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The Effects of Dry Sludge from Waste Water Treatment Plant on the Compressive Strength of Concrete

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ABSTRACT

One of the objectives of this study was to evaluate an option for waste minimization for the growing production of sludge from waste water treatment plants. Dry sewage sludge was investigated for it's potentials by adding this waste product to concrete with Portland cement. This study focused on preparing specimens of concrete with various percentages of sludge from a waste water treatment plant studying the compressive strength and slump tests was conducted for all specimens over certain period of time. The maximum compressive strength of 27.4 MPa was achieved using 5% of dried sludge after 28 days of curing which provided approximately the same strength of reference concrete at the age of 7 days (27.7MPa). The experimental result in this study can be use in certain specific application if use small percentage of dried sludge is added in mix design concrete. The usage of dry sludge in concrete will give better results by increasing the period of curing to obtain the optimum compressive strength of concrete and reduce the water cement ratio to increase strength of concrete.

Keywords: *Dry sludge, compressive strength, concrete, waste minimization, slump*

Introduction

Malaysia generates 3.2 million cubic meters of domestic sewage sludge per annum and the figure is rising in proportion to the population increase. However, facilities to treat and dispose of this sludge are limited. Currently, sewage treatment plants with excess capacity are being used to treat

septic tank sludge. By the year 2005, Malaysia will be producing 4.3 million cubic meters of domestic sludge annually. It means that the volume of sludge is increase annually by year. All sewerage systems from individual septic tanks to the most sophisticated mechanical plants produce sludge. Sludge is an active organic compound which can rapidly turn septic if left untreated. Untreated sludge is a significant environmental and public health hazard. Dried sludge can be done by removing the water in fresh sludge using methods of sludge treatment such as dewatering and filter presses. (Indah Water Konsortium, 2006)

The utilization of dry sludge as an addition to construction and building material including building bricks, lightweight artificial aggregates, and cement-like does not only converts the wastes into useful materials but it also alleviates the disposal problems. The prospective benefits of using sludge or sludge ash as the brick or tile additive include immobilizing heavy metals in the fired matrix, oxidizing organic matter and destroying any pathogens during the firing process, and reducing the frost damage based on the results of several full or bench scale studies. (Alleman, 2001) Most common used of waste water sludge is in the agriculture sector as fertilizers or in the form of compost. Nevertheless, the sludge contains high percentage of organic and heavy metals material which makes it unsuitable for some purposes. (S.Valls et al.)

The physical characteristic of dry sludge from previous study shows that its granulometric properties were similar to that of fine aggregates. Furthermore, it was a very spongy material with a very low density. (S.Valls, et al., 2004) However, the chemical and mineralogy characteristic mainly depends on the type of treatment for the waste water treatment plant and the characteristics of waste from the area itself.

The study attempts to find alternative for sludge minimization produced by waste water treatment plants by adding it as a component in concrete. Sludge is taken and collected from IWK Ipoh (Indah Water Konsortium) at Taman Lindungan Bercham Indah. The dry sludge was taken with permission from Branch IWK Ipoh. At the site, drying beds technique is use removal water dewatering process and produce dried sludge. By using dry sludge added as a construction material can reduce the bulk volume of sludge in sewage treatment system and hence, can benefit the optimum usage of dry sludge beside its potential in agricultural benefits.

Experimental Program

Materials and Concrete Mix Design

Table 1 shows the complete concrete design mix according to the sludge content. The design concrete consists of coarse aggregates, fine aggregates, ordinary Portland cement with added sludge, where four percentages of sludge in the cement mix; reference concrete or 0% sludge, 5% sludge, 10% sludge and 15% sludge. The design concrete mix should be based on the following factors such as the grade designation, type of cement, maximum nominal size of aggregates, minimum water cement ratio, workability, durability and quality control. The grade designation gives the characteristic compressive strength requirement of the concrete. The characteristic compressive strength is define as that the value below which not more than 5 percent of the test result are expected to fall. By the basic of concrete process, the dried of sludge is added as an additional substance in concrete mix design. Before the dry sludge is powder added in concrete mix design the value of sludge is decided first. In this research, the laboratory process of the concrete is occur by three time, firstly by add 5% of dried sludge in mix concrete, secondly 10% and lastly 15%.

