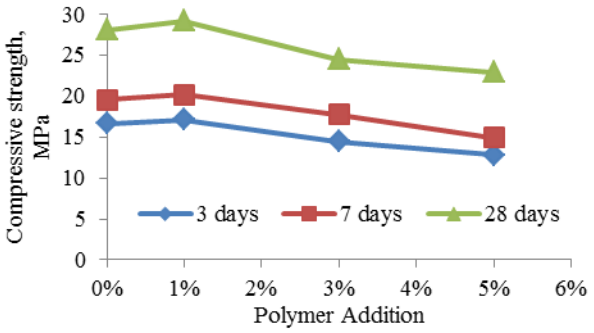

Figure 3. Effect of sodium sulfate on compressive strength

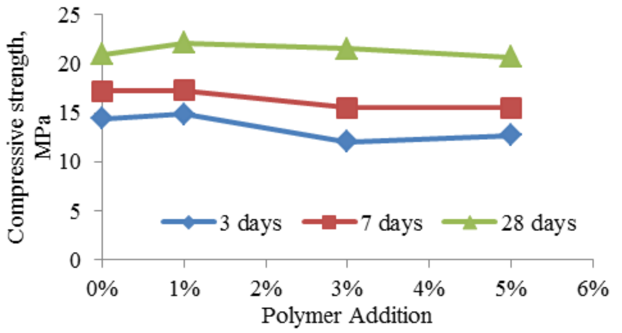

Figure 4. Effects of sulfuric acids on compressive strength

It can be observed that concrete containing 1% of vinyl acetate effluents contributed to a higher resistance after exposure to sodium sulfate solution. A similar observation was made on the concrete expose to sulfuric acid solution. However, as the percentages of vinyl acetate effluent increases the strength is gradually affected. The higher resistance may be attributed to the presence of the polymer film to fill up the pores that blocked the transport of respective ions through the concrete [22]. Prolong exposure tends to deteriorate the concrete properties. As such in base condition, sodium sulfate (Na_2SO_4) reacts with calcium hydroxide ($Ca(OH)_2$) to form calcium sulfate ($CaSO_4$) and sodium hydroxide (NaOH), whereas sulfuric acids (H_2SO_4) react with calcium hydroxide ($Ca(OH)_2$) to form calcium sulfate ($CaSO_4$) or gypsum in the cement matrix. In further attack, the gypsum would continue to react with the calcium aluminate hydrate (C_3A) to form ettringite, as an expansion product [23-25].

Conclusions

Based on the experimental conditions observed in the present study, the following conclusions can be drawn. Mechanical properties have shown a remarkable improvement on modification of concrete containing Vinyl acetate effluent has compared to the control specimen. Addition of 2.5% and 1% of vinyl acetate effluent in concrete confirmed the optimize level of compressive and tensile strength respectively. Polymer modified concrete incorporating vinyl acetate effluents have good resistance to water absorption as the capillaries pores and voids are sealed by polymer film. The use of concrete with 1% of Vinyl acetate effluent showed a minor effect of chemical resistance for both sodium sulfate and sulfuric acids.

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