Optimum Superplasticizer Added To Rubberized Concrete Prepare By Adding Powder Rubber As Cement Replacement

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***Abstract*— Rubberized concrete was produced by replacements 5% of cement by 0.15–0.6mm waste rubber powder. Rubberized concrete with 0.5%, 1.0%, 1.5% and 2.0% 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 1.5% superplasticizer produced better compressive strength, split tensile strength, flexural strengthd ultrasonic pulse velocity.**

Keywords— Rubber powder; Superplasticizer; Workability; Concrete strength.

I. INTRODUCTION

Cement consumption is increasing day by day as the main constituent of concrete which is the most widely used construction material. Increased use of cement poses environmental challenge as 5% of the global anthropogenic CO2 emission is originated from cement production [1]. Alongside this, there is increased generation of waste rubber which also has adverse ecological effects, due to its health hazards and difficulty for land filling. The high cost of disposal and requirement of large landfill area resulted in random and illegal dumping of waste rubber [2]. 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 [3,4]. Substantial works were reported on the use of polymers such as tire rubber as a replacement for cement, sand or aggregates in concrete mixtures [3-12]; these studies revealed that the addition of rubber to concrete enhanced the elastic behavior, while reducing the compressive strength. Son et al. [3] determined the strength, deformability and energy absorption capacity of reinforced concrete columns with waste tire rubber under static compression load. They found that using waste tire in concrete improved the energy absorption capacity and ductility. Sukontasukku et al. [4] demonstrated that replacing coarse aggregate and sand with crumb rubber, enhanced the flexibility, toughness, energy absorption and ductility of concrete, with reduction in compressive and flexural strengths. During an impact test by 10 kg hammering from 60 mm height, Reda-Taha et al. [5] observed that the crump or chipped tire rubber particles in concrete could enhance the impact resistance. Ganjian et al. [6] studied the effect of partial replacement of cement by rubber powder and coarse aggregate by chipped rubber, on the flexural strength of concrete. They showed that the former process caused more reduction (37%) in flexural strength compared with the latter (29%). Al-Tayeb et al. [7] 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. [8] 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. [9] 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 replacements 5% of cement by 0.15–0.6mm waste rubber powder. Superplasticizer with 0.5%, 1.0%, 1.5% and 2.0% contents were added into rubberized 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 with 40MPa were prepared by 5% replacements of cement by the rubber powder (Fig.1) of particle 0.15–0.6 mm (Fig 2) and relative density 0.6. In this study, a variable percentage of superplasticizer 0%, 0.5%, 1.0%, 1.5% and 2.0% were used. The compositions of the plain and rubberized concrete with different superplasticizer's percentage samples are presented in Table 1. The maximum coarse aggregate size was 20 mm, and the fine aggregate was natural sand, with specific gravities 2.64 and 2.66 respectively. Water/cement was 0.48.

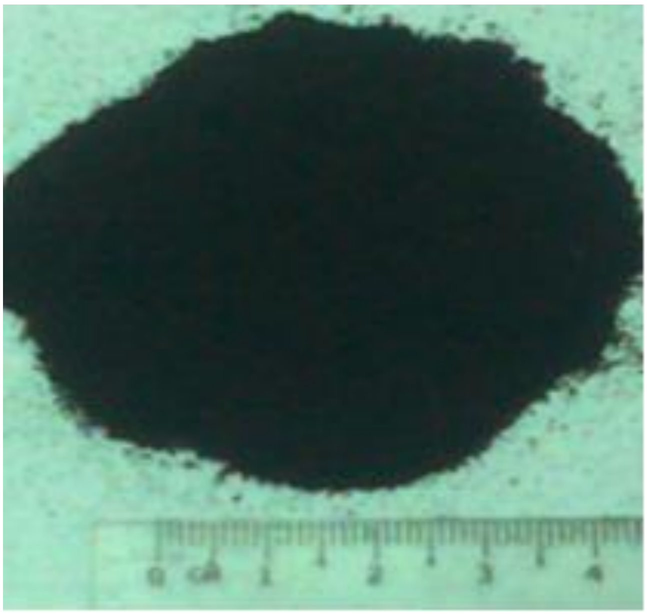

Fig. 1: Images of the waste rubber powder sample.

