Journal of Multidisciplinary Engineering Science and Technology (JMEST)
ISSN: 2458-9403
Vol. 6 Issue 12, December - 2019

Mechanical Propagates Of Concrete With Partial Replacements Of Coarse Aggregate By Plastic Waste Of Vehicles Under Impact Load

Sulaiman R. S. Wafi
School College of Applied Engineering and Urban Planning,
University of Palestine, PO Box 1075, Gaza, Palestine
E-mail of the corresponding author: s.wafi@up.edu.ps

***Abstract*—Plastic waste of vehicle causes serious health and environmental problems all over the world such as fire hazards and provides breeding grounds for rats, mice, vermin's and mosquitoes. Effects of partial replacements of coarse aggregate by plastic waste of vehicle on the performance of concrete under low velocity impact loading investigated. Specimens prepared for 5%, 10% and 15 % replacements by volume for coarse aggregate. For each case, six cubes of 100 mm ×100 mm × 100mm subjected to 4.5 kg hammer from 457mm height. The number of blows of the hammer required to induce the failure of the cubes recorded. The results presented in terms of impact energy required for failure of the cubes. The plastic waste of vehicle increased the impact energy for the ultimate failure with coarse aggregate replacement by plastic waste of vehicle until 10% replacements and then decreased, but is still higher than that of plain concrete.**

Keywords: Plastic waste of vehicle; Cement concrete; Compressive strength; Impact energy.

I. Introduction

The plastic waste of vehicle is considered as one of the major environmental problems faced by every country due to their health hazards and difficulty for land filling [1]. Hence, there is an urgent need to identify alternative solutions to reuse the plastic waste of vehicle for other applications, and concrete has been identified to be one of the feasible options. On the other hand, the concrete has limited properties such as low tensile strength, low ductility, and low energy absorption [2]. Substantial research was carried out on the application of polymers in concrete ([3];[4]; [5]; [6]; [7]; [8]; [9]; [10]; [11]; [12]; [13]).

Reference [14] investigated the effects of recycle polyethylene terephthalate (PET) plastic waste on properties of concrete. The plastic waste could reduce the weight by 2–6% of normal weight concrete. Reference [15] study the strength properties of polymer concrete using an unsaturated polyester resin based on recycle PET plastic waste. He found that addition of waste tire in concrete enhanced the fracture properties, while both compressive and flexural strengths were decreased.

Reference [16] observed that the 5% replacement of fine aggregates with PET particles yields better results in compression. However, with further increase in polyethylene terephthalate particles to 10% and 15% the compressive strength of concrete decreases due to weak cohesion between the texture and the PET particles. Reference [17] reported that the concrete containing plastic waste has better sulfuric acid attack resistance in industrial structures and sewer pipes. Reference [18] investigated the strength and behavior plain and fiber reinforced polymer concrete beam column joints and the results were compared with plain and steel fiber reinforced conventional concrete beam column joints. The comparison of test results revealed that the strength and behavior of plain and fiber reinforced polymer concrete beam column joints are marginally better than corresponding conventional concrete beam column joints.

Reference [19] 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. Reference [20] conducted tests to examine the ultimate failure resistance of concrete with 5%, 10% and 15 % of sand replacements by waste plastic of vehicles under impact load conditions. Their results showed that the addition of plastic improved the impact load behavior of concrete.

However, the mechanical properties of concrete with partial replacements of coarse aggregate by plastic waste of vehicles under impact load are yet to be explored. In this study, effects of partial replacements of coarse aggregate by plastic waste of vehicle on the performance of concrete under low velocity impact loading investigated. Specimens prepared for 5%, 10% and 15 % replacements by volume for coarse aggregate. For each case, six cubes of 100 mm ×100 mm × 100mm subjected to 4.5 kg hammer from 457mm height. The number of blows of the hammer required to induce the ultimate failure of the cubes recorded.

II. MATERIALS AND METHODS

A. Materials

For the development of the present research, conventional concrete compounds were prepared with type I ordinary Portland cement supplied by Bursa Cement Factory. The cement chemical compositions presented in Table I.

