Academic Journal of Science and Technology,
December, 2023, vol.2, No.1, p. 143-151

The effect of using Low density polyethylene (LDPE) fibers and sika on the properties of fresh and hardened concrete

Abdel Nader Khalil Aldabar [1], Abdulmutaleb Ahmidan [2], Mohammed Almousi[1].

1. Faculty of Civil Engineering – Azzaytuna University
2. The Higher Institute of Science & Technoogy-Tripoli

ABSTRACT

Due to the increasing growth of population and urban expansion and the accompanying increase in consumption rates, which in turn led to an increase in the amounts of plastic waste harmful to the environment, this study aims to use low-density polyethylene as an alternative to coarse aggregate, to study its effect on the mechanical properties of concrete, and a number of 6 cubes of size (150 x 150 x 150 mm) and 6 cylinders (300 x 150 mm) for each mixture, where compressive strength and tensile strength tests were conducted, which were in proportions (0, 4, 6, 8, 10%) of the weight of the coarse aggregate. In the second stage Cica was also used at a rate of 5% by weight of cement, with constant percentages of low-density polyethylene for coarse aggregate. The results showed that the minimum compressive strength at 7 days of age when adding low-density polyethylene is only 17.52 MPa for 10% and above 21.5 MPa for 4%. In the case of indirect tensile strength, the highest tensile strength is 4.98 MPa for 4% and the lowest tensile strength is 3.62 MPa for 10%. While the compressive strength at 7 days when adding low-density polyethylene and Sika was the highest compressive strength was 24.72 MPa, at a rate of 4%, and the lowest was 21.42 MPa, at a rate of 10%. Likewise, 28-day compressive strength results when using only low-density polyethylene were 31.06 MPa at 4% and the lowest was 28 MPa. The results of using low-density polyethylene and Sika were highest, reaching 32.5 MPa, at a rate of 4%, and the lowest, at 26.97 MPa, at a rate of 10%. In the case of indirect tensile strength at 28 days, the highest strength was 13.4 MPa, at a rate of 4%, and the lowest was 8.68 MPa, at a rate of 10%.

KEYWORDS: low density polyethylene, Sika, concrete properties, Compressive Strengt Indirect tensile strength.

** Corresponding author: A.aldabar@azu.edu.ly.*

INTRODUCTION

Due to the increasing population growth and urban expansion, there has been a rise in consumption rates, leading to an increase in the generation of harmful solid waste that is detrimental to the environment. One of the most significant pollutants is industrial cork waste. Polyethylene is considered important in all aspects of practical life due to its numerous advantages, including its ease of compression and manufacture, which align with daily human needs. One negative consequence of the industrial cork industry is the accumulation of large quantities of cork waste. Since cork does not decompose quickly in nature, its waste has contributed to environmental damage. Therefore, it is necessary to manage this solid waste through recycling and utilizing it in other areas [1].

And since concrete structures are the most common and widely used, as they are extensively used in all types of buildings, tunnels, and other construction uses due to their ease of formation and their superior ability to withstand applied compression loads. Concrete is considered one of the main components relied upon in the field of infrastructure in Libya, however, this material has shown an increase in its production cost and its basic materials (cement, aggregate, sand, water). Those working in the field of concrete, including designers and implementers, pay great attention to obtaining concrete that meets the minimum requirements of compressive strength, as this property is of great importance in ensuring the structural efficiency of the concrete structure [2].

In this research, a study was conducted to produce a new type of concrete used in the production of non-load-bearing structural elements (precast walls) [3]. Different proportions of low-density polyethylene (LDPE) were added as a ratio to cement. This material was chosen because of its low density compared to other types of aggregates used in concrete production, especially in thermal insulation. In addition to its abundant availability in landfills, it is considered one of the most important environmental waste materials that threaten human health and all environmental elements, as it takes hundreds of years to decompose into basic elements.

Therefore, the importance of this study has emerged for the use of this material in the concrete industry for purpose of protecting the environment, reducing solid waste, controlling it, and recycling it, which ensures the preservation of human health and environmental safety [4].

RESEARCH SIGNIFICANCE:

The objectives of this study are to replace a quantity of coarse aggregate with a different percentage of raw low-density ethylene and sika as percentage of cement (5%).

