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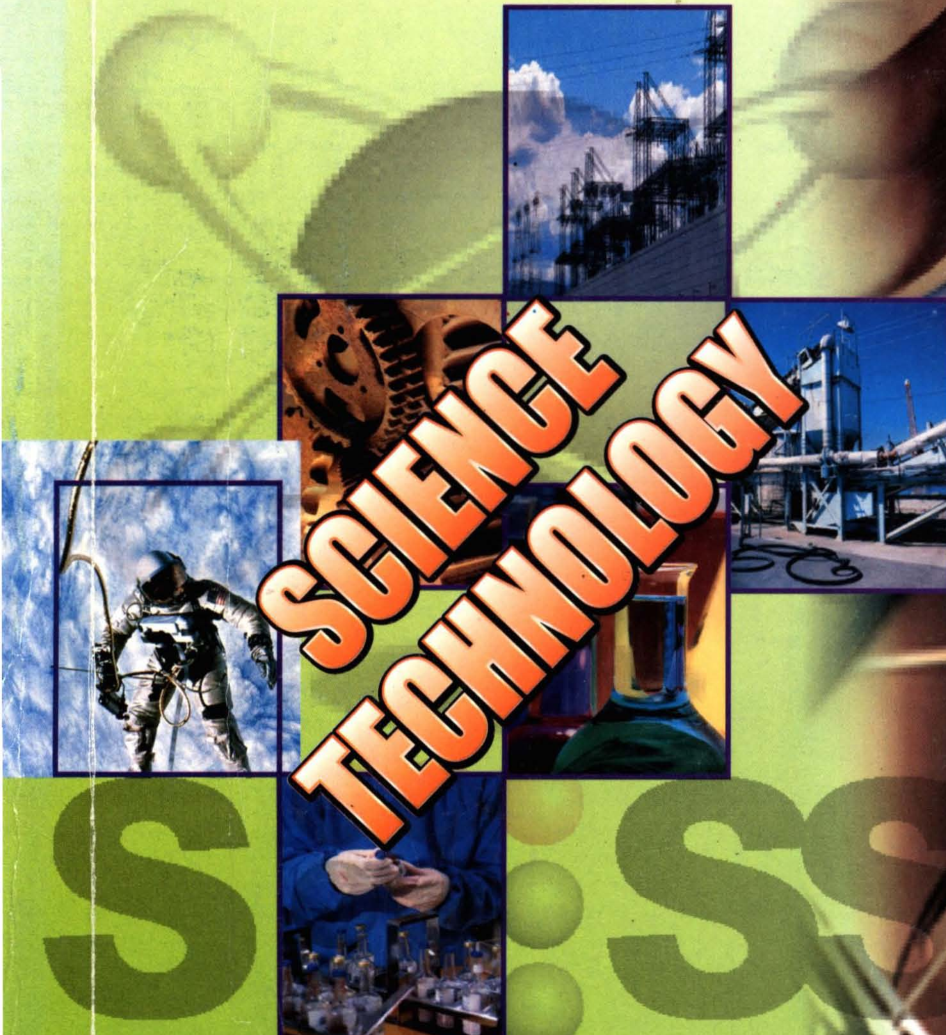

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Effects of Waste Paper Sludge Ash on Compressive Strength of Concrete Cubes

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ABSTRACT

Waste paper sludge incinerator ash (WPSIA) was investigated for its potential use as a replacement for cement in concrete. The physical and chemical properties of raw materials were determined. The water cement ratio was fixed at 0.55 while WPSIA was used at 5%, 10%, 15%, 20%, 25% and 30% replacement by weight of cement. The grade design of proportions was 30 N/mm^2. Slump and compressive strengths were performed on all specimens. Results indicate the WPSA caused a reduction in slump values when it was used as a cement replacement. The replacement of WPSIA up 30% exhibited, generally similar to control mix (0% WPSIA) after 28 days of curing. The maximum compressive strength of 44.1 N/mm^2 was achieved using 15% of WPSIA after 60 days of curing. The experimental results presented in this study suggest the potential of WPSIA as a cement replacement. With strength contributing and nontoxic characteristic, the use of WPSIA as a cement replacement may be technically and environmentally feasible.