TABLE I. CHEMICAL COMPOSITIONS OF CEMENT

Item	Percentage in Cement (%)
Oxide compositions	
SiO_3	19.98
Al_2O_3	5.17
Fe_2O_3	3.27
CaO	64.17
MgO	0.79
SO_3	2.38
Total alkalis	0.90
Insoluble Residue	0.20
Loss on Ignition	2.50
Mineral compositions	
C_3S	63.13
C_2S	9.61
C_3A	8.18
C_3AF	9.94

The maximum coarse aggregate size was 20 mm, and the fine aggregate was graded natural silica sand. Figure 1 shows the fine and coarse Aggregates Grading. The specific gravities of fine and coarse aggregates were 2.67and 2.65 respectively. The composition of this concrete is presented in Table II. Concrete mixes were prepared with replacements of sand volume by 5, 10, and 15% with plastic waste of particle size 0.1–10 mm (Figure2). The compositions of the plastic waste concrete are presented in Table III. Figure 3 shows the images of plastic waste sample (relative density, 0.8) used in the present study.

For the compression test, cubic specimens of 100mm side were prepared for each type. For split-tensile test, three cylinders of 160mm height and 100 mm diameter were prepared with the aforementioned proportions of plastic waste. In the case of impact test, 6 cubic specimens of 100mm side were prepared for each type. All specimens were cured in water for 28 days [21].

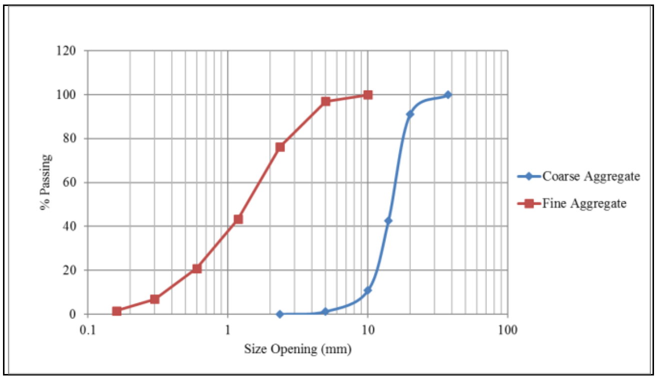

Fig. 1. *Fine and coarse aggregates grading.*

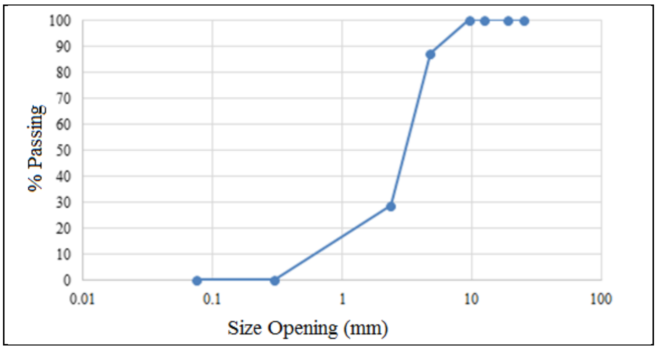

Fig. 2. *Particle size distribution of plastic waste.*

Fig. 3. *Images of the plastic waste.*

TABLE II. MIXTURE PROPERTIES OF NORMAL CONCRETE

Unit	Cement	Water	Fine aggregate	Coarse aggregate
Weight (kg)	454	195	670	1072
Volume(m^3)	144	195	251	405

TABLE III. MIXTURE PROPERTIES OF POWDER PLASTIC CONCRETE

Unit	***Plastic percent***	***Cement***	***Water***	***Fine aggregate***	***Coarse aggregate***	***Plastic waste***
Weight (kg)	-	454	195	638	1072	10.0
Volume (m3)	5%	144	195	239	405	12.5
Weight (kg)	-	454	195	603	1072	20.1
Volume (m3)	10%	144	195	226	405	25.1
Weight (kg)	-	454	195	569	1072	30.2
Volume (m3)	15%	144	195	213	405	37.7

B. Experimental set-up and procedure

Figure 4 shows the hammer of modified proctor which was used as drop weight machine to investigate the impact resistance of plastic concrete.

Fig. 4. *Hammer of modified proctor.*

A 4.5 kg impact drop hammer was raised to 457 mm above the specimen, and then released by following the procedure of Mohammadi [22]. The hammer was dropped repeatedly and the number of blows required to produce the ultimate failure in the specimen was recorded. The impact energy imparted by the hammer for 'n' number of bows (U) with a hammer velocity 'v' was calculated as follows:

$$U = n * 1/2(mv^2) \quad (1)$$

where,

$$v = \sqrt{2 * (0.9g) * h} \quad (2)$$

m = mass of the hammer, h = drop height, and g = gravitational acceleration. The factor, 0.9 accounts for effect of the air resistance and friction between the hammer and the guide rails [23].

