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Study Effect of Adding Expanded Polystyrene as A Percentage of Cement Weight on The Properties of Concrete Mixture in Construction

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ABSTRACT

In this research, a study was conducted to produce a type of lightweight concrete to try to use it in building units, where different proportions of polystyrene granules were used, and this material was tested because of its low density compared to other types of aggregates. The addition of polystyrene (waste) to the components of concrete has an effect on the density, which is related to all other mechanical and physical properties of concrete. The study focused on the use of polystyrene granules in concrete mixtures as a percentage of the weight of cement at (0%, 2%, 3.5%, 5%) to obtain lightweight concrete. From the results of the pressure tests, it became clear that the highest compressive strength was recorded in the addition of polystyrene at a rate of 2% with a value of 18.5MPa at 28 days, where it decreased from the reference mixture by 14.5% and the lowest at a rate of 5% with a compressive strength of 4MPa and decreased from the reference by 29%. In tensile strength, the highest was 2% with a tensile strength of 1.99MPa and recorded a decrease compared to the reference by 1.56% and the lowest in the tensile strength at 5% was 0.78MPa and the reference reduction was 2.77%. In terms of density results, the highest additions were at 2% with a value of 2247.4Kg/m^3 and the lowest was at 5% with a density of 17742Kg/m^3, and the reference absorption rate was 1.2%, and for 2% polystyrene the absorption rate was 4%, and for 5% polystyrene the absorption was 6.2%. Through experiments, the density decreases with increasing polystyrene percentage as a percentage of cement, although the compressive strength decreases as the percentage of polystyrene increases in concrete mixtures, it can be used in non-load-bearing structural elements such as concrete blocks, the possibility of using harmful industrial waste from polystyrene after recycling it in useful fields such as manufacturing lightweight concrete, and this contributes to preserving the environment.

1. Introduction

Nowadays, advanced industrialized countries tend to find many means of economic management in all fields of life, including the building and construction sector, and since concrete has become the most common material in construction, the trend has increased to find different types of concrete that are cheap and have distinctive properties such as thermal insulation and light weight.

The trend of using plastic waste in concrete has emerged as a field with a dual benefit. On the one hand, it represents an environmental treatment (which is the problem of the age) and is represented by the disposal of industrial waste that if not treated may cause harmful pollution to the environment. On the other hand, there is a great economic return as a result of recycling materials and reusing them without the need for the trouble and cost of raw materials.

Where Cork is classified among the list of environmental pollutants, and that Cork is important in all aspects of practical life due to the many advantages that it enjoys, the most important of which is the ease of compressing and manufacturing in accordance with the needs of human daily and life, and one of the negative results in the manufacture of Cork is the accumulation of large quantities of Cork residues that were consumed, since most Cork does not decompose rapidly, its droppings contribute in a dehumanizing manner to the environment, and this industrial waste has accumulated and threatened human health and all environmental elements.[1][2][3][4]

The development of cement mortar and concrete by polymer began in different countries and as a result in 1970 both polymer mortar (PM) and polymer concrete (PC) became the most widely used industrial construction materials in Japan and the United States of America and then became popular in large areas of the world [5].

The American Institute of Concrete Committee No. (548) defines polymeric Portland cement mixes (PPCC) as ordinary mixes to which soluble polymers or polymers of the diffusible type (Iatex) are added, where these types of polymers are added during the mixing process, the polymer has an effect in addition to the effect of the hydration process of Portland cement by forming a continuous polymer network throughout the concrete structure [6].

2. Objectives of the study

The main objective of this study is the possibility of obtaining concrete containing polystyrene granules by using local materials in implementing concrete mixtures, by adding polystyrene to concrete, using polystyrene (waste) in different proportions to obtain the best and to obtain reliable and dependable results, and to study the physical and mechanical properties of lightweight concrete and conduct tests of compressive, tensile, density and absorption resistance and compare them with normal concrete.

3. Materials and experiential

cement

Ordinary Portland cement is used [N42.5], produced by Al Borj Zlitan plant, and is identical to Libyan specifications specific weight (3.15) N/m3 [7].

Water

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Ordinary water was used from the public water network, which is safe to drink, and used in the concrete laboratory of the research center is water free of organic materials and impurities in the layers of Libyan Standard specifications (L.S.S 294) [8].

