Construction and Building Materials 140 (2017) 562–569

Contents lists available at ScienceDirect

Construction and Building Materials

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

Mechanical and fracture characteristics of self-compacting concretes containing different percentage of plastic waste powder

Mehmet Gesoglu [c,*], Erhan Güneyisi [c], Osman Hansu [a], Serkan Etli [b], Mahammed Alhassan [c]

[a] *Civil Engineering Department, Gaziantep University, 27310 Gaziantep, Turkey*
[b] *Civil Engineering Department, Munzur University, 62000 Tunceli, Turkey*
[c] *Akademipark Eng. & Const. Inc. Gazintep, Turkey*

HIGHLIGHTS

- PW powder partially replaced the cement.
- Self-compacting concrete was made of different percentages of PW powder.
- Strength properties were adversely affected by the use of PW powder.
- Using PW powder lowered fracture energy and increased characteristic length.
- PW powder modified concrete seemed to be less brittle.

ARTICLE INFO

Article history:
Received 13 July 2016
Received in revised form 7 February 2017
Accepted 24 February 2017

Keywords:
PW powder
Self-compacting concrete
Fracture energy
Compressive strength

ABSTRACT

This study addresses the mechanical and fracture properties of self-compacting concretes (SCCs) containing plastic waste (PW) powder in varying amounts used as a cement replacement material. Partial amount of cement was replaced by PW powder at 5%, 10%, 15%, 20% and 25% by weight so as to design six SCC mixtures with a constant slump flow of 700 ± 30 mm, total binder content of 550 kg/m^3 and water-to-binder (w/b) ratio of 0.35. Mechanical characteristics of SCCs were tested for compressive and splitting tensile strengths, net flexural strength as well as modulus of elasticity at 28 day. Moreover, failure characteristics of the concrete were monitored via three-point bending test on the notched beams. The findings indicated that mechanical properties of PVC powder modified SCCs decreased while the concretes became less brittle.

1. Introduction

As an economically developing country, turkey has produced about 25 million tons of municipal solid in 2004. Only 7 million of them were disposed in sanitary landfills while 17 million tons were disposed without any control [1]. Though developed countries have established regulatory programs, Turkey has generally continued to use unsophisticated methods such as open dumps [2]. However, it is aimed that 60% of marketed products packaging wastes are obliged to be collected and recovered up to 2020 [3]. In effect, plastics and rubber subsectors represent 8.33% of total real sector [4] and about 15% of total waste materials [5]. Plastic as one of the most popular wastes can be present in any disposal site regardless of the source of collection, whether it is commercial, residential or a tourist site. It constitutes about 15–20% of the material recovery facilities outputs [2]. Unfortunately, plastic products are formed from several toxic chemicals which pollute soil, air and water. Disposal of plastic waste (PW) in nature is taken into account as a huge problem. It has very low biodegradability and takes up to 450 year to decompose in landfills [6]. Hence, the utilization of these wastes in other fields might be quite useful to inhibit the negative effects of plastic disposing [7]. Particularly, the construction industry is deemed as the most promising field in recycling PW.

A wide range of literatures has already been done on the application of PW in concrete mixture such as polyethylene terephthalate (PET) bottle [3–7], poly vinyl chloride (PVC) pipe [8], high density polyethylene (HDPE) [9], thermo- setting plastics [10], shredded and recycled plastic waste [11–13], expanded polystyrene foam (EPS) [14,15], glass reinforced plastic (GRP) [16], polycarbonate [17], polyurethane foam [18,19], poly-propylene fiber [20] as an aggregate, fiber and powder [10,21].

---

* Corresponding author at: Akademipark Eng. & Cons. Inc. 27310 Gaziantep, Turkey.

E-mail address: mgesoglu27@gmail.com (M. Gesoglu).

http://dx.doi.org/10.1016/j.conbuildmat.2017.02.139
0950-0618/

In effect, not all waste materials are suitable to use in concrete nor it can beneficially integrate its properties as part of the cementitious binder or as aggregates [22]. Therefore, it is important to investigate the effect of waste materials on the properties of produced concretes. Generally, PW as the component of municipal solid waste is becoming a major research issue for possible use in concrete, particularly in self-compacting concrete (SCC). As'ad et al. [23] prepared SCCs via utilizing PW as fiber form and investigated the fresh state behavior of the produced concrete. In the same regard, Choi et al. [10,11] examined the properties of mortar and concrete containing PW as fine aggregate. Pezzi et al. [24] utilized plastic particles as aggregate in concrete and evaluated the chemical, physical and mechanical properties. Soroushian et al. [25] stated that polypropylene is used only as synthetic fibers in order to increase the toughness of concrete. Hınıslıoglu and Agar [26] investigated the possibility of using high density polyethylene as additives to asphalt concrete. Likewise, the effect of PW bottles on concrete behavior at different w/c ratios had been investigated by Albano et al. [9].

