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Increasing Concrete Strength by using Water Based Polymers

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This paper investigates to increase concrete strength by using water-based polymers. To increase the concrete strength, there are various methods are available. Especially, recovery of cracks in concrete is one of the important problems that affect the sustainability of concrete. Researchers have developed many different techniques to increase the strength or repair the damaged concrete structures. However, these techniques require enormous efforts and resources to complete the process. Therefore, many alternative methods have been developed to provide inexpensive solutions to increase the strength and remediate the cracks in concrete. In this paper, water-based polymer materials as a curing method have been used to increase the strength of and concrete and repair the cracked concrete. Different types of concrete including self-healing ones using different cementitious (fly ash and slag) and polymeric materials. A set of experimental tests on the different concrete mixes were carried out using the Ultrasonic Pulse Velocity and compression tests. The study results show that, curing method applied on the concrete samples is promising and increase the compressive strength of concrete. The polymer treatments appear to be an appropriate treatment on concrete.

Keywords: Concrete strength, concrete cracks, water-based polymers, curing

Introduction

Concrete is one of the major construction materials used in the world. Therefore, concrete industry is one of the biggest industry and in this industry, there are various additives available that increase the concrete strength or help to repair the damaged concrete structures (Bungey, and Millard, 1996; Wang, 2006). Especially cracked concrete cause big problems in the structural resistance of the buildings (Bouzoubaâ and Foo, 2005, Concrete Experts International, 2016). After the concrete poured, with numerous reasons, concrete cracks or in many cases, concrete strength is not at the satisfactory level. In such problematic cases, especially in the site, a practical and inexpensive method to cure concrete material is needed to solve the problem and continue to the next phases of the construction. Since structural deficiencies result with vital problems in construction sites, an applicable method in site conditions will be beneficial to the construction professionals.

Many researchers have developed different methods including polymer modification, using fly-ash, silica fume, and bio-concrete. These methods have been developed to provide more convenient solutions for the construction industry. These solutions are generally in preventive level as using various additives to increase strength or to solve the concrete cracks problem. Using polymers in various level is one of the best alternative solutions that can be integrated into the concrete industry. By using polymers, concrete strength can be increased integrated within the concrete structural matrix (Ye, 2001; Barnett, 2006; Spaeth, 2013). Currently, there are various polymers are available in the industry to increase the strength of concrete. Different types of polymers give different results (Qasrawi and Marie, 2003). In various design codes, there are various approaches for the design specifications for the concrete strength (ACI Committee 224, 2007; ACI 301-10, 2010).

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In this research, to investigate a simplified method that can be applied in the site to increase concrete strength and heal concrete cracks, response of the concrete to the water-based polymers have been recorded by using various samples with different additives. Hence, an applicable, inexpensive, and an effective method has been applied with various materials and results have been discussed. The polymer treatments appear to be an appropriate treatment on concrete. In the study, in different percentages, water-based polymer has been used to cure various concrete samples. The concrete samples were created by using fly ash, slag, SBR, and cement.

Samples were tested by using The Ultrasonic Pulse Velocity (UPV) test and Compression Test equipment. Samples were submerged into different percentage of water-based polymer added water. Mixing the water with water-based polymer with percentage 1% polymer of water weight, 3% polymer of water weight and 5% polymer of water weight. The used polymer is eco-friendly prime coat material and easy to use and not require any special equipment or instructions. Water-based and environmental friendly rime coat. It is non-petroleum-based, evaporating only water during the curing process and emitting no volatile organic compounds. It does not contain solvents or cause damage to roads or vehicles.

Methodology

In this paper, the efficiency of water-based polymer curing on concrete samples has been investigated. Therefore, 3 samples were created in 5 different sets. In total, 15 samples were tested by using 3 different polymer percentages. In the testing, UPV and Compression test equipment were used to record the effects of curing by using water-based polymer.

To create sample sets, 5 different sets with 3 samples of each were created as seen in Figure 1-a. First set was control samples with normal curing without using polymer. Second set was SBR samples curing with solution in 1%, 3% and 5% polymer as seen in Figure 1-b. The third set was 25% slag and 25% fly ash cured with solution in same percentage with the first set. 4th set was 25% fly ash and the fifth one was 50% slag cured with the same solution percentages. The created concrete samples are given in Table 1.

