Journal of Materials and Construction Vol 11 - No. 2 (11 - 2021)

JOURNAL OF VIETNAM INSTITUTE FOR BUILDING MATERIALS
ISSN 2734 - 9438 ISSN 1859 - 381X
Website: www.jomc.vn

Research on the use of fly ash to make reactive powder concrete

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KEYWORDS

Concrete
Reactive powder concrete
Fly ash

ABSTRACT

Reactive powder concrete is a type of concrete using materials with fine grains and high activity that can participate in chemical reactions in hydration process. Reactive powder concrete has a high compressive strength, usually greater than 100 MPa. However, such materialutilized in applicationsmust also go through selection and must be of good quality, i.e. high activity and fineness, and loss when heated. In this study, the use of locally available untreated raw materials such as natural sand, fly ash partially replacing cement for the fabrication of reactive powder concrete with a minimum strength requirement is examined and proposed.

1. Introduction

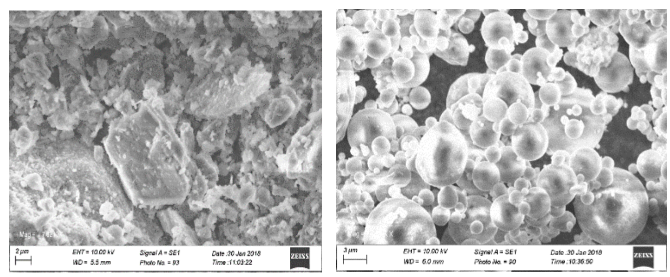
Reactive powder concrete is a type of concrete usingmaterials with fine grains and high activity that can participate in chemical reactions in the hydration process.,Reactive powder concrete exhibits high tensile strength (usually above 100 MPa [1]) and good resistance to fire [2-3] and negative external impacts [4].To produce reactive powder concrete, however, it is necessary to use a large amount of cement and silicon soot, leading to high costs, and the amount of heat generated during the hydration reaction is large, causingheavy concrete shrinkage phenomenon. To limit these shortcomings, previous studies have used fly ash [5-6], steel slag [6-8], or a combination of fly ash and steel slag [9-11] to reduce the cement content in the aggregate composition of concrete. The materials used must be well selected and of good quality such as high activity and fineness, and small heating loss, so production costs are still a matter of concern and to handle.

Due to the fact that the construction works in Vietnam require not too high tensile strength (less than 100 MPa) for concrete, this study proposes to use available materials at the local region (fly ash, natural sand) in the fabrication of reactive powder concrete to reduce production costs.

2. Materials and experimental programs

2.1 Materials

The material components employed to make the concrete mixture include cement, fly ash, sand, water, and superplasticizer. This study uses cementitious binders combined with fly ash; their physical and chemical properties shown in Table 1. Cement used is Nghi Son PC40 cement with density of 3.12 T/m^3. Fly ash is taken from Nghi Son thermal power plant, whichhas low CaO content, and total content (SiO_2 + Al_2O_3 + Fe_2O_3) is greater than 70 %. According to ASTM C618 [12], it belongs to group F fly ash. Note that, fly ash used in this study is crude fly ash (i.e. not yet selected), with a large amount of loss on ignition (15.76 %). The microstructure image of cement particles and fly ash is shown in Figure 1.



(a) (b)

Figure 1. Microstructure image of a) cement and b) fly ash

Table 1.
Physical and chemical properties of cement and fly ash.