This is to maintain the appropriate limit for the physical and mechanical properties of concrete, in addition to verifying whether the coefficient of concrete properties conforms to the requirements specified by ACI Committee ACI-8.5.1 also to produce lightweight concrete from available materials at the lowest possible cost and is environmentally friendly

MATERIALS USED IN THE STUDY

CEMENT

Ordinary Portland Cement (Type N42.5) qualitative weight (3.15) n/m^3 was used in all mixtures It is produced by the Arab Union Contracting Company (Burj Factory - Zliten City) [5].

FINE AGGREGATE

Natural sand supplied from Zliten area was used for all mixtures, table [1] granular gradient results for fine aggregate used in concrete mixtures and shape [1] lays out the results of sieve analysis and table [2] shows the physical and mechanical tests of fine aggregate [6].

Table 1. Gradient granular results for Fine Aggregate and Specification Limits [BS: 882-1992].

Sieve size (mm)	Mass Retained (g)	Mass Retained %	Passing %	Specification Limits [BS: 882-1992].
5.0	0.0	0.0	100.0	_ _ _
2.36	0.0	0.0	100.0	80~100
1.18	0.0	0.0	100.0	70~100
0.600	2.86	0.34	99.66	55~100
0.300	378.1	44.33	55.34	5~70
0.150	414.4	48.58	6.75	_ _ _
Fineness Modulus (F.M)		1.38		

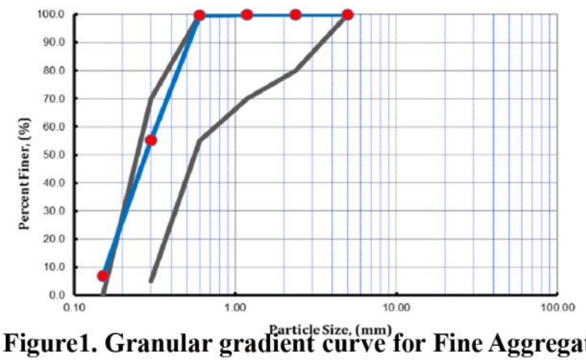

Figure1. Granular gradient curve for Fine Aggregate

Table 2. illustrates the physical and mechanical tests for the fine aggregate

Test	Result	Specification Limits	Test specification
specific gravity	2.636	2.7 – 2.5	ASTM C127
water absorption	0.47	3%	(L S S 257,258)
Fineness Modulus	1.38	----	----

COARSE AGGREGATE

Coarse aggregate was used with a nominal size of 14 mm supplied from Wadi Al-Lifa area. Table [3] Gradation results for coarse aggregate 14 mm. Figure [2] shows the grain gradient curve of coarse aggregate used in the concrete mix. Table [4] results of gradation of coarse aggregates 20 mm. Figure [3] shows the curve of granular gradation of coarse aggregates used in the concrete mixture. Table [5] summarizes the results of the physical and mechanical tests of the aggregates [7][8][9].

Table 3. Results of coarse aggregate granular gradient 14 mm and specification limits [BS: 882-1992]

Sieve size (mm)	Mass Retained (g)	Mass Retained %	Passing %	Specification Limits [BS: 882-1992].
37.5	0.0	0.0	100.00	100
20	0.00	0.0	100	85~100
14	4.15	0.19	99.81	0~70
10	739.74	33.85	65.96	0~25
5	1430.98	65.48	0.48	0~5
2.36	2.4	0.11	0.37	---
Pan	0	0	0	---
Fineness Modulus		0.17		

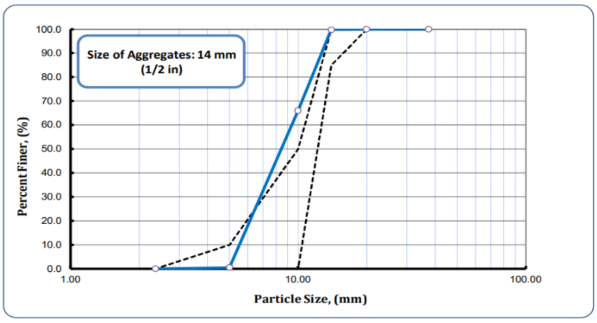

Figure 2. Gradation curve of 14 mm coarse aggregate [BS 882: 1992].

