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Behavior of Concrete with Polymer Additive at Fresh and Hardened States

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Abstract

Discarding waste materials from factories to landfills is becoming difficult lately as public awareness on their effects on earth is getting better. One of such material comes from paint factory (waste latex paint), which at the moment being tried as additive by many researchers. This paper presents results of laboratory work carried out on emulsion by-product polymer in order to evaluate its performance as an additive in concrete. Series of concrete mixes containing 1%, 2%, 3%, 5% and 10% polymer contents by weight of cement were prepared, cured and tested for workability, mechanical and durability properties at 7, 28 and 60 days. Test parameters include compressive, indirect tensile and flexural strengths, water absorption and chemical resistance. Results indicated that workability of the modified concrete reduced with increasing amount of polymer content. In addition, specimens mixed with 2% polymer performed better than other percentages. However, higher polymer content is necessary for better performance in durability aspects. Thus, while 2% of polymer is the optimum quantity for mechanical strength, durability is at best when this percentage is exceeded.

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Keywords: Waste latex paint, polymer concrete, mechanical properties, durability, sustainability.

1. INTRODUCTION

Concrete is one of the mostly used materials in construction field all over the world (Lomborg, 2001). However, in cement production process, release of CO_2 contributes to air pollution. So, concrete industry has considered using recycle industrial by-products as concrete additives in order to reduce demand for

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cement and use more sustainable construction material. One of the additives that have been tried in recent years was polymer. The idea of using polymers in cement-based materials dates back to early 1920s when the first patents on using natural rubber polymer- modified cementitious systems were issued (Ohama, 1984). The first patent on the use of synthetic rubber latexes in such application was issued in 1932 (Ohama, 1984). Since then many products, patents, and applications have been developed. In North America, latex-modified concrete (LMC) was used as a bridge overlay in Michigan as early as 1958. In Ontario, the first major application of LMC was a 1980 overlay on collector lanes of Highway 401 in North York. Polymer-modified mortar and concrete are prepared by mixing either a polymer or monomer in a dispersed, powdery, or liquid form with fresh cement mortar and concrete mixtures, and subsequently curing, and if necessary, the monomer contained in the mortar or concrete is polymerized in situ. Information on the use of waste latex paint in concrete is not yet established, and it is not understood whether waste latex paint could improve properties of concrete similar to those imparted by virgin latexes. From previous research by Nehdi and Sumner (2002), there are two ways of using WLP in concrete. First, is by partially replacement of virgin latex. The second method is to use the WLP in concrete. The WLP and virgin latex in their research are in liquid form.

The purpose of this research was to study the effect of the semi-solid WLP to the behavior of concrete. Besides that, the optimum quantity of the polymer additive that should be added into the concrete mix would also be determined.

2. MATERIAL AND RESEARCH METHODOLOGY

2.1 Aggregates

Coarse aggregate of maximum size 20 mm from Kulai Johor and sand was from River Sayong, Kota Tinggi, Johor.

2.2 Cement

Cement was Ordinary Portland Cement (OPC) of Holcim brand. This cement is conforming to BS EN 197-1:2000. The chemical compositions of the OPC are as shown in Table 1.

2.3 Waste latex paint

Waste latex paint used was supplied by a factory in Johor, Malaysia. The chemical composition of the material is as shown in Table 1.

3. LABORATORY TESTS

3.1 Fresh concrete test

Three different types of tests were conducted on fresh cement paste and fresh concrete. Normal consistency cement paste test was conducted according to ASTM C-187, Initial setting and final setting time test was conducted according to BS EN 196-3 2005. Slump test was conducted according to BS 1881: Part 102:1983 and Vebe test was according to BS1881: Part 104:1983.

3.2 Hardened Concrete test

At hardened state the concrete were subjected to strength and durability tests. For compressive strength test, nine cubes were prepared and tested according to BS 1881: Part 116:1983. at 7, 28 and 60 days. Tensile splitting strength test was according to BS 1881: Part 117:1983 and Flexural strength test according to BS 1881: Part 118:1983. Two durability tests were Chemical Resistance Test according to BS1881: Part 121: 1983 and Water Absorption Test according to BS1881: Part 122:1983.

