

## Reuse Water Treatment Sludge for Hollow Concrete Block Manufacture

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**Abstract: Problem statement:** This research reuses the water treatment sludge from a water treatment plant to make hollow concrete blocks. The main objectives are to increase the value of the water treatment sludge from a water treatment plant and to make a sustainable and profitable disposal alternative for the water treatment sludge. Attempts were made to utilize the water treatment sludge as a fine aggregate in the concrete mix for hollow concrete blocks. **Approach:** This study presented the results of these studies on potential applications of the water treatment sludge for beneficial uses. A concrete block is used as a building material in the construction of walls. The concrete block construction is gaining importance in developing countries. **Results:** The results in this study showed that the water treatment sludge mixtures can be used to produce hollow non-load bearing concrete blocks, while 10 and 20% water treatment sludge mixtures can be used to produce the hollow load bearing concrete blocks. Economically, the 10 and 20% water treatment sludge mixtures can reduce the cost at 0.64 and 1.05 Thai baht per block, respectively. The 50% of water treatment sludge ratio in mixture to make a hollow non-load bearing concrete block can reduce the maximum cost at 2.35 baht per block. **Conclusion:** Finally, the production of the hollow concrete blocks mixed with water treatment sludge use as a fine aggregate in hollow concrete blocks, could be a profitable disposal alternative in the future and would be of the highest value possible for the foreseeable future.

**Key words:** Water treatment sludge, reuse, hollow concrete block, compressive strength

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### INTRODUCTION

Water treatment sludge is the sludge generated from the water treatment plant. Most of the water treatment sludge is used as land filling. In Thailand, there are many water treatment plants resulting in an increasing of sludge which in turn increasing problems in disposal. The final destination of water treatment sludge affects the environment. Since land is limited, alternative technologies to dispose of water treatment sludge are essential. Incineration may be a profitable alternative technology of disposal but the final disposal of a huge quantity of water treatment sludge ash would pose another problem (Jones *et al.*, 1977). Therefore, this study was conducted to investigate the feasibility of using the water treatment sludge for producing concrete aggregates and concrete products like hollow concrete blocks.

A concrete block is used as a building material in the construction of walls (Koski, 1992). It is sometimes called a Concrete Masonry Unit (CMU). The concrete block is one of several precast concrete products used in construction. The term precast refers to the fact that the blocks are formed and hardened before they are

brought to the job site. Most concrete blocks have one or more hollow cavities (Gambhir, 1995). Hollow concrete blocks are the most common types of concrete blocks, having one or more holes that are open at both sides. The first hollow concrete block was designed in 1890 by Harmon S. Palmer in the United States (Koski, 1992) where concrete blocks were first used as a substitute for stone or wood in the building of homes. A mixture of powdered Portland cement, water, sand and gravel are mixing to make concrete blocks (Koski, 1992; Gambhir, 1995; Neville and Brooks, 1987; Teychenné, 1978; Neville, 1991). A typical concrete block weighs from 17.2-19.5 kg. The concrete block construction is gaining importance in developing countries. Even in low-cost housing, it has become a valid alternative to fired clay bricks, stabilized soil, stone, timber and other common constructions. The ingredients are available locally and are of good quality. Concrete blocks are produced in a large variety of shapes and sizes, either solid cellular or hollow, dense or lightweight, air-cured or steam-cured, load bearing or non-load bearing and can be produced manually or with the help of machines. The most common concrete block size in Thailand is 90×190×390 mm.

The main properties of the most common type of concrete are: (a) high compressive strength, resistance to weathering, impact and abrasion; (b) low tensile strength; (c) capability of being molded into components of any shape and size and (d) good fire resistance up to about 400°C.

The use of concrete hollow blocks has several advantages: (i) they can be made larger than solid blocks; (ii) they require far less mortar than solid blocks and construction of walls is easier and quicker; (iii) the voids can filled with steel bars and concrete, achieving high seismic resistance and (iv) the cavities can be used as ducts for electrical installation and plumbing.

### MATERIALS AND METHODS

The manufacture of concrete blocks consists of four basic processes: Mixing, molding, curing and cubing (Koski, 1992). To reuse the dewatered water treatment sludge in a hollow concrete block manufacture, the experiments were set up as follow.