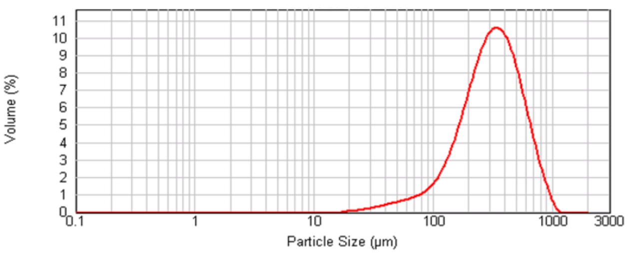

Fig. 2: Particle size distribution of rubber powder.

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

Unit	Superplasticizer /cement weight	Cement	Fine aggregate	Coarse aggregate	Crumb rubber
Weight [kg]	0.0%	374	797	973	3.80
Volume[m3]	-	119	301	367	6.25
Weight [kg]	0.5%	374	797	973	3.80
Volume[m3]	-	119	301	367	6.25
Weight [kg]	1.0%	374	797	973	3.80
Volume[m3]	-	119	301	367	6.25
Weight [kg]	1.5%	374	797	973	3.80
Volume[m3]	-	119	301	367	6.25
Weight [kg]	2.0%	374	797	973	3.80
Volume[m^3]	-	119	301	367	6.25

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 C143[13] Standard.

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 [14]. The specimens were cured accordance with ASTM C192/C192M-06 [15]. 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 [16]. The specimens were cured accordance with ASTM C192/C192M-06 [15].

2.2.4 Flexural Test

The three-point static flexural strength tests were performed according to ASTM C78-94 [17]. 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 [15]. 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 [18]. 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

The workability property of concrete mixes was measured by conducting slump cone test according to ASTM 143 [13] Standard. The slump value of fresh concrete containing 5% rubber powder 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 5 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.

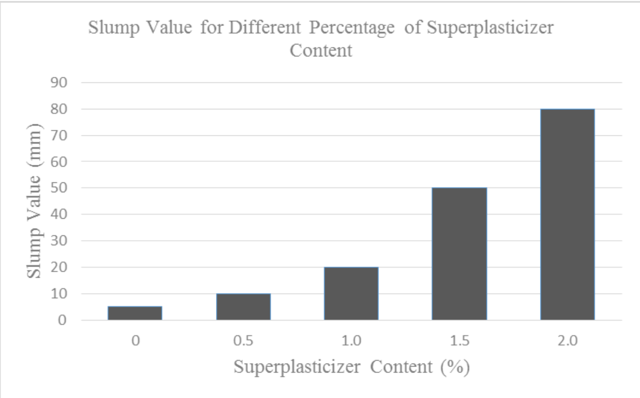

Fig. 3: Slump value for rubberized concrete with different percentage of superplasticizer

3.2 Compressive strength

The results of compressive strength tests are given in Table 2 and Fig. 4. It is seen that the average compressive strength of the plain concrete in 28th days is 30.27 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 5%, 8% and 13% with addition of 0.5%, 1.0% and 1.5% of superplasticizer respectively, and then decrease with added 2.0% of superplasticizer content but it still more than the control mix by 3%. It can be deduced from the results that the 1.5% of superplasticizer will have the best effect on compressive strength. However, Al-Tayeb et al. [9] found that the compressive stresses of rubberized concrete containing fine crumb rubber (0.6mm) as sand replacement 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)
Rubberized concrete	0.0%	30.27
	0.5%	31.64
	1.0%	32.73
	1.5%	34.15
	2.0%	31.03

