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Leachability of Heavy Metals of Interlocking Block made from Wastewater Sludge, Fly Ash and Cement

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***Abstract*: This research was conducted to study of the leachability of heavy metals in the interlocking blocks made from wastewater sludge binding with fly ash and cement. Dried sludge from wastewater treatment plant of Bangkok Metropolitan Administration mixed with fly ash, cement and tap water was used to different ratios of mixtures (weight by weight) as 4:1:1, 4:3:1 and 4:4:1 (cement, fly ash and wastewater sludge ratios). After that, this mixture was used to make interlocking blocks. All the interlocking blocks were cured for 7 days and tested for compressive strength by the method of TIS 109-2517 and leachability of heavy metals by the method of Waste Extraction Test (WET). The results of the compressive strength for the ratios of 4:1:1, 4:3:1 and 4:4:1 were 6.77, 10.82 and 11.77 MPa, respectively. The leachabilities of Cadmium in those ratios were 2.282, 0.993 and 0.267 µg/L, respectively. For the Chromium, they were 203.496, 103.064 and 98.421 µg/L, respectively. Whereas, those for Lead were 1.251, 0.616 and 0.282 µg/L, respectively. Finally, the leachabilities of Arsenic were 84.433, 53.182 and 26.277 µg/L, respectively. The compressive strength for all three ratios of the interlocking blocks was met the Thai Community Product Standard (≥ 2.5 MPa). The leaching concentration of heavy metals was also not over the Standard of Thai Ministry of Industry. Results suggest that the three ratios can be used to produce interlocking block.**

***Keywords*: wastewater sludge, fly ash, interlocking block, heavy metals, leachability.**

1. INTRODUCTION

At present, the Din Daeng wastewater treatment plant have had the capacity of treating wastewater 350,000 cubic meters/day [1]. In 2022, approximately 2,718 cubic meters of sludge were produced [1]. This amount of wastewater sludge can seriously cause many environmental problems. Although, there are various methods to remove the sludge such as disposing in the sanitary landfill, or burning in the incinerator but they are costly.

Moreover, fly ash, the residue from the infectious waste burning, is capable of creating environmental problems as well. It can be clearly seen in the Krungthep Thanakom Co.,Ltd who has currently provided the infectious waste collection more than 2,329 health service places in Bangkok and disposed of in the incinerator [2]. This large amount of infectious waste was noted with the average of 814 tons / month [2]. All collected infectious wastes have been routinely disposed in the incinerator and a lot of fly ashes were daily produced. These fly ashes, considering hazardous waste, must finally disposed safely in the secure landfill which is also quite expensive.

Thus, attempts have been made to utilize both the sludge and fly ash not only to reduce environmental pollutions but also increase the efficiency of natural resource use. This research was therefore conducted to explore an alternative method to utilize and minimize both wastes in the environment. For this reason, the aim of the study was to determine the utilization of wastewater sludge and fly ash to make interlocking block together with the cement binder. The compressive strength and

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leachability of heavy metals from the block were then determined. The outcome of this experiment will be expected to help the reduction of the cost of final waste disposal and the present production interlocking blocks as well as the minimization of their impacts in the environment.

2. MATERIALS AND METHODS

Preparation of samples

Wastewater sludge sample: Wastewater sludge was spread out on a clean plastic bag. Then, this sludge was allowed to dry under the sunlight. After that, the sample was allowed to air-dry, next it was crushed, using a crusher machine. Sample was then sieved using the 4 mm. sieve (No. 5 sieve). The sieved materials were homogeneously mixed and kept in the clean plastic bag until use.

Fly ash sample: Fly ash were crushed, using a crusher machine. The sample was sieved using the No. 20 sieve. The sieved materials were homogeneously mixed and kept in the clean plastic bag until use. **Procedure and analytical method:** The interlocking block at ratios 4:1:1, 4:3:1 and 4:4:1 of cement, fly ash and wastewater sludge ratios (weight by weight) of materials was determined for the compressive strength by pressing under the compressive machine. The finished interlocking block have the size 13.0 x 24.0 x 14.0 cm. (width x length x height). This interlocking block was allowed to air dry in the civil engineering laboratory for one day. Lastly, the interlocking block was allowed to cure for 7 days. The interlocking blocks [Figure1] were cured for 7 days were brought for the compressive strength test (Method of TIS 109-2517) [Figure 2] and the leachability of heavy metals test (Waste Extraction Test according to Ministry of Industry Notice,2005) [3].