Keywords: *waste paper, incinerator, compressive strength, slump, portland cement*

Introduction

Currently, the disposal of about 80 tons per day to fly ash to a landfill imposes a considerable load and shortens the life span of the facility in Temerloh area. The problem to find additional sites will become increasingly more difficult due to acute shortage of land as the pace of development around Temerloh progresses. An economical and environmentally sound disposal method for ash is needed and a viable solution is to reutilize this waste material for civil engineering applications. This will help to alleviate the disposal costs of ash, preserve land capacity, conserve dwindling supplies natural raw materials and mitigate potential environmental impacts.

The use of ash as a component in concrete and special grade is not new to the cement industries and has proven records in term of application and meets all safety and quality standards. With a view of reducing the quantities to be landfilled, the Malaysian Newsprint Industries Sdn Bhd. (MNI), in collaboration with Universiti Teknologi MARA Pahang, has been working on development of concrete using WPSIA as a cement replacement in concrete.

Previous studies conducted by Tay and Cheong, (1991); Cheong et al. (2000), indicated that the ash collected from incinerators equipped with lime-base and physical characteristic that render it suitable for use in civil engineering applications. Therefore, interpretation of these results will assist authorities to alleviate, if not eliminate, the difficult disposal problems associated with increasing amount of WPISA. In this regards, several studies were conducted on the use of incinerator ash in various engineering applications such as: (1) partial replacement for cement (Al-Amoudi 1996 and Taha 2000), (2) a replacement for natural aggregates in structural grade concrete (Rivard 1997 and Ghafoori 1993), (3) a soil stabilizing agent (Ferguson 1993). However, in concrete, partial replacement of cement by incinerator fly ash results in lower compressive strength at early ages (about 3 – 6 months) but greater strength at beyond 6 months (Taha 2000)

Also, the sludge has been conditionally classified as non-schedule by Director General of Department of Environmental (DOE). But all the primary work to get sand and replacement are so increasing the pollution and some of landslide problem. So, by using waste material added with cement composites can reduce the pollution and utilised the waste material for the cement composites and become more strength and durable.

Experimental Program

Materials and Concrete Mixes

The cementitious materials used in this test were the Ordinary Portland Cement (OPC) in compliance with MS 522: 1989 and Waste Paper Sludge Incinerator Ash (WPSIA) was collected from Malaysian Newsprint Industries, Pahang. The chemical compositions of Ordinary Portland Cement (OPC) and WPSIA are given in Table 1 based on this table, the principal constituents present in this ash are lime (CaO) and silica (SiO_2). For the control mixes, the coarse aggregate used was 20 mm and the fine aggregate used was medium graded natural sand complying with BS 882: 1992. Details of the mix proportions for concrete are given in Table 2. The control mix was cast using Ordinary Portland cement, while the other mixes were prepared by replacing part of the cement with WPSIA at 5%, 10%, 15%, 20%, 25% and 30%. The water cement ratio was fixed at 0.55.

Table 1: Chemical Properties of OPC and WPSA

Chemical Components	Chemical Composition (% w/w)		
Chemical Constituents	Empirical Formula	OPC*	WPSIA**
Calcium oxide (lime)	CaO	64.8	67.4
Silicon dioxide (silica)	SiO_2	20.6	20.4
Aluminium troxide	Al_2O_3	5.8	8.85
Ferric trioxide	Fe_2O_3	3.5	Not applicable
Magnesium oxide	MgO	0.6	2.5
Sulphate	SO_3	2.4	0.41
Potassium oxide	K_2O	0.6	Not applicable
Sodium oxide	Na_2O	0.1	Not applicable
Insoluble residues	IR	0.8	Not applicable
Loss of ignition	LOI	1.3	3.51
Lime saturation factor	LSF	0.96	Not applicable
Free calcium oxide	F CaO	2.2	Not applicable

* Rahim, (1997)
** Marzuki et al. (2005)

Table 2: Mix Proportions (kg/m^3) and Properties of Fresh Concrete for 12 Cubes.

