JOURNAL OF MATERIALS & CONSTRUCTION

Journal of Materials and Construction
ISSN 2734-9438
Website: www. jomc.vn

Study on using high-volume fly ash from Phu My thermal power plant to manufacture concrete bricks in infrastructure construction

Nguyen Thi Thu Thuy[1*], Nguyen Cong Hau[1]

[1] Campus in Ho Chi Minh City, University of Transport and Communications, No. 450-451 Le Van Viet Street, Tang Nhon Phu A Ward, Thu Duc City, Ho Chi Minh City, Vietnam

KEYWORDS

Fly ash
High-Volume Fly Ash Concrete (HVFAC)
Mechanical properties
Concrete brick

ABSTRACT

This paper presents the research results of using fly ash (FA) of Phu My thermal power plant with high content and southern raw materials to make concrete bricks in infrastructure construction. This concrete can achieve a 28-day compressive strength higher than 50 MPa. The mixing ratio to replace fly ash compared to the volume of binder is designed in 6 cases: concrete using 0 %FA; 30 %FA, 40 %FA, 50 %FA, 60 %FA, 70 %FA. With the fly ash content replaced at 0 %, 30 %, 40 %, 50 % compared to the tested binder, the 28-day-old concrete has an increased compressive strength from 55,2 MPa to 60,8 MPa; tensile strength when being split increased from 8,5MPa to 9,2MPa; the corresponding abrasiveness of concrete at the rate is 0,12; 0,20; 0,24 and 0,25 g/cm^2. With the replacement fly ash content at too high 60 %, 70 % compared to the binder, the values of these experimental parameters tend to decrease compared to the control sample. The study proposes that the reasonable mixing ratio of concrete is 50 % of cement, replaced by 50 % of Phu My fly ash, to simultaneously meet the criteria of workability, strength, abrasion, and cost.

1. Introduction

Annual fly ash in the world emits about 900 Mt (billion tons), of which India 169,25 Mt, China 580 Mt, USA 43,5 Mt, Vietnam is at 16 Mt. In the world, the reuse of fly ash on the total amount of ash is at an average level, for Vietnam, the utilization rate is not high and it takes hundreds of hectares to make a fly ash dump, causing a great impact on the environment. According to previous studies, fly ash is often used to partially replace the binder in concrete with the content usually limited to less than 30 %. Recent studies on fly ash have focused on making concrete with high fly ash content, which can replace fly ash up to 50 % for use in concrete for road pavements, or some other researches to replace fly ash; fly ash up to 60 % binder to make high strength concrete up to 60 MPa. Thus, the use of fly ash waste at thermal power plants to make concrete not only solves the problem of environmental pollution caused by burying fly ash, but also replaces a large amount of cement to help reduce cost of concrete, limiting CO_2 emissions causing greenhouse effect in the cement production process [1].

On the other hand, concrete bricks have been used to pave the streets of urban areas quite a lot in the Americas and Europe, bringing many advantages in construction. Today, Vietnam is a country that has a lot of demand for infrastructure construction, so the study of concrete bricks using a large amount of fly ash is highly practical [2].

This study designs high fly ash cement concrete composition for concrete bricks according to ACI211.1 Standard with cement replacement rate from 30 % to 70 % by mass with target compressive strength of 50 MPa. The technical requirements of concrete bricks with high fly ash content are assessed, including concrete mix hardness, compressive strength, tensile strength, and abrasion with high content of Fly ash replaces 30 to 70 % by weight of binder.

2. Experimental investigation

2.1. Material

The input materials used for the study are summarized in Table 1 [3].

2.2. Mix rate

Experimental study conducted to design concrete composition using high fly ash content with required compressive strength at 28 days of age is f'c = 50 MPa. Design of cement concrete composition using high fly ash as self-inserting concrete bricks for 6 cases: concrete using 0 %FA(M0), 30 %FA(MFA30), 40 %FA(MFA40), 50 %FA(MFA50), 60 %FA(MFA60), 70 %FA(MFA70).

Design concrete composition according to standard ACI211.1-91 [4] for normal heavy concrete. The control concrete mix (M0) does not use fly ash, does not use crushed sand, has the same composition as commercial concrete.

Data on mixing raw materials according to the ratios are presented in Table 2.

Corresponding author: thuyntt_ph@utc.edu.vn
Received 20/01/2022, Revised 25/2/2022, Accepted 05/05/2022
Link DOI: https://doi.org/10.54772/jomc.v12i01.328

Table 1. Characteristics of input materials.