(a) Concrete Samples

(b) Water curing for 28 days

Figure 1: Concrete Samples and Curing

Table 1

Prepared Sample Sets

Set 1	3 concrete control samples without using any polymer inside the sample
Set 2	3 concrete SBR samples curing with water and 1%, 3% and 5% polymer of water weight
Set 3	3 concrete samples contain 25% slag and 25% fly ash curing with water and 1%, 3% and 5% polymer
Set 4	3 concrete samples contain 25% fly ash curing with water and 1%, 3% and 5% polymer
Set 5	3 concrete samples contain 50% slag curing with water and 1%, 3% and 5% polymer
-	Total 5 concrete sets each one contains 3 samples = **15 samples**

To determine the effectiveness of the polymer curing on concrete samples, created samples were first put in the water for 28 days and investigated initially by using UPV test, 14 days after removed from the water. Then submerged to solution. After 14 days waiting period for drying, samples were tested by using UPV. Then, Samples were put in water mixed with polymer 1%, 3% and 5% for the 3 sample of each set. Samples were removed from water and polymer for 14 days to dry and run the second UPV test. Samples were cracked by using compression equipment up to 50K loading as seen in Figure (2-b). After cracking the samples, third UPV test was run. The samples were soaked in to the solution again for 14 days. After 14 days, the samples were taken out to dry for another 14 days. After 14 days for the samples to dry, the UPV test was run for the 4th time, then, the samples were put under the compression load until they got crashed as seen in Figure (2-c). Crashed loads were recorded. Experimental steps are given in Table 2.

(a) UPV Test

(b) Small crack into the sample

(c) Crash the sample

Figure 2: Testing Procedure

Table 2

Experimental steps

Steps	Action
1	- Poured concrete into molds
2	- After waiting 48 hours, put in water for 28 days
3	- Removed from water to dry for 14 days
4	- *1) Run the UPV test for the 1st time:* calculating the time and velocity (10 trial for each sample). Then put in water mixed with polymer 1%, 3% and 5% for the 3 sample of each set.
5	- Removed from water and polymer for 14 days to dry.
6	- *2) Run the UPV test for the 2nd time*
7	- Create small crack inside samples up to 50K loading
8	- *3) Run the UPV test for the 3rd time* then put in polymer again.
9	- After waiting 14 days, took the samples out of polymer to dry.
10	- *4) Run the UPV test for the 4th time* after waiting 14 days for the samples to dry, put the sample under the compression load until it crashed.

Research Findings

In the present research, samples were tested by using The Ultrasonic Pulse Velocity (UPV) test and Compression Test equipment to investigate to increase the strength of concrete. Samples were submerged into different percentage of water-based polymer added water. Mixing the water with water-based polymer with percentage 1% polymer of water weight, 3% polymer of water weight and 5% polymer of water weight. As a result, UPV test and compression test results are given in charts. Figure 4 gives the UPV test results. Four different sets of UPV tests results are summarized. These results were recorded with the same order of experimental steps as given in Figure 4. Figure 5 gives the comparison of compression test results.