III. RESULTS AND DISCUSSION

A. Slump test

One of the problems when adding plastic waste into the concrete is the reduction of workability of the concrete. The reduction of workability is also consistent with the earlier investigation [24]. Therefore, Superplasticizer with 1% will increase the workability. The procedure of slump test was according to ASTM C143 [25]. Figure 5 summarizes the results of workability measurements. The concrete containing plastic waste showed workability lower than concrete without plastic particles. It is believed that the effects of plastic waste in preventing the free flow of the mixture are attributable to the greater number and higher aspect ratio. The reduction of the slump with increase in the amount of plastic particles in the concrete might be attributed to the increase in the interior voids and the rough surface of the plastic particles which might result in increasing friction between the fresh concrete ingredients.

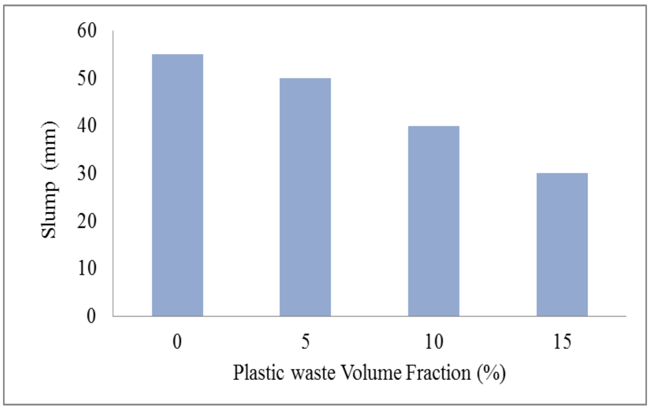

Fig. 5. *Effect of sand replacement ratio on slump of plastic concrete.*

B. Compressive stress and modulus of elasticity

The compressive strength and modulus of elasticity were tested according to ASTM C 39 [26] and ASTM C 469 [27]. The results presented in Table IV show a systematic reduction in concrete compressive strength with the increase of plastic content. The initial 28-day compressive strength of almost 43 MPa decreased to about 26 MPa when 15% replacement of sand by plastic waste was made. The compressive stress are reduced by 21, 33 and 40% with the sand replacement by plastic by 5, 10, and 15% of volumes, respectively. Similar is the case of elastic modulus which reduces by 7, 15 and 20%.

Although strength reduction is certainly a negative property that may hinder the use of plastic waste, elastic modulus results appear the positive effect in the form of the failure mode. The results sustained a much higher deformation than the control mix. With plastic content 15%, the samples exhibited significant elastic deformation, which was retained on unloading. Thus, flexibility and ability to deform elastically is increased significantly.

Reference [28] found that the compression stress was decreased by approximately 70% when plastic waste was added to concrete as a substitute for sand, with 15% by volume. The reduction in compressive stress and modulus of elasticity with the addition of plastic to the concrete as sand replacement is also consistent with the earlier investigation [29]. The reduction of compressive stress of concrete is attributed to the weak compressive stress of the plastic particles compared to the compressive stress of the natural sand. In addition to that the weak bond between plastic particles and the cement paste and the deformability of the plastic particles, which result in the initiation of cracks around the plastic particles in a fashion similar to that, occur in normal concrete due to air voids, cause reduction in stress. This reduction may also be due to grading, as the particle size of sand used in this research was smaller than the particle size of the plastic waste which increased the voids between the aggregate. These results corroborate with those obtained by [30] and [31].

TABLE IV. COMPRESSIVE STRENGTH AND MODULUS OF ELASTICITY

Plastic percent %	Average compressive stress (Mpa)	Average elastic modulus (kN/mm^2)
0%	43	29.4
5%	34	27.3
10%	29	25.1
15%	26	23.5

For split-tensile test, three cylinders of 160 mm height and 100 mm diameter were used for each concrete mixture. The test was carried out in accordance with the procedures stated in the ASTM C 496 [32]. Fig .6 shows the result of splitting-tensile test, which indicates that the plain concrete is yielded at 4.1 MPa, while with the sand replacement (5, 10, and 15 % of volumes) by plastic waste it is reduced by 10, 24 and 32% respectively. The reduction of split-tensile is also consistent with the earlier investigation [33] and the result of compression stress. Further, the reduction in tensile strength is lower than that in compression strength.