No	Kinds	Name	Production place	Testing Standard	Properties
1	Fine aggregate	River Sand	Hau River Delta – An Giang	TCVN 7572:2006	Fineness Modulus of 1,4; Density of 2,60 g/cm^3; Unit weight by shoveling of 1320 kg/m^3; Porosity of 49,5 %.
2	Small aggregate	Crused Stone	Dong Nai Province	TCVN 7572:2006	Fineness Modulus of 3,8; Density of 2,65 g/cm^3; Unit weight by shoveling of 1530 kg/m^3; Porosity of 42,5 %.
3	Coarse aggregate	Coarse aggregate	Binh Duong Province	TCVN 7572:2006	Density of 2,70g/cm^3; absorption of 0,5%
4	Cement	Blended Portland Cement (PCB40)	Sai Gon Company	TCVN 6260:2009, ASTM C595	Density 3,15 g/cm^3; fineness (residual on 90μm sieve) 6,0 %; Compressive and flexural strength at 28 days 46 MPa; 5,5 MPa.
5	Fly ash	Phu My	Phu My Electrothermal Plant in Ba Ria- Vung Tau Province	TCVN 10302:2014	Complied with the requirements of F type Fly ash
6	Admixture	Viscorete V-3000-10	Sika	TCVN 8826:2011	Superplasticizers based on Polycarboxylate
7	Water	Tap water		TCVN 4506:2012	

Table 2. Composition of cement concrete using fly ash per 1 m^3.

N_0	Component material	M0	MFA30	MFA40	MFA50	MFA60	MFA70
1	Cement PCB40 (CM), kg/m^3	480	336	288	240	192	144
2	Fly ash (FA), kg/m^3	0	144	192	240	288	336
3	Dong Nai Crushed Stone (CS), kg/m^3	0	296	296	296	296	296
4	Fine Sand (FS) , kg/m^3	740	444	444	444	444	444
5	Binh Duong Coarse aggregate (CA), kg/m^3	1090	1090	1090	1090	1090	1090
6	Water (W), litter	160	160	160	160	160	160
7	Superplasticizer Admixture (Sup), l/m^3	4,8	4,8	4,8	4,8	4,8	4,8
8	Water Binder ratio (W/B)	0,33	0,33	0,33	0,33	0,33	0,33
	Vebe test for Concrete mix , (s)	25	22	20	15	17	18

2.3. Research Methods

In the study, experimental standards were applied: TCVN 7572:2006; TCVN 6260:2009; TCVN 10302:2014; TCVN 8826:2011; TCVN 4506:2012; ACI211.1-91; TCVN 3107:1993; TCVN 3118:1993; TCVN 8862:2011; TCVN 3114:1993; TCVN 6477:2011.

The fabrication and testing of concrete and concrete mixture samples complies with the requirements of Vietnamese standards and is conducted at the LAS-XD225 laboratory of University of Transport and Communications – Campus in Ho Chi Minh City.

3. Results and discussion

3.1. Properties of concrete mix

The hardness of the heavy concrete mixture is tested according to TCVN 3107:1993 [5]. Since the concrete mix is hard (slump of fresh concrete is zero), it is advisable to conduct a hardness test with a Vebe viscometer. The hardness of the concrete mixture is one of the main test in the shaping process of concrete bricks.

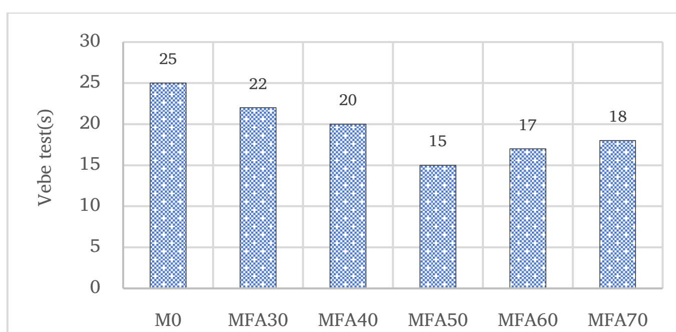

Figure 1. Relationship between hardness of concrete mix over time.

The results in Figure 1 show that, the higher the percentage of fly ash instead of cement in the concrete mix, the lower the hardness value (decreased sharply at the rate of fly ash 30 %, 40 %, 50 %, then increased) at the rate of fly ash 60 %, 70 %) the concrete mixture becomes more flexible when fly ash is replaced with cement. This can be explained that when replacing the same volume of cement by fly ash, the cement paste volume will increase (due to the higher density of cement than that of fly ash), the amount of binder paste increases, the paste layer will increase, surrounding aggregate particles increase, then the aggregate particles will slide over each other easily and increase the mobility of the concrete mix. In addition, fly ash has a spherical shape, smooth surface, equivalent or smaller size compared to cement particles, which will create a "rolling ball" effect that increases the workability of the concrete mixture when kneading [6,7, 8]. However, when the fly ash replacement rate is too high up to 60 %, 70 % will make the viscosity of the binder too large, this may be the cause of the decrease in ductility or the increased hardness of the concrete mix at these rates of substitution [9]. But this problem does not affect much to the technology of vibrating pressing in making concrete bricks.