A standard Portland cement is used with basic ingredient of concrete, mortar and most non-specialist grout. It is a finely-ground powder produced by grinding Portland cement clinker (more than 90%), about a maximum of 5% gypsum which controls the set time and up to 5% minor constituents (as allowed by various standards). Coarse aggregate were material retained on 5 mm (3/16 inch) BS4110 test sieve and containing only so much of finer material as is permitted from the various size in MS 29: 1995 with maximum size of 20 mm. Fine aggregate were sand which passed thought a 5 mm (3/16 inch) BS 4110 test sieve.

Table 1: Concrete Mix Design for 8 Cubes

Concrete Mix	W/C	Cement (kg)	Dry Sludge (kg)	Water (kg)	Aggregate	
					Fine Aggregate (kg)	Coarse Aggregate (kg)
0% sludge	0.50	11.91	0	5.95	20.07	30.11
5% sludge	0.50	11.91	3.40	5.95	20.07	30.11
10% sludge	0.50	11.91	6.80	5.95	20.07	30.11
15% sludge	0.50	11.91	10.21	5.95	20.07	30.11

Making and Conserving Specimens

The casting and cure test cubes according to BS 1881. The test cubes size is 150mm x 150mm a standard size of steel moulds. In assembling the cleaned mould ready for use, it must make sure the joints between the bottom of the mould and the base plate shall be thinly coated with grease to prevent the water escape it. Steel bar weight 1.8 kg of 380 mm long with a ramming face 25 mm square is used to compact the concrete commonly in three layers. One layer approximately was compact 50 times. Concrete product generally takes 30 day to cure after casting. By curing we mean the process achieving full with internal strength. From curing process it means evaporation should be prevented or reduced at all. In this study, the process of curing takes 28 days and can be tested for its compressive strength. The slump test was performed according to BS 1881. Slump test is to determine the workability of a sample from fresh concrete. The compressive strength of concrete at the ages of 7, 14 and 28 days were performed.

Results & Discussion

Slump Test

Result for slump test performed according to the percentage of dry sludge added in the concrete mix is presented in Figure 1. As it can be seen from the figure, when compared to the reference concrete, concrete with 5% dry sludge nearly reach the slump height of the reference concrete. However, the slump height with 10% and 15% dry sludge decline rapidly compare to the reference concrete and 5%. This might be caused by the adsorption of dry sludge known to be spongy material that easily can absorb water at certain amount in the concrete mix.

Compressive Strength

Table 2, 3 and 4 shows the compressive strength according to the amount of dry sludge added with different curing times.

The compressive strength after 7 days provided with same clear results indicating that the strength decreased as the percentage of sludge increased. The strength of concrete with 10% and 15% dry sludge after 7 days was very low although it increased with respect to time.

