Tentative to use wastes from thermal power plants for construction building materials

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Abstract. Thermal power plants (TPP) generates wastes (bottom and fly ashes) which become a serious environmental problem in Vietnam. Indeed, although in several countries fly ash can be used for cement industry, fly ash from actual TPP in Vietnam does not have enough good quality for cement production, because the fly ash treatment phase has not yet included in the generations of existing Vietnamese TPP. That is why bottom ash and fly ash purely become wastes and their evacuation is an urgent demand of the society. This paper presents an investigation using fly and bottom ashes in the manufacturing of construction materials. The main aims of this study is to reduce environmental impacts of fly and bottom ashes, and to test another non-conventional binder to replace cement in the manufacture of unburnt bricks. Several proportions of fly ash, bottom ash, cement, gravel, sand and water were tested to manufacture concretes. Then, geopolymer was prepared from the fly ash and an activator. Specimens were tested in uniaxial compressions. Results showed that the cement concrete tested had the compressive strengths which could be used for low rise constructions and the material using geopolymer could be used for non-load-bearing materials (unburnt bricks).

1. Introduction

Thermal power plants (TPP) generates wastes (bottom and fly ashes) which become a serious environmental problem in Vietnam. Indeed, although in several countries fly ash can be used for cement industry, fly ash from actual TPP in Vietnam does not have enough good quality for cement production, because the fly ash treatment phase has not yet included in the generations of existing Vietnamese TPP. That is why fly ash and bottom ash purely become wastes and their evacuation is an urgent demand of the society.

On the other hand, to reduce environmental impacts in the construction factor, Vietnamese government has demanded to replace clayed burnt bricks by other more “green” materials and unburnt bricks are the current strategy adopted by construction companies. However, unburnt bricks still have several difficulties to find their places on the construction site in Vietnam, due to several reason: economic, environment, tradition. One of the main reasons is the use of important cement amount in the unburnt brick manufacturing (about 25% by weight), this increased both the manufacturing cost and the carbon footprint.

This paper presents an investigation on the use of fly ash and bottom ash from a Vietnamese TPP (Vinh Tan) in the manufacturing of construction materials. The compositions of these fly and bottom ashes are analyzed following ASTM standard 0 and the results are presented in Tables 1 and 2 [2]. The aim of this study is to reduce environmental impacts of fly ash and bottom ash which are actually considered as waste in Vietnam. Several proportions of fly ash, bottom ash, cement, gravel, sand and...
water are investigated to manufacture low strength materials which can be used for non-load-bearing walls.

2. Specimens manufacturing

2.1. Materials used

Gravels and sand are classical materials used for conventional concrete. The maximal diameters for sand and gravels are of 4mm and 20 mm, respectively. The optimum mix between Sand and Gravel was determined by using Dreux-Gorisse’s method [3], which gave a ratio of Sand/Gravel = 2/3 (by weight and volume).

The cement used was a current Portland cement, named PC 30, where a specified compressive strength at 28 days of the cement mortar (1 cement : 3 sand by weight) was 30 MPa. Because the scope of this study was to manufacture low-strength materials with reasonable costs, other higher quality cements were not tested.

The specific densities of the fly and bottom ashes used were determined following Vietnamese standard. Results gave mean densities of 2.26 and 2.24 respectively for fly ash and bottom ash. The fineness modulus of bottom ash was also obtained from sieving analysis, giving a value of 2.7.

2.2. Concrete materials using fly ash and bottom ash

First, a classical concrete was formulated, as a reference for the comparison. The reference concrete corresponds to a 450kg of cement in 1 m³ concrete. The composition of this referent concrete was calculated following the well-known Dreux-Gorisse’s method. The water was chosen (W/C=0.55) to give a plastic concrete with a slump value of 7 ± 1cm, which is the current value for current concretes. The result is detailed in Table 3. This reference case is named “18%C” (18% cement).

From this reference case, other compositions were tested by replacing one part of cement by fly ash and bottom ash. The following compositions were tested: 7% cement + 14% Fly Ash (called “7%C + 14%FA”); 7% cement + 28% Fly Ash (called “7%C + 28%FA”); 7% cement + 28% Fly Ash + 14% Bottom Ash (called “7%C + 28%FA + 14%BA”).

Specimens were manufactured in steel cubic 15 cm x 15 cm x 15 cm molds (Figure 1). It is well-known that cylinder specimens gave more realistic results [4] and the compressive strength obtained on cubic specimens should be multiplied by a corrector factor (about 0.9) to obtain the corresponding strength on cylinder specimens. However, cubic specimens were chosen because of the simplicity in their manufacturing and testing (no need of surfacing).