Table 4. Results of coarse aggregate granular gradient 20 mm and specification limits [BS: 882-1992]

Sieve size (mm)	Mass Retained (g)	Mass Retained %	Passing %	Specification Limits [BS: 882-1992].
37.5	0	0	100	100
20	474.5	15.82	84.18	85-100
14	1899.15	63.32	20.85	0-70
10	603	20.1	0.75	0-25
5	8.1	0.27	0.48	0-5
2.36	0	0	0.48	---
Pan	0	0	0	---
Fineness Modulus		0.09		

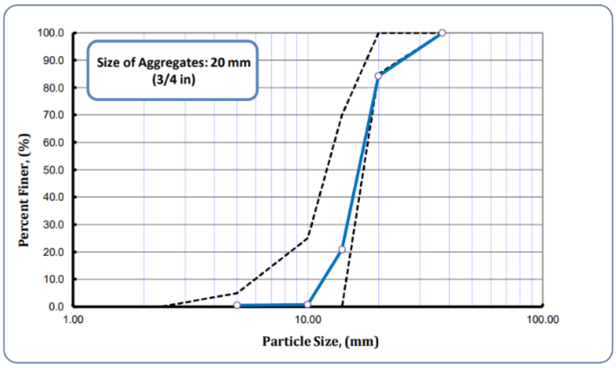

Figure 3. Gradation curve of 20 mm coarse aggregate [BS 882: 1992].

MIXING WATER

Potable water, used in the concrete plant of the Arab Union Contracting Company, has been used, which is free of organic materials and impurities. According to many references, water is generally valid when the total weight of dissolved salts is less than 2,000 ppm.

LOW DENSITY POLYETHYLENE

A type of polymer (low-density polyethylene) has been added, which was taken from the Qalaa Company for Pipes as showing in figure [4].

Figure 4. illustrates the low-density polyethylene polymer used in the study.

Table 5. illustrates a summary of the physical and mechanical test results for coarse aggregate and the permissible limits within the American, Libyan, and British standard specifications.

Test	Result 14mm	Result 20mm	Specification Limits	Test specification
specific gravity	2.698	2.677	2.7 – 2.5	ASTM C127
Bulk unit weight	1446.4	8.2514	1800-1400 kg/ m^3	ASTM C29 C29M
water absorption	0.64	0.61	not more than 3%	ASTM C128
Agg. impact value	7.525	7.531	not more than 30%	BS 812-112
Agg. crushing value	27.65	27.20	not more than 40%	BS 812-110
Fineness Modulus	0.17	0.09	----	[ASTM C 131 AASHTO T96 and]

CONCRETE MIX DESIGN

Concrete mixtures are designed to meet the requirements of structural design, where concrete mixtures are designed for suitable workability and 25 N/mm^2 compressive strength. In this project the concrete mixture is designed according to the absolute size method and table [6] shows the proportions and quantities of materials in the composition ($1.0m^3$) of concrete.

$$Absolute\ Volume = \frac{C}{G_c} + \frac{S}{G_s} + \frac{G}{G_g} + \frac{W}{1.0} = 1000 \qquad (1)$$

Where:
C = content of cement (kg/m^3)
W = content of mixing water (kg/m^3)
S = content of fine aggregate (kg/m^3)
G = content of coarse aggregate (kg/m^3)
G_C = specific gravity of cement (---)
G_g = specific gravity of coarse aggregate (---)
G_s = specific gravity of fine aggregate (---)

Table 6. shows the ratios and quantities of the materials entering the composition (1 m^3) of concrete and its characteristics for compressive strength 25 N/mm^2.

Materials	Quantities (Kg/m^3)				
Low-Density Polyethylene Ratio LDPE(%)	0%	4%	6%	8%	10%
	0	46.26	69.38	92.5	115.62
Water to cement ratio (W/C)	0.40	0.40	0.40	0.40	0.40
Sika Ratio 5 %	19.27	19.27	19.27	19.27	19.27
Cement	385.42	385.42	385.42	385.42	385.42
Water	154.17	154.17	154.17	154.17	154.17
Fine aggregate	770.84	770.84	770.84	770.84	770.84
Coarse aggregate 14mm	578.13	555	543.44	531.88	520.32
Coarse aggregate 20mm	578.13	555	543.44	531.88	520.32

MATERIAL PREPATION AND MIXING PROCESS

To determine the workability of fresh concrete and its resistance to segregation, the slump test was conducted according to British standards (BS 1881 PART 102). Figure [5] illustrates the slump test, where it was observed that the flowability and ease of handling the concrete, as well as the increase in the particle segregation resistance of its components were directly proportional to the increase in the percentage of the admixture represented by polyethylene.