Table 1 Chemical composition and physical properties of cementitious materials

Chemical Composition (%)	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	LOI	Surface area (m^2/kg)
OPC	20.2	4.9	2.4	65	2.6	2.5	0.16	0.87	2.0	314
WLP	2.8	0.96	51.2	32.6	0.23	4.89	-	0.94	-	-

4. RESULTS AND DISCUSSIONS

4.1 Normal consistency test (ASTM C 187)

Normal consistency is the degree of wetness of cement grout where its workability is considered suitable or acceptable. Figure 1 shows the overall trend of the results. Table 2 shows the normal consistency value of the cement paste for various polymer contents. According to the results shown, 1% polymer content was the optimum quantity to be added into cement mix because it can reduce usage of water. However, when more polymer additive was added, the normal consistency value becomes higher. This is because the polymer particles cause the cement paste become more viscous and the plunger is more difficult to penetrate into the fresh cement.

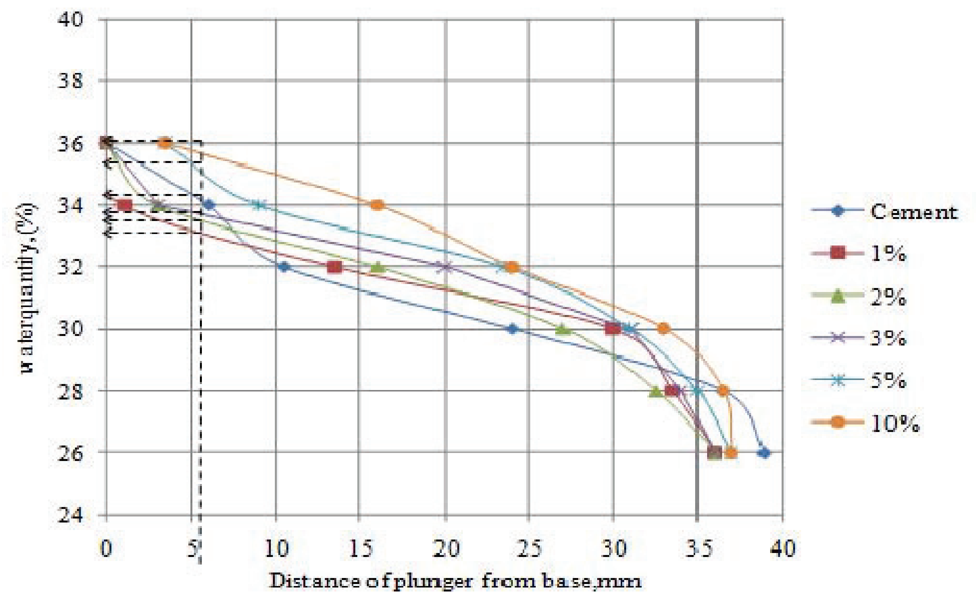

Figure 1: Normal consistency cement paste test

Table 2: Effect of Polymer Additive to the Normal Consistency, initial and final setting time

	Polymer amount (g)	Cement amount (g)	Normal Consistency (%)	Suitable water amount (ml)	Initial setting time (min)	Final setting time (min)
Cement only (0% Polymer)	0	500	34.2	171.0	60	285
Cem + 1% Polymer	5	500	33.0	165.0	60	270
Cem + 2% Polymer	10	500	33.5	167.5	55	255
Cem + 3% Polymer	15	500	33.7	168.5	55	255
Cem + 5% Polymer	25	500	35.0	175.0	50	225
Cem + 10% Polymer	50	500	35.7	178.5	40	180

4.2 Initial setting and final setting time test (BS EN 196-3 2005)

From Table 2, both initial and final setting time of cement paste was decreasing when the amount of polymer additive was increasing. This was due to the micro filler particles in the polymer additive act as an agent for the growth of hydration products (Abdulrahman et. al., 2008). During the hydration process, the cement particles will bind together and fill the voids within it. So, the polymer's micro filler particles help in filling the void space and accelerate the hydration process.

