USE OF SLUDGE FROM WATER AND WASTEWATER TREATMENT PLANTS IN THE PRODUCTION OF CONCRETE: AN EFFECTIVE END-OF-WASTE ALTERNATIVE

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ABSTRACT

Concrete is the most used material construction material in the industrialized countries thanks to its technical characteristics. However, the concrete production needs natural resources (water and aggregates) and cement whose production is costly due to the energy required. Indeed, cement manufacturing is recognized to be a major source of carbon dioxide (CO2). In order to reduce the use of natural materials (Directive 2008/98/EC del 19/11/2008), the CO2 production (Decision n. 406/2009/CE del 23/04/2009) and the amount of wastes to be disposed in the landfill (Directive 1999/31/CE), several studies have been carried out to investigate the possibility of using dissimilar wastes for partial replacement of aggregates and/or cement in the concrete production. Also the use of sludge produced from the treatment of surface water or wastewater has been considered. Although obtained results are promising, other research is needed to guarantee the standardized production of concrete based on wastes having the required mechanical, physical and chemical characteristics.

Sludge from different water and wastewater treatment plants (e.g. chemical precipitation, biological treatment) and with different organic content and humidity (i.e. raw sludge, digested sludge, digested + dewatered sludge) was employed as partial or total replacement of water (from 10% to 100%) in the production of concrete.

The mechanical characterization (i.e. specific mass, consistency, compressive strength, tensile strength, modulus of elasticity) and environmental compatibility (toxicity characteristics leaching procedures – TCLP) of specimens produced at varying curing time has shown that the sludge produced from the water treatment plant can be effectively used as partial or total replacement of water in concrete production, while those coming from wastewater treatment plants often reduce the mechanical characteristics of the concrete.

Keywords: End-of-Waste, Recovery, Resource, Water, Sludge, Concrete.

1. Introduction

Concrete is the most used material construction material in the industrialized countries thanks to its technical characteristics. However, the concrete production needs natural resources (water and aggregates) and cement whose production is costly due to the energy required. Indeed, cement manufacturing is recognized to be a major source of carbon dioxide (CO_2). In order to reduce the use of natural materials (Directive 2008/98/EC del 19/11/2008), the CO_2 production (Decision n. 406/2009/CE del 23/04/2009) and the amount of wastes to be disposed in the landfill (Directive 1999/31/CE), several studies have been carried out to investigate the possibility of using dissimilar wastes for partial replacement of aggregates and/or cement in the concrete production (Bertolini et al., 2004; Aubert et al., 2006; Etxeberria et al., 2010; Guney et al., 2010; Siddique, 2010; Patel and Pandey, 2011). Also the use of sludge produced from the treatment of surface water or wastewater has been considered (Barrera-Díaz et al., 2011).

Sludge is the main waste produced during water purification. The volume and characteristics of disposed sludge depends on the type of treated water. For instance, wastewater treatment plants produce more sludge than that discharged from water treatment plant. Furthermore, the sludge

from wastewater contains more organic material while that from water treatment plant has less organic content but higher concentration of chemicals used for coagulation (e.g. aluminum salts, ferric ion salts, and ferrous iron salts) (Metcalf & Eddy, 2002).

Although obtained results are promising, other research is needed to guarantee the standardized production of concrete based on wastes having the required mechanical, physical and chemical characteristics (Sales and de Souza, 2009; Chang et al., 2010; Barrera-Díaz et al., 2011; Alqedra et al., 2011).

The purpose of this study was to evaluate the possibility of recycling water or wastewater treatment sludge as partial or total replacement of water in the production of concretes.

2. Materials and methods

Sludge from different water and wastewater treatment plants (e.g. chemical precipitation, biological treatment) and with different organic content and humidity (i.e. raw sludge, digested sludge, digested + dewatered sludge) was employed as partial or total replacement of water (from 10% to 100%) in the production of concrete (Table 1).

The mechanical characterization (i.e. specific mass, consistency, compressive strength, tensile strength, modulus of elasticity) and environmental compatibility (toxicity characteristics leaching procedures – TCLP) of specimens were investigated.

3. Results and discussion

Table 1 shows the experimental results as compressive strength obtained by the concrete specimens with different type of sludge used as partial or total water substitution.

Obtained results have shown that the sludge produced from the water treatment plant can be effectively used as partial or total replacement of water in concrete production, while those coming from wastewater treatment plants often reduce the mechanical characteristics of the concrete.
The toxicity characteristics leaching procedures (TCLP) showed that the released metals concentration in solution was always lower than that set by the Italian regulation on waste disposal or recovery.

Table 1. Compressive strength of concrete specimens obtained by partial or total substitution of water with sludge produced by water or wastewater treatment plants.

Specimen	Sludge (kg/m^3)	Water (L/m^3)	Water/cement	Observed axial compressive strength (Mpa)
Control	0	175	0.5	44
10 % WS-T	20	157.5	0.5	55
10 % WS-D	35	157.5	0.53	46
50 % WS-T	100	87.5	0.52	54
50 % WS-D	170	87.5	0.61	10
100 % WS-T	200	0	0.54	48
100 % WS-D	350	0	0.71	1
100 % WWS-AD	200	0	0.57	31
100 % WWS-AND	300	0	0.75	1
50 % WWS-AD	100	875	0.53	36
50 % WWS-AND	150	87.5	0.63	1
10 % FWWS-AD	20	157.5	0.51	39
10 % WWS-AND	35	157.5	0.54	45

WS-T = water treatment sludge thickened; WS-T = water treatment sludge dewatered; WWS-AD = wastewater treatment sludge aerobically digested; WWS-AND = wastewater treatment sludge anaerobically digested.

4. Conclusions

In this study, it was observed that sludge from water treatment plants can be used as partial or total substitution of water in the production of concrete. Indeed, no significant reduction of the compressive strength was observed and the environmental compatibility was also accomplished according to the toxicity characteristics leaching procedures. On the other hand, the wastewater treatment sludge showed a negative impact on the concrete strength even when it was used to replace 10% of the water in concrete production. This negative effect also depends on the type of sludge treatment train.

Overall, the use of sludge as water replacement seems a very good End-of-Waste alternative.

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