Environment friendly concrete block made from Portland cement and aggregate replacement materials

B Kaewsai[1,2], P Torkittikul[3] and A Chaipanich[1,4]*

[1] Advanced Cement-based Materials Laboratory, Department of Physics and Materials Science, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand
[2]Master Degree's Program in Materials Science, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand
[3] Department of Civil Technology, Faculty of Industrial Technology, Lampang Rajabhat University, Lampang 52100, Thailand
[4] Center of Excellent in Materials Science and Technology, Chiang Mai University, Chiang Mai 50200, Thailand

*Corresponding author's E-mail address: arnon.chaipanich@cmu.ac.th

Abstract. This research work investigated the properties of concrete block made from Portland cement and aggregate replacement materials. Portland cement (PC) was replaced by fly ash (FA) at 10%, 20%, 30% and sand was replaced by bottom ash (BA) at 10% by weight. Water was used at 7% by weight of total solid mass. Binder : Sand : Stone dust ratio of 1 : 5 : 6, 1 : 4 : 5 and 1 : 3.5 : 4.5 were used. Compressive strength were tested after curing in air for 28 days. The results showed that compressive strength of 1 : 5 : 6 ratio was lower than others. Concrete block replaced PC by fly ash had lower compressive strength when amount of fly ash increased. Concrete block had lower compressive strength when replaced sand by bottom ash. As a result, the mixes with FA as PC replacement and BA as sand replacement at the ratio of 1 : 5 : 6 did not meet the requirement of Thai industrial standard. However, concrete block with PC replaced by fly ash at 10%, 20% and sand replaced by bottom ash at 10% of 1 : 3.5 : 4.5 ratio was higher than 1 : 5 : 6 ratio and this ratio meet the requirement of Thai industrial standard.

1. Introduction

Industrial by-products with pozzolanic properties have been used as a binder material to partly replace Portland cement. Today the Portland cement manufacturing industry emits 8% of the global carbon footprint [1]. Therefore, efforts have been made to reduce the use of Portland cement and replace it with other materials that can also improve the properties of various concrete. Reducing the use of cement by using pozzolans as an alternative binder is one of the accepted and effective methods. Pozzolans material according to ASTM C618 standard is defined as "pozzolans material is a silica-based material, or silica and alumina as the main component. Pozzolan by itself does not have the ability to set and bind like Portland cement. But if there is enough moisture, it can react with calcium hydroxide at normal temperature and resulting in a compound that has the ability to bind (cementitious)" [2]. In the electricity generation industry from the coal power plant, fly ash and bottom ash is obtained as a by-product. The storage or disposal is a necessary process in this industry [3]. Efforts to replace Portland cement with fly ash have been attempted as fly ash can then be pozzolanic reaction. The product is a binder. Silica

or alumina in fly ash can react with calcium hydroxide under normal water and temperature conditions [4]. Then, it forms a binder that can be used as a replacement for cement, but the reaction takes place slowly. In general, the fly ash contains about 50% and 20% of the main components, namely silica and alumina, respectively [5]. While fly ash has been used more widely and is well known as a Portland cement replacement, bottom ash has not used in the same extent. In this work, a variety of mixes was used (FA was used to replace PC and BA was used to replace sand, different ratio liquid to solid was also used) to investigate the compressive strength compared to the industrial standard to determine the possibility of using the combination fly ash and bottom ash at a certain composition in order to meet the requirement of Thai Industrial Standard.

2. Materials and methods

2.1. Materials

Ordinary Portland cement from Siam Cement Group was used in this study. Fly ash and bottom ash are a by-product of electricity generation from Mae Moh coal Power Plant, Lampang Province, Thailand. Portland cement was replaced by FA at 10%, 20% and 30% by weight and sand was replaced by BA at 10% and 20% by weight.