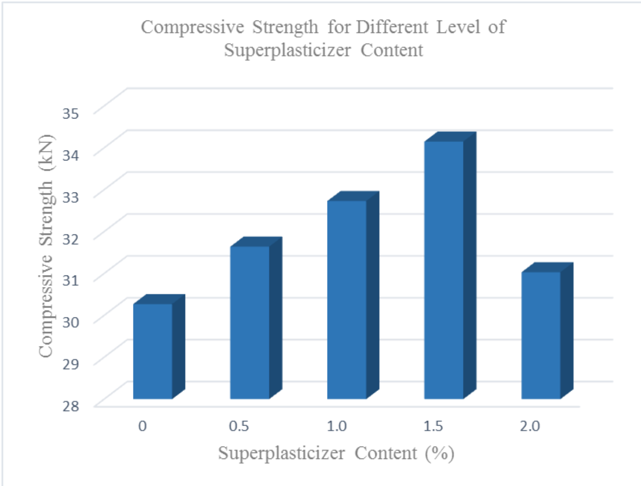

Fig. 4: Compressive strength for rubberized concrete with different level of superplasticizer

3.3 Splitting-tensile strength

Table 3 and Fig 5 show the effect of superplasticizer on the splitting-tensile strength which illustrates that the splitting tensile strength are increase by 4%, 9% and 17% with addition of 0.5%, 1.0% and 1.5% of superplasticizer respectively, and then decrease with added 2.0% of superplasticizer content. However, Al-Tayeb et al. [9] found that the Splitting-tensile stresses of rubberized concrete containing fine crumb rubber (0.6mm) as sand replacement was increased with increase the percentages of superplasticizer up to 0.5% then it decreased.

Table 3: Splitting-tensile strength

Concrete sample	Superplasticizer %	Average splitting-tensile strength (kN)
Rubberized concrete	0.0%	1.87
	0.5%	1.94
	1.0%	2.03
	1.5%	2.18
	2.0%	2.01

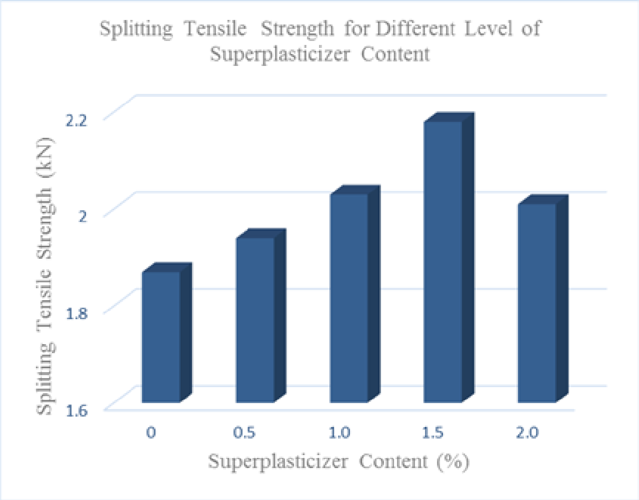

Fig. 5: Splitting Tensile strength for rubberized concrete with different level of superplasticizer

3.4 Flexural strength

Table 4 and Fig. 6 show that for 28th day test, the relative flexural strength illustrates that the splitting tensile strength are increase by 3%, 7% and 11% with addition of 0.5%, 1.0% and 1.5% of superplasticizer respectively, and then decrease with added 2.0% of superplasticizer content.

Table 4: Flexural strength

Concrete sample	Superplasticizer %	Average Flexural strength (kN)
Rubberized concrete	0.0%	2.95
	0.5%	3.03
	1.0%	3.16
	1.5%	3.28
	2.0%	3.08

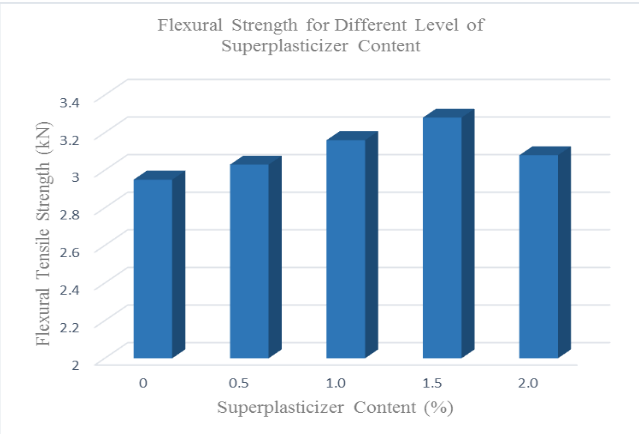

Fig. 6: Flexural strength for rubberized concrete with different level of superplasticizer

