Technium Vol. 3, Issue 2 pp.1-12 (2021)
ISSN: 2668-778X
www.techniumscience.com

The possibility of utilization of tamper-evident bands (TEB) as fibers in concrete blends

Sarmad Fadhil Abdullah[1], Mohanad Yaseen Abdulwahid[2*] and Imad Adel AL-qasem[3]
[1]Department of Civil Engineering, Faculty of Engineering, Koya University, Koya KOY45, Kurdistan Region - F.R. Iraq; sarmad.fadhil@koyauniversity.org.
[2]Department of Civil Engineering, Faculty of Engineering, Koya University, Koya KOY45, Kurdistan Region - F.R. Iraq; mohanad.yaseen@koyauniversity.org.
[3]Department of Civil Engineering, An-Najah National University, Nablus, Palestine: imad-qa@najah.edu.
*Correspondence: mohanad.yaseen@koyauniversity.org

Abstract: The impact of tamper-evident bands (TEB) as fiber on the distinctive properties of concrete was examined through a few laboratory tests. In this study, the tamper-evident band (TEB) is the plastic ring left around the neck of bottled drinking water.The properties examined incorporate workability, compressive strength, flexural strength, and splitting tensile strength at 7 and 28 days of moist curing. Three varied fiber volumes were added to concrete mixes at 0.5%, 1.0%, and 1.5% by volume of concrete. The test results show that the employment of 1% (TEB) fibers by volume of concrete lead to the increment of flexural and splitting tensile strengths of concrete 34.5% and 38.56% respectively in comparison to the reference concrete at 28 days of moist curing. It can be inferred, according to a preliminary analysis, that tamper-evident bands (TEB) are modern forms of fibers that have a good effect on the improvement of concrete's tensile properties.
Keywords: Tamper-evident bands, HDPE fiber, flexural strength, splitting strength

1. Introduction

Concrete is one of the construction materials that is completely vital for any project in civil engineering. The fundamental composition of normal concrete consists of: cement, coarse aggregate, fine aggregate, and water. Admixtures (Chemical, mineral), and fibers (industrial, agricultural) can be included to improve the execution of concrete. Despite the concrete is one of the building's momentous materials, it has brittle property. That is, it is good under compression loads but weak under tension and shear loads. The presence of a large number of cracks has a considerable adverse effect on the mechanical properties and durability of concrete structures, which can lead to shortening of the structures' service life. Lots of researchers have done a lot of work to develop the concrete properties, particularly the durability of concrete, in order to resolve the material defects. Fibres have been used in building materials globally for a very long time [1]. The use of fibers has been proven to improve the mechanical properties and toughness of concrete [2]. On The other side, fiber reinforced concrete is picking up growing interest among the concrete community for the diminished construction time and labor costs [3]. Fiber concrete utilization could engage in higher sustainability with increased structural durability [4]. The optimization of the concrete mixture's composition and the dispersed reinforcement dosage is a very important role in the perspective of structural reliability and economically [5]. Fibers are one of the admixtures widely used in building construction application .There are two kinds of fibers that may be used in concrete, namely: synthetic fibers and natural fibers. Synthetic fibers include polypropylene [6-9], nylon [10, 11], polyethylene [12, 13] etc. Natural fibers, however, include sisal [14, 15], jute [16, 17], palm [18, 19] etc. The uses of fibers in concrete mixes have a number of benefits as listed below [20-22]:

1. Reduce concrete cracking.
2. Moisture resistance and thermal stress.
3. Strength against impulse and abrasion.
4. Fatigue strength enhancement.