**Materials:** Water treatment sludge from a local water treatment plant is used in this research. It is first dried at 105°C before it is used as a fine aggregate in the concrete block mixtures. The water treatment sludge sample was taken for pH and conductivity analysis (Table 1).

**Mixture of concrete blocks:** The concrete commonly used to make hollow concrete blocks in this research is a mixture of powdered Portland cement, sand, waster treatment sludge, crushed stone dust and water. To find the suitable mixture of water treatment sludge, weight batching method was used. The hollow concrete mix proportion was designed in five different mixes. These were prepared using, fine aggregate partially replaced by water treatment sludge at varying percentages of 10, 20, 30, 40 and 50 as shown in Table 2.

**Curing procedure:** Specimens were cured in accordance with BS 1881: Part3: 1970 (BSI, 1970).

**Manufacturing process:** The dry materials are blended together in a pan mixer for several minutes. After blended, a small amount of water is added to the mixer. The concrete is then mixed for 6-8 min. The concrete is forced downward into the block molds. Later, the block structure was moved from the block mold and removed excess moisture from the block structure.

**Testing:** The water absorption and compressive strength of hollow concrete blocks were tested (Thai Industrial Standards Institute, 1974; KMUTT, 2009). The specimens were tested for compressive strength after 7, 14 and 28 days.

To test the water absorption, the specimens were dried at a temperature of 105°C for 72 h and this dry weight was designated as C. After final drying, cooling and weighing, the specimens were immersed in the water for 72 h. Then the specimens were taken out and their surfaces were dried by removing surface moisture with a towel and weighed. The final saturated-surface dry weight was designated as weight B. The absorption of concrete was calculated as follow (1):

$$\text{Absorption (\%)} = \frac{B - C}{B} \times 100 \quad (1)$$

To test the compressive strength, the point loading was used and the compressive strength was computed by using the following expression (2):

$$b_c = \frac{P}{A} \quad (2)$$

Where:

- $b_c$  = The compressive strength (ksc)
- P = The maximum applied load (kg)
- A = The area of specimen (cm<sup>2</sup>)

Table 1: Characteristics of water treatment sludge

Parameter	Water treatment sludge
pH	7.3
Conductivity (m sec cm <sup>-1</sup> )	3.2

Table 2: Proportion of mixture for hollow concrete blocks

Sample	Mixture (%)				
	Water treatment sludge	Sand	Crushed stone dust	Cement	Water
Mix 1	10	35	35	10	10
Mix 2	20	30	30	10	10
Mix 3	30	25	25	10	10
Mix 4	40	20	20	10	10
Mix 5	50	15	15	10	10

**RESULTS**

In this research, the amount of cement and water were kept constant for all mixes. Only the percentages of water treatment, sand and crushed stone dust are varied.

**Water absorption test:** Table 3 shows the results of water absorption test of the concrete produced by each mix after 28 days period. The tests were conducted 3 times for each concrete. The average value of 3 tests is shown in the Table 3.

**Compressive strength test:** Table 4 shows the results of compressive strength tests after 7, 14 and 28 days of Mix 1 to Mix 5 which are also graphically presented in Fig. 1. Figure 1 represents the average of three tests for each set (i.e., after 7, 14, 28 days). The compressive strength in Mix 1 to Mix 5 is 84.90, 52.35, 43.05, 37.23 and 27.92 ksc, respectively.

Table 3: Water absorption test results

Sample	Water absorption (%)
Mix 1	6.56
Mix 2	5.52
Mix 3	10.47
Mix 4	9.95
Mix 5	18.70

Table 4: Compressive strength test results

Sample	Average compressive strength (ksc)		
	7 days	14 days	28 days
Mix 1	83.74	82.58	84.90
Mix 2	48.85	50.01	52.35
Mix 3	38.38	41.87	43.05
Mix 4	34.89	73.22	73.23
Mix 5	25.59	26.75	27.92

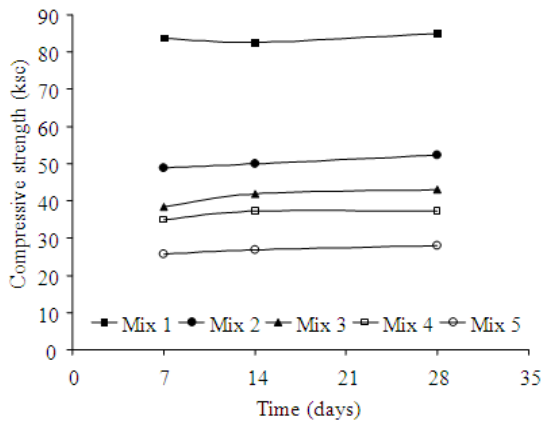


Fig. 1: Compressive strength of hollow concrete block with water treatment sludge