4.3 Slump test (BS 1881: Part 102:1983)

From Table 3, the slump value was decreasing when the quantity of polymer increases. This means that the polymer additive will reduce the workability of the concrete. This was because the polymer causes the concrete become viscous and the solid particles of polymer which fill up the voids of the concrete will obstruct the concrete mix from slump. There is no slump value for 5% and 10% of polymer content, because the concrete mix became too harsh and sticky.

Table 3: Slump and Vebe Test Result

Polymer content (%)	Slump (mm)	Vebe degree (second)
0	70	6.0
1	50	6.5
2	50	7.5
3	30	8.0
5	-	9.5
10	-	12.5

4.4 Vebe test (BS1881: Part 104:1983)

As shown in Table 3, the increase of polymer content causes the rise of Vebe degree which means the decrease of workability. The stickiness of the concrete mix with polymer additive lower the workability compare with normal concrete mix. Besides that, the polymer solid particles in the concrete disable the concrete to disperse freely and make the concrete mix immobile.

4.5 Compressive strength test (BS 1881: Part 116:1983)

Figure 2 shows the difference of compressive strength between the concrete with various quantity of polymer additive at different curing age. From the figure it was shown that the polymer additive does not help in enhancing the compressive strength of the concrete. Although the polymer particles have filled up the void space in the concrete, they are not totally integrated into the concrete mix. This causes the bonding between the concrete particles become weak. This was different with the previous research by Nehdi and Sumner (2002) who use waste latex paint (WLP) in liquid form. The compressive strength of concrete samples with different percentage of WLP and virgin latex at 28 days curing age are higher than that of control. This was likely due to polymerization of the latex monomers that form a latex film filling pores in the internal structure of concrete (Abdulrahman et. al., 2008).

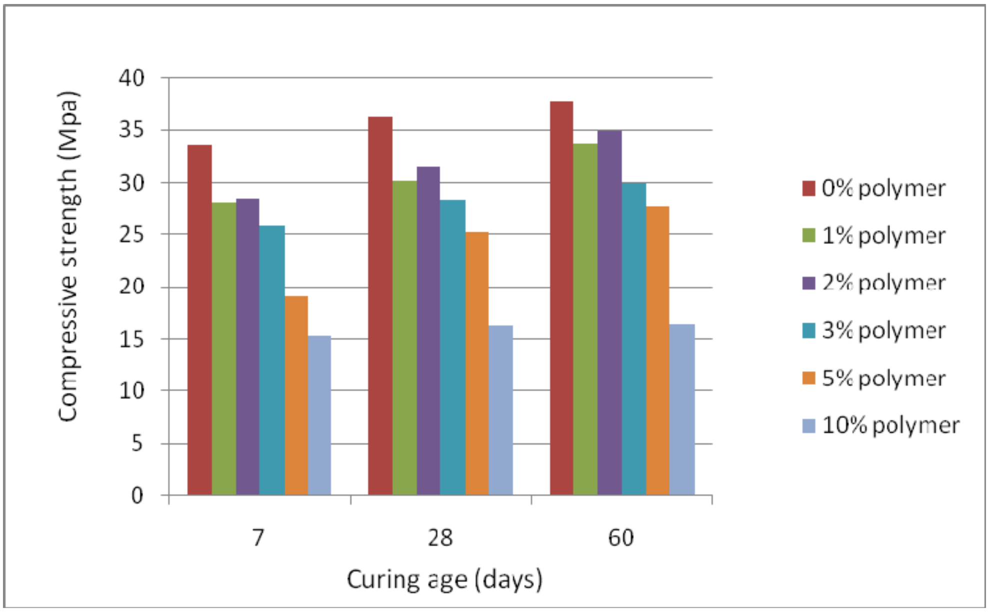

Figure 2: Compressive strength of concrete samples

4.6 Tensile splitting strength test (BS 1881: Part 117:1983)

For overall, the tensile splitting strength of the concrete seems does not have much improvement after mixing with the polymer additive as shown in Figure 3. Only the concrete with 2% polymer content can be compare to control concrete. Up to 60 days, the tensile splitting strength of concrete with 2% polymer is slightly higher than control. This was due to the function of the polymer additive in the concrete which possesses high tensile strength.

