Optimum Superplasticizer Added to Concrete Containing Waste Crumb Rubber

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Abstract
Rubberized concrete was produced by replacements 10% of sand by 1 mm waste crumb rubber. Rubberized concrete with 0.25%, 0.5%, 0.75% and 1.0% superplasticizer contents were prepared without change the water-cement ratio purposely to study the effects of superplasticizer to the rubberized concrete. 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 0.75% superplasticizer produced better compressive strength, split tensile strength, flexural strengthd ultrasonic pulse velocity.

Keywords: Crumb rubber, Superplasticizer, Workability, Concrete strength.

1. Introduction

The increase in the world population leads to increase numbers of road vehicles such as cars, motorcycles, busses, trucks, etc, as they are necessity from the perspective of transportation. However, the increase in numbers of road vehicles brings about a negative impact on the environment where millions of scrap tires are discarded to the environment every year after the expiry of their usable life. Some of these used tires are reused, recycled or sometimes sent for energy recovery. The other remaining parts will be sent for landfill; stockpiled or tires will be dumped in illegal tire dumps. In the United States, the amounts of waste tires discarded have been estimated about 2 billion tires. Most of them are stockpiled around the country. The Environmental Protection Agency (EPA) stated that more than 279 million waste tires are being added annually to the estimated number mentioned above (Jang, 1997). In United Kingdom, disposing waste tires has become a major problem for waste products management in the country. The estimated numbers of discarded waste tires is about 37 million tires of cars and trucks each year. With the growth of road traffic annually it is estimated that the increase in the discarded waste tires may reach up to 39% in 2011 and 63% in 2021 (Marten, 2001). In France, the government has legislated a new law that forbids supplying new landfill area's in the country and the discarded waste tires should be managed in order to prevent the damage and pollution to our environment and that law came due to the increasing numbers of disposed waste tires which has been estimated to be 10 million waste tires discarded annually (Siddique, 2008). 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 crumb 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. Al-Tayeb et al., (2015) the addition of 0.5% of superplasticizer into the concrete containing fine crumb rubber (0.6 mm) will improve the workability and mechanical properties of rubberized concrete. In this study rubberized concrete was produced by using 10% of waste crumb rubber 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 effect of superplasticizer on several tests such as slump test, compression test, split tensile test, flexural test and ultrasonic pulse velocity test were studied.

2. Methodology

2.1 Materials

Concrete mixes were prepared with replacements of sand volume by 10% with waste crumb rubber (Fig.1) of particle size 1 mm and relative density 0.66. 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.The control mix was designed 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.

Fig. 1: Images of the waste 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	718	973	19.3
Volume [m^3]	10%		125	190	271	367	30.1
Weight [kg]	-	0.25%	395	190	718	973	19.3
Volume[m3]	10%	-	125	190	271	367	30.1
Weight [kg]	-	0.50%	395	190	718	973	19.3
Volume[m3]	10%	-	125	190	271	367	30.1
Weight [kg]	-	0.75%	395	190	718	973	19.3
Volume[m3]	10%	-	125	190	271	367	30.1
Weight [kg]	-	1.00%	395	190	718	973	19.3
Volume[m^3]	10%	-	125	190	271	367	30.1

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, 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. The compression stresses were tested on the age of 28th day.

2.2.3 Splitting Tensile Test

For the splitting tensile test 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. The specimens were cured accordance with ASTM C 192/C192M-06.

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 in accordance with ASTM C 192/C192M-06. The three-point static flexural stresses were tested on the age of 28th day.

2.2.6 Ultrasonic Pulse Velocity (UPV) Test

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

3. Results and discussion

The results of all tests have been performed and compared with the control mixes as shown below.