Mix No.	W/C	Cement	WPSA	Water	Aggregate	
					Fine	Coarse
Mix 1 (0%)	0.55	18.04	0.00	9.80	25.64	59.80
Mix 2 (5%)	0.55	17.14	0.90	9.80	25.64	59.80
Mix 3 (10%)	0.55	16.20	1.80	9.80	25.64	59.80
Mix 4 (15%)	0.55	15.33	2.71	9.80	25.64	59.80
Mix 5 (20%)	0.55	14.43	3.61	9.80	25.64	59.80
Mix 6 (25%)	0.55	13.53	4.51	9.80	25.64	59.80
Mix 7 (30%)	0.55	12.63	5.41	9.80	25.64	59.80

Specimens

The concrete mixed were cast into 150 x 150 x 150 mm cubes at normal consistency for compressive strength. All the cubes were cast in standard steel moulds. Specimens were compacted in three layers using a vibrating table. After

24 hours of casting, the specimens were removed from the mould and cured in water at 27 ± 2°C for 3, 7, 28 and 60 days and tested for the compressive strength. Three cubes were tested for each age (12 cubes per mix).

Result and Discussion

Slump Test

From Figure 1, the slump values decreased as the replacement by WPSIA increased. As a results, the 15%, 20%, 25% and 30% mix is not achieved target strength that it value or near to the value of 5% and 10%. This might be not correctly or not good in mixing them and then it come from the WPSIA absorb so many water at certain percentage of mix.

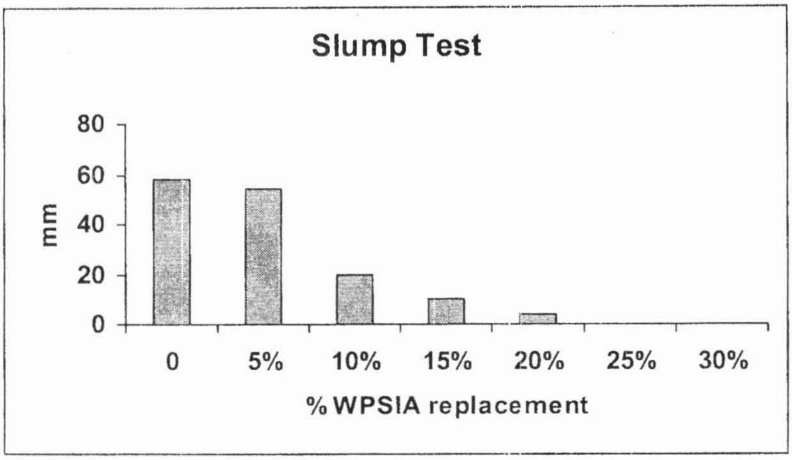

Fig. 1: Slump Test Values

Compressive Strength

The details results of compressive strength test at age 3, 7, 28 and 60 days for 0%, 5%, 10%, 15%, 20%, 25% and 30% replacement level of cement with WPSIA are presented in Table 3,4,5 and 6. The results for compressive strength test for six different concrete mixtures are also illustrated in Figure 2.