The use of fiber is not limited to concrete, but many studies have proven the efficiency of fibers in road construction [23-27]. Using fiber-reinforced asphalt concrete can be used as a sustainable paving material reliable [28]. Length, percentage, shape, and method of fibers mixing affect significantly the behavior of concrete. Amongst different fibers, recycled plastic fibers have been tackled a lot by researchers in civil engineering to improve the sustainability of concrete. On the other side, the use of recycled plastic fibers leads to eliminate the environmental problems arising from these waste materials since environmental pollution will decrease. Plastics have ideal properties compared to other materials such as glass and metal, plastics have lower cost, a higher strength-to-weight ratio, are more durable (resistant to deterioration), simple to work and shape, and have a low density[29]. Waste plastics have been used in different ways as fibers, aggregate, and fillers to improve the mechanical and physical properties of concrete. Some researchers concluded that using recycled plastic as fibers could improve the tensile strength and impact resistance of concrete [30-39]. The inclusion of fibers in concrete would be an economical and environmentally friendly solution [40].On the other hand; studies mention that the use of recycled plastics as an aggregate improves the physical and mechanical properties concrete [41-48]. Regarding the official figures discharged by the Kurdistan Regional Government (KRG), 700 to 750 tons of plastic are tossed by premises daily within the Kurdistan Region. In Erbil alone, 200 to 250 tons of plastic are tossed, as 10 percent of it is reused [49]. Engineers have to decide how to reuse or repurpose this waste plastic in a naturally neighborly and economically reasonable way to create a feasible recycled plastic and offer assistance to decrease the huge plastic contamination issue [50]. Considerable researches and studies have been carried out in Kurdistan region of Iraq on this topic. However, there have been very limited studies in Kurdistan region of Iraq on plastics in concrete [51-53]. The plastic ring cleared out around the neck of a bottle is commonly called a tamper-evident band or tamper-evident function to a screw cap, lid, or closure. Tamper-evident band is a type of HDPE plastic. Many researchers have investigated the effect of HDPE plastic as aggregate in concrete mixtures for producing light weight concrete for non-structural application [54-57]. On another hand, HDPE plastic has efficient behave as a fiber in concrete mixtures to enhance the tensile properties of concrete [58-62]. According to the Association of Plastic Recyclers, the reason consumers were previously asked to take the cap off is that the cap is made from a different kind of plastic than the bottle, meaning that the bottle and its cap could not be recycled together [63]. That was leading to think about using tamper evident caps of bottled water as a fiber in concrete mixes.The main objective of this study is to investigate the effects of tamper- evident band as fiber on the workability, compressive strength, splitting strength, and flexural strength of normal concrete. This research tends to study the possibility 8of using tamper-evident bands (TED) to improve the tensile strength of the concrete. Many tests are required to be assessed in this experimental work such as: Compressive strength using (100 mm) cubes, flexural strength using (100 mm × 100 mm × 500 mm) simply supported prisms, and splitting tensile strength using (100 mm × 200 mm) cylinders.

2. Materials and Methods

2.1 Materials

1. In carrying out the tests, ordinary Portland grade cement (CEM I 42.5R) was used as it is the most widely used for common construction purposes. Tables 1 and 2 demonstrate the chemical composition and physical properties of the cement. The chemical compositions were performed using an x-ray fluorescence test at Koya University. All the testing procedures were carried out in accordance with (IQS No.5/1984) [64].

Table 1. Chemical analysis of the cement used in this study

Chemical composition (wt. %)	
SiO_2	24.20
AL_2O_3	4.87
CaO	62.41
Fe_2O_3	2.79
MgO	1.51
Na_2O	0.49
K_2O	0.58
SO_3	2.31
Tio_2	0.31
Zro_2	0.48

Table 2. Physical and mechanical properties of the cement used in this study

Physical properties	**Test result**	**Limitation of IQS 5-1984**
Specific Surface area (Blaine method) m^2/kg	290	$\geq$230 m^2/kg
Initial setting (Vicat Method) min.	89	$\geq$45 min
Final Setting (Vicat Method) hrs.	3:45	$\leq$ 10 hrs
Compressive strength (MPa)		
3 days	16.5	$\geq$15 MPa
7 days	25.4	$\geq$23 MPa

2. Natural fine aggregate was used after sieving at sieve No.8 (2.36 mm). The chemical composition and physical properties of the sand are presented in Tables 3 and 4.

Table 3. Chemical analysis of the fine aggregate used in this study

Chemical composition (wt. %)	
SiO_2	34.61
AL_2O_3	9.71
CaO	42.22
Fe_2O_3	5.42
MgO	3.17
Na_2O	1.29
K_2O	1.56
SO_3	0.12
Mno	0.15
Tio_2	0.89
Zro_2	0.63

Table 4. Physical properties of the fine aggregate used in this study

Physical properties	Test result	Limitation of IQS 5-1984
Fineness modulus	2.8	-
Specific gravity	2.65	-

3. Water is an important concrete element as it takes part in the chemical reaction with cement to form binding compounds that give the concrete strength. In the concrete blends, tap water was utilized.
4. The natural gravel river with an irregular shape used as a coarse aggregate was obtained from the Gorashin area, with all mixes having a maximum size of 12.5 mm. The choice of this size is based on the consideration of suitable workability being obtained. The grading used for coarse aggregates is illustrated in Table 5.