3.2. Compressive strength

Compressive Strength is tested according to the standard TCVN 3118:1993 [10], casting a standard cube of 15x15x15 (cm). The results of determining compressive strength are shown in Table 3, Figures 2 and 3.

Table 3. Results of compressive strength at 3,7 and 28 days of age with the ratio of fly ash replacing cement.

No	Compressive strength (MPa)	M0	MFA30	MFA40	MFA50	MFA60	MFA70
1	Rc 3 days	43,1	34,9	33,4	31,6	24,3	19,3
2	Rc 7 days	49,7	45,7	40,6	40,1	31,1	24,2
3	Rc 28 days	55,2	60,1	59,7	60,8	48,6	40,3

Figure 2. Test of compressive strength of concrete.

The compressive strength of all samples using fly ash was lower than that of the control samples at 3 days and 7 days early. Specifically, the compressive strength of 3 days old compared to 28 days old of concrete using fly ash at the ratios of 30 %, 40 %, 50 %, 60 %, 70 % is 58 %, 56 %, 52, respectively. %, 50 %, 48 % compared with the control sample is 78 %; The age of 7 days corresponds to the concrete samples using fly ash 30 %, 40 %, 50 %, 60 %, 70 % respectively 76 %, 68 %, 66 %, 64 %, 60 % compared to the samples for the samples. evidence is 90 %. But at the late age of 28 days, the compressive strength of concrete samples using fly ash was increased. Specifically, at 30 %, 40 %, and 50 % fly ash replacement concentrations, the 28-day Rn is 60,1 MPa, respectively; 59,7 MPa; 60,8 MPa is higher than the R28 day of the control sample of 55,2MPa. Only at 2 concentrations of fly ash replacement up to 60 %, 70 %, the 28-day Rn is only 88 % (48,6 MPa) and 73 % (40,3 MPa) compared with the 28-day Rn of the control sample (55,2 MPa). The results of this study are also consistent with the conclusions of [9,11,12,13]. Thus, at the replacement content of 50 % of fly ash, the highest 28-day Rn result was obtained, which is also quite suitable. The fact that the concrete samples using high fly ash content (60 %, 70 %) had a decrease in strength of Rn 28 days compared with the control samples and did not meet the requirements for making concrete bricks for the construction of the lower buildings. Urban strata (according to ASTM C936, the compressive strength of concrete must be above 55 MPa) can be explained that: when used as high fly ash over 60 %, the amount of cement used is very low, when That will not be enough $Ca(OH)_2$ to perform Pozelanic reaction with amorphous SiO_2 in fly ash to create CSH to help increase strength for concrete [12, 14].

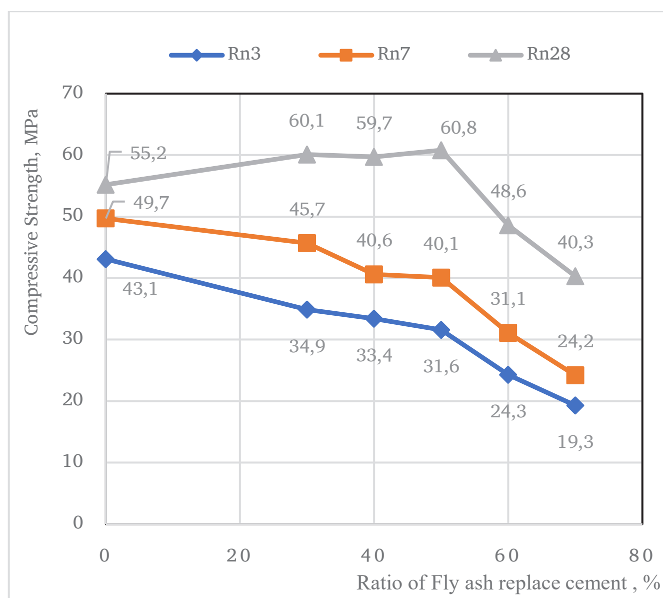

Figure 3. The relationship between Compressive Strength at 3,7, 28 days of ages with the ratio of fly ash replacing cement.