Table 3: The Average Results of Three Cube Tests for Five Different Concrete Mixtures for 3 Days

MIX	Compressive Strength (MPa) (3 Days)				Maximum Load (N) (3 Days)			
	1	2	3	AVERAGE	1	2	3	AVERAGE
0%	28.70	29.71	28.24	28.88	645.70	668.50	635.30	649.83
5%	29.81	28.14	29.30	29.08	670.80	633.10	659.30	654.40
10%	27.30	29.14	30.24	28.89	614.20	655.70	680.30	650.07
15%	25.44	27.11	27.45	26.67	572.50	609.90	617.60	600.00
20%	27.18	27.48	26.43	27.03	611.60	618.30	594.70	608.20
25%	26.88	26.81	26.59	26.76	604.32	603.17	602.00	603.16
30%	26.91	24.93	26.51	26.12	605.40	561.00	596.40	587.60

Table 4: The Average Results of Three Cube Tests for Five Different Concrete Mixtures for 7 Days.

MIX	Compressive Strength (MPa) (7 Days)	Maximum Load (N) (7 Days)						
	1	2	3	AVERAGE	1	2	3	AVERAGE
0%	34.28	36.50	35.96	35.58	771.20	821.30	809.20	800.57
5%	36.84	36.19	36.43	36.49	828.90	814.20	819.70	820.93
10%	35.23	36.23	33.62	35.03	792.70	815.10	756.30	788.03
15%	32.31	31.13	33.87	32.44	727.00	700.40	762.10	729.83
20%	31.21	31.66	31.48	31.45	702.30	712.30	708.20	707.60
25%	31.88	32.04	32.24	32.05	716.56	720.80	725.50	720.95
30%	30.05	30.14	30.03	30.07	680.33	698.01	679.14	685.83

Table 5: The Average Results of Three Cube Tests for Five Different Concrete Mixtures for 28 Days.

MIX	Compressive Strength (MPa) (28 Days)	Maximum Load (N) (28 Days)						
	1	2	3	AVERAGE	1	2	3	AVERAGE
0%	40.32	42.50	41.33	41.38	907.20	956.00	929.90	931.03
5%	42.25	42.23	44.32	42.93	950.50	950.20	997.20	965.97
10%	34.65	42.82	42.28	39.92	779.50	963.60	951.30	898.13
15%	38.19	40.22	39.45	39.29	859.30	904.90	887.50	883.90
20%	38.98	39.98	36.08	38.35	877.10	899.60	811.90	862.87
25%	38.05	37.96	38.30	38.10	833.26	820.56	843.51	832.44
30%	36.46	37.89	36.04	36.80	815.03	819.98	809.45	814.82

Table 6: The Average Results of Three Cube Tests for Five Different Concrete Mixtures for 60 Days.

MIX	Compressive Strength (MPa) (60 Days)	Maximum Load (N) (60 Days)						
	1	2	3	AVERAGE	1	2	3	AVERAGE
0%	42.90	41.97	44.06	42.98	965.30	944.30	991.30	966.97
5%	45.56	45.60	41.50	44.22	1025.00	1025.00	934.00	994.67
10%	45.15	42.22	45.00	44.12	1016.00	949.90	1002.64	989.51
15%	44.20	44.06	43.63	43.96	995.00	991.30	981.70	989.33
20%	40.55	41.37	34.85	38.92	912.40	930.90	784.00	875.77
25%	39.51	33.15	34.37	35.68	888.90	745.80	773.20	802.63
30%	36.44	32.33	34.23	34.33	816.00	719.13	770.46	768.53