3.1 Workability of concrete mixes

According to ASTM 143 standard, the workability property of concrete mixes was measured by conducting slump cone test. The slump value of fresh concrete containing crumb rubber with different percentage of superplasticizer content is presented in the Figure 2 below. As for rubberized concrete without superplasticizer added results of low slump value which is 30 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

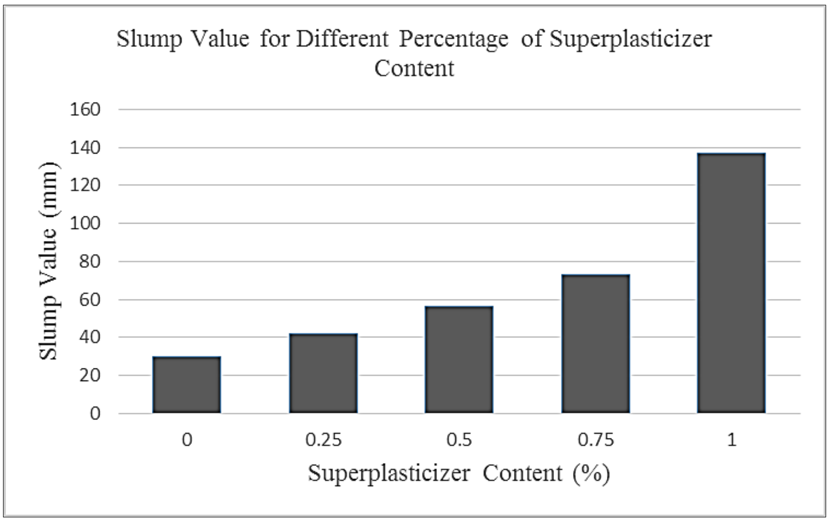

Fig. 2: Slump value for rubberized concrete with different percentage of superplasticizer

3.2 Compressive strength

The results of compressive strength tests are given in Table 2 and Fig. 3. It is seen that the average compressive strength of the plain concrete in 28th days is 36.94 kN. The compressive stresses of rubberized concrete with different percentages of superplasticizer were obtained. It can be deduced from the results that the compressive strength increases by 3%, 4% and 5% with addition of 0.25%, 0.5% and 0.75% of superplasticizer respectively; while with added 1 % of superplasticizer a slightly reduction are observed but it still more than the control mix by 4%. It can be deduced from the results that the 0.75% of superplasticizer will have the best effect on compressive strength. However, Al-Tayeb et al., (2015) found that the compressive stresses of rubberized concrete containing fine crumb rubber (0.6mm) was increased with increase the percentages of superplasticizer up to 0.5% then it decreased.

Table 2: Compressive strength

Concrete sample	Superplasticizer %	Average compressive strength (kN)
	0.00%	36.94
	0.25%	38.21
Rubberized concrete	0.50%	38.46
	0.75%	38.92
	1.00%	38.31

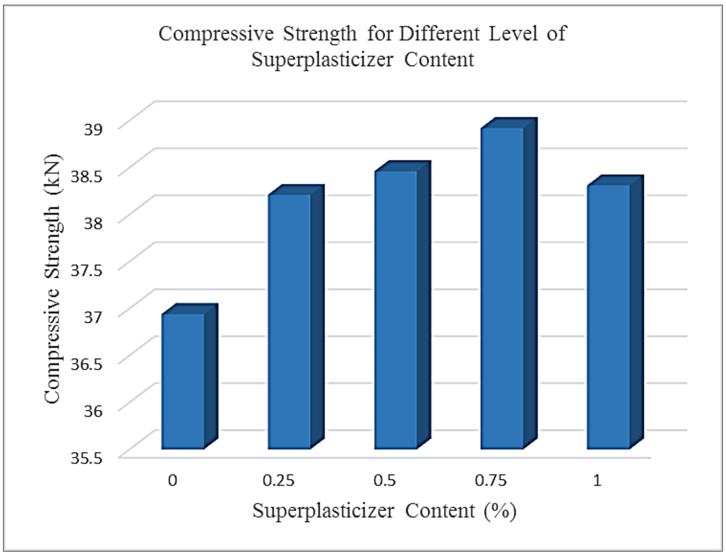

Fig. 3: Compressive strength for rubberized concrete with different level of superplasticizer

3.3 Splitting-tensile strength

Table 3 and Fig 4 show the effect of superplasticizer on the splitting-tensile strength which illustrates that the splitting tensile strength are increase by 2%, 3% and 5% with addition of 0.25%, 0.5% and 0.75% of superplasticizer respectively, and then decrease slightly with added 1% of superplasticizer content.

