Construction and Building Materials 105 (2016) 572–578

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Properties of concrete containing waste expanded polystyrene and natural resin

Ayse KAYA *, Filiz KAR

Department of Chemical Engineering, Firat University, 23119 Elazig, Turkey

HIGHLIGHTS

- New lightweight materials are produced by using EPS and resin.
- The new produced materials are subjected to thermal and mechanical tests.
- The new produced samples can be used as partition walls, floorings, ceiling concretes, briquettes or bricks and plaster.

ARTICLE INFO

Article history:
Received 28 January 2015
Received in revised form 8 December 2015
Accepted 22 December 2015

Keywords:
Expanded polystyrene waste
Tragacanth
Light concretes
Insulation materials

ABSTRACT

In this study, the waste expanded polystyrene (EPS) was used in a mixture of cement and tragacanth resin in order to produce a new concrete material. The amount of the resin in the mixture was 0.5%, 1% and 1.5% of the total cement + EPS. The EPS ratios in the samples were determined as 20%, 40%, 60% and 80% of the total volume.

The new samples were subjected to some tests to find out some thermal and mechanical properties. It was concluded that, when EPS ratios and resin ratios of the samples increased, the density, thermal conductivity, compressive strength and tensile strength decreased, and the porosity increased. The change in the physical properties shows that, some artificial pores (except from EPS's pores) are formed in concrete blocks which allow to increase the insulation characteristic of the material.

As a result, it was recommended that; using EPS aggregated and resin-added concrete, (i) the waste EPS can be evaluated and environmental pollution can be prevented, (ii) the new produced samples can be used as partition walls, floorings, ceiling concretes, briquettes or bricks and plaster instead of building-carrier systems such as columns or beams and by this the load of the building can be decreased.

1. Introduction

Lightweight aggregates are broadly classified into two types; natural (pumice, volcanic cinders etc.) and artificial (perlite, expanded clay, fly ash etc.). The expanded polystyrene (EPS) beads is a type of artificial ultra-lightweight [1]. The EPS is a packaging and insulation material which is widely used in a variety of industrial fields in the world. This material is released to the nature after it is used once and is hard to disappear through natural means. For this reason, recycling of EPS is essential in terms of economy and environmental pollution. The research on the recycling of waste EPS can be grouped under two categories. The first category includes the studies on using EPS as aggregate in concrete and the second group of studies is on recycling methods of EPS namely mechanical, thermal and chemical.

The mechanical recycling researches are related to the usage of EPS as aggregate in the concrete. The EPS concrete is a mixture that consists of cement, sand and polystyrene aggregate. The lightweight concrete can be obtained by totally or partially replacing the standard aggregate with low-weight components which are summarized below.

Babu et al. [2] examined the mechanical features of light concretes produced by using fly ash with EPS. The composite material which includes 50% of fly ash and from 0% to 66.5% of EPS, instead of conventional aggregate and found that the density varied from 2.200 to 0.550 g/cm^3 and the compressive strengths ranged from 22 MPa to 0.55 MPa.

Some researchers who preferred to use new ingredients instead of conventional ones are as follows: Benazzouk et al. [3] used rubber particles (30–50%) instead of sand, Demirel [4] used cement

* Corresponding author.
E-mail address: abicer@firat.edu.tr (A. KAYA).

http://dx.doi.org/10.1016/j.conbuildmat.2015.12.177
0950-0618/

and pumice alternatively to the sand, Bourvard et al. [5] studied the physical properties of cement with millimetre-size EPS spheres. Three of the mentioned researches have shown that the density, the thermal conductivity and the compressive strength varied according to the mixture ratios of each component. Table 1 exhibits those measured values comparatively to the present study's results.

Chen and Liu [6] investigated the density and concrete strength values of the concretes created by partial replacement with rough and thin natural aggregate of EPS beads with 3 mm and 8 mm diameters. Nabajyoti and Brito [7] reported the properties of plastic aggregates and the various fresh and hardened concrete properties of cement mortar and concrete in presence of plastic aggregate in their paper. Milled et al. [8,9] presented that EPS foams could also be used in panel walls, concrete briquettes and similar construction applications.

Kan and Demirboga [10,11] developed a new recycling process of the waste EPS foams by using heat treatment. Before the heat treatment, the average density, thermal conductivity and compressive strength of waste EPS foams were 0.010 g/cm^3, 0.0368 W/m K, and 0.12 MPa, respectively. After the modification, the density, thermal conductivity and compressive strength of waste EPS, increased to 0.217 g/cm^3, 0.0555 W/m K and 8.29 MPa, respectively.