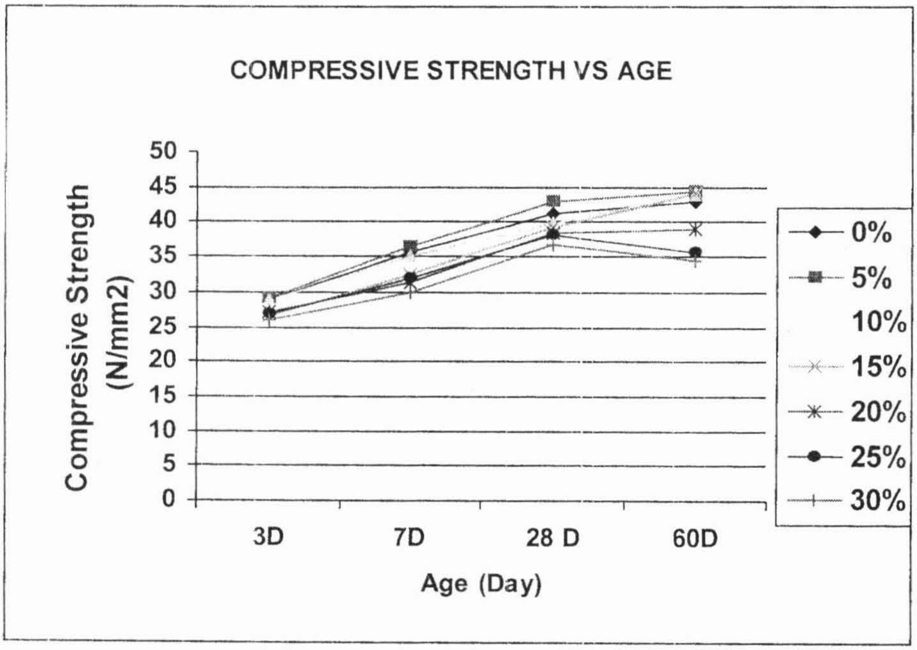

Fig. 2: The Development in Compressive Strength of Six Different Concrete Mixes

Discussion

The results indicate that the concrete mix with 5% replacement level with WPSIA to cement has higher compressive strength as that of control mix. While the concrete mix with 10% replacement level has a quiet similar compressive strength with control mix. As expected, as the cement replacement percentage increased, the compressive strength of concrete cubes decreased. However, up to 10% of Portland cement can be replaced by WPSIA without deteriorating the strength. In fact, the compressive strength of the 5% and 10% WPSIA cubes consistently exceeded that of the control cubes from an early age of three days. It is important to note that 5% of replacement, the absorb loading and rate for waste paper sludge incinerator ash is low compared to 15%, 20%, 25% and 30% of replacement. It also because level of cement and waste paper sludge incinerator ash have more relate with each other on 5% mix. Other replacement level such as 15%, 20%, 25% and 30% regardless of the age and the compressive strength are below than control mix. Although 30% of waste paper sludge incinerator ash using in concrete mix is become easy to harden because the rate of water absorb is very high. It is important to note that 30% proportion is the maximum value that can be replace as cement.

At age 3 days, the concrete mix with 30% replacement of cement with waste paper sludge reduced by 9.56% of the control mix in terms of compressive strength. At age 7 days, the concrete mix with 30% replacement of cement reduced by 15.49% of the control mix. While at age 28 days, the concrete mix with waste paper sludge incinerator ash reduced by 11.07% of the control mix and at age 60 days, the concrete reduced by 20.13% of the control mix.

A considerable reduction in strength occurs for WPSIA replacement level beyond 20%. Clearly, this inferiority in strength because of a lower cement content. It also indicated that there was no pozzolanic activity because of a delayed gain in strength as the cubes matured.

The experimental results presented in this study suggest the potential of WPSIA as a cement replacement material. With strength contributing and nontoxic characteristics, the use of WPSIA may be technically and environmentally feasible. However, low compressive strength might be attributed to the high ability of waste paper sludge incinerator ash to absorb water. The concrete mixes with waste paper sludge incinerator ash were observed as a dry mix and hardly bound.

Conclusion

The test results clearly indicate that the waste paper sludge incinerator ash with 5%, 10% and 15% cement replacement is a suitable percentage to replace cement in the concrete. Conversely, other percentages of replacement are not suitable for replacing the cement and it produces a lower of compressive strength, as compared to control mix. In general, the waste paper sludge incinerator ash is potentially attractive as cement replacement for the production of concrete.

Future Recommendation

Further investigation is necessary to study the effect of water cement ratio on compressive strength. Some additional additives may be required to enhance setting time of concrete. However this study can be investigate with addition of admixture or superplasticiser to enhance workability, strength and durability of the concrete

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