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Fresh properties of self-compacting concrete with plastic waste as partial replacement of sand

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Abstract

This work aimed to investigate effecting of using plastic waste as partial replacement of fine aggregate, on the fresh characteristics of self-compacting concrete (SSC). For this purpose, different self-compacting concrete mixes were designed at constant water-to-binder ratio of 0.32 and 520 kg/m^3 of binder content. Class F fly ash was used as partial replacement of cement (30% by weight of cement). The six designated plastic waste contents of 0, 2.5, 5, 7.5, 10, and 12.5% and three different sized Plastic wastes (fine plastic wastes, coarse plastic wastes, and mixed plastic waste) were considered as experimental parameters. The workability properties of self-compacting concrete mixtures were performed regarding to slump flow diameter, T_{50} slump flow time, V-funnel flow time, L-box height ratio, and L-box T_{20} and T_{40} flow times. The 28-day compressive strengths of self-compacting concretes were also measured. The experimental results of this work are showed that the plastic waste with the sizes and contents that used in this work can be used successfully as a fine aggregate in self-compactingconcrete.

Keywords: Plastic waste content; Plastic waste size; Fresh property; Self-compacting concrete; Waste plastic

1. Introduction

European Environment Agency (2014) defined waste material, as an unwanted or undesired material or substance, is remained over from a manufacturing process such as industrial, commercial, mining or agricultural operations or from household activities. Environmental Protection Agency (European Environment Agency, 2014) grouped waste of materials as hazardous and non-hazardous. Hazardous wastes, which may include chemicals, heavy metals, or substances created from byproducts of commercial manufacturing processes and disposed household products, are potentially harmful to both human health and environment (National Institute of Environmental Health Sciences, 2014). However, non-hazardous wastes, which may have the opportunities for reduction, reuse, and recycling, are not specifically hazardous (United States Environmental Protection Agency, 2014). Several researchers were investigating the effect of plastic waste on concrete. Rebeiz concluded through his work that a precast concrete with a good quality could be produced using resins based on recycled plastic waste (PET bottles) (Rebeiz, 1995). Choi et al. studied the using

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of plastic waste (PET bottles) as aggregate on some properties of concrete. Their results showed that decreasing in weight using plastic wastes was about 2–6% of the normal weight concrete while compressive strength reduced up to 33% compared with compressive strength of normal concrete (Choi et al., 2005). Batayneh et al. concluded through their work that decreasing in compressive strength was function of increasing in plastic content. They found that for a 20% replacing of sand by plastic waste, compressive strength was reduced up to 70% compared with normal concrete (Batayneh et al., 2007). Other researchers (Yazoghli-marzouk et al., 2007; Mesbah and Buyle-Bodin, 1999; Remadnia et al., 2009; Hannawi et al., 2010) investigated about using plastic bottle waste to improve some properties of normal concrete. SCC is characterized by a high fluidity which provides spreading and compacting under its own weight, easily filling small interstices of formwork and complex shapes in structural members without vibration and it can also be pumped through long distances (Al-Manaseer and Dalal, 1997 and 18). The amount and size of coarse aggregate in the SCC manufacturing is limited and generally mineral and chemical admixtures are used (Güneyisi, 2010). In the literature, there are a number of studies reporting that the use of mineral admixtures improves the self-compact ability properties of the SCC (Gesoglu and Özbay, 2007; Güneyisi, 2010; Zhu and Bartos, 2003; Madandoust and Mousavi, 2012). Recently, research works showed that, the plastic is becoming a major research issue for its possibilities of using in self-compacting concrete and light weight concrete (Bayasi and Zeng, 1993; Al-Manaseer and Dalal, 1997; Avila and Duarte, 2003; Rossignolo and Agnesini, 2004; Rebeiz, 1995; Mesbah and Buyle-Bodin, 1999). The plastic wastes can beneficially be incorporated in concrete, as fine aggregates or as supplementary cementitious materials, it is important to notice that not all type of material's wastes are suitable for such use.

Batayneh et al. reported a decrease of slump with increasing PET waste as partial aggregate replacement. At 20% replacement the slump decreasing by 20–58 mm (Batayneh et al., 2007).

Al-Hadithi studied the using of plastic bottle wastes with different percentages (0.5%, 1% and 1.5%) of concrete volumes. Test results showed an improvement in both compressive and splitting tensile strengths of concretes. The improvement in splitting tensile strength appeared more clearly (Al-Hadithi, 2013). Albano et al. try with (10% and 20%) PET waste replacement percentages with different PET dimensions (2.6 mm, 11.4 mm and a mix of the two). Concretes with 20% waste content with (11.4 mm) dimensions gave the higher compressive strength loss above 60% (Albano et al., 2009).

This work covers the effecting of both plastic wastes contents and sizes on the fresh properties and compressive strength of SCC. Three different sized of plastic wastes (Fine, Coarse, and Mixed Plastic wastes) were used as partial replacement of natural sand at six different contents of 0, 2.5, 5, 7.5, 10, and 12.5% by volume. The fine plastic waste (FPW) is defined as a fine material passing from 1-mm sieve while the coarse plastic waste (CPW) is a fine material retaining on 1-mm sieve and passing from 4-mm sieve. Besides, FPW and CPW plastic wastes were mixed to achieve a new fine material with a gradation close to the natural sand. Constant water-to-binder (w/b) ratio of 0.32 and binder content of 520 kg/m^3 were designated to produce SCCs. To improve the workability of SCC, Class F fly ash (30% of cement content by weight) was incorporated in the mixture. The workability of SCC were investigated in terms of slump flow diameter, slump flow time, V-funnel time, L-box height ratio and L-box flow time. In addition, 28-days compressive strength were also measured. The experimental test results were evaluated and compared statistically.

2. Experimental study

2.1. Materials

- *Cement:* Ordinary Portland cement (CEM I 42.5R) was used in this work with specific gravity of 3.15 g/cm^3 and Blaine fineness of 326 m^2/kg. Chemical compositions and physical properties of using cement are recorded in Table 1.
- *Fly ash:* Class F fly ash (according to ASTM C 618) with a specific gravity of 2.25 g/cm^3 and Blaine fineness of 379 m^2/kg was utilized in the manufacturing of the SCCs. The chemical compositions and physical properties of using fly ash are recorded in Table 1.
- *Coarse aggregates:* A river gravel was used as coarse aggregate with a maximum size of 16 mm with specific gravity 2.71. The result of sieve analysis of using coarse aggregates are given in Fig. 1.
- *Fine aggregate:* Fine aggregate was a mixture of natural river sand and crushed limestone with a maximum size of 4 mm. Specific gravities were 2.65 and 2.43 for river sand and crushed sand respectively. The result of sieve analysis of using fine aggregates are given in Fig. 1.

Table 1
Physical properties and chemical compositions of Portland cement and fly ash.

Analysis report (%)	Cement	Fly ash
CaO	62.58	4.24
SiO_2	20.25	56.2
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
Blaine fineness (m^2/kg)	326	287