Table 5. Grading of coarse aggregate

Sieve size(mm)	Percentage passing (%)
12.5	100
10	96.5
4.75	15.1
2.36	0.5

5. The waste plastic bottle rings of a single brand are collected from local consumers. It's made from (HDPE) plastic-type. The plastic bottle ring waste is sliced to a small uniformed piece size (length 45 mm × width 3 mm) and with a corrugated surface that is expected to enhance the adherence with concrete. The fiber has been added at proportions (0.5%, 1.0 % and 1.5 %) by volume of total mixture. The fibers used in this study as shown in Figure 1.

Figure 1 Plastic bottle ring

Preparation of specimens

As built according to the British system B.S., the reference concrete mix In 1881. To have a 28-day cubic compressive strength of 35MPa, all mixes were made. One mix ratio was used in this study (1:2:2.35) (cement: sand: gravel) by weight and W/C was 0.52 after several trials. The specifics of the blends used in this analysis are shown in Table 6.

Table 6. Mix proportions for 1 m^3 of concrete

Percent (%)	Cement (kg)	Sand (kg)	Gravel (kg)	Water (kg)	Tamper-evident bands(TEB) (kg)
0	360	720	846	187.2	0
0.5	360	720	846	187.2	5.52
1	360	720	846	187.2	11.04
1.5	360	720	846	187.2	16.56

The mixes were batched in a 0.1 m3 rotational mixer. Initially, the dry constituent cement, sand and aggregate are mixed for one minute at first, then the appropriate amount of water is applied and the entire components of the mix are mixed for another minute. Then the fibers are applied depending on the amount of fiber for a time ranging from (1 to 3) minutes.It is avoided over mixing because the fiber will suffer damage and loss of power, resulting in good fiber dispersion and preventing balling problems. Prior to casting, the moulds are thoroughly oiled to achieve a fair face casting and promote demoulding.During the mixing phase, care is taken to prevent segregation and achieve a uniform distribution of fibers in the concrete that contributes to stress distribution and microcracking enhancement.For each depth of 50 mm of concrete, casting is carried out. Throughout this job, a vibrating table is used. To prevent any segregation, each layer will vibrate for 20 seconds. Using a trowel, the surface of the concrete is then hit. After 24 hours, the specimens are dismolded and preserved in water at a relatively constant temperature of around (24 ± 2) °C until the time of examination.

Testing procedure of all mixtures

1. By using the standard slump test apparatus, the workability of the fresh concrete is measured. The slump test was carried out according to B.S.1881:1952 figure 2. The internal surface of the mold was thoroughly cleaned and freed from superfluous moisture before conducting the test. The mold was placed on a smooth, horizontal, rigid and nonabsorbent surface metal plate, and then filled with four layers. Each layer is one-fourth the mold height and was tamped with 25 strokes of the rounded end of a tamping rod. The strokes were distributed in a uniform manner over the cross-section of the mold, and for the subsequent layers, penetrated into the underlying layer. The mold was removed from the concrete by raising it in a vertical manner and then allowing the concrete to subside. The slump was immediately determined by finding the difference between the height of the mold and the specimen's highest point.

Figure 2 Typical slump test

2. The compressive strength test was determined according to B.S.1881: part 116:1989 using 100 mm cubes. The compressive strength cubes were tested using (ELE-Digital Elect.2000) at loading rate of 15 MPa per minute. The average of three cubes was adopted at each test. Flexural strength was carried out on (100×100×500) mm simply supported prisms with clear span of 400 mm under one point loading according to B.S.1881: part 112:1989. The splitting tensile strength was determined according to B.S.1881: part117: 1989, using (100×200) mm cylinders. The splitting tensile strength cylinders were tested using (ELE-Digital Elect. 2000). The average compressive strength, flexural strength and splitting strength of three samples was recorded for each test.

3. Results

Experimental results and discussion

3.1 Effect of TEB fibers on the workability

The slump cone test was adopted to assess the workability of concete, test results are presented in Table 7. From these results it can be observed that the addition of fibers to plain concrete increases the stability and cohesion of the mix, thus reduce its workability signfictly.This observation was confirmed by similar researchers to the addition of plastic waste fibers has led to reducing the workability noticeably [65, 66]. The slumps of concrete with (TEB) fibers that have been obtained are lies between 95 mm to 75 mm that is required for the medium workability of concrete [67] . On the other hand, fiber (TEB) volume has added to the concrete did not cause any slump issues.