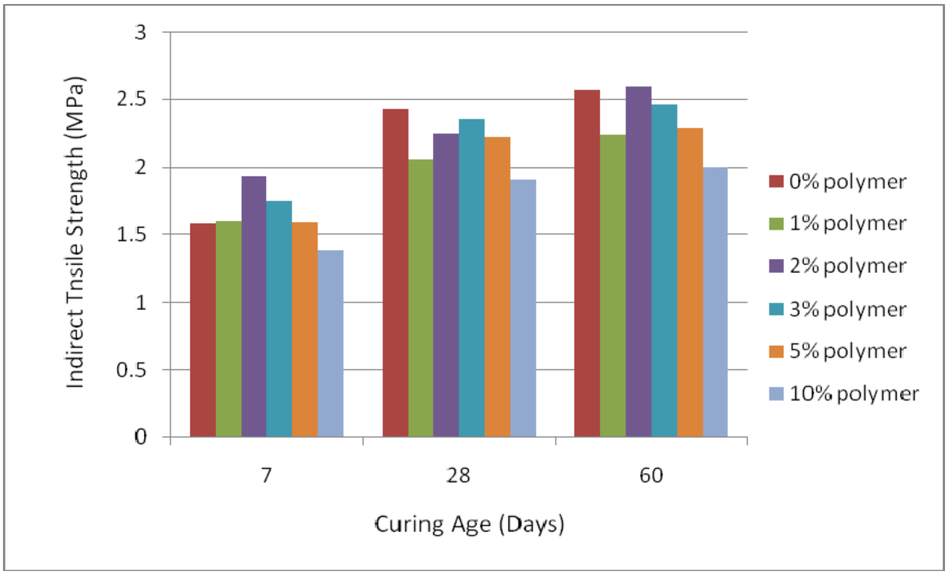

Figure 3: Tensile strength of concrete samples

4.7 Flexural strength test (BS 1881: Part 118:1983)

From Figure 4, the concrete with 2% polymer has better performance compared to other percentage. At 28 and 60 days curing age, the concrete with 2% polymer has the highest flexural strength. Previous research by (Nehdi and Sumner, 2002) shown that WLP can help in improving the flexural strength of concrete.