2.2. Methods

2.2.1. Mixing. Binder to sand to stone dust ratio of 1 : 5 : 6, 1 : 4 : 5 and 1 : 3.5 : 4.5. Water was used at 7% by weight of total solid mass. Mixing for 60 s, then resting for 90 s and mixing again 60 s. All the ingredients are pressed into a concrete block mold, the size of which is width x height x length is 70 x 190 x 390 mm. according to Thai industrial standard.

2.2.2. Curing. Curing was the processed by which the hydration reaction of the cement continues. This will result in a hardened concrete block. In this study, concrete blocks were cured for 28 days in air.

2.2.3. Chemical technical methods. X-ray fluorescence (XRF) was used to determine the chemical composition of Portland cement and fly ash.

2.2.4. Physical technical methods. Compressive strength of concrete blocks were tested in accordance to Thai industrial standard 109-1974 [6].

3. Results and discussion

3.1. Chemical composition of Portland cement

Oxides in Portland cement are composed of two major groups the main oxides are CaO, SiO_2, Al_2O_3 and Fe_2O_3, which together comprise approximately 90% of the cement weight and the secondary oxide is MgO, Na_2O, SO_3, K_2O, TiO_2, P_2O_5 and gypsum. The various oxide content in Portland cement is expressed as a percentage by weight as shown in table 1.

3.2. Chemical composition of fly ash

The fly ash obtained from the Mae Moh coal power plant is class C, the compositions are shown in table 1. It was shown that fly ash from the Mae Moh coal Power Plant, Lampang Province, Thailand. contains silicon oxide (SiO_2), Alumina oxide (Al_2O_3), iron oxide (Fe_2O_3) and calcium oxide are 90.12%

Table 1. Chemical composition of Portland cement and fly ash by XRF.

Chemical composition	PC	FA
	%	%
SiO_2	19.13	37.26
CaO	64.47	19.46
Al_2O_3	4.98	20.64
Fe_2O_3	3.20	12.76
SO_3	3.23	2.35
MgO	1.88	2.65
K_2O	0.61	2.36
Na_2O	0.09	1.11
P_2O_5	0.06	0.21
TiO_2	-	0.44
MnO	0.01	0.11
Loss On ignition (LOI)	2.30	0.29
Specific gravity	3.15	2.1

3.3. Bottom ash as sand replacement

The results showed that the compressive strength of concrete block replaced sand by bottom ash lower compressive strength when amount of bottom ash increased. But the compressive strength of concrete block that used Binder : Sand : Stone dust ratio of 1 : 3.5 : 4.5 and replaced sand by bottom ash at 10% had the highest compressive strength for PC Mix as a result of increasing the ratio of cement to aggregates are shown in figure 1.

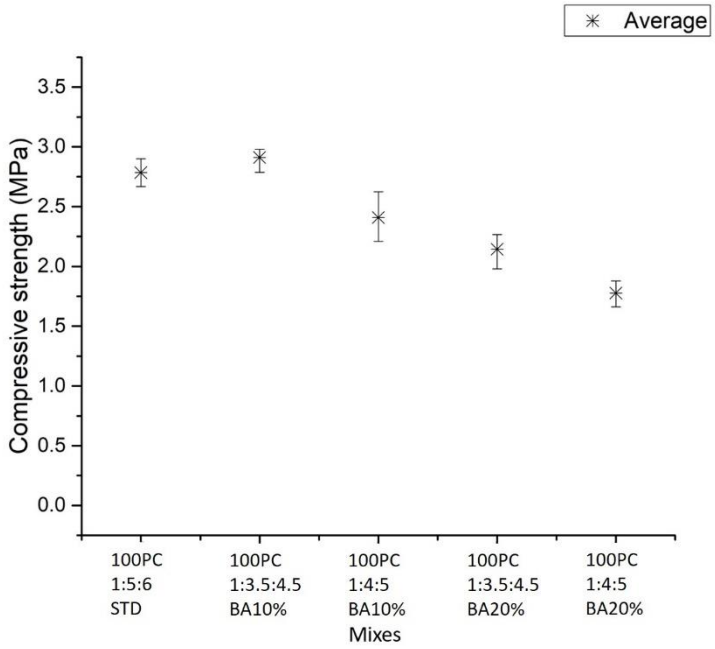

Figure 1. Compressive Strength of concrete blocks with Bottom ash as sand replacement.