Figure 5. shows slump test

PROCESSING SPECIMENS

After removing the molds and extracting the samples, they were placed in a basin containing water with a temperature not exceeding 24 degrees Celsius until the sample testing date for a duration of 7 days and 28 days as shown in figure [6].

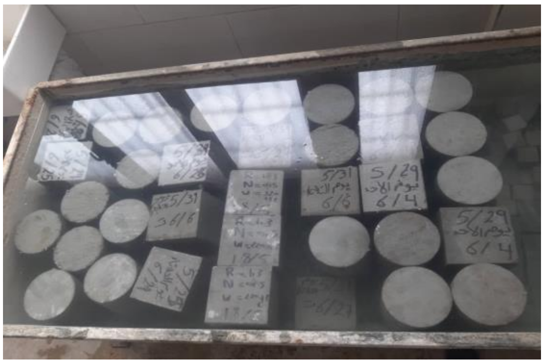

Figure 6. specimens processing in a water basin

HARDENED CONCRETE TESTS

This test was conducted to determine the maximum pressure of hardened concrete using a precision pressure machine with an accuracy of (±10N) to determine compressive strength and determine the load at failure for the samples. This test was conducted after 7 days and 28 days of casting according to British specifications (BS: 1881 Part 116), and the compressive strength is calculated from the following relationship [10].

$$fc' = \frac{P}{A} \qquad (2)$$

Where:

Fc`= uniaxial compressive strength (N/mm2)

P = the applied compressive load at failure (N)

A = the cross-sectional area of the specimen (mm2)

Figure [7] shows the placement of the sample in the testing machine and applying the load on it, as well as how the sample collapses, and the shape of the sample after its collapse. Table [7] presents the results of compressive strength for both the reference concrete and the polyethylene-modified concrete.

It is evident from figures [8] and [9] that there is an increase in compressive strength values with a decrease in the percentage of added low-density Polyethylene. The highest percentage of decrease in compressive strength after 7 days was 35% and the lowest percentage was 20%, and after 28 days the highest percentage of decrease was 13% and the lowest percentage was 5%.

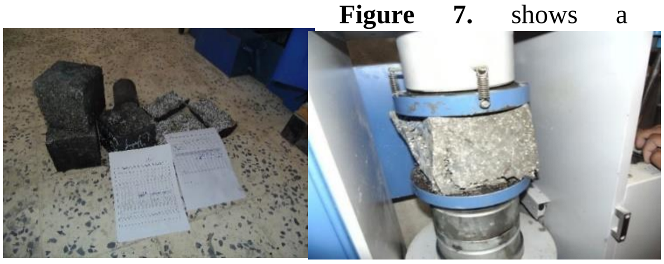

Figure 7. shows a compressive strength test for a sample of concrete

Table 7. shows the effect of a percentage of Low-density polyethylene only on compressive strength

Mix Number	LDPE Percentage %	Compressive Strength (MPa)	
		After 7 days	After 28 days
1	0	27.13	32.87
2	4	21.5	31.063
3	6	18.49	30.85
4	8	18.20	28.34
5	10	17.52	28

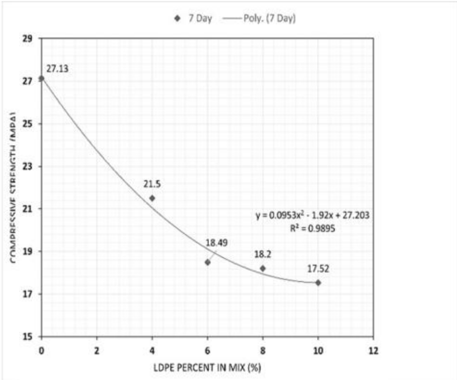

Figure 8. shows the change in compressive with a change in the percentage of (LDPE) at 7 days.

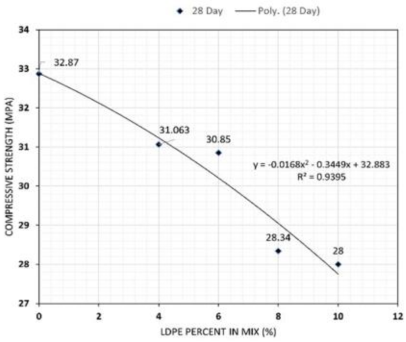

Figure 9. shows the change in compressive with a change in the percentage of (LDPE) at 28 days.