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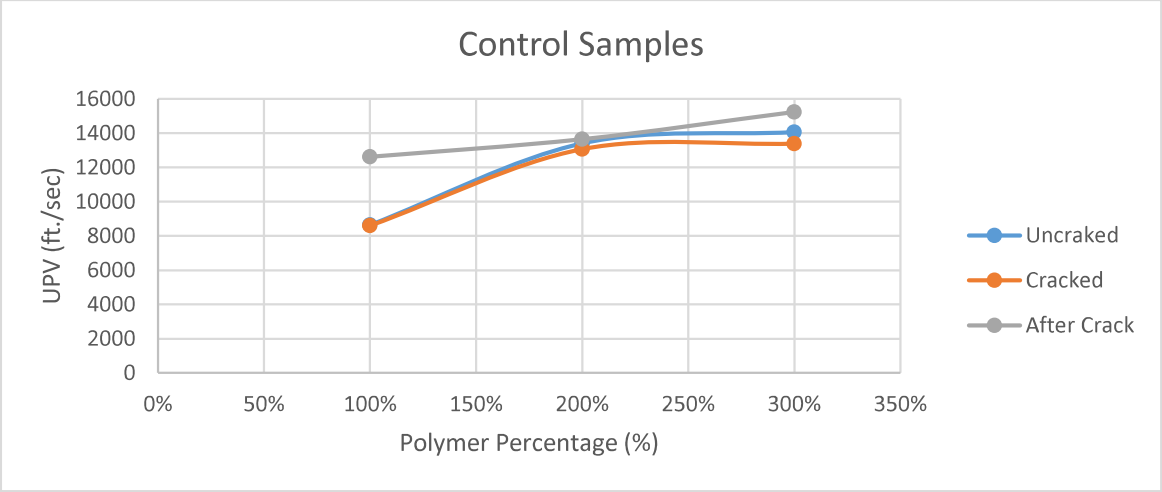
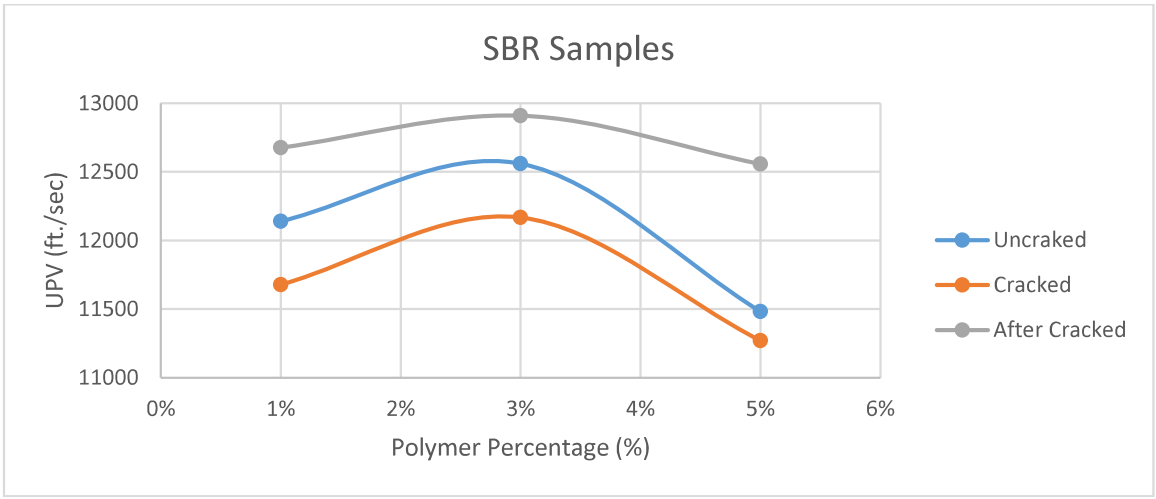
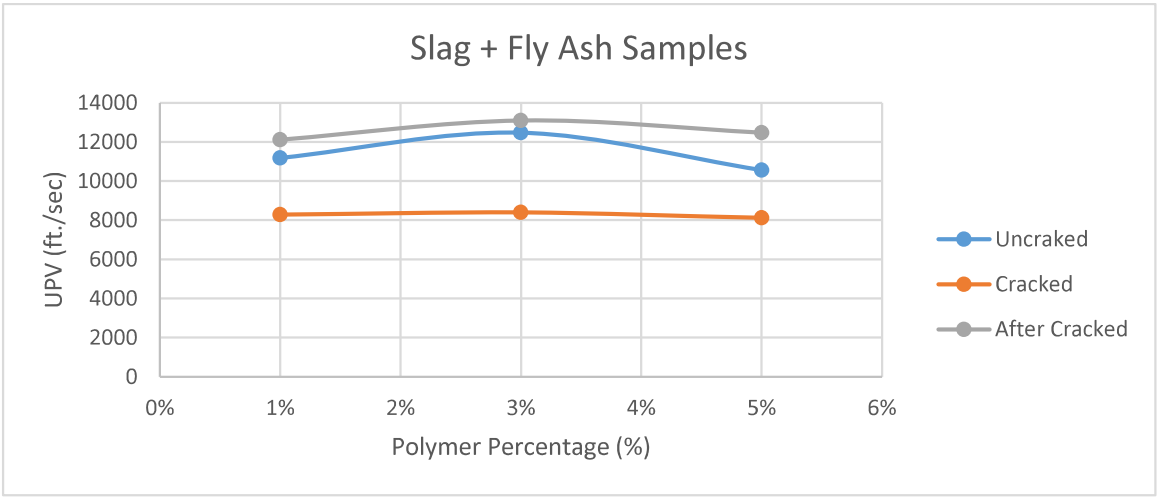


