Civil and Environmental Research
ISSN 2224-5790 (Paper) ISSN 2225-0514 (Online)
Vol.7, No.2, 2015

Effect of Superplasticizer on Workability of Concrete Containing Crumb Rubber

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Abstract

Crumb rubber concrete was produced by using 10% of recycled fine rubber 400 µm as the sand replacement. Superplasticizer with 0.25%, 0.5%, 0.75% and 1.0% contents were added into crumb rubber concrete without changing the water-cement ratio purposely to study the effects of superplasticizer to the concrete. The specimens were tested on the age of 28th day. Several tests were carried out to study the effect of superplasticizer such as slump test, compression test, split tensile test, flexural test and ultrasonic pulse velocity test. The results show that an increase of superplasticizer will increase the workability of the concrete without changing the water-cement ratio. It was found that the rubberized concrete with content 0.5% superplasticizer produced better compressive strength, split tensile strength, flexural strength ultrasonic pulse velocity.

Keywords: Crumb rubber, Superplasticizer, Workability, Concrete strength

1. Introduction

Disposal of waste rubber is a serious environmental issue all around the globe, on account of its health hazard and difficulty in land filling. The high cost of disposal and the requirement of large landfill area often result in random and illegal dumping of waste rubber (Siddique and Naik, 2004) and over 281 million scrap tires are generated in United States every year (Baker et al., 2003). According to "Markets for Scrap Tires"1991 edition, published by US Environmental Protection Agency (EPA), only 7% of the tires are recycled into new products and about 11% are converted into energy. Over 77.6%, or about 218 million tires per year, are land filled, stockpiled, or illegally dumped and the remaining 5% are exported. Landfilling of scrap tires in open piles causes number of problems such as degradation of the landscape, health diseases vectored by mosquito, and serious open tire fires which is difficult and need long time to extinguish. Moreover it has serious impact on health and the environment due to dangers of air emissions via black and carbon smoke and also contamination of water and soil due to the run-off water and pyrolytic oil released from the burning tires (EPA, 1991 and Siddique and Naik, 2004). Due to the high cost of disposal and the requirement of large landfill area for waste rubber, the issue of random and illegal dumping is alarming (Siddique and Naik, 2004). Hence, there is an urgent need to identify alternative solutions to reuse the tire rubber for other applications, and concrete has been identified to be one of the feasible options. On the other hand concrete has limited properties such as low ductility and crack resistance associated with hardening, As a promising solution to the aforementioned problems, the idea of adding waste crumb rubber to concrete as sand replacement has recently gained attraction, as it improves the flexibility and ductility of concrete (Son et al. 2011). However, Eldin and Senouci (1992) concluded that increasing the size or ratio of rubber as an aggregate will decrease the workability of the mixture and that will cause a reduction in the slump value. They also found that the size of rubber aggregate and its shape affecting the slump. The values of slump of mixes containing angular rubber aggregate were lower than mixes containing round rubber aggregate. The workability of rubberized concrete decreases with the increase of rubber content. According to the test using 40% of rubber as a partial replacement of aggregate will give a slump equal to zero and the concrete is not workable. Using crumb rubber in mixtures gives more workability than using coarse rubber in mixtures (Khatib and Bayomy 1999). Khaloo et al., (2008) studied the toughness of concrete specimens containing tire chips, crumb rubber, and a combination of tire chips and crumb rubber. Toughness was enhanced by the additions of all the aforementioned types of rubber, and the maximum toughness index was found with 25% replacement beyond which the toughness decreased. While ultimate strength and modulus of elasticity were decrease. Sukontasukkul and Chaikaew (2006) determined the strength the effect of replace coarse aggregate and sand with crumb rubber.

They found that using waste tire in concrete resulted higher flexible, toughness, and energy absorption and improved the ductility. While both strength and workability was decrease. Al-Tayeb et al., (2012) investigated the effect of partial replacements of sand and cement by waste rubber on the fracture characteristics of concrete. They found that addition of waste tire in concrete enhanced the fracture properties, while both compressive and flexural strengths were decreased. Al-Tayeb et al., (2013) observed that the replacement of sand with the crump rubber particles in concrete cured in water for 90 days enhanced impact resistance. However, previous studies, found that, the workability of the rubberized concrete is decrease with increase the portion of sand replacement with rubber. Thus, the addition of superplasticizer into the rubberized concrete might improve the workability of the concrete containing recycled rubber. In this study rubberized concrete was produced by using 10% of recycled fine rubber 0.4–1 mm as the sand replacement. Superplasticizer with 0.25%, 0.5%, 0.75% and 1.0% contents were added into crumb rubber concrete without changing the water-cement ratio purposely to study the effects of superplasticizer to the concrete. The specimens were tested on the age of 28th day. Several tests were carried out to study the effect of superplasticizer such as slump test, compression test, split tensile test, flexural test and ultrasonic pulse velocity test.