Fine Aggregate (Sand)

Natural sand supplied from the Zliten area was used for all mixes, Table 1 shows the results of the sieve analysis gradient and **Figure 1** shows the results of the sieve analysis of fine aggregates according to [BS:882-1992] [9].

Table 1 shows the granular gradient of fine aggregate according to the British Standard

Sieve Size (mm)	Reserved weight (gm)	Reserved %	Passing (%)	Specification limits [Bs:882-1992]
5.0	0	0.0	100.0	---
2.36	0	0.0	100.0	100- 80
1.18	0	0.0	100.0	100- 70
0.600	2.86	0.34	99.66	100- 55
0.300	378.1	44.33	55.34	70 - 5
0.150	414.4	48.58	6.75	---
Smoothie factor (F.M)		1.88		Fineness Modulus (F.M)

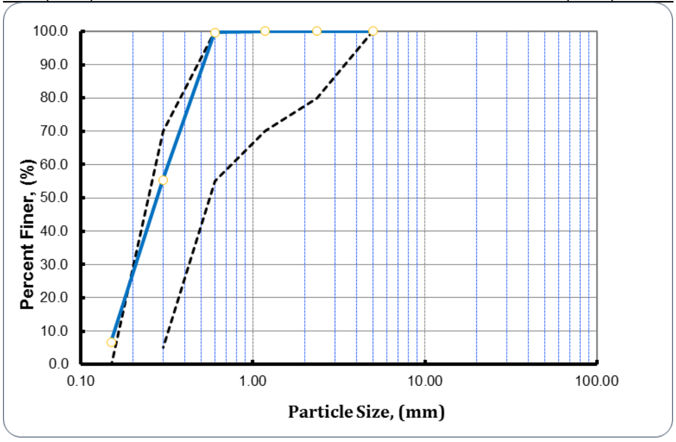

Figure 1 shows the granular gradient curve for fine aggregates [BS 882-1992 F-Sand].

Table 2 shows the physical and mechanical tests of fine aggregates and the limits allowed under the British Standard.[2]

Table 2 shows the physical and mechanical tests of the fine aggregate.

Testing	Result	Specification limits	Test specification
Specific gravity	2.587	2.5 – 2.7	[Bs 812 - 2:1995]
Absorption ratio	0.47	4%	[Bs 812 - 2:1995]
Softness coefficient	1.38	---	---

Coarse Aggregate

Coarse aggregate with a standard size (14mm) supplied from Al-Azizia area was used, **Table 3** shows the results of the sieve analysis gradient and **Figure 2** shows the results of the sieve analysis of coarse aggregate according to the specifications [BS:882-1992] [9].

Table 3 shows the granularity of coarse aggregates

Sieve Size (mm)	Reserved weight (gm)	Reserved %	Passing (%)	Specification limits [BS:882-1992]
37.5	0.0	0.0	100.0	100
20	0.20	0.01	98.81	85 - 100
14	3050	90.75	11.69	0 -70
10	277.0	8.24	0.99	0 -25
5	0 .0	0.0	0.50	0 -5
2.36	0.0	0.00	0.46	---
Smoothie factor (F.M)		1.88		Fineness Modulus (F.M)

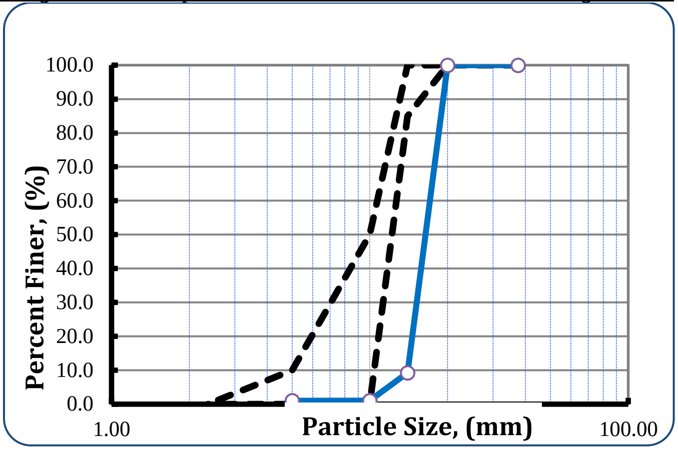

Figure 2 Granular gradient curve for coarse aggregates (BS 882-1992).