(a) Control Sample UPV Test Results



(b) SBR Sample UPV Test Results



(c) Slag+Fly Ash Sample UPV Test Results

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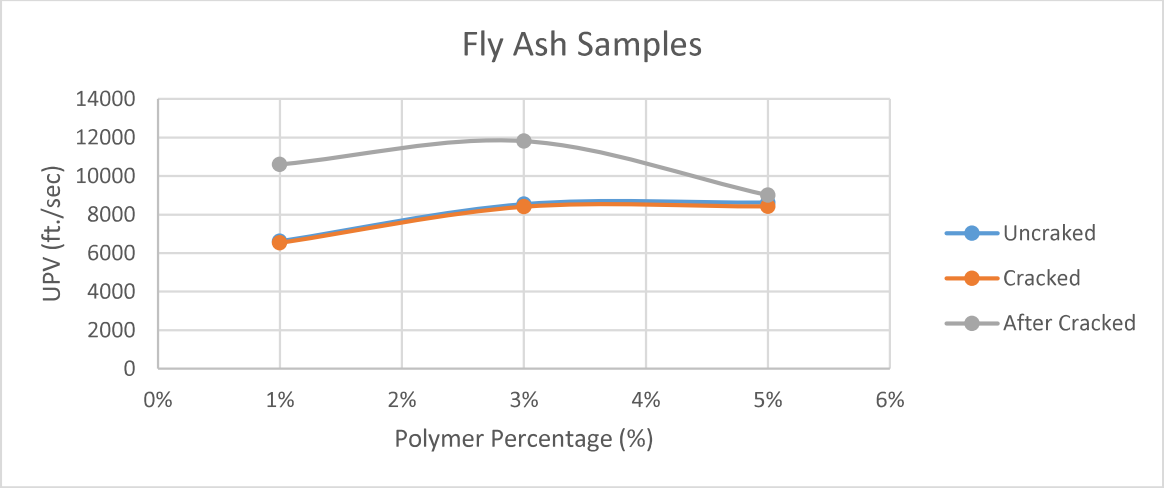
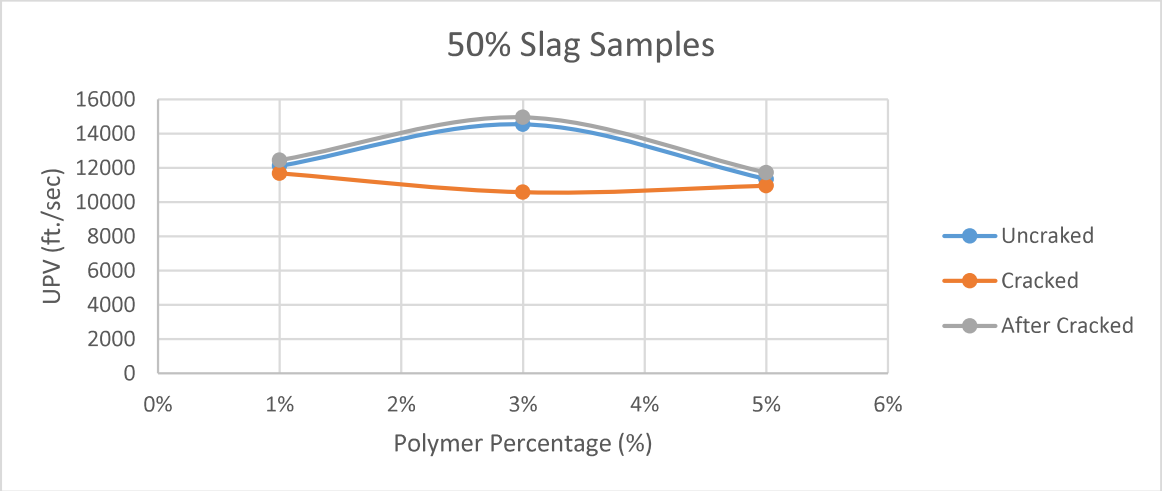