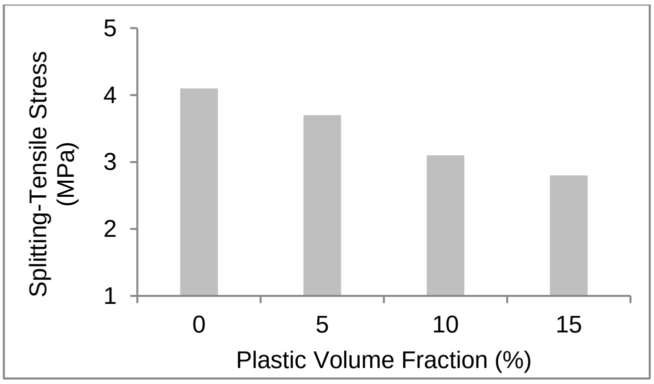

Fig. 6. *Splitting tensile stress against volume fraction of plastic waste.*

C. Impact test

Six concrete cubes of each type of mixtures were prepared for this test. The tested cubes were 100×100 mm. The numbers of impact blows required for producing the ultimate failure, for each type of concrete specimen were recorded in Table V, and the corresponding plot is shown in Figs. 7.

Figs. 8 presents the results in terms of ultimate failure impact energy. The results show that the ultimate failure resistance increases by 28, 51 and 83% with 5, 10, and 15 % of plastic replacements respectively. The enhanced ultimate failure impact resistance is due to the enhanced flexibility of the composite mix by the addition of plastic. The increases in flexibility are attributed to the high ductility of plastic which when added to the concrete, improves the mix ductility and the ability to absorb the impact load [34].

TABLE V. IMPACT TEST RESULTS FOR PLAIN AND PLASTIC CONCRETE.

Type of concrete	Plastic (%)	No. of blows of ultimate failure	Average no. of blows	Impact energy (kN mm) ultimate failure	Average impact energy (kN mm)
Plain	0	88	80	1865	1695
	0	73		1547	
	0	77		1632	
	0	82		1737	
	0	84		1780	
	0	76		1610	
Coarse aggregate replaced with plastic waste	5%	111	102	2352	2161
	5%	102		2161	
	5%	97		2055	
	5%	112		2373	
	5%	96		2034	
	5%	93		1971	
	10%	136	121	2882	2564
	10%	118		2500	
	10%	96		2034	
	10%	134		2839	
	10%	112		2373	
	10%	129		2733	
	15%	163	123	3454	3094
	15%	157		3327	
	15%	133		2818	
	15%	148		3136	
	15%	125		2649	
	15%	152		3221	

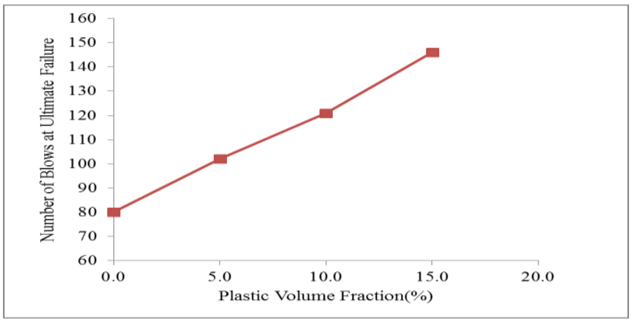

Fig. 7. *Ultimate failure impact resistance against volume fraction of plastic.*

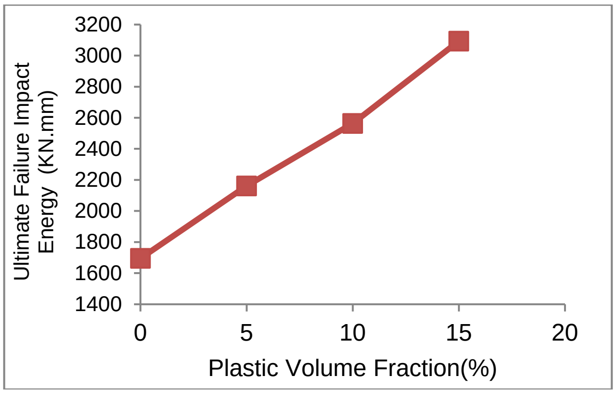

Fig. 8. *Ultimate failure impact energy against volume fraction of plastic.*

IV. Conclusion

This study examined how different volume fractions of plastic waste affect the mechanical properties of concrete under static and impact load. The following conclusions were found:

- The slump of the plastic concrete decreases with increase in plastic content. Superplasticizer with 1% will solve this problem.
- The results show that the compressive stress and modulus of elasticity decrease with increase in plastic content.
- The results show that the splitting-tensile stress decreases with increase in plastic content.
- Further, the reduction in tensile strength is lower than that in compression strength.
- The ultimate failure resistance increases by 21, 52 and 81% with 5, 10, and 15 % of plastic replacements respectively. The enhanced ultimate failure impact resistance is due to the enhanced flexibility of the composite mix by the addition of plastic.
- Extended work is underway, to investigate the mechanical properties of concrete with Partial Replacements of coarse aggregate by Waste Plastic of Vehicles

Reference

[1] Ruiz-Herrero, J. L., Nieto, D. V., López-Gil, A., Arranz, A., Fernández, A., Lorenzana, A., Merinoe, S., De Sajaa, J. A., Rodríguez-Pérez, M. Á. Mechanical and thermal performance of concrete and mortar cellular materials containing plastic waste. Construction and Building Materials, (2016) 104, 298-310.

[2] Wang , Y. ; Wu , H.C. ; Li , V.C. Concrete reinforcement with recycled fibers. J. Mater. Civ.Eng. 2000 , 12 (4), 314-319.

[3] Hama, S. M., & Hilal, N. N. (2017). Fresh properties of self-compacting concrete with plastic waste as partial replacement of sand. International Journal of Sustainable Built Environment. https://doi.org/10.1016/j.ijsbe.2017.01.001

[4] Abdulla, A. I. (2016). Thermal properties of sand modified resins used for bonding CFRP to concrete substrates. International Journal of Sustainable Built Environment, 5(1), 176-182.

[5] Abdulla, A. I., Razak, H. A., Salih, Y. A., & Ali, M. I. (2016). Mechanical properties of sand modified resins used for bonding CFRP to concrete substrates. International Journal of Sustainable Built Environment, 5(2), 517-525.

[6] Spaeth, V., & Tegguer, A. D. (2013). Improvement of recycled concrete aggregate properties by polymer treatments. International Journal of Sustainable Built Environment, 2(2), 143-152.

[7] Sen, T., & Paul, A. (2015). Confining concrete with sisal and jute FRP as alternatives for CFRP and GFRP. International Journal of Sustainable Built Environment, 4(2), 248-264.

[8] Rashad, A. M. (2016). A comprehensive overview about recycling rubber as fine aggregate replacement in traditional cementitious materials. International Journal of Sustainable Built Environment, 5(1), 46-82.

[9] Sen, T., & Reddy, H. J. (2013). Strengthening of RC beams in flexure using natural jute fibre textile reinforced composite system and its comparative study with CFRP and GFRP strengthening systems. International Journal of Sustainable Built Environment, 2(1), 41-55.

[10] Benosman, A. S., Taibi, H., Mouli, M., Senhadji, Y., Belbachir, M., Bahlouli, I., & Houivet, D. (2015). Effect of addition of PET on the mechanical performance of PET-Mortar Composite materials. J. Mater. Environ. Sci, 6(2), 559-571.

[11] Omrane, M., Benosman, A. S., Mouli, M., & Senhadji, Y. (2016). Use of Thermoplastic Polymer in Mortar Composites to Improve Its Chloride Penetration Resistance. International Journal of Engineering Research in Africa, JERA.22, Vol. 22, Pages 33-44, 2016. doi.org/10.4028/www.scientific.net/JERA.22.33.

[12] Benosman, A. S., Taïbi, H., & Mouli, M. (2016). Performances Mécaniques et Durabilité des Composites Mortier-PET: Recherche et Développement dans la Revalorisation et L'Application des Déchets du PET en Génie Civil. Editions universitaires européennes EUE, p. 268, 8 Aout 2016, (ISBN : 978-3-8417-4459-3).

[13] Islam, G. S., & Gupta, S. D. (2016). Evaluating plastic shrinkage and permeability of polypropylene fiber reinforced concrete. International Journal of Sustainable Built Environment, 5(2), 345-354.