Table 4 shows a summary of the results of the physical and mechanical tests for coarse aggregates and the allowable limits within the American, Libyan and British standards.

Table 4 shows the physical and mechanical tests for coarse aggregates.

Test	Result	Specification limits	Test specification
specific gravity	2.605	2.5 – 2.7	[ASTM C127]
Unit weight of volumes	1446.3	1400 -1800 kg/ m^3	[ASTM C29M]
Absorption ratio	0.63	Not more than 3%	[ASTM C128]
Impact coefficient	7.526	Not more than 30%	257 to 258 […
Crushing coefficient	27.64	Not more than 40%	[BS 812:Part 110:90]
Percentage of soft materials	0.64	4%	[ASTM C117]
---	3.86	---	---

4. Concrete mix design method

Using the absolute volume method, the proportions of the concrete mix components were determined and Table 5 shows the proportions and weights of the materials used per cubic meter [8].

$$Absolute\ Volume = \frac{C}{G_C} + \frac{S}{G_S} + \frac{G}{G_g} + \frac{W}{1.0} = 1000$$

Where:

C = content of cement (kg/m3)

W = content of mixing water (kg/m3)

S = content of fine aggregate (kg/m3)

G = content of coarse aggregate (kg/m3)

GC = specific gravity of cement

Gg = specific gravity of coarse aggregate

Gs = specific gravity of fine aggregate

The concrete mixes are designed to meet the structural design requirements. The concrete mixes are designed to have a workability of up to 120 mm and a compressive strength of 25 N/mm² at 28 days.

Table 5 shows the proportions of internal materials in the composition of ($1m^3$) concrete.

Materials	Polystyrene	Polystyren (Kg)	Cement(kg)	Coarse aggregates(kg)	Sand (kg)	Water(kg)
Mix (1)	%0	0	374.5	1100	680	195.5
Mix (2)	%2	7.49	367.01	1100	680	195.5
Mix (3)	%3.5	13.11	361.39	1100	680	195.5
Mix (4)	%5	18.725	355.775	1100	680	195.5

After preparing the materials and weighing them to calculate the quantities needed for 24 cubes with a size of (150*150*150) mm and 24 cylinders with a size of (200*100) mm, the materials were mixed well on the dry to give a homogeneous mixture, then water was added to it, then polystyrene was added and mixing was repeated for three minutes according to British specifications [BS 1881-125].

5. Fresh concrete testing

To determine the degree of flow of fresh concrete and its resistance to segregation, a slump test was conducted according to British specifications [BS 1881-101] [BS 1881 PART 102] and **Table 6** shows the slump results.

Table 6 shows the slump ratios for concrete mixes.

Polystyrene percentage	0%	2%	3.5%	5%
Slump (mm)	80	82	82.8	88

6. Hardened concrete testing

compressive strength

After curing the concrete samples according to the British specification [BS 1881-111], the compressive strength test was performed and the collapse load was determined for the samples, and this test was performed after 7 days and 28 days of the samples according to the British specification [15] [BS: 1881 Part 116]. **Table 7** shows the compressive strength values in all mixes, where it is clear from **Figure 3** a decrease in the compressive strength values as a result of adding polystyrene until a value lower than the design value (25N/mm^2) at (2%) of polystyrene at 7 days old as well as at 28 days, this is due to the increase in the percentage of polystyrene the compressive strength decreases.

Table 7 shows the compressive strength results.

Mix number	Polystyrene (%)	Compressive Strength (MPa)	
		7-day	28-day
Mix (1) reference	%0	26	33
Mix (2)	%2	12.25	18.5
Mix (3)	%3.5	3.5	5.3
Mix (4)	%5	3.3	4

BS 1881-116 Testing concrete. Compressive strength of concrete cubes (Superseded by BS EN 12390-3)