For each composition studied, nine specimens were manufactured: each three specimens were tested in uniaxial compression tests at 7, 14 and 28 days, respectively.
2.3. Geopolymer materials using fly ash and bottom ash

Geopolymer is a product in which amorphous three-dimensional inorganic structures are formed through the reaction of alumino-silicate precursor, with an alkaline activator solution [5]. Geopolymer can be used as a binder in concrete to replace the cement. Since the fly ash possesses alumino-silicate in its composition (Tab. 1), it is interesting to test if the fly ash can be used for the creation of geopolymer and therefore the replacement of cement may be possible [6], [7]. The activators are typically sodium or potassium hydroxides or silicates. In the present study, NaOH and Na$_2$SiO$_3$ were used as activator [8]. In the previous composition 7%C +14%FA, the cement was totally replaced by the activator (7% cement is replaced by 2%NaOH + 5% Na$_2$SiO$_3$). The values 2% and 5% were chosen to have the ratio Na$_2$SiO$_3$ / NaOH = 2.5 which is well known as an optimum ratio. So the composition tested was 14%FA + 2%NaOH + 5% Na$_2$SiO$_3$. It was observed in previous studies that for geopolymer, when the curing temperature increases, the compressive strength increases also. For this exploratory study, the specimens were cured in ambient conditions (in air), so the curing temperature was about 25°C. It is observed that the specimens manufactured with geopolymer had a colour darker than that of cement concrete (Figure 1).

2.4. Uniaxial compression tests

The specimens were tested at 7, 14 and 28 days after the casting, under uniaxial compression test (Figure 2). The loading rate was of 0.1mm/min. For each composition and at each moment of test, three specimens were tested.

Figure 1. Cubic specimens: concrete specimens (on the right) have clearer colour than specimens with geopolymer (on the left).

Figure 2. Uniaxial compression test on cubic specimens.
3. Results

For each three specimens tested, the mean compressive strength were calculated and the obtained results are presented in Figure 3 and Figure 4, respectively for the case of concrete specimens (with fly and bottom ashes) and specimens using geopolymer.

From Figure 3, the mean compressive strength of the referent case (18% cement) after 28 days was about 30 MPa. It is worth noting that in this study, no plasticizer was used, if a plasticizer was used, the water/cement ratio could be reduced and therefore the compressive strength obtained could be better.

**Figure 3.** Compressive strengths of cement concrete using fly and bottom ashes.

From Figure 3, it is also observed that the compressive strength of all specimens increase following the time, from 7 days to 28 days. It is interesting to observe that the compositions 7%C + 14%FA and 7%C + 28%FA have similar compressive strengths after 28 days and these compressive strengths are about 21-22 MPa. These values can be used in Vietnam for concrete of individual houses where in many cases the specific compressive strength is only of 7.5 MPa or 11.5 MPa.

**Figure 4.** Compressive strengths of specimens using geopolymer.
Figure 4 presents the comparison between specimens using cement (7%C + 14%FA) and specimens using geopolymer. It is observed that geopolymer specimens has also the compressive strength increasing following the time, between 7 and 28 days. However the compressive strengths of the geopolymer specimens were relatively low (12 MPa at 28 days), compared to conventional concrete. So this material can be used for non-load-bearing material (bricks for example) but not for structural material (concrete). When this material is used for brick application, the temperature if the curing can be increased to improve its mechanical properties.

4. Conclusions and outlook
This paper presents an investigation using fly ash and bottom ash which are actually the wastes in Vietnam, in the manufacturing of construction materials. The first scope was to reduce the environmental impacts of these wastes and the second scope was to formulate non-conventional materials having low embodied energy by using less cement than the conventional concrete or current unburnt bricks. Several proportions of fly ash, bottom ash, cement, gravel, sand and water were investigated and finally two types of materials were selected to study in detail: the cement concrete with low quantity of cement, by using fly ash and bottom ash; the geopolymer concrete by replacing the cement by geopolymer, which is established from fly ash. The results showed that cement concrete using fly and bottom ashes had satisfying compressive strength for small construction projects (for example individual houses) while the mixes with geopolymer could only be used for non-load-bearing material (unburnt brick for example). The low compressive strength of the mixes with geopolymer could explained by the low quality of the ashes used, which is the general case for ashes from Vietnamese TPP. The effects of the curing temperature on the mixes with geopolymer will be investigated in the further studies. Further studies at the microscale of materials to investigate the potential reactions of fly and bottom ashes will also be interesting.

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