2. Methodology

2.1 Materials

The control mix was concrete with a compressive strength of 40MPa. The maximum coarse aggregate size was 20 mm, and the fine aggregate was natural sand, with specific gravities 2.64 and 2.66 respectively. Concrete mixes were prepared with replacements of sand volume by 10% with waste fine crumb rubber (Fig.1) of particle size 0.4–1 mm (Figure 2) and relative density 0.64. In this study, a variable percentage of superplasticizer 0%, 0.25%, 0.5%, 0.75% and 1.0% were used. The compositions of the plain and rubberized concrete with different superplasticizer's percentage samples are presented in Table 1.

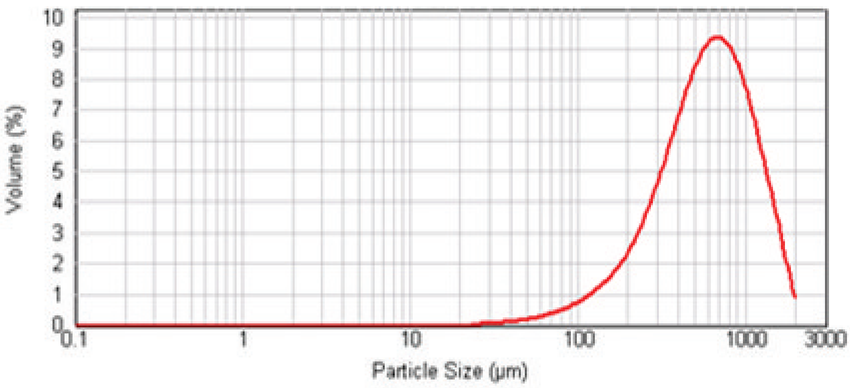

Fig. 1: Particle size distribution of fine rubber.

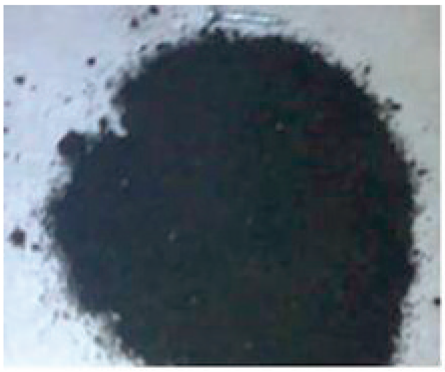

Fig. 2: Images of the fine crumb rubber sample.

Table 1: Mixture properties of plain and fine crump rubber concrete with superplasticizer

Unit	Rubber percent	Superplasticizer /cement weight	Cement	Water	Fine aggregate	Coarse aggregate	Crumb rubber
Weight [kg]	-	0.00%	395	190	758	973	10
Volume [m^3]	10%		125	190	286	367	15.1
Weight [kg]	-	0.25%	395	190	758	973	10
Volume[m3]	10%	-	125	190	286	367	15.1
Weight [kg]	-	0.50%	395	190	758	973	10
Volume[m3]	10%	-	125	190	286	367	15.1
Weight [kg]	-	0.75%	395	190	758	973	10
Volume[m3]	10%	-	125	190	286	367	15.1
Weight [kg]	-	1.00%	395	190	758	973	10
Volume[m^3]	10%	-	125	190	286	367	15.1

2.2 Laboratory Test

2.2.1 Slump Test

The workability property of concrete mixes was measured by conducting slump cone test according to ASTM Standard C143.

2.2.2 Compression Test

For the compression tests on the age of 28th day, three cylinders of height 200mm and diameter 100 mm were used for each type, according to ASTM C 39-01. The specimens were cured accordance with ASTM C 192/C192M-06.

2.2.3 Splitting Tensile Test

For the compression tests on the age of 28th day, three cylinders of height 200mm and diameter 100 mm were used for each type and age, according to ASTM C 496-96.

2.2.4 Flexural Test

The three-point static flexural strength tests were performed according to ASTM C78-94. The specimens were 100 mm wide, 100 mm deep and 500 mm long, with a loaded span of 400 mm. Three beams specimens were cured and tested on the age of 28th day in accordance with ASTM C 192/C192M-06.