[14] Choi, Y. W. ; Moon, D. J. ;Chung, J. S. ; Cho, S. K. Effects of waste PET bottles aggregate on the properties of concrete. Cement and Concrete Research 2005, 35 (4), 776–781.

[15] Rebeiz, K. S. Precast use of polymer concrete using unsaturated polyester resin based on recycled PET waste. Construction and Building Materials 1996, 10 (3) 215–220.

[16] Rahmani, E., Dehestani, M., Beygi, M. H. A., Allahyari, H., & Nikbin, I. M. On the mechanical properties of concrete containing waste PET particles. Construction and Building Materials, (2013) 47, 1302-1308.

[17] Araghi, H. J., Nikbin, I. M., Reskati, S. R., Rahmani, E., & Allahyari, H. An experimental investigation on the erosion resistance of concrete containing various PET particles percentages against sulfuric acid attack. Construction and Building Materials, (2015), 77, 461-471.

[18] Deepa Raj, S., Abraham, R., Ganesan, N., & Sasi, D. Fracture properties of fibre reinforced geopolymer concrete. Int J Sci Eng Res, (2013), 4(5), 75-80.

[19] Al-Tayeb , M.M. ; Abu Bakar , B. H. ; Akil , H.M. ; Ismail , H. Effect of partial replacements of sand and cement by waste rubber on the fracture characteristics of concrete. Polym.-Plast. Technol. Eng. 2012 , 51 (6), 583-589.

[20] Al-Tayeb M.M, Abu Bakar B.H, Ismail. H, and Akil. H.M, Effect of partial replacement of sand by recycled fine crumb rubber on the performance of hybrid rubberized-normal concrete under impact load: experiment and simulation. Journal of Cleaner Production. 2013, 59 (15), 284–289

[21] Standard, A. S. T. M. (2007). Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory. ASTM C, 192, C192-2007.

[22] Mohammadi , Y. ; Carkon-Azad , R. ; Singh , S.P. ; Kaushik , S.K. Impact resistance of steel fibrous concrete containing fibres of mixed aspect ratio. Constr. Build. Mater. 2009 , 23 (1), 183–189.

[23] Xu , H. Specialized fiber reinforced concretes under static and impact loading, PhD thesis, University of British Columbia, Heritage Branch, Canada (1987).

[24] Rahmani, E., Dehestani, M., Beygi, M. H. A., Allahyari, H., & Nikbin, I. M. On the mechanical properties of concrete containing waste PET particles. Construction and Building Materials, (2013) 47, 1302-1308.

[25] Standard, A. S. T. M. (2010). Standard Test Method for Slump of Hydraulic-Cement Concrete. ASTM C, 143, C143M-2010.

[26] Standard, A. S. T. M. (1997). Standard test method for compressive strength of cylindrical concrete specimens. C39-86, 20-24-1997.

[27] Standard, A. S. T. M. C469/C469M-10. (2010). Standard Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression.

[28] Choi, Y. W. ; Moon, D. J. ;Chung, J. S. ; Cho, S. K. Effects of waste PET bottles aggregate on the properties of concrete. Cement and Concrete Research 2005, 35 (4), 776–781.

[29] Rebeiz, K. S. Precast use of polymer concrete using unsaturated polyester resin based on recycled PET waste. Construction and Building Materials 1996, 10 (3) 215–220.

[30] Saikia, N., & de Brito, J. (2012). Use of plastic waste as aggregate in cement mortar and concrete preparation: A review. Construction and Building Materials, 34, 385-401.

[31] Sharma, R., & Bansal, P. P. (2016). Use of different forms of waste plastic in concrete–a review. Journal of Cleaner Production, 112, 473-482.

[32] Standard, A. S. T. M. C. 496, (2011). Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens. ASTM International.

[33] Rahmani, E., Dehestani, M., Beygi, M. H. A., Allahyari, H., & Nikbin, I. M. On the mechanical properties of concrete containing waste PET particles. Construction and Building Materials, (2013) 47, 1302-1308.

[34] Al-Tayeb , M.M. ; Abu Bakar , B. H. ; Akil , H.M. ; Ismail , H. Effect of partial replacements of sand and cement by waste rubber on the fracture characteristics of concrete. Polym.-Plast. Technol. Eng. 2012 , 51 (6), 583-589.