Table 7. Slump test outcomes for different concrete mixtures

Mix designation	Fibers volume fraction (%)	Slump values (mm)
R*	0	110
TEB	0.5	95
	1.0	80
	1.5	75

3.2 Effect of TEP fibers on the mechanical properties

3.2.1 Compressive Strength

Table 8 shows the effect of (TEB) on the compressive strength of concrete for moist curing periods 7 and 28 days. The results show that there is no considerable increase in the compressive strength of concrete by adding (TEB) fibers to it.In general, using a plastic fiber percentage greater than 1% decreases compressive strength, whereas a plastic fiber percentage between 0.5% and 1% is no a significant effect on the compressive strength [68]. The high percentage of (1.5% TEB) leads (11%) lower compressive strength for fiber-reinforced concrete compared to samples without fibers.This observation is also assured by Yuhazri et al [63].

Table 8. Compressive strength outcomes for different concrete mixtures

Mix designation	Fibers volume fraction (%)	Compressive strength (MPa)		Rate of increase for 28-days (%) [(TEB-R)/R]*100
		7-days	28-days	
R	0	24.5	36.65	--------
TEB	0.5	26.3	38.98	6.36
	1.0	25.2	37.84	3.25
	1.5	22.1	32.57	0

3.3 Tensile strength

The flexural strength and splitting tensile strength determined for concrete mixes at different volume fractions of (TEB) are shown in Tables 9 and 10 for moist curing periods 7 and 28 days. It is indicated from the test results that the flexural strength and splitting strength of plain concrete improved by the addition of fibers and increased up to 1.0% (by volume) then decreased as the (TEB) content increased. This confirmed by Guendouz et al.[69], Mohammed and Hammadi [70], Małek et al.[71].In another side, the using larger volume fraction often leads to clumping or balling of fibers [72], which is leading them less effective in strengthening the concrete blends.

Table 9. Flexural strength outcomes for various concrete mixtures

Mix designation	Fibers volume fraction (%)	Flexural strength (MPa)		Rate of increase for 28-day (%)
		7-days	28-days	[(TEB-R)/R]*100
R	0	4.77	5.77	--------
TEB	0.5	5.56	6.78	17.5
	1.0	6.53	7.76	34.50
	1.5	4.89	6.11	5.90

Table 10. Splitting tensile strength outcomes for different concrete mixtures

Mix designation	Fibers volume fraction (%)	Splitting strength (MPa)		Rate of increase for 28-day (%)
		7-days	28-days	[(TEB-R)/R]*100
R	0	2.96	3.76	-------
TEB	0.5	3.72	4.88	29.79
	1.0	4.2	5.21	38.56
	1.5	3.21	4.10	9.04

4 Study conclusions

Based on the experimental results obtained from this study, the following conclusions can be drawn:

1. Plastic bottle ring can be considered as a new type of fibers that can be used in the concrete blends.
2. The addition of plastic rings improves slightly the compressive strength of plain concrete mixes.
3. The tensile strength of plain concrete was improved by the addition of 1.0% by volume of (TEB) and the percentages of increase were, 34.5% for flexural and 38.56% for splitting tensile.
4. The use of (TEB) fibers of plastic bottle for strengthening brittle concrete has an efficient effect on improving the tensile strength of concrete and gets rid of the waste plastic.

3. References

[1.] Mohajerani, A., Hui, S. Q., Mirzababaei, M., Arulrajah, A., Horpibulsuk, S., Abdul Kadir, A., ... & Maghool, F. (2019). Amazing Types, Properties, and Applications of Fibres in Construction Materials. Materials, 12(16), 2513.

[2.] Zhang, P., Han, S., Ng, S., & Wang, X.-H. (2018). Fiber-Reinforced Concrete with Application in Civil Engineering. Advances in Civil Engineering, 2018, 1–4. doi:10.1155/2018/1698905.

[3.] Cajka, R., Marcalikova, Z., Kozielova, M., Mateckova, P., & Sucharda, O. (2020). Experiments on Fiber Concrete Foundation Slabs in Interaction with the Subsoil. Sustainability, 12(9), 3939.

[4.] MINELLI, F., & PLIZZARI, G. A. (2009). ROUND PANEL VS. BEAM TESTS TOWARD A COMPREHENSIVE AND HARMONIC CHARACTERIZATION OF FRC MATERIALS. Brittle Matrix Composites 9, 23–32. doi:10.1533/9781845697754.23.