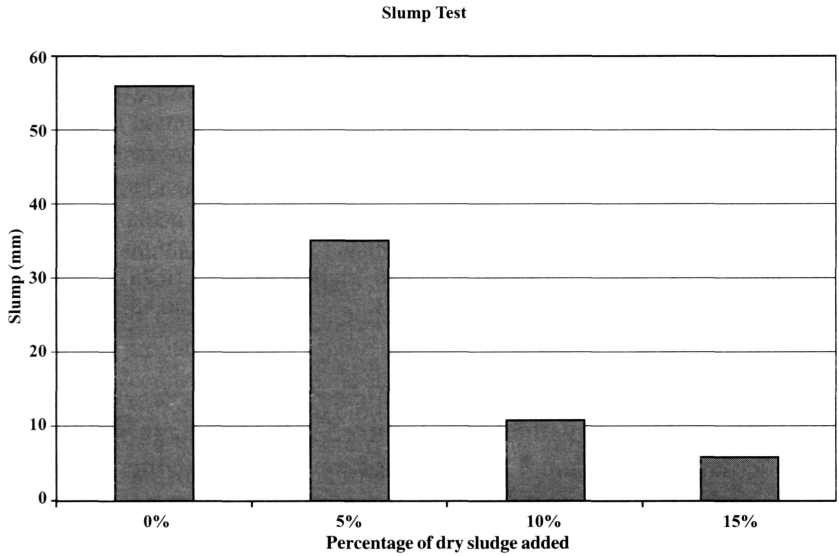

Figure 1: Slump Test According to the Different Percentage Sludge Content

Table 2: Compressive Strength and Loading for Two Concrete Cubes at Age 7 Days

Concrete Mix with dry sludge	Loading (N)			Compressive Strength (MPa)		
	1	2	Average	1	2	Average
0% sludge	625.45	621.35	623.4	28.9	26.5	27.7
5% sludge	269.20	258.20	263.70	12.49	10.95	11.72
10% sludge	9.90	10.30	10.10	0.47	0.53	0.50
15% sludge	8.10	8.50	8.30	0.33	0.40	0.37

Table 3: Compressive Strength and Loading for Two Concrete Cubes at Age 14 Days

Concrete Mix with dry sludge	Loading (N)			Compressive Strength (MPa)		
	1	2	Average	1	2	Average
0% sludge	668.10	676.70	672.40	28.25	31.51	29.88
5% sludge	388.20	355.60	371.90	17.40	16.10	16.75
10% sludge	12.10	11.06	11.58	0.57	0.55	0.56
15% sludge	9.10	10.30	9.70	0.41	0.45	0.43

Table 4: Compressive Strength and Loading for Two Concrete Cubes at Age 28 Days

Concrete Mix with dry sludge	Loading (N)			Compressive Strength (MPa)		
	1	2	Average	1	2	Average
0% sludge	984.20	1009.80	997.00	42.50	45.92	44.21
5% sludge	596.80	589.00	592.90	28.90	25.90	27.40
10% sludge	12.90	14.62	13.76	0.59	0.75	0.67
15% sludge	12.95	11.71	12.33	0.66	0.48	0.57

Nevertheless, this concrete mix is insufficient as construction materials. From results in Figure 2, the concrete mixed with 5% sludge yielded the compressive strength more than 60% of the reference concrete. After 28 days, the compressive strength for reference concrete increased uniformly but the compressive strength for quantity of dry sludge in concrete was increasing slowly. It can be seen that postponed increase in compressive strength for dry sludge specimens particularly during the first 7 days of curing gives lower strength. As curing time increased, the