3.3. Splitting Tensile Strength

Splitting Tensile Strength is tested according to TCVN 8862:2011, casting standard cylinders [15]. The results of the Splitting Tensile Strength are shown in Figure 4 and Table 4.

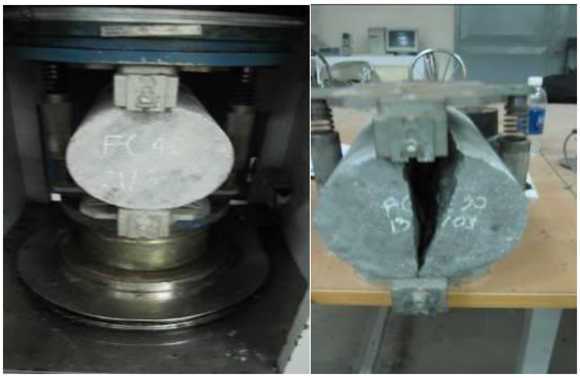

Figure 4. Splitting Tensile Strength Test.

Table 4. Results of Splitting Tensile Strength at 3,7 and 28 days of age with the percentages of fly ash replacing cement.

N_0	Splitting Tensile Strength (MPa)	M0	MFA30	MFA40	MFA50	MFA60	MFA70
1	R_{st} 3 days	6,4	6,2	6,0	6,1	4,7	3,8
2	R_{st} 7 days	7,7	7,3	7,2	7,4	5,6	4,4
3	R_{st} 28 days	8,5	8,9	8,8	9,2	7,3	5,8

Splitting Tensile Strength of concrete when replacing different proportions of high fly ash and the control samples were all satisfactory for making concrete bricks. According to ASTM C936, the compressive strength of concrete for pavement is 55 MPa or more, Splitting Tensile Strength is high compared to concrete of the same compressive strength level as prescribed, so it can meet requirements for concrete brick paving.

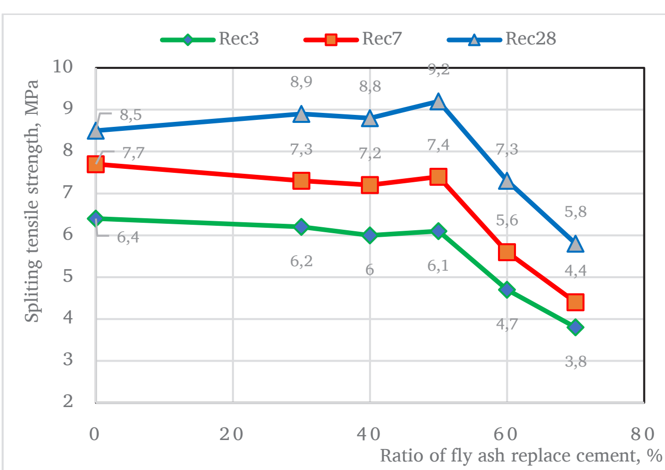

Figure 5. Relationship Splitting Tensile Strength at 3,7 and 28 days with the ratio of fly ash replacing cement.

The law of Splitting Tensile Strength development for concrete samples with fly ash replaced at different rates compared with the control samples at the early age of 3,7 days and the late age of 28 days are appropriate with the law of compressive strength development. At replacement content of 50 % fly ash gives the highest Splitting Tensile Strength (9,2 MPa). From Figure 5, it can be seen that the Splitting Tensile Strength of the concrete samples performed on the standard sample is greater than 4,5 MPa. So this concrete can be suitable for both 5 m long and 5 m wide cement concrete pavement slabs, not only for making concrete bricks with technical requirements according to the research.

3.4. Abrasion of concrete

Cube concrete samples with 7,07 x 7,07 x 7,07 mm in size were de-molded and placed under standard curing for 28 days in water. Testing the abrasion of concrete according to TCVN 3114:1993[16], the results as shown in Table 5.

Table 5. Experimental results to determine the abrasion with the fly ash replacement ratios.

N_0	Abrasion of concrete (g/cm^2)	M0	MFA30	MFA40	MFA50	MFA60	MFA70
1	Mn 28 days	0,12	0,20	0,24	0,25	0,35	0,40

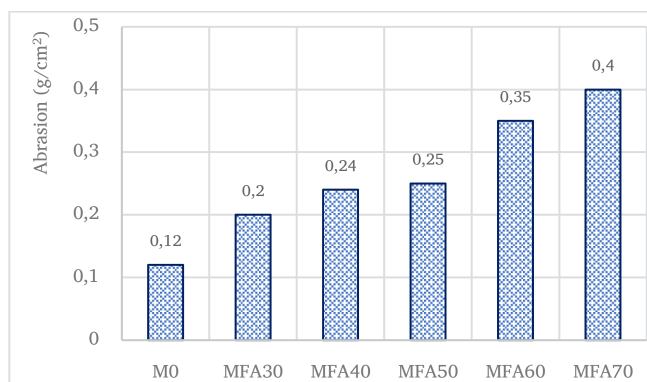

Figure 6. Effect of fly ash content on the abrasion of concrete.