Figure 1: Finished Interlocking Block

Figure 2: Compressive Strength Test

Figure 3: Waste Extraction Test

Statistical Analysis: The compressive strength and leachability of heavy metals of the interlocking blocks each different ratios at curing times of 7 days were analyzed using the One-way ANOVA. The significant level was determined at $p \leq 0.05$. The multiple comparison by LSD (Least Significant Difference) test were used to separate the different means.

3. RESULTS AND DISCUSSIONS

The result of compressive strength by interlocking block with different ratios as 4:1:1, 4:3:1 and 4:4:1 of cement, fly ash and wastewater sludge ratios were 6.77, 10.82 and 11.77 MPa, respectively, as shown in Table 1. The compressive strength of the interlocking block all of 3 ratios were met the Thai Community Product Standard (≥ 2.5 MPa)[3]. The compressive strength of interlocking block increased as the fly ash proportion increased. Because fly ash is pozzolanic material. Pozzolanic materials are chemical bond (covalent or Van der Waals bonds) which are the bond strength [4] affecting the strength of interlocking block.

Table 1: Compressive strength of the interlocking block

The ratios Cement : Fly ash : Sludge / compressive strength (MPa)	n	x̄	SD	F	*p*-value
4:1:1	5	6.77[a]	0.53	145.510	<0.001
4:3:1	5	10.82[b]	0.41		<0.001
4:4:1	5	11.77[c]	0.51		<0.001

Note: Different letters with superscript showed the significantly different in pair.

The Pozzolan chemical composition is Silicon dioxide and Aluminium oxide, etc. Pozzolanic materials (Silicon dioxide and Aluminium oxide) reaction with Calcium Hydroxide from hydration reaction between Portland cement with water. Their products are Calcium Silicate hydrate and Calcium Aluminates hydrate. Calcium Silicate hydrate and Calcium Aluminates hydrate have property for the binder similar to cement affect to the ability of the compressive strength more increased [4]. Reaction of fly ash was increased by the amount of its replacement in cement. Fly ash reacts with Calcium Hydroxide in cement. The products are Calcium Silicate Hydrate and Calcium Aluminates hydrate cause these compounds also increased, resulting the decreased size porous in the interlocking block. Consequently, the interlocking block had ratios of fly ash increased affect to the compressive strength increased [5],[6]. The result of this study agreed with previous investigators [5],[6] who found that the ratio of fly ash in the interlocking block increased as the compressive strength increased.

The Cadmium-leaching concentrations of interlocking block at the ratios 4:1:1, 4:3:1 and 4:4:1 were 2.282, 0.993 and 0.267 µg/L, respectively, as shown in Table 2. The highest concentration was 2.282 µg/L at the ratios 4:1:1. When the ratios of cement, fly ash and wastewater sludge were 4:1:1, 4:3:1 and 4:4:1, the Cadmium-leaching concentrations decreased as the portion of fly ash increased. The Cadmium- leaching concentrations all of 3 ratios were also not over the Standard of Thai Ministry of Industry (≤ 1mg/L) [7].

The Chromium-leaching concentration of interlocking block at the ratios 4:1:1, 4:3:1 and 4:4:1 were 203.496, 103.064 and 98.412 µg/L, respectively, as shown in Table 2. The highest concentration was 203.496 µg/L at the ratios 4:1:1. When the ratio of cement, fly ash and wastewater sludge were 4:1:1, 4:3:1 and 4:4:1, the Chromium-leaching concentrations decreased as the portion of fly ash increased. The Chromium-leaching concentrations all of 3 ratios were also not over the Standard of Thai Ministry of Industry (≤ 5 mg/L) [7].