3.5 Ultrasonic Pulse Velocity Test

From Fig. 7 to 11, 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 1.5% then the velocity decreases by added 2.0% superplasticizer. This indicated that the quality of the concrete was increase with increase the percentage of superplasticizer up to 1.5% which means the little of voids existed in the concrete.

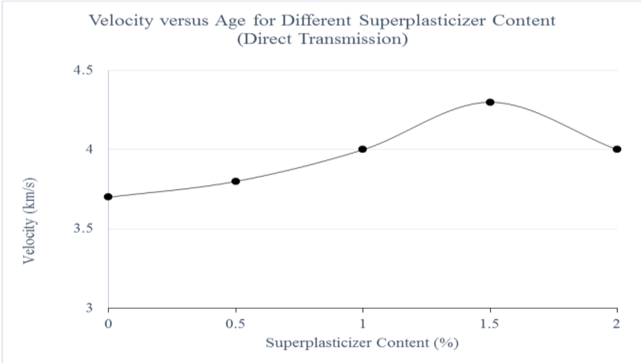

Fig. 7: Velocity versus superplasticizer content (Direct Transmission 100 x100 x100 mm cube)

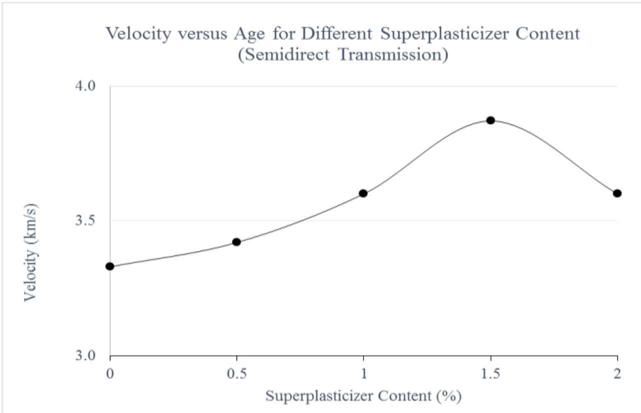

Fig. 8: Velocity versus superplasticizer content (Simidirect Transmission 100 x100 x100 mm cube)

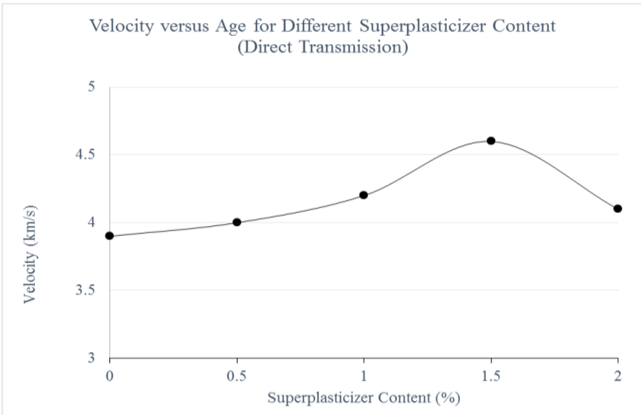

Fig. 9: Velocity versus superplasticizer content (Direct Transmission 100 x100 x500 mm cube)

