Feasibility study of lightweight structural concrete using LECA and PET and determination of its mechanical properties

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Abstract

Attention to lightness in modern construction and the need to produce and use lightweight concrete in tall buildings has also led researchers to use lightweight synthetic materials. The aim of the research is to replace natural sand with (0-4) mm LECA sand in the production of lightweight structural concrete. Therefore, four mix designs were made with LECA sand and water-to-cement ratios of 600 kg/m^3 and 0.42 in the first and third designs, and 200 kg/m^3 and 0.35 in the second and fourth designs. After determining the compressive strength of the samples, the fourth mix design was determined as the reference design. Next, three new mix designs were made with 10%, 20%, and 30% replacements of polyethylene terephthalate aggregates and LECA sand. Standard cubic and cylindrical samples were prepared to determine the compressive strength and static modulus of elasticity, respectively, and were cured in water for 28 days. For all mix designs, slump and specific gravity tests were performed in the fresh and hardened states of the concrete. The results showed that the design with 10% polyethylene terephthalate replacement with LECA sand achieved an increase in compressive strength and static modulus of elasticity of 18.4% and 6.1%, respectively, compared to the reference mix design. The results showed that it is possible to use polyethylene terephthalate aggregates to produce structural lightweight concrete, even in such a way that this type of concrete has superior mechanical properties compared to the reference concrete.

Keywords: Structural lightweight concrete, Polyethylene terephthalate aggregates, Manufacturing feasibility, Mechanical properties

1. Introduction

In the construction of tall buildings, the weight of the structure must be considered. Now, considering that the components of these buildings are often made of concrete, the use of lightweight concrete reduces the weight of these buildings. The construction of lightweight buildings is a new topic in construction, the development of which will lead to the emergence of new methods in the production of lightweight concrete. Lightweight structural concretes have densities in the range of (1400-1900) kg/m3 and compressive strengths of more than 17 MPa, and in some cases, it is possible to increase the strength to 60 MPa. The goal of researchers is to achieve concrete that, in addition to being lightweight, also has acceptable strength, in a way that meets the increasing need of the construction industry for high strength on the one hand and low production cost on the other. In the last few decades, research has been conducted to reuse worn-out plastics. One of the proposed solutions for recycling and reusing these waste plastics in the field of civil engineering could be to utilize them in concrete production [1]. Therefore, it is interesting to study the effects of PET waste on the properties of various types of concrete, including lightweight structural concrete, and research has also been conducted in this direction [2]. Ramses et al., in a study, compared the properties of lightweight concrete containing recycled polyethylene and expanded clay aggregates and observed that the concrete mixture with a density of kg/m3 (1950-2050) with high-density polyethylene plastic waste aggregates and low-density polyethylene plastic waste has a 28-day compressive strength higher than 40 MPa [3]. Considering that in previous research, PET replaced only a percentage of natural sand, the aim of this research is to investigate the possibility of using PET as a substitute for LECA in the production of structural lightweight concrete and to determine its effects on the mechanical properties of this type of concrete. Considering that the aim of this research is to assess the feasibility of producing lightweight structural concrete using PET aggregates and determine its mechanical properties, after various studies and using different mixing designs, to reduce the weight of concrete and produce lightweight structural concrete, while using PET aggregates, LECA aggregates with a size of (0-4) mm were used instead of regular sand; the LECA used in this research is LECA with a size of (0-4) mm because it is replaced with natural sand for the production of lightweight concrete. In this study, LECA (0-4) mm was completely replaced with sand and the PET present in the study was replaced with a percentage of LECA (0-4) mm; to investigate the mechanical properties of the concrete produced in this way and to compare and verify with previous studies in which the optimal percentage of PET consumption to increase the mechanical properties of the produced concrete was in the range of (10-15)%, PET with percentages of 10%, 20% and 30% was selected to replace LECA (0-4) mm and the results of the failure of the samples in the 7 and 28-day periods were examined in the form of three designs P10, P20 and P30 to determine the mechanical properties.