2.2.6 Ultrasonic Pulse Velocity (UPV) Test

This test was conducted based on ASTM C 597-97. Direct transmission and semidirect transmission methods were used to determine the quality of 100 x 100 x 100 mm of rubberized concrete cube. Direct transmission, semidirect transmission and indirect transmission methods were used to determine the quality of 100 x 100 x 500 mm of rubberized concrete beam.

3. Results and discussion

The results of all tests that have been performed on the trial mixes are shown below.

3.1 Workability of Concrete Mixes

The workability property of concrete mixes was measured by conducting slump cone test according to ASTM 143 Standard. The slump value of fresh concrete containing crumb rubber with different percentage of superplasticizer content is presented in the Figure 3 below. As for rubberized concrete without superplasticizer added results of low slump value which is 20 mm. This was due to the increase in the interior voids and the rough surface of the tire rubber particles which might result in increasing friction between the fresh concrete ingredients. The workability of the concrete increased significantly by increasing the superplasticizer content. That because superplasticizer produced the same electrostatic charges on the cement particles surface. This result to the repulsion among the cement particles, prevent the coagulation and minimized the air entrained. Thus, the fluidity of the concrete increased. The particles have, therefore, a greater mobility and water freed from the restraining influence of flocculated system becomes available to lubricate the mix so that the workability is increased

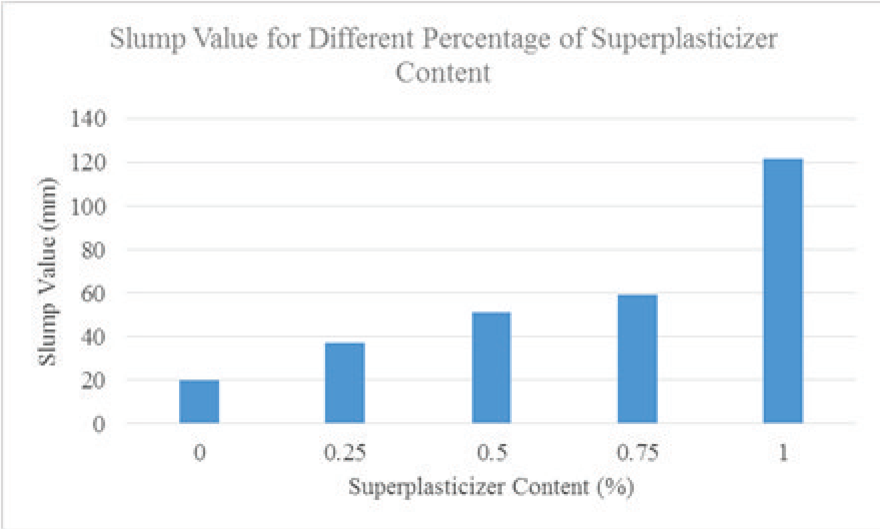

Fig. 3: Slump value for rubberized concrete with different percentage of superplasticizer

3.2 Compressive Strength

The results of compressive strength tests are given in Table 3. It is seen that the average compressive strength of the plain concrete in 28th days is 37kN. The compressive stress of rubberized concrete with different percentages of superplasticizer were obtained. It can be deduced from the results that the compressive strength increases by 2% and 4% with addition of 0.25% and 0.5% of superplasticizer; with added 0.75% and 1 % of superplasticizer a slightly reduction are observed by 2% and 3% respectively. It can be deduced from the results that the 0.5% of superplasticizer will not have an adverse effect on compressive strength or strength development of concrete when added to produce highly workable concrete

Table 2: Compressive strength

Concrete sample	Superplasticizer %	Average compressive strength (kN)
Rubberized concrete	0.00%	37.14
	0.25%	38.02
	0.50%	38.59
	0.75%	36.22
	1.00%	35.87

3.3 Splitting-Tensile Strength

Fig 4 shows the effect of superplasticizer on the splitting-tensile strength which illustrates that the splitting tensile strength are increase by 3 and 5% with addition of 0.25% and 0.5% of superplasticizer respectively, and then decrease slightly with 0.75% and 1% addition of superplasticizer concrete.