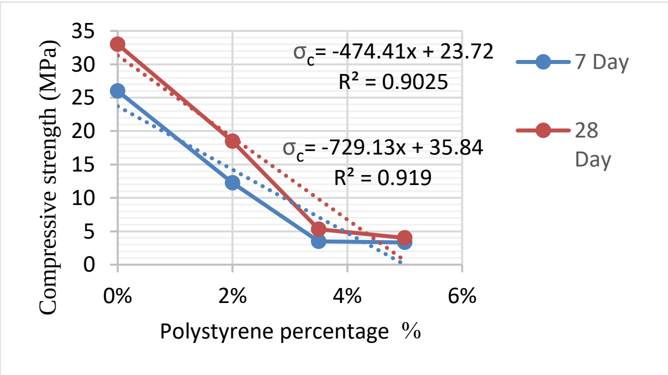

Figure 3 shows the relationship between polystyrene ratio and compression resistance.

tensile strength

The compressive strength test was conducted on samples of concrete cylinders with dimensions (200*100 mm) with different percentages of polystyrene (2%), (3.5%) and (5%) at ages of 7 days and 28 days to determine the indirect tensile strength according to the British specification [BS1881-117] in order to find the relationship between the indirect tensile strength and the percentage of polystyrene. **Table 8** shows the results of the indirect tensile strength, and **Figure 5** shows the relationship between the percentages of polystyrene and the indirect tensile strength, where it became clear that there was a decrease in the tensile strength values resulting from the addition of polystyrene, but a slight decrease compared to the decrease that occurred in the compressive strength.

Table 8 shows the indirect tensile strength results.

Mix number	Polystyrene (%)	Tensile splitting strength of test specimens (MPa)	
		7-day	28-day
Mix (1) reference	%0	2.41	3.55
Mix (2)	%2	1.6	1.99
Mix (3)	%3.5	0.86	1.05
Mix (4)	%5	0.56	0.78

BS EN 12390-6 Testing hardened concrete. Tensile splitting strength of test specimens

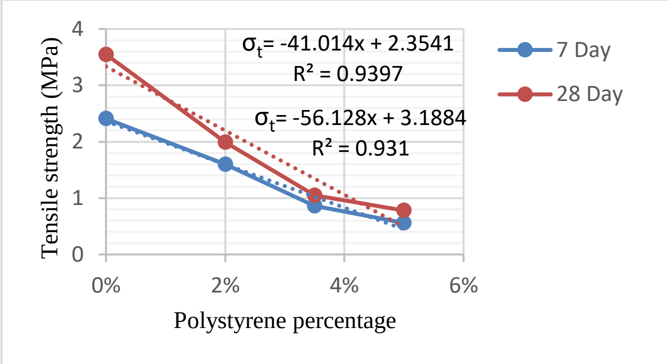

Figure 5 shows the relationship between the polystyrene ratio and the indirect tensile strength.

Density testing

This test was carried out on 28-day-old cube samples, where they were weighed with a sensitive scale before the test, the density of concrete was determined according to British specifications [BS:1881 Part 114] The apparent density was calculated as it was observed that the density value decreases as the polystyrene percentage increases, as shown in **Table 8** and **Figure 6** shows the relationship between polystyrene ratios and density.

Table 8 shows the density results for the concrete mixes.

Polystyrene percentage	0%	2%	3.5%	5%
Density rate (Kg/m^3).	2376	2247.4	1947	1742

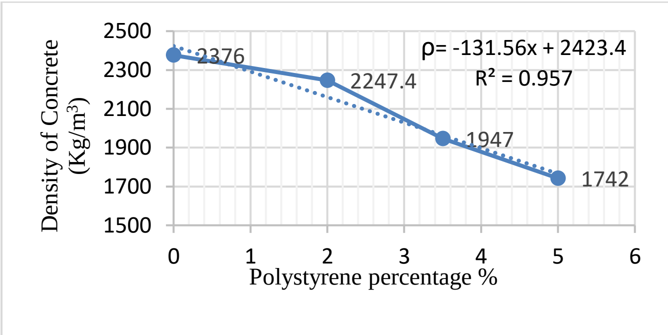

Figure 6 shows the effect of the polystyrene ratio on the density rate.

Absorption rate testing

In this test, the absorption rate is checked by weighing the samples after removing them from the water, then weighing them after drying them in an electric oven at a specific temperature and for a specific period of time. The absorption rate is calculated according to the American specifications [ASTM C127]. Here we notice that the higher the percentage of polystyrene, the higher the absorption rate, as shown in **Figure 7**.