**Economic estimation:** The economic estimation for a hollow concrete block production in this work is shown in Table 5. The total capital cost, including the machine cost, the labor cost, the electricity cost and the material cost, is estimated for a production of 1,200 blocks per day. According to Table 5, the cost estimate of our water treatment sludge ratios shows a reduction of 0.64, 1.05, 1.48, 1.90 and 2.35 Thai baht per block for hollow non-load bearing concrete block production at 1,200 blocks per day for Mix 1, 2, 3, 4 and 5, respectively. For the hollow load bearing concrete block production, Mix 1 and 2 can reduce the cost at 0.64 and 1.05 Thai baht per block, respectively.

**DISCUSSION**

Results of water absorption test show that all of our water treatment sludge ratios pass the Thai Industrial Standards (TIS 109) which requires the level of water absorption to be lower than 25% (Table 3).

The Thai Industrial Standards (TIS 109) gives the minimum compressive strength for hollow load bearing and hollow non-load bearing concrete block as 50 and 25 ksc, respectively. The results showed that all of the water treatment sludge ratios (10%, 20%, 30%, 40% and 50%) pass the compressive strength test from the Thai Industrial Standards for hollow non-load bearing concrete block. While the 10 and 20% of water treatment sludge ratios also pass the minimum value of the compressive strength test for hollow load bearing concrete block from the Thai Industrial Standards (as shown in Table 4). It can be concluded that all of Mix (10%, 20%, 30%, 40% and 50%) can be used to produce hollow non-load bearing concrete block. Especially, the property of 10% and 20% of water treatment sludge ratios passed all the tests for hollow load bearing concrete blocks.

The costs estimated, compared to typical hollow concrete block production, are reasonable for the water treatment plant to manufacturing hollow concrete blocks from the water treatment sludge as the fine aggregate, where the alternative disposal options of water treatment sludge are extremely limited.

As a result, the disposal costs for landfill would be reduced. The reuse water treatment sludge for hollow concrete blocks will be the valid disposal alternative for the foreseeable future.

Table 5: Comparisons of manufacture costs for hollow concrete block

Item	Typical concrete block	Concrete block mixed with water treatment sludge				
		Mix 1	Mix 2	Mix 3	Mix 4	Mix 5
Sludge ratio (%)	-	10.00	20.00	30.00	40.00	50.00
Cement (baht/block)	1.57	0.45	0.45	0.45	0.45	0.45
Crushed stone dust (baht/block)	1.73	1.59	1.37	1.14	0.91	0.68
Sand (baht/block)	0.73	1.35	1.16	0.96	0.77	0.58
Electricity (baht/block)	0.70	0.70	0.70	0.70	0.70	0.70
Labor cost (baht/block)	1.00	1.00	1.00	1.00	1.00	1.00
Total costs (baht/block)	5.73	5.09	4.68	4.25	3.83	3.38

Assume: Production 1,200 block day<sup>-1</sup>, 2 workers Unit price: Machine 150,000 baht Crushed stone dust 650 baht m<sup>-3</sup> Sand 550 baht m<sup>-3</sup> Cement 188 baht/50 kg

### CONCLUSION

The following conclusions can be derived:

- About 10% and 20% of the water treatment sludge ratio in mixture to make a hollow load bearing concrete block can reduce the cost at 0.64 and 1.05 baht block<sup>-1</sup>, respectively
- 50% of water treatment sludge ratio in mixture to make a hollow non-load bearing concrete block can reduce the maximum cost at 2.35 baht block<sup>-1</sup>
- Dewatered water treatment sludge can be used for construction works such as hollow non-loading concrete blocks and hollow load bearing concrete blocks
- Production of various mixed ratio of hollow concrete blocks from dewatered water treatment sludge used as a fine aggregate in hollow concrete blocks, could be a profitable disposal alternative in the future and will be of the highest value possible for the foreseeable future

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