The Lead-leaching concentration of interlocking block at the ratios 4:1:1, 4:3:1 and 4:4:1 were 1.252, 0.616 and 0.282 mg/L, respectively, as shown in Table 2.The highest concentration was 1.252 mg/L at the ratios 4:1:1. When the ratio of cement, fly ash and wastewater sludge were 4:1:1, 4:3:1 and 4:4:1, the Lead-leaching concentrations decreased as the portion of fly ash increased. The Lead-leaching concentrations all of 3 ratios were also not over the Standard of Thai Ministry of Industry (≤ 5 mg/L) [7].

The Arsenic-leaching concentration of interlocking block at the ratios 4:1:1, 4:3:1 and 4:4:1 were 84.433, 53.182 and 26.277 µg/L, respectively, as shown in Table 3. The highest concentration was 84.433 µg/L at the ratios 4:1:1. When the ratio of cement, fly ash and wastewater sludge were 4:1:1, 4:3:1 and 4:4:1, the Arsenic-leaching concentrations decreased as the portion of fly ash increased. The Arsenic-leaching concentrations all of 3 ratios were also not over the Standard of Thai Ministry of Industry (≤ 5 mg/L) [7].

Table 2: The leachability of heavy metals of the interlocking blocks

The leachability of heavy metals	The ratios Cement: Fly ash: Sludge	n	x̄	SD	F	*p*-value
Cadmium (µg/L)	4:1:1	5	2.282[a]	0.15	355.339	<0.001
	4:3:1	5	0.993[b]	0.13		<0.001
	4:4:1	5	0.267[c]	0.04		<0.001
Chromium (µg/L)	4:1:1	5	203.496[a]	11.44	118.40	<0.001
	4:3:1	5	103.064[b]	5.66		<0.001
	4:4:1	5	98.421[b]	16.84		0.558

Lead (mg/L)	4:1:1	5	1.251[a]	0.34	23.203	0.001
	4:3:1	5	0.616[b]	0.16		<0.001
	4:4:1	5	0.282[c]	0.12		0.039
Arsenic (µg/L)	4:1:1	5	84.433[a]	16.72	61.665	<0.001
	4:3:1	5	53.182[b]	7.36		<0.001
	4:4:1	5	26.277[c]	5.13		0.002

Note: Different letters with superscript showed the significantly different in pair.

The results showed that the leaching concentration of 4 heavy metals in 3 ratios of the interlocking block found that when the ratios of cement, fly ash and wastewater sludge were 4:1:1, 4:3:1 and 4:4:1. The leaching concentrations of heavy metals decreased as the portion of fly ash increased. This is probability because the hydration reaction of cement with water occurred. This reaction caused product to form Calcium Silicate hydrate which it had property storage heavy metals [6]. Addition of fly ash to replace cement in the interlocking affected to amount of Silica increased. When Silica reacted with Calcium Hydroxide in cement. Because the products contained the Calcium Silicate hydrate and Calcium Aluminates hydrate, they had property storage heavy metals. Reaction of fly ash increased by the amount of its replacement in cement was observed. The products are Calcium Silicate hydrate and Calcium Aluminates hydrate cause these compounds to increase. This will result in the increase of property storage heavy metals. The result of this study agreed with earlier investigator [6] who found that the leachability of heavy metals in the interlocking block decreased as fly ash proportion increased. While, other investigator [8] revealed that Pb and Cd–leaching concentrations in solidification increased when the ratios of bagasse ash decreased. The bagasse ash was pozzolanic materials to cause the reaction in the interlocking block.

4. CONCLUSION

The compressive strength decreased as the of wastewater sludge increased when compare to the same portion of fly ash while the compressive strength of interlocking block increased, followed by the portion of fly ash. The compressive strength for all three ratios of the interlocking blocks was higher than the Thai Community Product Standard (≥ 2.5 MPa). The ratio of cement: fly ash: sludge were 4:1:1, 4:3:1, 4:4:1. The leaching of heavy metals for all three ratios of the interlocking blocks were determined by Waste Extraction Test (WET), indicating that leaching concentration of heavy metals also not over the Standard of Thai Ministry of Industry for the leaching test. In addition, the interlocking block at the ratio 4:4:1 was better than the ratios 4:3:1 and 4:1:1.

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