[5.] Cajka, R., Marcalikova, Z., Kozielova, M., Mateckova, P., & Sucharda, O. (2020). Experiments on Fiber Concrete Foundation Slabs in Interaction with the Subsoil. Sustainability, 12(9), 3939. doi:10.3390/su12093939

[6.] Zhang, P., & Li, Q.-F. (2013). Freezing–thawing durability of fly ash concrete composites containing silica fume and polypropylene fiber. Proceedings of the Institution of Mechanical Engineers, Part L: Journal of Materials: Design and Applications, 228(3), 241–246. doi:10.1177/1464420713480984

[7.] Behfarnia, K., & Behravan, A. (2014). Application of high performance polypropylene fibers in concrete lining of water tunnels. Materials & Design, 55, 274–279. doi:10.1016/j.matdes.2013.09.075

[8.] Wang, Y., Zheng, T., Zheng, X., Liu, Y., Darkwa, J., & Zhou, G. (2020). Thermo-mechanical and moisture absorption properties of fly ash-based lightweight geopolymer concrete reinforced by polypropylene fibers. Construction and Building Materials, 251, 118960.

[9.] Song, P. S., Hwang, S., & Sheu, B. C. (2005). Strength properties of nylon- and polypropylene-fiber-reinforced concretes. Cement and Concrete Research, 35(8), 1546–1550. doi:10.1016/j.cemconres.2004.06.033

[10.] Ozger, O. B., Girardi, F., Giannuzzi, G. M., Salomoni, V. A., Majorana, C. E., Fambri, L., … Di Maggio, R. (2013). Effect of nylon fibres on mechanical and thermal properties of hardened concrete for energy storage systems. Materials & Design, 51, 989–997. doi:10.1016/j.matdes.2013.04.085

[11.] Ahmed, S. F. U., Maalej, M., & Paramasivam, P. (2007). Flexural responses of hybrid steel–polyethylene fiber reinforced cement composites containing high volume fly ash. Construction and Building Materials, 21(5), 1088–1097. doi:10.1016/j.conbuildmat.2006.01.002

[12.] Yuan, T.-F., Lee, J.-Y., Min, K.-H., & Yoon, Y.-S. (2019). Experimental Investigation on Mechanical Properties of Hybrid Steel and Polyethylene Fiber-Reinforced No-Slump High-Strength Concrete. International Journal of Polymer Science, 2019, 1–11. doi:10.1155/2019/4737384

[13.] Jr Savastano, H., Turner, A., Mercer, C., & Soboyejo, W. O. (2006). Mechanical behavior of cement-based materials reinforced with sisal fibers. Journal of Materials Science, 41(21), 6938–6948. doi:10.1007/s10853-006-0218-1

[14.] Okeola, A., Abuodha, S., & Mwero, J. (2018). Experimental Investigation of the Physical and Mechanical Properties of Sisal Fiber-Reinforced Concrete. Fibers, 6(3), 53. doi:10.3390/fib6030053

[15.] Salih, Y. A., Sabeeh, N. N., Yass, M. F., Ahmed, A. S., & Khudhurr, E. S. (2019). Concrete Beams Strengthened with Jute Fibers. Civil Engineering Journal, 5(4), 767–776. doi:10.28991/cej-2019-03091286

[16.] Wang, H., Memon, H., A. M. Hassan, E., Miah, M. S., & Ali, M. A. (2019). Effect of Jute Fiber Modification on Mechanical Properties of Jute Fiber Composite. Materials, 12(8), 1226. doi:10.3390/ma12081226

[17.] Ramli. (2010). Effects of Palm Fiber on the Mechanical Properties of Lightweight Concrete Crushed Brick. American Journal of Engineering and Applied Sciences, 3(2), 489–493. doi:10.3844/ajeassp.2010.489.493

[18.] Fadhil, S., & Yaseen, M. (2015). The Effect of Adding Different Types of Natural Fibers on Mechanical Properties and Impact Resistance of Concrete. Research Journal of Applied Sciences, Engineering and Technology, 9(12), 1091–1096. doi:10.19026/rjaset.9.2602

[19.] Kakooei, S., Akil, H. M., Jamshidi, M., & Rouhi, J. (2012). The effects of polypropylene fibers on the properties of reinforced concrete structures. Construction and Building Materials, 27(1), 73–77. doi:10.1016/j.conbuildmat.2011.08.015

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

[21.] Umair, M., Khan, M. I., & Nawab, Y. (2020). Green Fiber-Reinforced Concrete Composites. *Handbook of Nanomaterials and Nanocomposites for Energy and Environmental Applications*, 1-32.