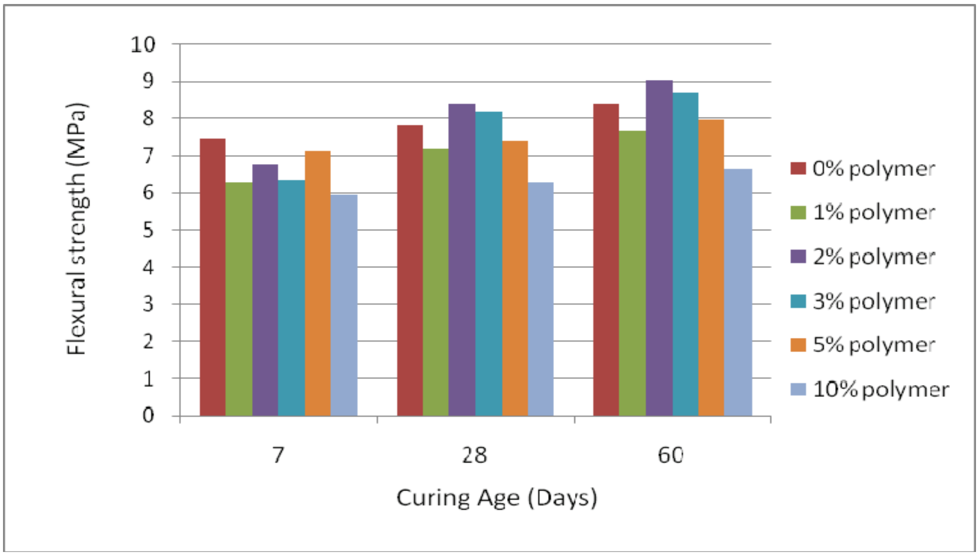

Figure 4: Flexural strength between of concrete Samples

4.8 Chemical Resistance Test (BS1881: Part 121: 1983)

Figure 5 shows that the decrease of compressive strength from the concrete with 0% to 2% and 5% polymer was smaller than the result in compressive strength test. This means that polymer can protect the concrete from external agent without losing much of its compressive strength. The relatively lower resistance of the control mixture to sulfuric acid could be due to higher absorption of acid and higher porosity.

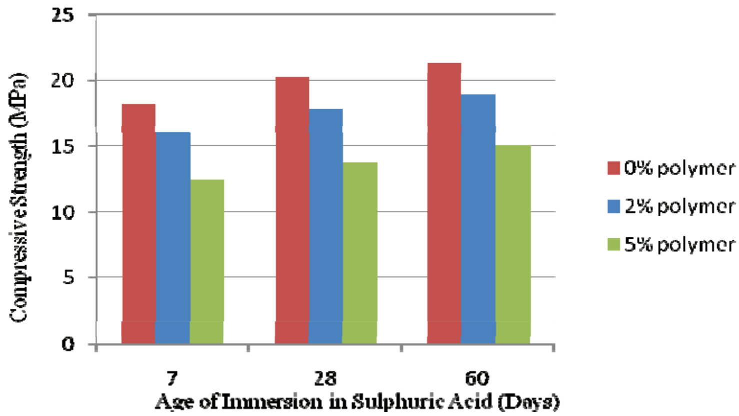

Figure 5: Effect of chemical on concrete compressive strength

4.9 Water Absorption Test (BS1881: Part 122:1983)

From the result shown in Figure 6, the water absorption of concrete is decreasing when the polymer content was increasing. This was due to the pore-blocking effect of the polymer particles (Abdulrahman et. al., 2008). In addition, polymer is a water- impermeable material, so the polymer particles which distribute in the concrete pores will block the water to infiltrate through the concrete particles. This finding was different from results by (Mohammad et.al., 2009) which shows that the water absorption was minimum at 5% latex/water (L/w) ratio and then increase at 7.5% and 10% L/w ratio. This was because concentrated latex was used to replace the amount of water in concrete.

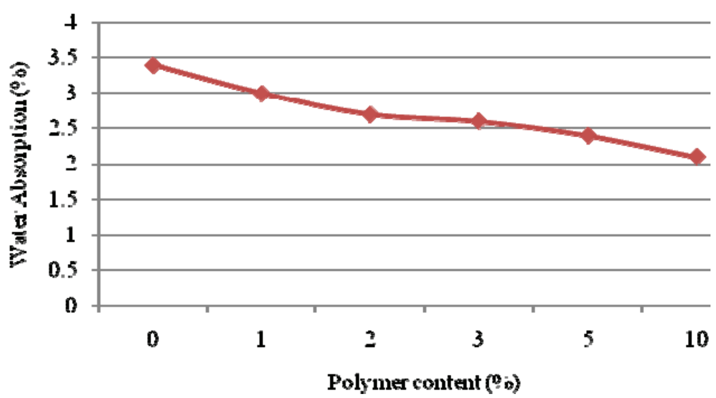

Figure 6: Water absorption of concrete with different polymer content

5. CONCLUSIONS

From the results of laboratory tests, the optimum quantity of polymer to be added into the concrete was 2% by weight of cement. For the effects of polymer to the properties of concrete, the conclusions are as below:

1. Polymer does not help in enhancing the workability of fresh concrete as shown from slump and Vebe test, the data shows that. When more polymers were added, the workability decreases.
2. Polymer does not contribute much in improving compressive strength of the concrete. However, 2% of polymer added in concrete provides the highest tensile strength and flexural strength.
3. For chemical properties, when more polymers were added, water absorption was lower. In this research, the highest percentage of polymer content in concrete was 10%.

Acknowledgements

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