Table 3: Splitting-tensile strength

Concrete sample	Superplasticizer %	Average splitting-tensile strength (kN)
Rubberized concrete	0.00%	2.19
	0.25%	2.24
	0.50%	2.25
	0.75%	2.31
	1.00%	2.16

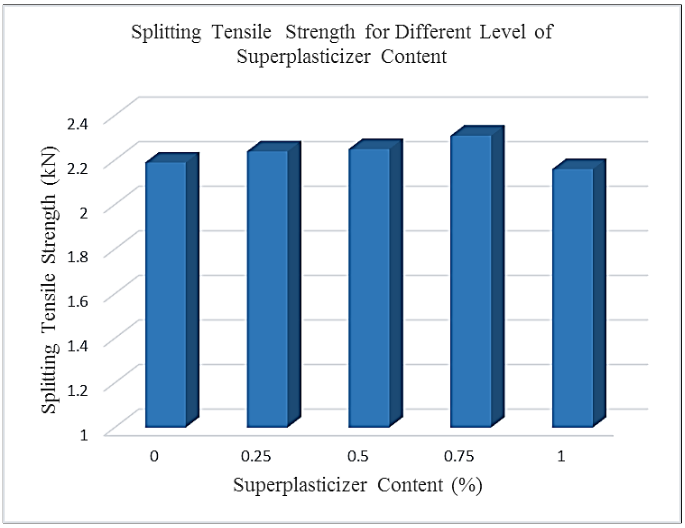

Fig. 4: Splitting Tensile strength for rubberized concrete with different level of superplasticizer

3.4 Flexural strength

Table 4 and Fig. 5 show that for 28th day test, the relative flexural strength illustrates that the splitting tensile strength are increase by 1%, 2% and 4% with addition of 0.25%, 0.5% and 0.75% of superplasticizer respectively, and then decrease slightly with added 1% of superplasticizer content.

Table 4: Flexural strength

Concrete sample	Superplasticizer %	Average Flexural strength (kN)
Rubberized concrete	0.00%	3.24
	0.25%	3.29
	0.50%	3.32
	0.75%	3.38
	1.00%	3.22

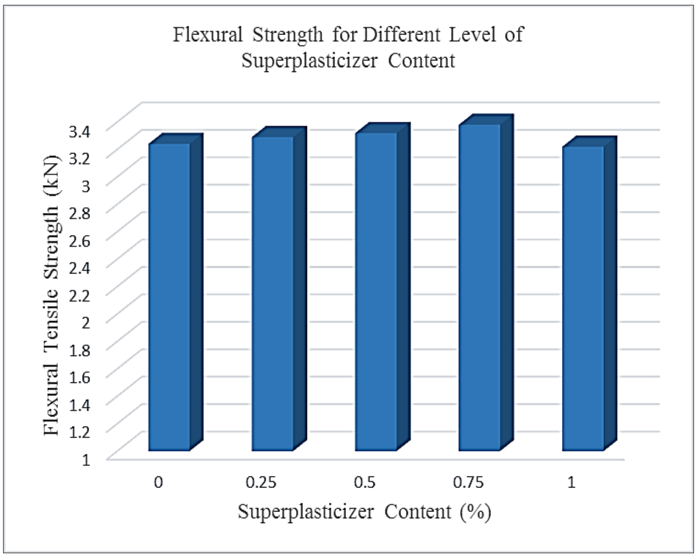

Fig. 5: Flexural strength for rubberized concrete with different level of superplasticizer

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 It can be deduced from the results that the velocity increases by increase the percentage of superplasticizer up to 0.75% then the velocity decreases by added 1% superplasticizer. This indicated that the quality of the concrete was increase with increase the percentage of superplasticizer up to 0.75 which means the little of voids existed in the concrete.