[22.] Hussain, I., Ali, B., Akhtar, T., Jameel, M. S., & Raza, S. S. (2020). Comparison of mechanical properties of concrete and design thickness of pavement with different types of fiber-reinforcements (steel, glass, and polypropylene). Case Studies in Construction Materials, 13, e00429.

[23.] Mrema, A. H., Noh, S. H., Kwon, O. S., & Lee, J. J. (2020). Performance of Glass Wool Fibers in Asphalt Concrete Mixtures. Materials, 13(21), 4699.

[24.] Khater, A., Luo, D., Abdelsalam, M., Yue, Y., Hou, Y., & Ghazy, M. (2021). Laboratory Evaluation of Asphalt Mixture Performance Using Composite Admixtures of Lignin and Glass Fibers. Applied Sciences, 11(1), 364.

[25.] Zhang, Y., & Huang, Z. (2020). Transverse Crack Behavior in Continuously Reinforced Concrete Pavement with Basalt Fiber Reinforcement. Applied Sciences, 10(21), 7458.

[26.] Mrema, A. H., Noh, S. H., Kwon, O. S., & Lee, J. J. (2020). Performance of Glass Wool Fibers in Asphalt Concrete Mixtures. Materials, 13(21), 4699.

[27.] Stempihar, J. J., Souliman, M. I., & Kaloush, K. E. (2012). Fiber-reinforced asphalt concrete as sustainable paving material for airfields. Transportation research record, 2266(1), 60-68.

[28.] HadjMostefa, A., & Slimane, M. (2019). Study of Concretes Reinforced by Plastic Fibers Based on Local Materials. International Journal of Engineering Research in Africa, 42, 100–108. doi:10.4028/www.scientific.net/jera.42.100

[29.] Babafemi, A., Šavija, B., Paul, S., & Anggraini, V. (2018). Engineering Properties of Concrete with Waste Recycled Plastic: A Review. Sustainability, 10(11), 3875. doi:10.3390/su10113875

[30.] Siddique, R., Khatib, J., & Kaur, I. (2008). Use of recycled plastic in concrete: A review. Waste Management, 28(10), 1835–1852. doi:10.1016/j.wasman.2007.09.011

[31.] Bhogayata, A. C., & Arora, N. K. (2018). Impact strength, permeability and chemical resistance of concrete reinforced with metalized plastic waste fibers. Construction and Building Materials, 161, 254–266. doi:10.1016/j.conbuildmat.2017.11.135

[32.] Mazaheripour, H., Ghanbarpour, S., Mirmoradi, S. H., & Hosseinpour, I. (2011). The effect of polypropylene fibers on the properties of fresh and hardened lightweight self-compacting concrete. Construction and Building Materials, 25(1), 351–358. doi:10.1016/j.conbuildmat.2010.06.018

[33.] Khalid, F. S., Irwan, J. M., Wan Ibrahim, M. H., Othman, N., & Shahidan, S. (2018). Splitting tensile and pullout behavior of synthetic wastes as fiber-reinforced concrete. Construction and Building Materials, 171, 54–64. doi:10.1016/j.conbuildmat.2018.03.122

[34.] Waroonkun, T., Puangpinyo, T., & Tongtuam, Y. (2017). The Development of a Concrete Block Containing PET Plastic Bottle Flakes. Journal of Sustainable Development, 10(6), 186. doi:10.5539/jsd.v10n6p186

[35.] Foti, D., & Paparella, F. (2014). Impact behavior of structural elements in concrete reinforced with PET grids. Mechanics Research Communications, 57, 57–66. doi:10.1016/j.mechrescom.2014.02.007

[36.] Al-Hadithi, A. I., Abdulrahman, M. B., & Al-Rawi, M. I. (2020). Flexural behaviour of reinforced concrete beams containing waste plastic fibers. IOP Conference Series: Materials Science and Engineering, 737, 012173. doi:10.1088/1757-899x/737/1/012173

[37.] Madallah Mohammed, A., & Ahmed Hammadi, A. (2018). EFFECT OF ADDING THE PLASTIC WASTE AS FIBERS ON MECHANICAL PROPERTIES OF CONCRETE. Journal of Engineering and Sustainable Development, 22(02), 86–95. doi:10.31272/jeasd.2018.2.85