Some thermal recycling studies, including modification of waste EPS and its reuse after the changes in its physical characteristics, were performed by Xue et al. [12]. He used the EPS packages in a thermal decomposition method, exposed them to temperatures over 400 °C and obtained some kind of fuel–oil from these EPS at this temperature. Gnip et al. [13] investigated the thermal conductivity of EPS at 10 °C and its conversion to temperatures within interval from 0 to 50 °C.

Sulkowski et al. [14] examined the chemical recycling of polymers. Bajdur et al. [15] studied the chemical recycling of EPS. They performed a synthesis of sulfonic derivatives of EPS wastes in order to obtain efficient polyelectrolytes. Abes et al. [16] transformed waste polystyrene to cation exchange resin and used it to remove lead and cadmium metals from aqueous solution. Thomas et al. [17] reviewed the basic literature on polymers which harden with heat and recycling of their mixtures and components. Choi et al. [18] obtained a solution by melting waste EPS in a solvent material and mixing it with silica sand and observed the changes in the mechanical properties of this mortar in cold and hot water.

In the present study, instead of conventional components, tragacanth resin and EPS particles were added in a mixture. As known, the tragacanth absorbs the water during the time that it is kept in the water then it swells. After the swelled tragacanth is added into the cement and EPS, it remains to dye, and so the absorbed water inside the mixture vaporizes and this results with new pores. That's to say that, additionally to the EPS's pores extra artificial pores occur in the mixture. In order to determine the impact of resin addition on the material, the produced samples are subjected to mechanical and thermal tests. The results of the test are compared to the properties of similar materials.

2. Experimental

2.1. Materials

The EPS is a material that it consists of air in 98%, and the rest is polystyrene [19,20]. Block EPS obtained from EPS manufacturing facility are used in the production of samples at the disintegration unit of the same factory according to 0–3 mm particle diameters.

Tragacanth is a kind of glue which leaks from the wounds opened on the body of astragalus plant. It is in the form of circular plates or different shaped parts with 0.5–3 mm thickness and 1–3 cm diameter. Its color is white or light yellow and it is odorless [21,22]. It is a polysaccharide mixture. The portion which dissolves in water is coined trigakantin and the part which is not dissolved in water is called bassorin. It is used in pharmaceutics technique for making such preparations as emulsion, suspension, pastille and tablet; in marbling art it is used in dye and fabric industry. Tragacanth resin, which is obtained dry, is remained in water and waited for 48 h for swelling and expansion; then it is knead and filtered to make a solution.

CEM IV/B (P) 32.5 R pozzolanic cement is used to a gum tragacanth-water solution as a binder to EPS. The cement components are given in Table 2.

Table 2
Chemical composition of cement used (%).

Chemical characteristics	Cement (%)
Silica (SiO_2)	23.51
Alumina (Al_2O_3)	6.15
Ferric oxide (Fe_2O_3)	4
Calcium oxide (CaO)	58.51
Magnesium oxide (MgO)	2.27
SO_3	2.37
Sodium oxide (Na_2O)	–
Sodium oxide (Na_2O)	–
Chlorine, (Cl)	0.10
Loss on ignition (L0I)	2.04
Not available	1.05

Table 1
Physical properties of similar studies.

Material	Experimental values			Literature
	Density (g/cm^3)	Thermal conductivity (W/m K)	Compressive strength (MPa)	
Cement and rubber particle (30%)	1.473	0.625	23.30	[3]
Cement and rubber particle (40%)	1.300	0.516	16.00	
Cement and rubber particle (50%)	1.150	0.470	10.50	
EPS + pumice blocks	0.578–0.600	0.130	1.77 (N/mm^2)	[4]
Cement + EPS	0.492–0.961	0.164–0.300	0.8–9.2	[5]
Waste EPS (before heat treatment)	10	0.0368	0.12	[9]
Waste EPS (after heat treatment)	217	0.0555	8.12	
Cement + clay + wood pellet (10%)	1.010	0.220	2.67	[23]
Cement + clay + wood pellet (20%)	0.870	0.160	2.35	
Cement + clay + wood pellet (30%)	0.700	0.140	1.35	
Sample 1	**0.65**	**0.061**	**1.82**	Present
Sample 4	**1.57**	**0.390**	**16.87**	
Sample 5	**0.593**	**0.056**	**1.12**	
Sample 8	**1.390**	**0.350**	**14.6**	
Sample 9	**0.536**	**0.050**	**0.89**	
Sample 12	**1.232**	**0.320**	**10.85**	
Sample 13	**0.482**	**0.048**	**0.46**	
Sample 16	**1.083**	**0.284**	**5.87**	