EFFECT OF LOW-DENSITY POLYETHYLENE RATIOS ON INDIRECT TENSILE STRENGTH

Indirect tensile strength is calculated from the following relationship [11].

Splitting tensile strength

$$f_c' = \frac{2P}{\pi DL} \qquad (3)$$

Where:

P= load at failure in N

L= the length of the line of contact in mm

D= the diameter in mm

Table 8. shows the effect of a percentage of low-density polyethylene only on the indirect tensile strength of concrete mixes.

Mix Number	LDPE Percentage %	Tensile Strength (MPa)	
		After 7 day	After 28 day
1	0	5.62	12.28
2	4	4.98	10.73
3	6	4.78	9.53
4	8	4.34	8.97
5	10	3.62	7.79

Figure [10] shows the placement of the concrete cylinder sample in the test device and the load applied to it, how to place the sample in the indirect tensile test, and the shape of the sample after its collapse. Table [8] shows the indirect tensile strength results for normal and modified concrete. It is evident from Figure [11] and [12] a decrease in the tensile strength values as a result of the addition of low-density polyethylene. The highest percentage of decrease in compressive strength after 7 days was 35%, the lowest percentage was 11%, and after 28 days, the highest percentage of decrease was 36% and the lowest percentage was 12%.

Figure 10. Shows indirect tensile tester of a sample of modified concrete.

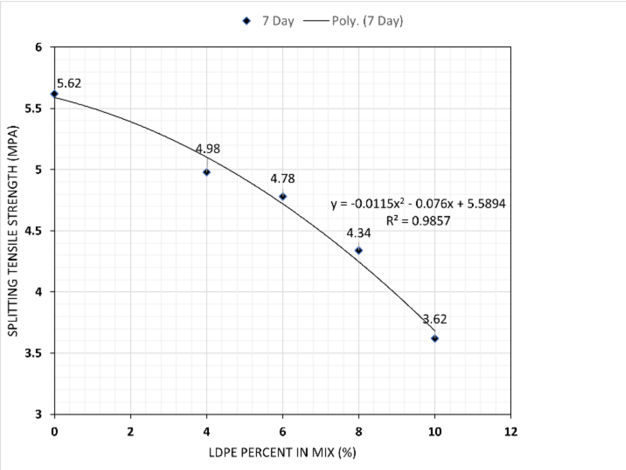

Figure 11. shows the change in indirect tensile strength with a change in the percentage of (LDPE) at 7 days.

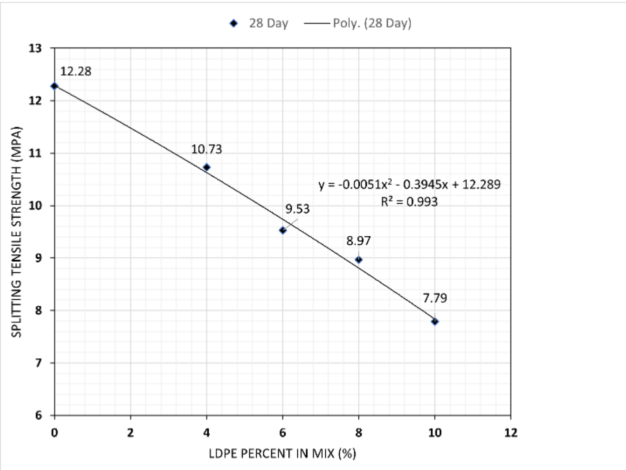

Figure 12. shows the change in indirect tensile strength with a change in the percentage of (LDPE) at 28 days.

EFFECT OF LOW-DENSITY POLYETHYLENE AND SIKA RATIOS ON COMPRESSIVE STRENGTH.

Table [9] shows the compressive strength results of low-density polyethylene and sika reference concrete. As it is evident from Figure [13] and [14] an increase in the compressive strength values against a decrease in the percentage of addition of low-density polyethylene and sika. The highest percentage of decrease in compressive strength after 7 days was 19% and the lowest percentage was 6%, and after 28 days the highest percentage of decrease was 22% and the lowest percentage was 6%.

Table 9. shows the effect of the ratio of low-density polyethylene and sika on the compressive strength.