[38.] Bui, N. K., Satomi, T., & Takahashi, H. (2018). Recycling woven plastic sack waste and PET bottle waste as fiber in recycled aggregate concrete: An experimental study. Waste Management, 78, 79–93. doi:10.1016/j.wasman.2018.05.035

[39.] Rahman, T., & Nurdiana, J. (2020). The Effect of HDPE Plastic Fibres on Concrete Performance. doi:10.20944/preprints202008.0413.v1

[40.] Suchorab, Z., Franus, M., & Barnat-Hunek, D. (2020). Properties of Fibrous Concrete Made with Plastic Optical Fibers from E-Waste. Materials, 13(10), 2414. doi:10.3390/ma13102414

[41.] Manjunath, B. T. A. (2016). Partial Replacement of E-plastic Waste as Coarse-Aggregate in Concrete. Procedia Environmental Sciences, 35, 731–739. doi:10.1016/j.proenv.2016.07.079

[42.] Panyakapo, P., & Panyakapo, M. (2008). Reuse of thermosetting plastic waste for lightweight concrete. Waste Management, 28(9), 1581–1588. doi:10.1016/j.wasman.2007.08.006

[43.] 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, 6(2), 299–308. doi:10.1016/j.ijsbe.2017.01.001

[44.] Pavlík, Z., Pavlíková, M., & Záleská, M. (2019). Properties of concrete with plastic polypropylene aggregates. Use of Recycled Plastics in Eco-Efficient Concrete, 189–213. doi:10.1016/b978-0-08-102676-2.00009-8

[45.] Demirboga, R., & Kan, A. (2012). Thermal conductivity and shrinkage properties of modified waste polystyrene aggregate concretes. Construction and Building Materials, 35, 730–734. doi:10.1016/j.conbuildmat.2012.04.105

[46.] Poonyakan, A., Rachakornkij, M., Wecharatana, M., & Smittakorn, W. (2018). Potential Use of Plastic Wastes for Low Thermal Conductivity Concrete. Materials, 11(10), 1938. doi:10.3390/ma11101938

[47.] Tutikian, B. F., Nunes, M. F. O., Leal, L. C., & Marquetto, L. (2012). Impact Sound Insulation of Lightweight Concrete Floor with EVA Waste. Building Acoustics, 19(2), 75–88. doi:10.1260/1351-010x.19.2.75

Solanki, P., & Bhattarai, S. (2018). Strength and permeability of pervious composite prepared by using post-consumer plastic waste bottles. MATEC Web of Conferences, 174, 02001. doi:10.1051/matecconf/201817402001

[48.] https://www.kurdistan24.net/en/news/0b99cc6f-3e16-4d98-9ef7-c8f0f5ef621b

[49.] Al-Salem, S. M., Lettieri, P., & Baeyens, J. (2009). Recycling and recovery routes of plastic solid waste (PSW): A review. *Waste Management,* 29(10), 2625-2643.

[50.] Monnet, W., Carroll, J. R., & Embery, P. D. (2018). Using Solar Thermal Collectors for Plastic Recycling in Additive Manufacturing. UKH Journal of Science and Engineering, 2(1), 43–47. doi:10.25079/ukhjse.v2n1y2018.pp43-47

[51.] Jibrael, M. A., & Peter, F. (2016). Strength and Behavior of Concrete Contains Waste Plastic. Journal of Ecosystem & Ecography, 6(2). doi:10.4172/2157-7625.1000186

[52.] Hasan, A., Maroof, N., & Ibrahim, Y. (2019). Effects of Polypropylene Fiber Content on Strength and Workability Properties of Concrete. Polytechnic Journal, 9(1), 7–12. doi:10.25156/ptj.v9n1y2019.pp7-12

[53.] Marzouk, O. Y., Dheilly, R. M., & Queneudec, M. (2005). REUSE OF PLASTIC WASTE IN CEMENTITIOUS CONCRETE COMPOSITES. In Cement Combinations for Durable Concrete: Proceedings of the International Conference held at the University of Dundee, Scotland, UK on 5–7 July 2005 (pp. 817-824). Thomas Telford Publishing.

[54.] https://www.considerable.com/home/cleaning-organizing/plastic-bottle-recycling-caps/

[55.] Al Bakri, A. M., Tamizi, S. M., Rafiza, A. R., & Zarina, Y. (2011). Investigation of HDPE plastic waste aggregate on the properties of concrete. Journal of Asian Scientific Research, 1(7), 340-345.