Properties		**Cement**	**Fly ash**
Physical Quality	Private volume (T/m^3)	3.12	2.16
Chemical composition (% by weight)	SiO_2	22.38	48.38
	Al_2O_3	5.31	20.42
	Fe_2O_3	4.03	4.79
	CaO	55.93	2.80
	MgO	2.80	1.41
	Other	4.45	4.28
	Mass loss on calcination	1.98	15.76

The physical properties of sand are shown in Table 2. Fine aggregate is natural sand with fineness modulus of magnitude (M) 2.87, density (γ_o) 2.62 T/m^3, volume of natural dry volume (γ_t) 1.50 T/m^3, natural self

https://doi.org/10.54772/jomc.v11i02.283

Received 23/04/2021, explanation 10/07/2021, Accepted 29/07/2021

humidity (ω_m) 4.35 %, water absorption (ψ) 1.08 %. The grading curve of sand is shown in Figure 2. To reduce the amount of water with purpose of ensuring quality and increasing the workability of concrete, superplasticizer Sikament R4 with a density of 1.15 T/m^3 is used with a content of 1 % according to total binder content.

Table 2.

Physical properties of sand.

Aggregate	**Physical properties**				
	D_{max} (mm)	γ_o (T/m^3)	γ_t (T/m^3)	ω_{tn} (%)	ψ (%)
Smooth (sand)	5.0	2.62	1.50	4.35	1.08

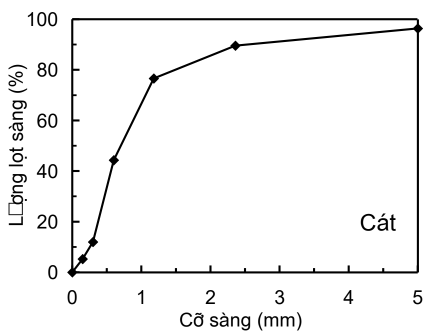


Figure 2. The grain grading curve of the sand.

In this research, the ratio of water-binder is 0.2, and 60 % of cement is substituted by fly ash.

2.2. Experimental program

- To determine the volume unit volume of the fresh concrete: Initially determine the mass of a cylindrical mold with a diameter of 10 cm and a height of 20 cm, m_k ; then put the concrete into the mold 3 times and make 25 compactions each time,which is similar to the test to determine the slump. Remove excess concrete from the mold mouth by flattening it, and the weigh to determine the mass of the sample (including mold and concrete): m_m . The volume unit mass of concrete is determined by the following formula (2-1):

$$\gamma_{bt} = \frac{m_m - m_k}{V_{bt}} = \frac{m_m - m_k}{\pi \frac{d^2}{4} h} \tag{2-1}$$

Note thatthe inner diameter of the cylinder, d = 10 cm; and the height of cylindrical mold, h = 20 cm.

- To determine flexural and compressive strength: Soak the concrete samples for curing in a water tank under normal conditions until being tested. Use concrete compressors and compressors Controls 300 tons as shown in Figure 3 to measure the flexural and compressive strength of concrete. Flexural and compressive strengths of concrete are determined according to ASTM C39 [13] at 3, 7, 14 and 28 days old. Experiment with 3 specimens each time and take the average value.

a- Flexural test

b- Compression test

Figure 3. Concrete strength test.

- Measurement of the ultrasonic pulse velocity in concrete: To evaluate the structural uniformity and relative quality of the concrete as well as the presence of pores and cracks, the ultrasonic pulse velocity measurement test in concrete was performed according to ASTM C597 [14]. In general, a high value in concrete reflects a relatively good consistency of concrete and thus corresponds to good quality concrete. According to a research by Malhotra [15], concrete has good quality when the ultrasonic pulse velocity in concrete measured is greater than 3660 m/s. Figure 4 shows the test of measuring the ultrasonic pulse velocity in concrete.

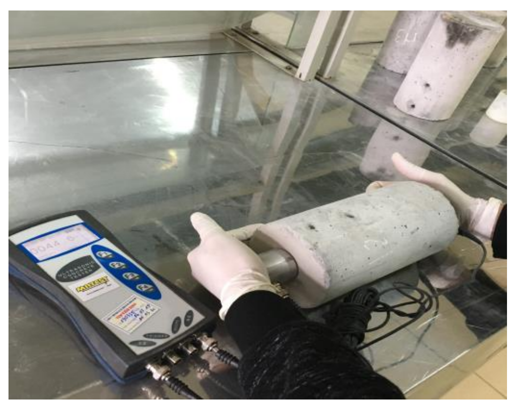


Figure 4. Testing of measuring ultrasonic pulse velocity in concrete.