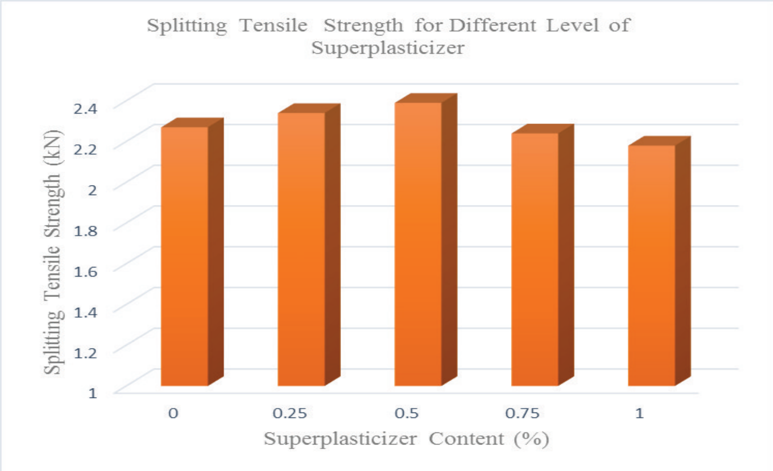

Fig. 4: Splitting Tensile strength for rubberized concrete with different level of superplasticizer

3.4 Flexural Strength

Figs. 5 shows that for 28th day test, the relative flexural strength for 0.25%, 0.75% and 1.0% superplasticizer content specimen were lower than the control mix while relative flexural strength for 0.5% superplasticizer content specimen is slightly larger than control mix.

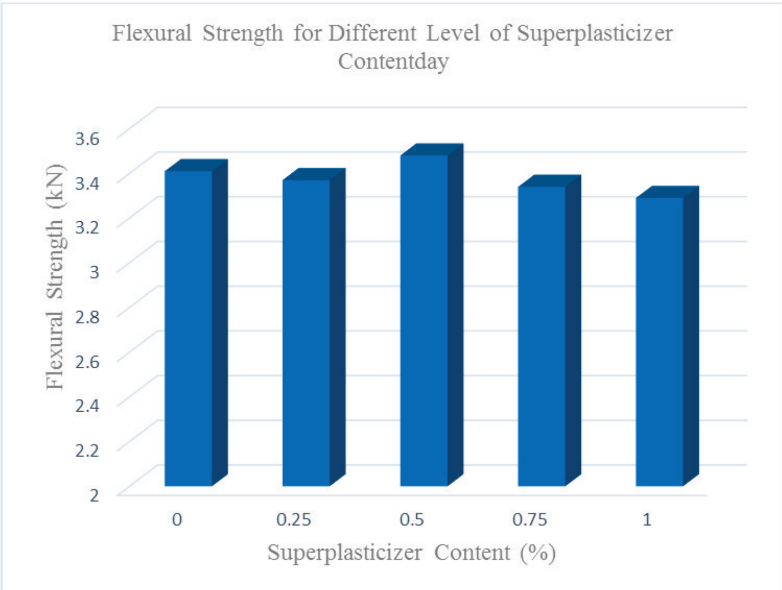

Fig. 5: Flexural strength for rubberized concrete with different level of superplasticizer

3.5 Ultrasonic Pulse Velocity Test

From Fig. 6 to 10, the result of 100 x 100 x 100 mm cubes and 100 x 100 x 500 beams test show that the 0.5% of superplasticizer content were produced velocity approximately same with the control mix which is 5.3 km/s for cube and 4.6 for beam. This indicated that the quality of the concrete was good which means the little of voids existed in the concrete. For cubes with 0.25%, 0.75% and 1.0% of superplasticizer content produced 4.5 km/s, 4.7 km/s and 4.4 km/s of velocity respectively and for beams with 0.25%, 0.75% and 1.0% of superplasticizer content produced 4.3 km/s, 4.2 km/s and 4.3 km/s of velocity respectively. This indicated that the quality of the concrete was fair.