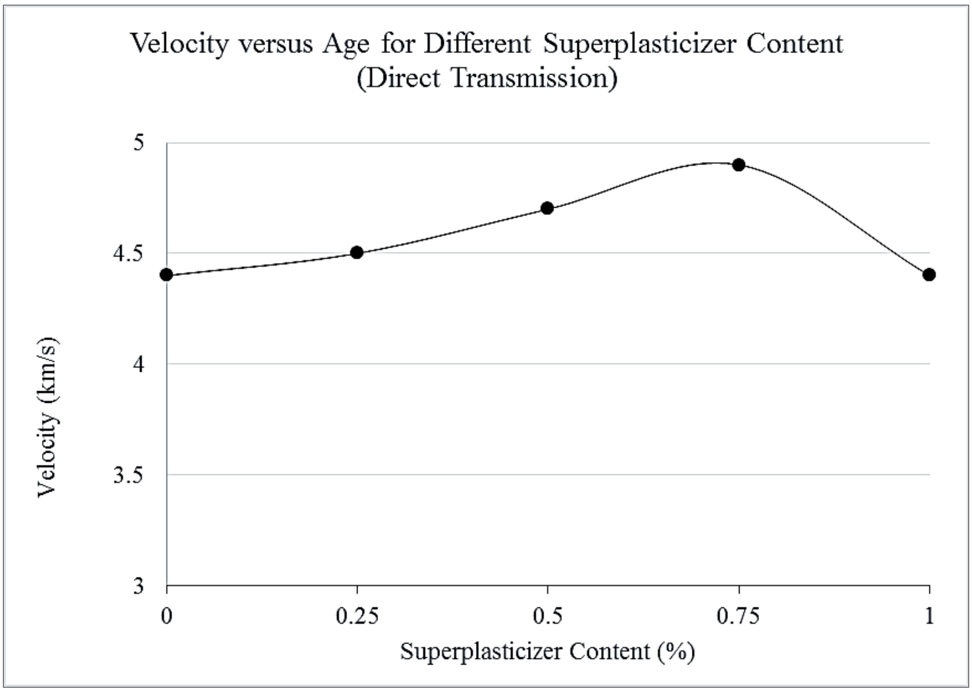

Fig. 6: Velocity versus superplasticizer content
(Direct Transmission 100 x100 x100 mm cube)