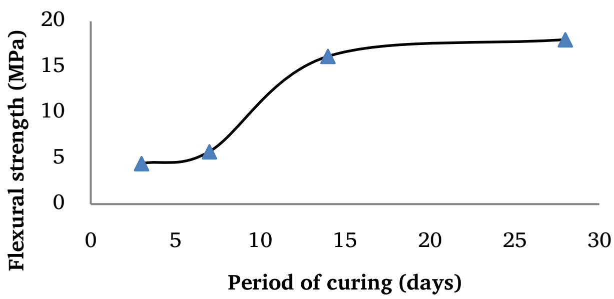
3. Results and discussion

3.1. Volume of fresh concrete

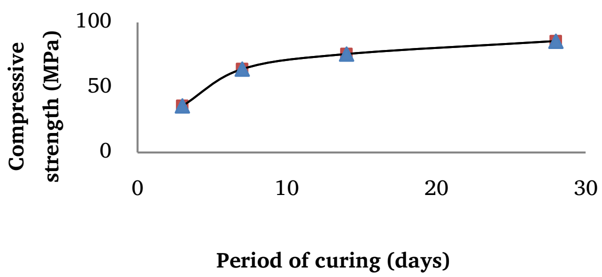
The experimental results show that the volume of fresh concrete of the aggregate in the study is γ_{bt} = 2.1055 kg/m^3 much smaller than the volume of conventional concrete. The reason is that the density of cement, 3.12 T/m^3, is greater than the density of fly ash, 2.16 T/m^3, (see Table 1), so with the same mass, the volume of ash is larger than the volume of cement . The increase of mortar volume leads to the increase of ductility and flowability, boosting workability of fresh concrete. Therefore, as the fly ash content increases, the slump of the concrete increases. This result is similar to the research result of Naik and Ramme [16].

3.2. Flexural and compressive strengths of concrete

Flexural and compressive strengths of concrete samples studied up to 28 days old are shown in Figure 5. The results indicated that the concrete aggregate in the study reached a flexural strength of 18MPa and a compressive strength greater than 85 MPa. This result was much higher than the strength of conventional concrete.



a- Flexural strength



b - Compressive strength

Figure 5. Strength of concrete.

3.3. Transfer velocity of ultrasonic pulses in concrete

The results of ultrasonic pulse velocity measurement showed that, with the gradation in the study at 28 days old, the ultrasonic pulse velocity was higher than 3600 m/s. This proves that the concrete quality in the study is quite good.

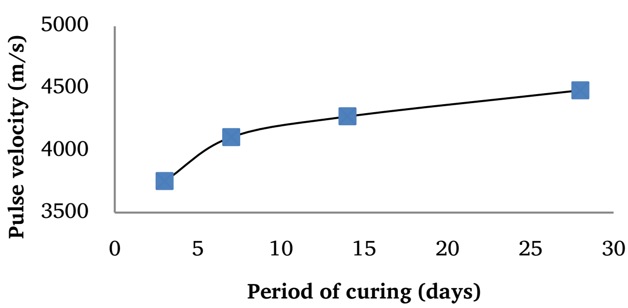


Figure 6. Ultrasonic pulses velocity.

4. Conclusion

In this study, when using locally available materials such as sand and fly ash to replace 60 % in weight of cement, together with the plasticizer additive, a reactive powdered concrete with high flexural strength (18 MPa) , and high compressive strength (> 85 MPa) was created after 28 days of age. The concrete has a large ultrasonic pulse rate, showing high structural uniformity. To be able to further assess the properties of concrete of this type as well as evaluate the compressive strength and flexural strength, it is necessary to conduct more tests on the ratio of water to the adhesive and likely a highercontent of fly ash replaced for cement in the future.

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