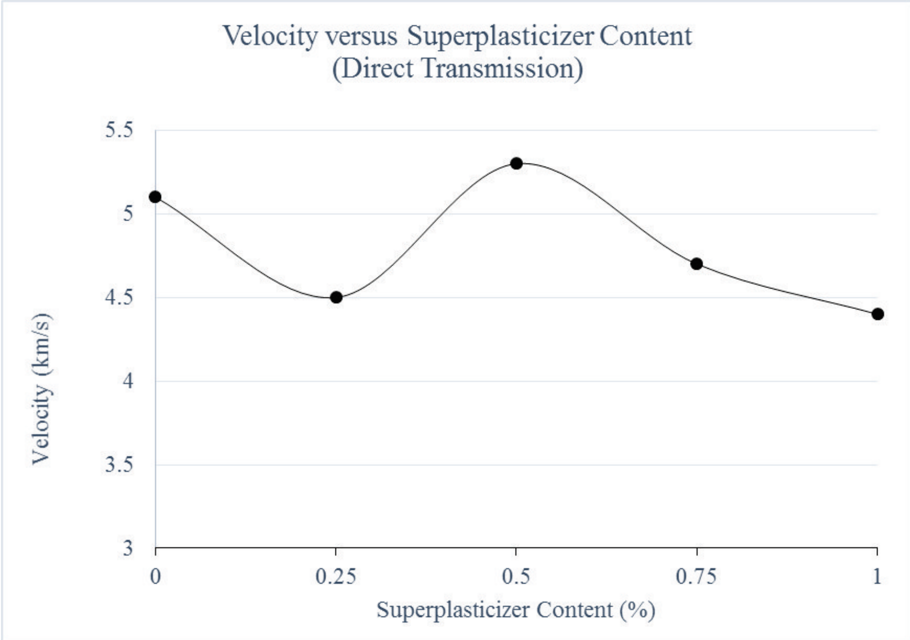

Fig. 6: Velocity versus superplasticizer content
(Direct Transmission 100 x100 x100 mm cube)

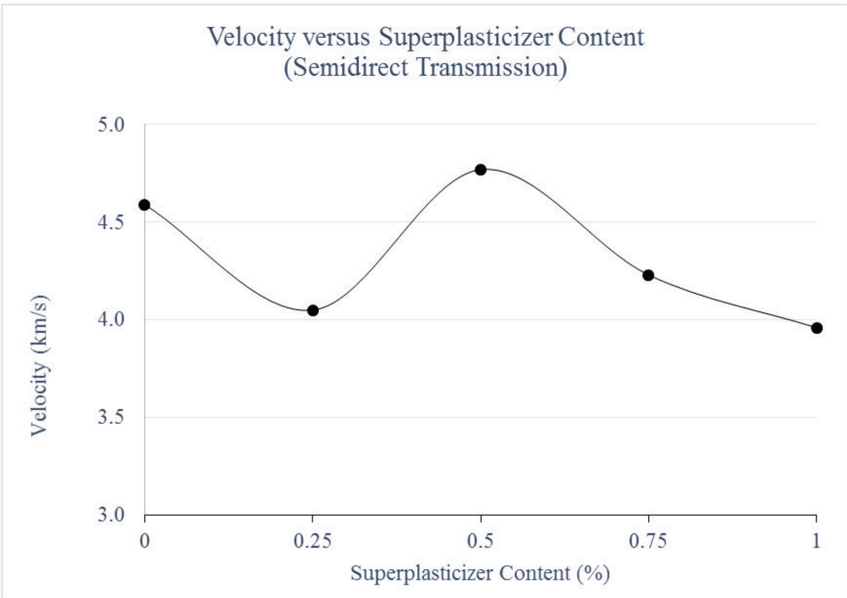

Fig. 7: Velocity versus superplasticizer content
(Simidirect Transmission 100 x100 x100 mm cube)

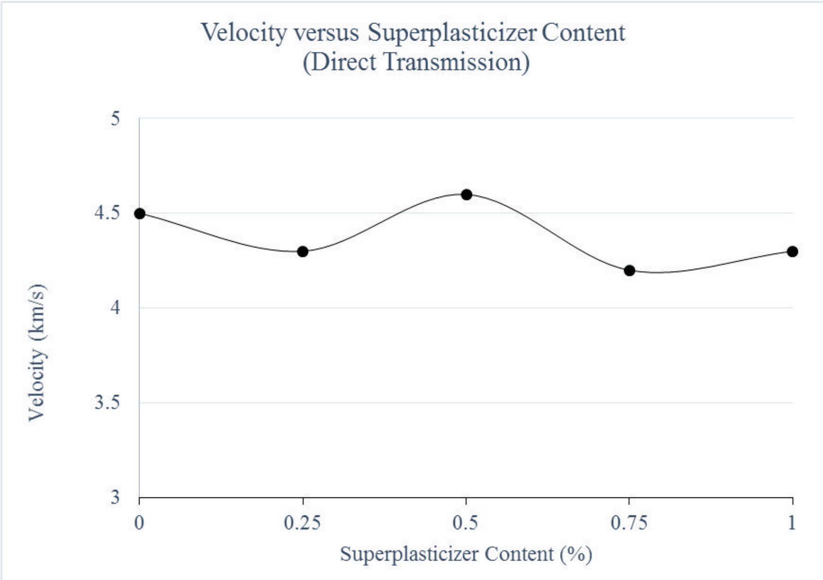

Fig. 8: Velocity versus superplasticizer content
(Direct Transmission 100 x100 x500 mm cube)