(d) Fly Ash Sample UPV Test Results



(e) 50% Slag Sample UPV Test Results

Figure 4: UPV Test Results for Fly Ash and 50% Slag

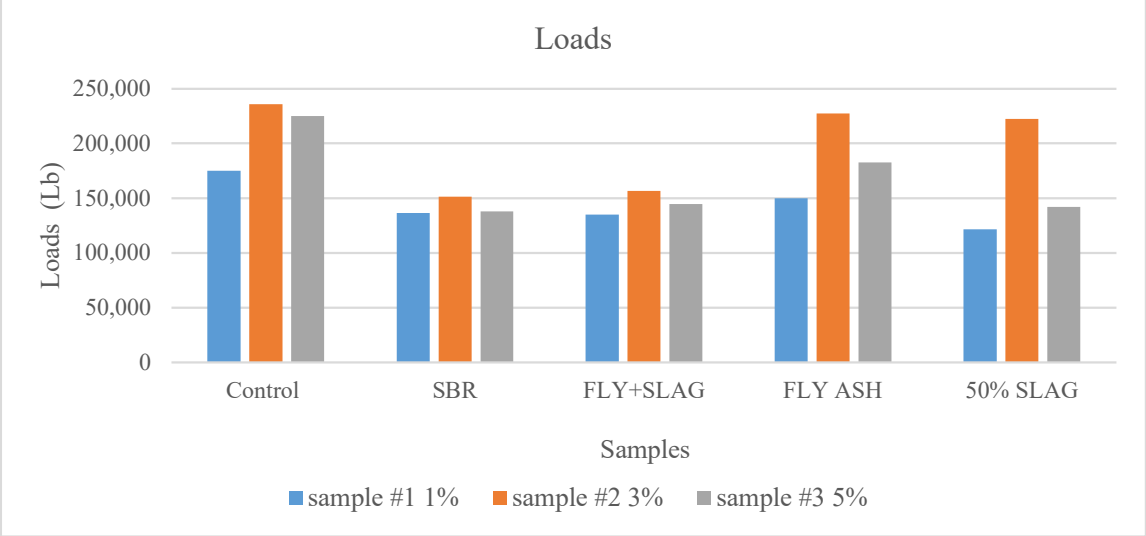


Figure 5: Compression Test Results for all Samples

Conclusion

The present paper investigates a simplified approach to increase the strength and repairing cracks in concrete. Effects of water-based polymers on different cementitious and polymeric materials, such as slag cement, fly ash and SBR polymer have been investigated and obtained results are given and discussed. The research methodology consisted of two different experimental tests as, the ultrasonic pulse velocity (UPV) and compression test. Results were compared in the figures. Based on obtained results, water-based polymers increase the strength of concrete. The results from UPV and compression tests, the curing method that was applied on the samples is promising and increase the compressive strength of concrete. The polymer treatments appear to be an appropriate treatment on concrete. The result shows that, there is an improvement when samples were cured with polymer 3% of polymer that added to the water. 3% water-based polymer gives the best result when crashing the samples. Then 5% and 1% provides increase in the strength.

References

ACI Committee 224—Cracking, & American Concrete Institute. (2007). Causes, evaluation, and repair of cracks in concrete structures. Farmington Hills, MI.: American Concrete Institute.

American Concrete Institute (ACI 301-10). (2010). Specifications for Structural Concrete. Retrieved from https://www.concrete.org/store/productdetail.aspx?ItemID=30110

Barnett, S. J., Soutsos, M. N., Millard, S. G., & Bungey, J. H. (2006). Strength development of mortars containing ground granulated blast-furnace slag: Effect of curing temperature and determination of apparent activation energies. Cement and Concrete Research, 36(3), 434–440.

Bouzoubaâ, N., & Foo, S. (2005). Use of Fly Ash and Slag in Concrete: A Best Practice Guide. Government of Canada Action Plan 2000 on Climate Change.

Bungey, J. H., & Millard, S. G. (1996). Testing of concrete in structures: Third Edition (3rd ed.). London; New York: Blackie Academic & Professional.

Concrete Experts International. (2016). Carbonation of concrete. Retrieved April 2, 2016, from http://www.concrete-experts.com/pages/carb.htm

Qasrawi, H. Y., & Marie, I. A. (2003). The use of USPV to anticipate failure in concrete under compression. Cement and Concrete Research, 33(12), 2017–2021.

Spaeth, Assia Djerbi Tegguer - (2013) 2, Improvement of recycled concrete aggregate properties by polymer treatments, International Journal of Sustainable Built Environment Valerie 143–152

Wang, K., Schaefer, V. R., Kevern, J. T., & Suleiman, M. T. (2006). Development of mix proportion for functional and durable pervious concrete. In Proceedings of the 2006 NRMCA Concrete Technology Forum—Focus on Pervious Concrete.

Ye, G., Van Breugel, K., & Fraaij, A. L. A. (2001). Experimental study on ultrasonic pulse velocity evaluation of the microstructure: TU Delft Institutional Repository, Delft Uni. of Technology