Application of Sewage Dry Sludge as Fine Aggregate in Concrete

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Introduction

Disposal of human sewage has become a necessity for societies, today. The construction of treatment plants has caused problems with huge contents of dry sludge. It has been found that each person produce 35 to 85 grams of solid sludge per day.

In recent years, waste production has increased dramatically in developing nations such as Iran. There are two methods for the disposal of solid waste (dry sludge) including landfilling and using the sludge as fertilizer. Both of these methods have been prohibited by Iran's Environmental Organization, due to the dangers of heavy metals present in the sludge. Due to these limitations, high volumes of dry sludge have been produced and collected in treatment plants.

Alborz sewer treatment plant is an industrial-domestic unit which collects sewage of more than 500 factories. The production of dry sludge is about 2.5 to 3 tons a day in this treatment plant.

In the present research, the dry sludge of Alborz treatment plant was used as filler in concrete. Worldwide, a great deal of research has been carried out to use dry sludge in concrete mixture. Valls et al. used sewage dry sludge in concrete up to 10% and investigated the performance of concrete. Also, the application of dry sludge in light weight concrete was studied by Moon et al.

In Iran, the application of dry sludge in construction materials is a new method. In this research, the dry sludge of a sewage treatment plant was characterized, and its effects on the performance of concrete were evaluated.

To evaluate the effects of dry sludge on concrete performance, its physical and mechanical properties were studied. Thereafter, concrete specimens were produced with water to cement ratios of 0.45 and 0.55, and with sludge contents of 0, 5, 10, 20 and 30 percent. Finally, compressive strength of the specimens was measured.

Materials and Methods

Materials

- *Dry sludge*

The dry sludge used in this study was prepared from treatment plant of Alborz Industrial city. Table 1 shows the properties of the wet sludge.

Table 1: Chemical properties of wet sludge

Property	amounts
pH	7.8
COD (mg/L)	2000
BOD (mg/L)	1200
TSS (mg/L)	7500

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Cement

Type II cement from Tehran cement manufacturing company was used in this study.

- *Aggregates*

Coarse and fine aggregates were prepared from Rahsar mine about 15 kilometers far from Qazvin city.

- *Superplasticizer*

To control the workability of concrete, Melcrete-type Superplasticizer was used in this study.

Mixing design

On the basis of ACI-211 a mixture was designed for this investigation which is shown in Table 2.

Table 2: Concrete materials mixture

w/c ratio	0.45				0.55			
materials	Sludge content (%)				Sludge content (%)			
	5	10	20	30	5	10	20	30
Cement	360	360	360	360	360	360	360	360
Coarse aggregate	861	861	861	861	861	861	861	861
Fine aggregate	852	834	798	762	852	834	798	762
Water	162	162	162	162	198	198	198	198
Superplasticizer	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
Dry sludge	18	36	72	108	18	36	72	108

Discussion of Results

TGA analysis

Results of TGA analysis are given in figure 1.

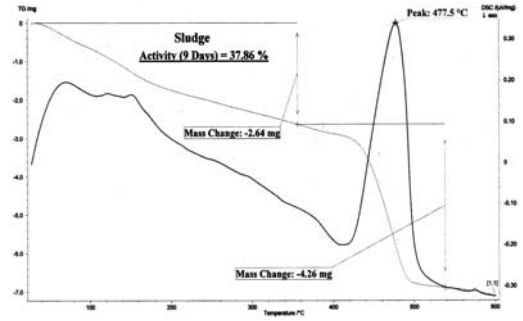

Fig. 1: TGA analysis of dry sludge after heat treatment

Results showed that the dry sludge has a pozzolanic activity of 37.86%. The minimum amount of pozzolanic activity required for a type of material to be considered as supplementary cementing material (SCM) is 70%. On this basis, the selected dry sludge does not have enough pozzolanic activity to perform as a cementing material in the mixture design.

X-ray analysis of dry sludge

The dry sludge was characterized using XRD and XRF analysis before and after heat treatment. Results of XRD analysis are shown in Table 3.

Table 3: XRD analysis results

Before heat treatment	After heat treatment
SiO_2	SiO_2
$KAl_2(Si_3Al)O_{10}(OH,F)_2$	$KAl_2(Si_3Al)O_{10}(OH,F)_2$
$CaCO_3$	$KAl_2(Si_3Al)O_{10}(OH)_2$
$CaMg(CO_3)_2$	-

This analysis shows that some crystals of the dry sludge remove or reform during the heating process.

Compressive strength

The compressive strength of different samples made on the basis of the mixture designs mentioned in table 3, was evaluated. Results are shown in figure 1 and 2.

It is evident that by increasing sludge content, compressive strength decreases. This can be attributed to the decrease in binder content with respect to other ingredients. Also, compressive strength increase s with the decrease in w/c ratio and the curing age of concrete which is a normal phenomenon in concrete materials. Producing concrete specimen at w/c ratio of 0.45, with 30% of dry sludge was impossible due to very low workability.

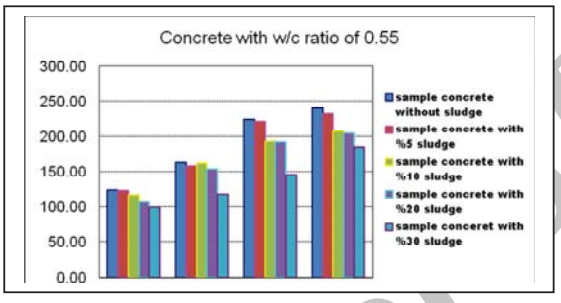

Fig. 1: Compressive strength of concretes containing dry sludge (w/c ratio of 0.55)

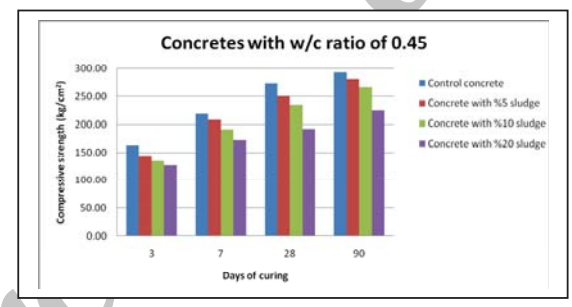

Fig. 2: Compressive strength of concretes containing dry sludge (w/c ratio of 0.45)

Conclusions

On the basis of the results, the findings are as follows;

- It was observed that the dry sludge of waste water treatment plant of Alborz city has a satisfying compatibility to concrete materials, due to high contents of SiO_2.
- The dry sludge due to low pozzolanic activity, acts as filler or fine aggregate in concrete.
- Utilization of 10% of dry sludge in concrete caused 8% decrease in compressive strength which was much lower than the decrease amounts reported in previous researches (about 42%).
- The water to cement ratio of 0.45 found to be the optimum ratio in the performance-mixture balance.
- On the basis of results, it is proposed to use concretes containing more than 10% of dry sludge as non-constructional concretes such as paving and flooring concretes.

Key words

Sludge, Concrete, Compressive Strength, XRF and XRD Analysis