[56.] Rahim, N. L., Sallehuddin, S., Ibrahim, N. M., Amat, R. C., & Ab Jalil, M. F. (2013). Use of plastic waste (high density polyethylene) in concrete mixture as aggregate replacement. In *Advanced Materials Research* (Vol. 701, pp. 265-269). Trans Tech Publications Ltd.

[57.] Badache, A., Benosman, A. S., Senhadji, Y., & Mouli, M. (2018). Thermo-physical and mechanical characteristics of sand-based lightweight composite mortars with recycled high-density polyethylene (HDPE). *Construction and Building Materials*, *163*, 40-52.

[58.] Kamsuwan, T., Amornsakchai, T., & Srikhirin, T. (2013). Mechanical Behaviors of HDPE Fiber Reinforced Cement Mortar. In Advanced Materials Research (Vol. 671, pp. 1893-1904). Trans Tech Publications Ltd.

[59.] Rahman, T., & Nurdiana, J. (2020). The Effect of HDPE Plastic Fibres on Concrete Performance.

[60.] Pešić, N., Živanović, S., Garcia, R., & Papastergiou, P. (2016). Mechanical properties of concrete reinforced with recycled HDPE plastic fibres. *Construction and building materials*, *115*, 362-370.

[61.] Bhavi, B. K., Reddy, V. V., & Ullagaddi, P. B. (2012). Effect of Different Percentages of Waste High Density Polyethylene (HDPE) Fibres on the Properties of Fibre Reinforced Concrete. *Nature Environment and Pollution Technology*, *11*(3), 461.

[62.] Yuhazri, M. Y., Hafiz, K. M., Myia, Y. Z. A., Jia, C. P., Sihombing, H., Sapuan, S. M., & Badarulzaman, N. A. (2017, October). The Effect of Different Shape and Perforated rHDPE in Concrete Structures on Flexural Strength. In *IOP Conf. Series: Journal of Physics: Conf. Series* (Vol. 914, No. 2017, p. 12023).

[63.] Iraqi Standard Specification (IQS), 'No.5/1984, Portland Cement', Central Organization for Standardization & Quality Control (COSQC), Baghdad, Iraq, (1984).

[64.] Khatab, H. R., Mohammed, S. J., & Hameed, L. A. (2019). Mechanical Properties of Concrete Contain Waste Fibers of Plastic Straps. IOP Conference Series: Materials Science and Engineering, 557, 012059. doi:10.1088/1757-899x/557/1/012059

[65.] Poonyakan, A., Rachakornkij, M., Wecharatana, M., & Smittakorn, W. (2018). Potential Use of Plastic Wastes for Low Thermal Conductivity Concrete. Materials, 11(10), 1938. doi:10.3390/ma11101938

[66.] Isal, C. (2020). Study of various Grades of Concrete with and without Admixture. International Journal for Research in Applied Science and Engineering Technology, 8(7), 677–689. doi:10.22214/ijraset.2020.30302

[67.] Shah, N., Mavani, V., Kumar, V., Mungule, M., & Iyer, K. K. R. (2019). Impact Assessment of Plastic Strips on Compressive Strength of Concrete. Journal of Materials in Civil Engineering, 31(8), 04019148. doi:10.1061/(asce)mt.1943-5533.0002784.

[68.] Guendouz, M., Debieb, F., Boukendakdji, O., Kadri, E. H., Bentchikou, M., & Soualhi, H. (2016). Use of plastic waste in sand concrete. J. Mater. Environ. Sci, 7(2), 382-389.

[69.] Madallah Mohammed, A., & Ahmed Hammadi, A. (2018). EFFECT OF ADDING THE PLASTIC WASTE AS FIBERS ON MECHANICAL PROPERTIES OF CONCRETE. Journal of Engineering and Sustainable Development, 22(02), 86–95. doi:10.31272/jeasd.2018.2.85

[70.] Małek, M., Jackowski, M., Łasica, W., &Kadela, M. (2020). Characteristics of Recycled Polypropylene Fibers as an Addition to Concrete Fabrication Based on Portland Cement. Materials, 13(8), 1827. doi:10.3390/ma13081827

[71.] Chen,Y., Cen, G., & Cui, Y. (2018). Comparative study on the effect of synthetic fiber on the preparation and durability of airport pavement concrete. Construction and Building Materials, 184, 34–44. doi:10.1016/j.conbuildmat.2018.06.223