2- Research Mixing Designs

To ensure the lightweight and structural properties of the produced concrete, 100% LECA (0-4) mm was substituted for natural sand and a reference design was determined. PET with percentages of 10%, 20% and 30% was selected to replace LECA (0-4) mm and the results of the failure of the samples at 7 and 28 days were examined in three designs: P10, P20 and P30. Table 1 presents the details of the final research mixing designs. SH indicates the reference samples in the reference mix design and the number after it indicates its number among the initial mix designs. Also, in these designations, P indicates samples containing PET and the number after it indicates the percentage of PET in the samples containing PET. For example, P20 indicates lightweight concrete containing 20% PET replaced with LECA.

Table 1- Details of the lightweight structural concrete mix designs made in the research (kg/m^3)

PET	Cement (kg)	water (lit)	LECA sand (0-4) mm	Pea gravel	Almond gravel	PET replacement ratio (%)	Mix name
0	350	122.5	200	400	800	0	(SH)4
20	350	122.5	180	400	800	10	P10
40	350	122.5	160	400	800	20	P20
60	350	122.5	140	400	800	30	P30

3- Methods and Experiments

Cubic and cylindrical specimens were used in the experiments. Mechanical property tests included determining compressive strength in 7 mixing designs using standard cubic specimens in a water-immersion curing environment at 7 and 28 days of age, and determining the modulus of elasticity in 4 mixing designs using standard cylindrical specimens in a water-immersion curing environment at 28 days of age.

4- Analysis of Results

The analysis of the research results in the main article is presented in three sections: aggregate grading, fresh concrete, and hardened concrete. These results for hardened concrete are presented in Table 2. Since numerous tests have been conducted for grading, fresh concrete, and especially the mechanical properties of hardened concrete, and the volume of the results is large, it is not possible to present them in this abstract and readers are advised to refer to the main article.

Table 2 - Results of tests on lightweight structural concrete in the hardened state

Static elastic Modulus (GPa)	Compressive strength of standard cylindrical specimens (MPa)		Compressive strength of standard cubic specimens (MPa)		Mix design name
Specimen' age (days)	Specimen' age (days)		Specimen' age (days)		
28	**28**	**7**	**28**	**7**	
16.5	18.5	12.9	23.0	16.1	(SH)4
17.5	21.9	14.2	27.4	17.7	P10
14	14.8	9.8	18.5	12.3	P20
12.9	12.2	8.0	15.2	10.0	P30

5- Conclusions

• By replacing PET by 10% with LECA lightweight aggregate, the slump of the mixture design containing PET was reduced compared to the reference mixture design (SH)4.

• In the P10 mix design, by replacing the amount of PET by 10% with LECA lightweight aggregate compared to the reference mix design (SH)4, the compressive strength increased by 10% at 7 days and by 18% at 28 days compared to the reference mix design (SH)4.

• In the P20 mix design, by increasing the amount of PET by 20% with LECA lightweight aggregate compared to the reference mix design (SH)4, the compressive strength decreased by 24% at 7 days and by 20% at 28 days compared to the reference mix design

• In the P30 mix design, the compressive strength decreased by 38% at 7 days and by 34% at 28 days, compared to the reference mix design (SH)4.

• In the P10 mix design, replacing the amount of PET with 10% of LECA, compared to the reference mix design (SH)4, caused the static modulus of elasticity at the age of 28 days to increase by 1.6%.

• Replacing PET with 20% of LECA in the P20 mix design, compared to the reference mix design (SH)4, caused the static modulus of elasticity at the age of 28 days to decrease by 15.2% compared to the reference mix design (SH)4.

• In the P30 mix design, by replacing PET with 30% LECA the static modulus of elasticity at the age of 28 days of this mix decreases by 21.8% compared to the reference mix design (SH)4.

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