Mix Number	LDPE Percentage %	Compressive Strength (MPa)	
		After 7 days	After 28 days
1	0	26.50	34.89
2	4	24.72	32.5
3	6	23.97	30.52
4	8	22.782	28.229
5	10	21.42	26.97

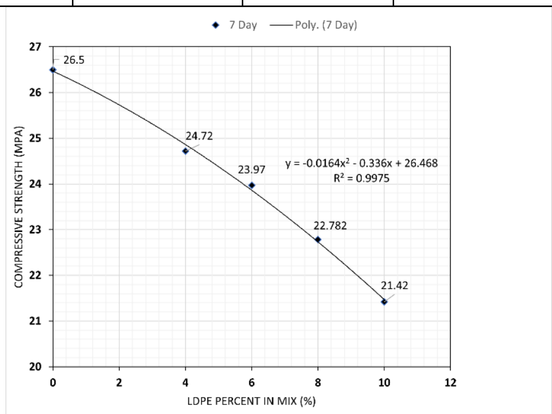

Figure 13. shows the relationship between compressive strength and the percentage of (LDPE and Sika) at 7 days

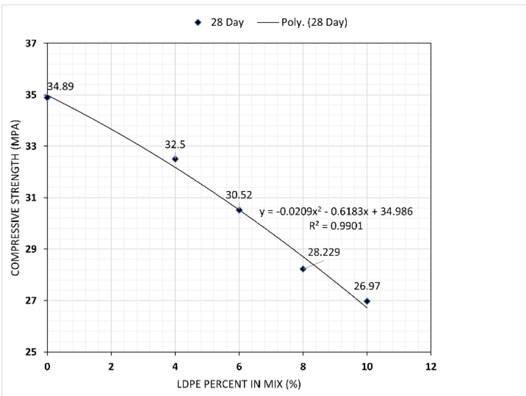

Figure 14. shows the relationship between compressive strength and the percentage of (LDPE and Sika) at 28 days

EFFECT OF LOW-DENSITY POLYETHYLENE AND SIKA RATIOS ON INDIRECT TENSILE STRENGTH.

Table [10] shows the tensile strength results for normal and modified concrete. It is evident from Figure [15] and [16] a decrease in the tensile strength values as result of the addition of low-density polyethylene.

The highest percentage of decrease in compressive strength after 7 days was 52%, the lowest percentage was 10%, and after 28 days, the highest percentage of decrease was 40% and the lowest percentage was 5%.

Table 10. shows the effect of a percentage of low-density polyethylene and sika on the indirect tensile strength of concrete mixes.

Mix Number	LDPE Percentage %	Tensile Strength (MPa)	
		After 7 day	After 28 day
1	0	10.46	14.22
2	4	9.402	13.4
3	6	7.05	13.05
4	8	6.607	12.01
5	10	4.97	8.68

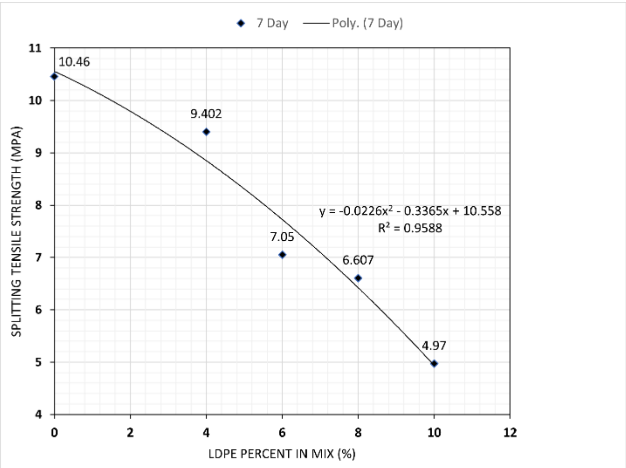

Figure 15. shows the change in indirect tensile strength with a change in the percentage of (LDPE and Sika) at 7 days.