The abrasion of the control concrete samples and the concrete samples using high fly ash with different replacement rates (Figure 6) shows that, as the fly ash replacement rate increases (from 30 to 70 %) the abrasion of concrete increases, that is, the abrasion resistance of concrete decreases. At the content of replacing fly ash 50 % of the concrete has suitable abrasion, not too high difference compared with the control sample. However, when the fly ash content replaces cement as high as 60 %, 70 %, the abrasion resistance is significantly reduced. But the results of abrasion at all ratios of fly ash replacing cement are satisfactory, less than the required level for concrete bricks, which is 0,5 g/cm^2.

4. Conclusion

With the main raw material source in the South, fly ash from Phu My thermal power plant can produce concrete with a compressive strength, greater than 50MPa with a large content of fly ash replacing cement up to 50 % to make concrete bricks for the construction industry urban infrastructure construction projects.

When the amount of fly ash replaces cement at 30 %, 40 %, and 50 %, it gives concrete better plasticity, compressive strength, Splitting Tensile Strength, and better abrasion resistance than concrete samples. witness. But when fly ash content replaces cement as high as 60 % or more, these properties of concrete are not better than that of the control sample.

The study proposes that the reasonable mixing ratio of concrete mix is 50 % of cement to be replaced by fly ash. This is a relatively high content of fly ash replacement, which helps to reduce the cost of concrete mix, but also meets the criteria of hardness, strength, and abrasion for this type of concrete brick.

References

[1]. C. Heidrich, H.-J. Feuerborn, A. Weir (2013), *Coal combustion products: a global perspective*, in: World of Coal Ash Conference.

[2]. C. Hua, X. Gruz and A. Ehrlacher (1995), "Thin sand concrete plate of high resistance in traction"*, Materials and Structures*, pp.550-553.

[3]. GS.TS Pham Duy Huu (2011), *Building materials Ebook, Transport Publishing House.*

[4]. ACI 211.1-91*, Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete.*

[5]. I. U.M. Bazenov, Bach Dinh Thien, Tran Ngoc Tinh (2004), *Concrete Technology,* Construction Publishing House.

[6]. Thomas, M. D. A. (2007). Optimizing the use of fly ash in concrete, volume 5420. *Portland Cement Association Skokie, IL.*

[7]. Bentz, D. P., Ferraris, C. F., Snyder, K. A. (2013). Best Practices Guide for High-Volume Fly Ash Concretes : Assuring Properties and Performance. Technical report, *U.S. Department of Commerce.*

[8]. Titarmare, A. P., Deotale, S. R. S., Bachale, S. B. (2012). Experimental Study Report on Use of Fly Ash in Ready Mixed Concrete. *International Journal of Scientific & Engineering Research*, 3:2–10.

[9]. Lâm, N. T., Linh, N. N., Nam, T. V., Kiên, V. D., Khải, T. V., Hieu, P. Đ. (2020). Effect of fly ash percentage replacing part of cement on the properties of commercial concrete. *Journal of Construction Science and Technology (KHCNXD) - ĐHXDHN*, 14(4V):96–105.

[10]. CVN 3118:1993*,* Heavy concrete - method for determining compressive strength.

[11]. Marceau, M. L., Gajda, J., VanGeem, M. G. (2002). Use of fly ash in concrete: Normal and high volume ranges. *PCA R&D Serial*, (2604).

[12]. Thomas, M. D. A. (2007). *Optimizing the use of fly ash in concrete*, volume 5420. Portland Cement Association Skokie, IL.

[13]. Mehta, P. K., Malhotra, V. M. (2004). *High-performance, high-volume fly ash concrete for sustainable development*. 2nd edition, Supplementary Cementing Materials for Sustainable Development, Ottawa, Canada.

[14]. Malhotra, V. M., M.-H., Z., Read, P. H., Ryell, J. (2000). Long-Term Mechanical Properties and Durability Characteristics of High-Strength/High-Performance Concrete Incorporating Supplementary Cementing Materials under Outdoor Exposure Conditions. *Materials Journal,* 97(5).

[15]. TCVN 8862:2011*,*Test procedure for determining the Splitting Tensile Strength of granular materials bound by binders.

[16]. TCVN 3114:1993, Heavy concrete - Method for the determination of abrasion.