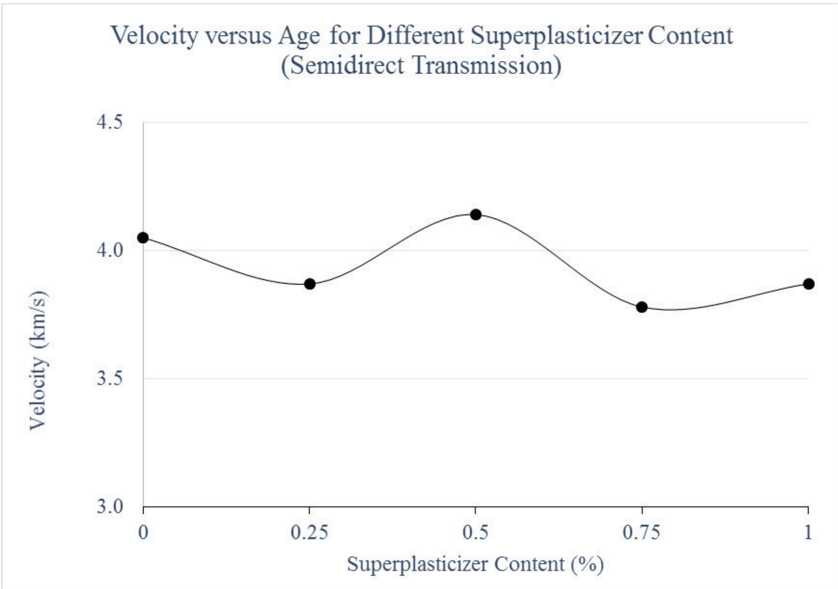

Fig. 9: Velocity versus superplasticizer content
(Simidirect Transmission 100 x100 x500 mm cube)

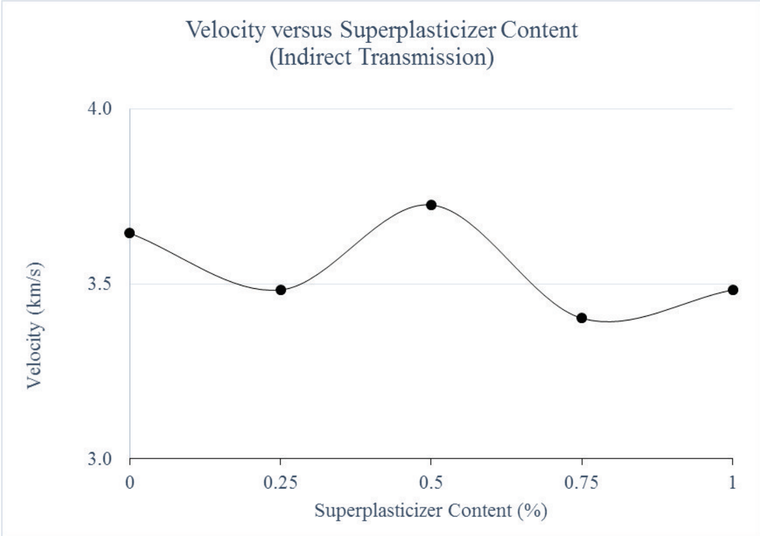

Fig. 10: Velocity versus superplasticizer content
(Indirect Transmission 100 x100 x500 mm cube)

4. Conclusions

Rubberized concrete was purposely introduced to reduce the rubber waste which widely becomes an issue nowadays. Many researches carried out this to investigate the quality and performance of rubberized concrete which can be used widely in construction field. This study was also carried out to investigate the potential of superplasticizer to improve the workability of crumb rubber concrete and other mechanical properties. Based on laboratory test results, it has been demonstrated that:

(a) The slump value for concrete increased from 20 mm to 120 mm with increasing the superplasticizer content by 1%.

(b) It can be deduced from the results that the 0.5% of superplasticizer will not have an adverse effect on compressive, Splitting-tensile and flexural strengths of rubberized concrete when added to produce workable concrete.

(c) Ultrasonic pulse velocity test show that the 0.5% of superplasticizer content were produced velocity approximately same with the control mix which is 5.3 km/s for cube and 4.6 for beam. This indicated that the quality of the concrete was good which means the little of voids existed in the concrete.

However, extended work is underway, to analyze the mechanical properties of rubberized concrete with superplasticizer under dynamic loading.

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