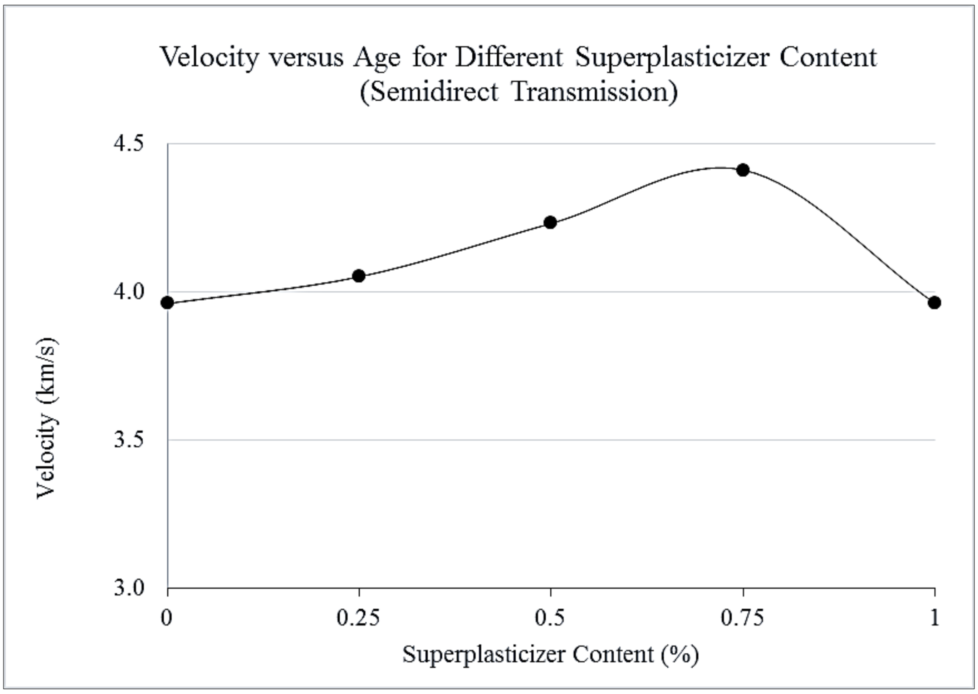

Fig. 7: Velocity versus superplasticizer content
(Simidirect Transmission 100 x100 x100 mm cube)

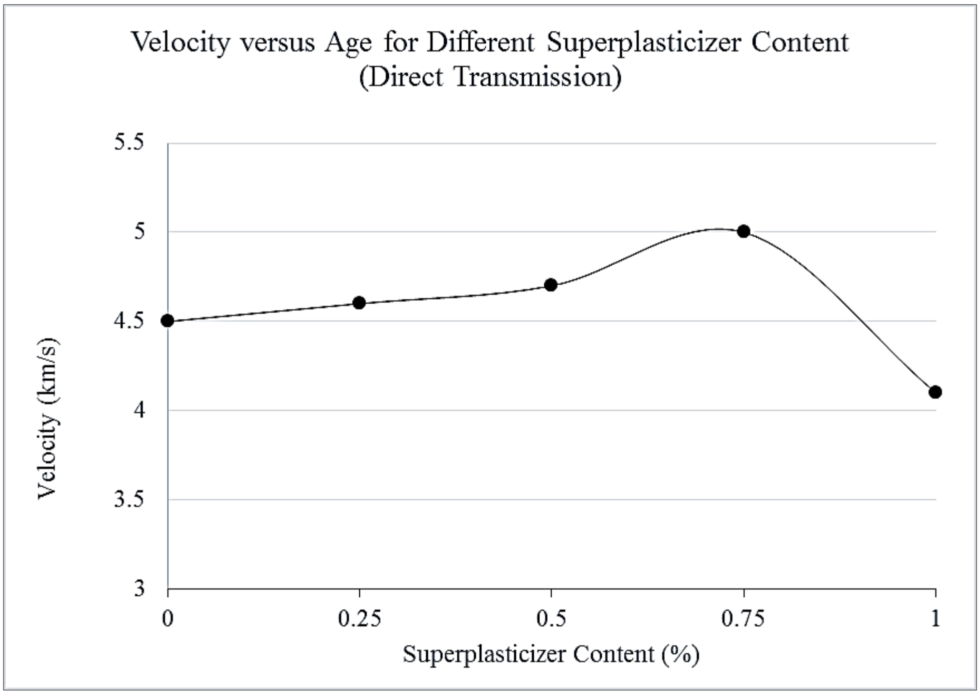

Fig. 8: Velocity versus superplasticizer content
(Direct Transmission 100 x100 x500 mm cube)