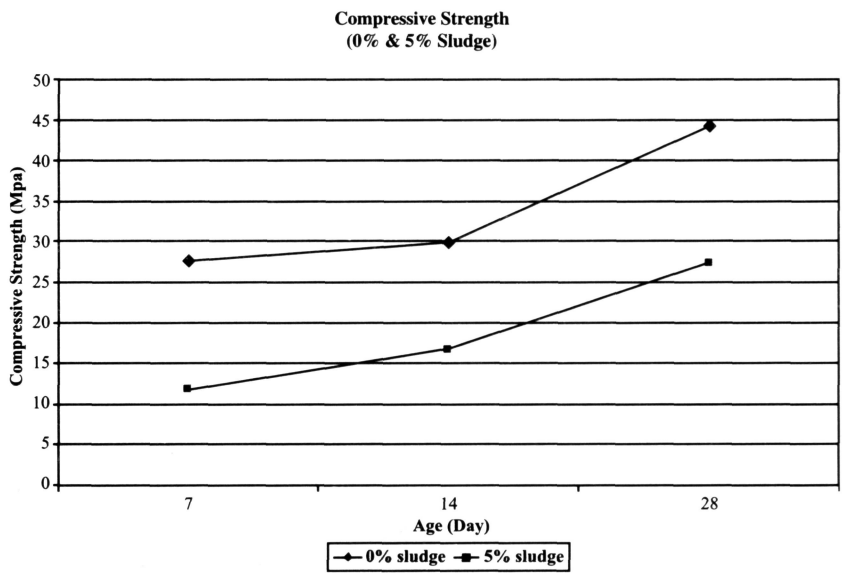

Figure 2: Compressive Strength for 0% and 5% Dry Sludge Content with Different Curing Times

compressive strength of the 5% dry sludge specimens gives almost the same strength with the reference concrete in the early stage. In the case of having a grade 30 concrete, the strength of the 5% sludge in the specimen is sufficient. However, the compressive strength remained lower for higher amount of dry sludge in the specimens. This can be seen in Figure 3 where 10% and 15% sludge content in the concrete mix. The compressive strength was about 98% lower compared to the reference concrete. Water cement ratio in concrete containing higher percentage of dry sludge such as 10% and 15% tends to reduce the compressive strength. Lower quantity of dry sludge can be used an addition to concrete. Thus, it would be sufficient for any application that requires high strengths such as road bases, cement mortar, bricks or as filling material. Sludge content more than 10% cannot be utilized immediately for construction due to low compressive strength. After 28 days, all compressive strength increased as the curing time increases.

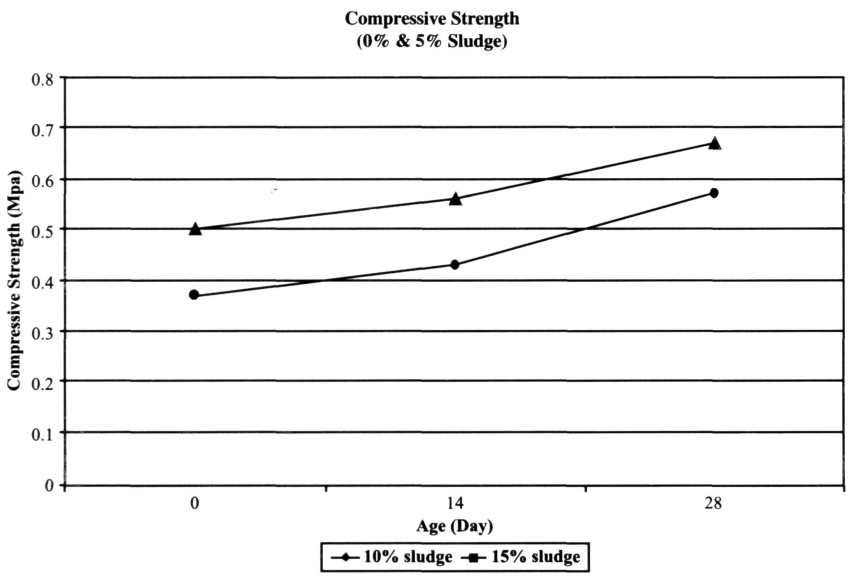

Figure 3: Compressive Strength for 10% and 15% Dry Sludge Content with Different Curing Times

Conclusion

In the test results, it can be concluded that the usage of dry sludge from waste water treatment plant as an additional construction material is promising. However, the proportion of dry sludge must be limited according to the compatibility with the to the construction application suggested due to the tendency of higher amount of sludge in reducing the compressive strength. Therefore, further investigation needed to analyze the other characteristics of sludge in concrete such as the mechanical properties of concrete such as elasticity, durability and flexural strength. The effect of water cement ratio also necessary to evaluate the result with dry sludge to improved the application of dry sludge from wastewater treatment plant as a construction material component. The test on specimens would be better if the cubes can be tested for 60 days and 90 days. The results might give higher strength to higher proportion of dry sludge in the specimens.

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