Despite aforementioned studies, there is a shortage in literatures that used PW as powder form and cement-substitution materials. The aim of this study is to investigate the effects of PW powder as cementitious material on the mechanical and fracture properties of SCCs. For this, aside from control mix (CTR), five SCCs mixtures were designed with PW replacement levels of 5%, 10%, 15%, 20% and 25% by weight of cement. The mechanical and fracture characteristics of concretes were examined via compressive strength, splitting tensile strength, net flexural strength, static modulus of elasticity, fracture energy, and characteristic length.

2. Experimental program

2.1. Materials

Portland cement used in all of the SCCs mixes was ordinary cement CEM I 42.5 R identical to the Turkish specifications TS EN 197 [27] which were fundamentally derived from the European EN 197-1 [28]. Fly ash (FA) was used in the concretes as a replacement material by 20% of the cement. The chemical and physical characteristics of cement and FA are listed in Table 1. Superplasticizer (SP) with specific gravity of 1.07 was employed to obtain the desired workability. In this regard, crushed rock natural coarse aggregates (NCAs) and river sand natural fine aggregates (NFAs) conforming to the TS 706 EN 12620-A1 [29] were used in the production of concretes. The maximum size of NCAs and NFAs were 16 and 4 mm while 24-h absorption capacity was 1.5%, 2.4% respectively. The physical characteristics and sieve analysis of the aggregates were determined according to ASTM C127 [30] and demonstrated in Table 2. In the current study, PW powder used had a specific gravity and a mean diameter of 1.53 and 153 μmm, respectively. It had a negligible water absorption capacity after 24 h submersion. Sieve analysis and physical properties of the PW powder are listed in Table 3.

Table 1
Physical properties and chemical compositions of cement and FA.

Analysis Report (%)	Cement	FA
CaO	62.58	4.24
SiO_2	20.25	56.20
Al_2O_3	5.31	20.17
Fe_2O_3	4.04	6.69
MgO	2.82	1.92
SO_3	2.73	0.49
K_2O	0.92	1.89
Na_2O	0.22	0.58
Loss on ignition	3.02	1.78
Specific gravity	3.15	2.25
Specific surface area (m^2/kg)	326	379

Table 2
Sieve analysis and physical properties of NAs.

Sieve size (mm)	NFAs (%)	NCAs (%)
16	100.0	78.19
8	100.0	67.94
4	83.06	2.05
2	49.35	0
1	30.85	0
0.5	14.27	0
0.25	3.79	0
Fineness modulus	3.79	6.7
Water absorption (%)	2.4	1.5
Specific gravity	2.58	2.65

2.2. Mixture proportioning and sample preparation

In addition to a control mixture (CTR) containing portland cement and fly ash as binder, five concrete mixes were produced in a pan-type mixer with a 30 L capacity according to ASTM C192 [31]. In these mixes, PW powder was replaced by weight of cement at replacement levels of 5%, 10%, 15, 20 and 25%. All concretes were prepared with a 570 kg/m^3 binder content and w/b ratio of 0.35. To enhance the flowability of the concrete, FA was used in all of the mixtures at 20% of total binder content. Moreover, the desired workability were achieved by using SP with varying amounts. As shown in Table 4, the concrete mixtures were designated regarding the mixture composition such that PWC5 indicated the SCC containing 5% of PW powder.

Concrete casting sequence started with mixing aggregate and/or PW powder with the binder for one minute until they homogenized. Then, the water containing SP was added in two parts to avoid segregation and the concretes were mixed for 3 min. Later, the concrete was left for 2 min at rest and mixed again for an additional 2 min to complete the mixing sequence. A slump flow diameter of 700 ± 30 mm was achieved to meet the limitation of EFNARC [32]. For this, trial batches were conducted for each mixture until the target slump flow diameter was obtained. To perform the mechanical tests, 150 × 150 × 150 mm cubic specimens were employed for compressive strength and modulus of elasticity tests. 100 × 200 mm cylindrical concrete specimens were also used to conduct the splitting tensile strength test. Likewise, 40 mm notched 100 × 100 × 500 mm prisms with a span of 400 mm were employed to evaluate the fracture parameters via three point

Table 3
Sieve analysis and physical properties of PVC powder.

Sieve size (μmm)	PVC powder (%)
1	1.88
10	5.28
45	7.08
80	9.34
90	12.65
120	30.32
175	67.01
200	78.83
250	92.15
320	98.23
400	100
Mean Diameter (μmm)	153
Water absorption (%)	0.0
Specific gravity	1.53