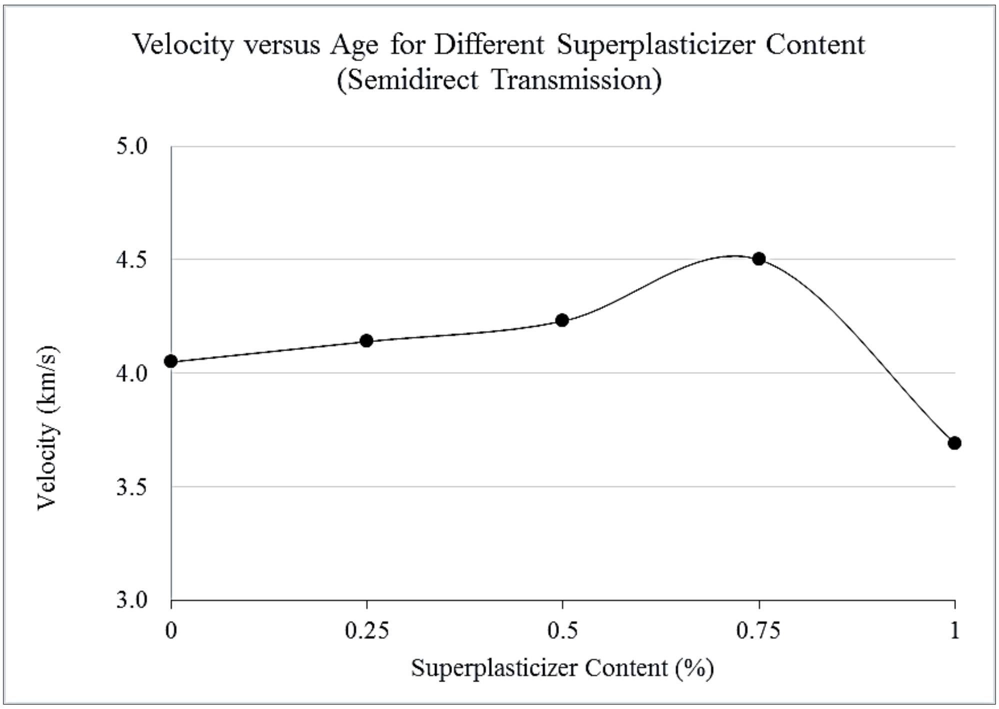

Fig. 9: Velocity versus superplasticizer content
(Simidirect Transmission 100 x100 x500 mm cube)

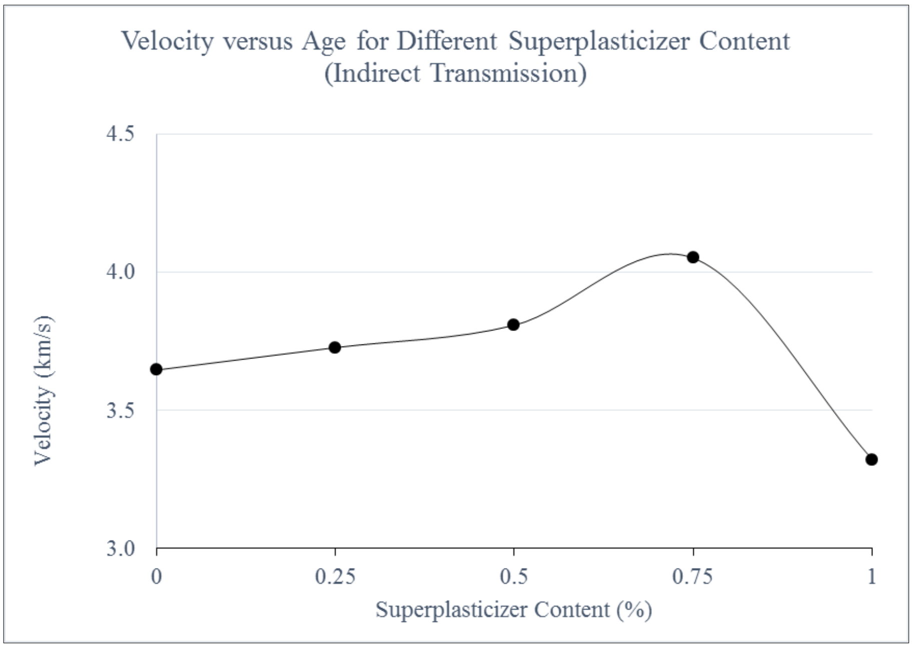

Fig. 10: Velocity versus superplasticizer content
(Indirect Transmission 100 x100 x500 mm cube)

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 and other mechanical properties of rubberized concrete containing 1 mm waste crumb rubber. Based on laboratory test results, it has been demonstrated that:

(a)The slump value for concrete increased from 30 mm to 140 mm with increasing the superplasticizer content by 1%.