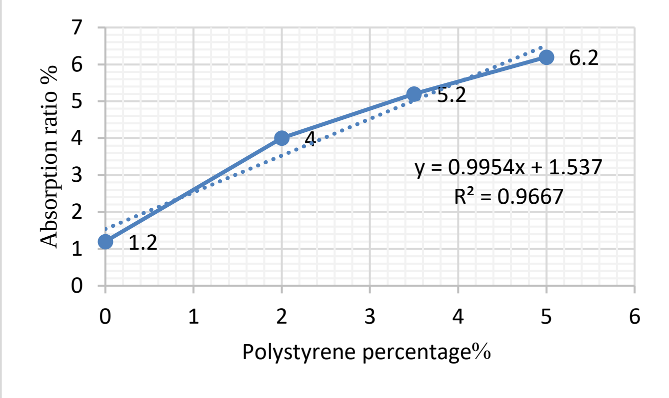

Figure 7 shows the effect of polystyrene ratio on the absorption rate of concrete.

7. Conclusions

1 The addition of polystyrene (residues) to the concrete components has an effect on the density, which is related to all other mechanical and physical properties of concrete, where the density decreases as the percentage of polystyrene increases as the percentage of cement increases.

2 Although the compressive strength decreases as the percentage of polystyrene in concrete mixes increases, it can be used in non-load-bearing structural elements such as concrete blocks.

3 The possibility of using harmful industrial waste from polystyrene after recycling it in useful fields such as manufacturing lightweight concrete, which contributes to the preservation of the environment.

4 Although the compressive strength decreases as the percentage of polystyrene in the mix increases, some mixes have good resistance that enables them to be used in structural elements.

8. Recommendations

1 The addition of polystyrene (residues) to the concrete components has an effect on the density, which is related to all other mechanical and physical properties of concrete, where the density decreases as the percentage of polystyrene increases as the percentage of cement increases.

2 Polystyrene can be used in concrete works as it has a positive effect on reducing the weight and cost of concrete.

3 Conduct future studies on the possibility of using polystyrene in hollow bricks.

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

5 Conduct future studies on the possibility of using polystyrene as a lightweight aggregate as an alternative to sand (fine aggregate).

6 Conduct a study on the effect of fire or exposure to high temperatures on polystyrene-containing concrete.

7 Conduct an economic feasibility study on the methods used for polystyrene waste.

9. References

[1] Fu, X.L., Lu,W.M. , and C hung, DDL,(Improving the bond Strength between Carbon Fiber and Cement by Fiber Surface Treatment and Polymer Addition To Cement Mix). Cement and Concrete Research.1996 July , pp.1007 – 1012.

[2] Haimei Zhang, "Building Materials in Civil Engineering", (Beijing : O.U.P.), PP 305-313, 2011

[3] H.Hamid , Hussein and S.Omar , "Effect of Additive of Expanded Polystyrene and Perlite on Some Mechanical Properties and Thermal Conductivity for Mass Concrete", Tikrit Journal of Engineering Sciences Technical College, Mosul,Iraq, PP55-59, 23 January 2016.

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

[5] Nagaral,T.S., Iyengar,S.R., and Viswanatha ,C.S. (PC and Polymer –Fibrous Concrete) . Int. Symposium, SP-58, ACI, Detriot, 1978, pp. 139-160.

[6] Fu, X.L., Lu,W.M. , and C hung, DDL,(Improving the bond Strength between Carbon Fiber and Cement by Fiber Surface Treatment and Polymer Addition To Cement Mix). Cement and Concrete Research.1996 July , pp.1007 – 1012.

[7] Libyan Standard Specifications No. (340), Portland Cement, for the year 2009.

[8] Libyan Standard Specifications No. (294) Water Used in Concrete, for the year 1988.

[9] Specification for aggregates from natural sources for concrete-British standard Institution, "BS 882,", London, 1992.

[10] Specification for aggregates from natural sources for concrete British standard Institution, "BS812,", London,1995.

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

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

[13] Standard 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.

[14] Methods for Organic Impurities in Fine aggregates, American Society for Testing and Materials, Washington.USA,2004, pp C40.

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