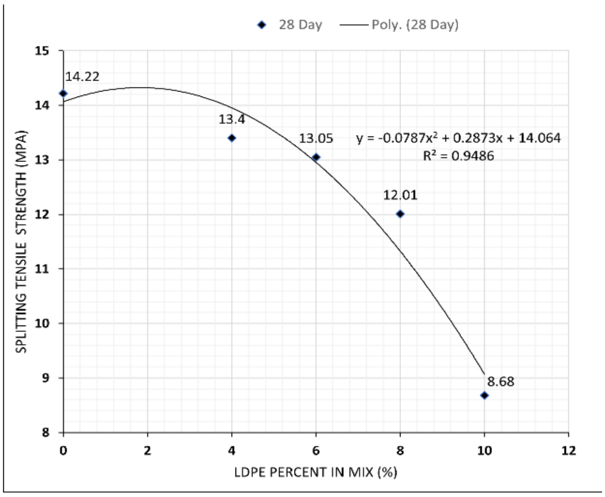

Figure 16. shows the change in indirect tensile strength with a change in the percentage of (LDPE and Sika) at 28 days.

CONCLUSION

Based on the results of the tests conducted in this study for the purpose of finding the mechanical and physical properties of the reference and modified concrete. From this research, the following can be concluded:

Although the compressive strength decreases as the percentage of low-density polyethylene increases in concrete mixes and compressive strength increases with the increase in the percentage of low-density polyethylene and sika in concrete mixes, it's can be used in some non-bearing structural elements

Obtaining a compressive strength ranging between [28~31.063 k/N] when adding low-density polyethylene granules in proportions ranging from (4 to 10%) of the aggregate weight after 28 days of treatment. This allows for the use of concrete in non-loaded construction units

Obtaining a compressive strength ranging from [26.97~32.5 K / N] when adding low-density polyethylene granules and sika in proportions ranging from (4 to 10%) of the weight of the aggregate after 28 days of treatment.

The possibility of using harmful industrial waste from polyethylene after recycling in useful areas such as the manufacture of lightweight low-density polyethylene-modified concrete, and this contributes to preserving the environment

Polyethylene can be used in concrete works because of its positive effect in reducing the weight and cost of concrete

Conducting future studies on the possibility of using ethylene in hollow bricks.

Conducting further tests that will determine the behavior of this type of concrete when it is used in the implementation of structural elements.

Conducting future studies on the possibility of using ethylene as a lightweight aggregate as an alternative to sand (fine aggregate).

It is possible to improve the compressive strength of polyethylene concrete by adding plasticizers in a different proportion and conducting a study on this type of mixture.

Conducting a study on the effect of fire or exposure to high temperatures on concrete containing polyethylene

REFERENCES

1. M., Imam, F. Salem, and M. Tantawy, "Fracture Mechanics of Fiberous High Strength Concrete" Scientific Bulletin, Faculty of Engineering, Ain Shams University, Vol. 40, No. 1, March 31, 2005, pp 213-234.

2. M. Imam, A. Abdel-Reheem, and A. Elmenshawi “One Day Instead of 28 Days for Achieving Concrete Strength” International Conference on Performance of Construction Materials in the New Millennium, Organized by the University of Calgary, Canada, and the University of Ain Shams, February 2003, Cairo, Egypt, Vol. 1, pp 319-328

3. M. Imam, A. Tahwia, A. Elagamy, and M. Yousef "Behavior of Reinforced Concrete Beams Strengthened With Carbon Fiber Strips" Mansoura Engineering Journal (MEJ), Vol. 29, No. 3, September 2004, pp C22-C40.

4. T. Eethar, Dawood, “Experimental study of lightweight concrete used for the production of canoe”, Department of Building and Construction Engineering, Technical College of Mosul, vol. 2, no. 1, pp. 66–70, 6 May 2014

5. L ibyan Standard Specifications No. (340), Portland Cement, for the year 2009

6. S pecification for aggregates from natural sources for concrete British standard Institution, "BS812,", London ,1995

7. Standard Test Methods for Specific Gravity and Absorption of Coarse Aggregates, American Society for Testing and Materials, Washington.USA,2004, pp C127.

8. Standard Test Methods for unit weight and voids in aggregates, American Society for Testing and Materials, Washington.USA,2003, pp C29/M29

9. S tandard Test Methods for Materials Finer Than 75-micron (No.200) sieve in mineral Aggregates, American Society for Testing and Materials, Washington.USA,2004, pp C117.

10. Libyan Standard Specifications No. (252) Concrete aggregate from natural sources - method of conducting sieve analysis for the year 2006.

11. Testing concrete. Method of compressive strength of concrete cubes - British standard Institution, "BS 1881: part 116, ", London, 1983.

12. American Society for Testing and Materials, ((C39 / C39M -04a)), Standard Test Method for Compressive Strength of cylinder concrete specimens