(b)It can be deduced from the results that the 0.75% of superplasticizer will have the best mechanical properties such compressive, Splitting-tensile and flexural strengths of rubberized concrete when added to rubberized concrete containing 1 mm waste crumb rubber.

(c)Ultrasonic pulse velocity test show that the 0.75% of superplasticizer content were produced highest velocity. 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.

References

Al-Tayeb M.M, Hamouda H., (2015), Effect of superplasticizer on workability of concrete containing crumb rubber, Civil and Environmental Research. 7 (2) pp. 35-43.

Al-Tayeb M.M, Abu Bakar B.H, Akil. H.M, and Ismail. H, (2012), Effect of partial replacements of sand and cement by waste rubber on the fracture characteristics of concrete, Polymer-Plastics Technology and Engineering. 51 (6) pp. 583-589.

Al-Tayeb M.M, Abu Bakar B.H, Ismail. H, and Akil. H.M, (2013), Effect of partial replacement of sand by fine crumb rubber on impact load behavior of concrete beam: experiment and nonlinear dynamic analysis. Materials and Structures, 46 (8) pp. 1299-1307

American Society for Testing and Materials (ASTM) C192/192 (2006) Standard practice for making and curing concrete test specimens in the laboratory, vol. 4.02, West Conshohocken, PA, USA.

American Society for Testing and Materials (ASTM) C39/C39 (2001) Test Method for Compressive Strength of Cylindrical Concrete Specimens, Annual Book of ASTM Standards, Pennsylvania.

American Society for Testing and Materials (ASTM) C496 (1996) Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens, Annual Book of ASTM Standards, Pennsylvania.

American Society for Testing and Materials (ASTM) C78 (1994) Standard test method for flexural strength of concrete (using simple beam with third-point loading). West Conshohocken, PA: ASTM International.

American Society for Testing and Materials (ASTM) C 597-97, Standard Test Method for Pulse Velocity through Concrete, Annual Book of ASTM Standards, 1998.

American Society for Testing and Materials (ASTM) C 143/C 143M. (2005) Standard Test Method for Slump of Hydraulic-Cement Concrete. West Conshohocken, PA: ASTM International.

Baker, T. E., Allen, T., Jenkins, D., Mooney, D., Pierce, L., Christie, R. and Weston, J. (2003) Evaluation of the use of scrap tires in transportation related applications in the State of Washington. Report to the Legislature as Required by SHB, 2308, p. 1-14.

Eldin, N. N., and Senouci, A. B. (1993), "Rubber-tire particles as concrete aggregate" J. Mater. Civ. Eng.,5(4), 478-496.

Jang J., Yoo T., Oh J., and Iwasaki I., (1997). Discarded tire recycling practices in the United States, Resources, Conservation and Recycling, 22, 1 -14.

Khaloo AR, Dehestani M, Rahmatabadi P (2008) Mechanical properties of concrete containing a high volume of tire–rubber particles, Waste Management 28: 2472–2482.

Martin, W. Tyres Crack-down to Help the Environment. UK government Environment Agency, November, 19, 2001

Siddique, R., and Naik, T. R. (2004), "Properties of concrete containing scrap-tire rubber-an overview." Waste. Manage., 24(6), 563-569.

Son, K. S., Hajirasouliha, I., and Pilakoutas, K. (2011), "Strength and deformability of waste tyre rubber-filled reinforced concrete columns." Construction and Building Materials, 25(1), 218-226.

Sukontasukkul, P., and Chaikaew, C. (2006), "Properties of concrete pedestrian block mixed with crumb rubber." Constr. Build. Mater., 20(7), 450-457

US EPA, 1991. Markets for Scrap Tires. Report No. EPA/530-SW-90-074A, Washington, DC, October 1991, p. 1-27.