3.4. Fly ash as PC replacement

As shown in figure 2, the results showed that the compressive strength of concrete block replaced by fly ash had lower compressive strength when amount of fly ash increased (70PC30FA) when compared to 100PC mix. However, concrete block with PC replaced by fly ash at 10% (90PC10FA) and 20% (80PC20FA) meet the requirement of the Thai industrial standard 58-1990 [7]. These mixes have compressive strength similar to 100 PC mix.

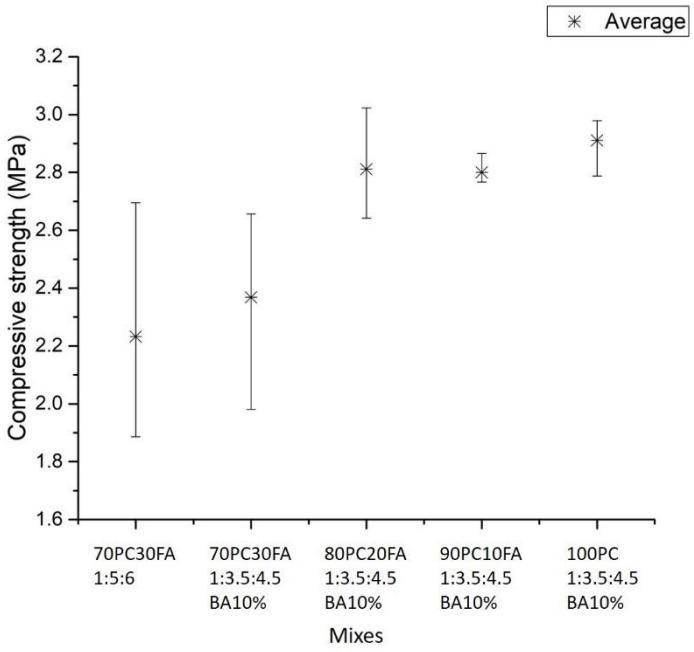

Figure 2. Compressive Strength of Concrete blocks with fly ash as PC replacement and bottom ash as sand replacement.

4. Conclusions

The results showed that concrete block that used Binder : Sand : Stone dust ratio of 1 : 3.5 : 4.5 and replaced sand by bottom ash at 10% by weight had the highest compressive strength for PC Mix and similar compressive strength were found in 10% and 20% fly ash mixes. From the results, fly ash can be used as a replacement for cement with fly ash up to 20% and bottom ash can be used as a replacement for sand at 10% by weight and meet the requirement of the Thai industrial standard 58-1990. For future work, the mixes will be analyzed using X-ray Diffraction (XRD) and Scanning Electron Microscope (SEM).

Acknowledgements

The authors are thankful to the members at the Advanced Cement- based Materials Laboratory (ACMRL). This research work was partially supported by Chiang Mai University.

References

[1] Robbie M A 2018 *Earth. Syst. Sci. Data* **10** 195

[2] ASTMC618-19 2019 *Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete 100* (West Conshecken, PA: American Society for Testing and Materials)

[3] Kayali O 2008 *Const. Build. Mater.* **22** 2393

[4] Goodarzi F 2006 *Fuel* **85** 1418

[5] Zhang M H and Gjorv O E 1991 *ACI Mater. J.* **88** 240
[6] TIS109 1974 *Standard for sampling and testing concrete masonry units* (Bangkok,Thai Industrial Standard Institute, Ministry of Industry)
[7] TIS58 1990 *Standard for hollow non-load-bearing concrete masonry units* (Bangkok, Thai Industrial Standard Institute, Ministry of Industry)