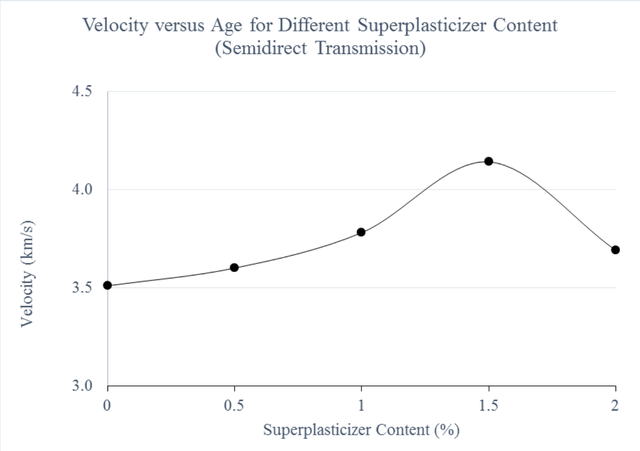

Fig. 10: Velocity versus superplasticizer content (Simidirect Transmission 100 x100 x500 mm cube)

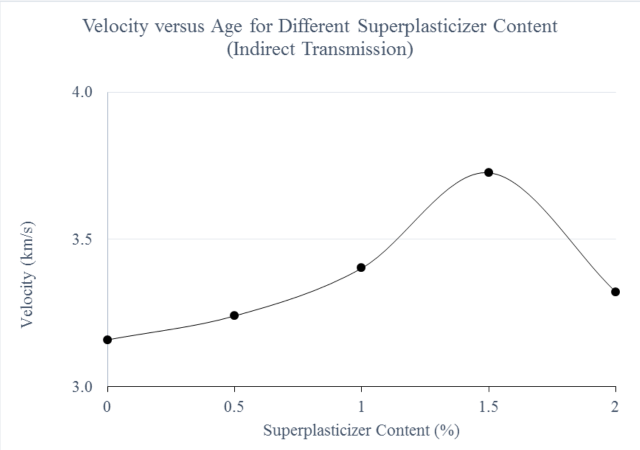

Fig. 11: Velocity versus superplasticizer content (Indirect Transmission 100 x100 x500 mm cube)

4. Conclusions

This study was carried out to investigate the effect of superplasticizer to improve the workability and mechanical properties of rubberized concrete was produced by replacements 5% of cement by 0.15–0.6mm waste rubber powder.

(a) The slump value for concrete increased from 5 mm to 80 mm with increasing the superplasticizer content by 2%.

(b) It can be deduced from the results that the 1.5% 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 1.5% 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

[1] Humphreys K, Mahasenan M. Toward a sustainable cement industry. Substudy 8, climate change. World Business Council for Sustainable Development; 2002.

[2] R. Siddique, and T. R.Naik, Properties of concrete containing scrap-tire rubber -An overview, Waste Manage 24 (6) (2004), pp. 563–569.

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

[4] P. Sukontasukkul and C. Chaikaew, Properties of concrete pedestrian block mixed with crumb rubber, Construction and Building Materials 20 (7) (2006), pp. 450–457.

[5] M.M. Reda-Taha, A.S. El-Dieb, M.A. Abd.El-Wahab and M.E. Abdel-Hameed, Mechanical, fracture, and microstructural investigations of rubber concrete, Journal of Materials in Civil Engineering 20 (10) (2008), pp. 640–649.

[6] Ganjian. E, Khorami. M and Maghsoudi. A.A, Scrap tyre rubber replacement for aggregate and filler in concrete, Journal of Construction and Building Materials 23(5): 1828–1836 (2005).

[7] M.M. Al-Tayeb, B.H. Abu Bakar, H.M. Akil., and H. Ismail, (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.

[8] M.M. Al-Tayeb, B.H. Abu Bakar, H. Ismail, and H.M. Akil, (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

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

[10] I.B. Topcu, The roperties of rubberized concretes, Cement and Concrete Research 25(2) (1995), pp. 304–310.

[11] I.B. Topcu, N. Avcular, Collision behaviours of rubberized concrete, Cement and Concrete Research 27 (12) (1997) pp. 1893-1898.

[12] N.N. Eldin, and A.B. Senouci, Rubber-tire particles as concrete aggregate, Journal of Materials in Civil Engineering, ASCE 5 (4) (1993), pp. 478–496.

[13] 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.

[14] 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.

[15] 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.

[16] 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.

[17] 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.

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