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Experimental study on thermo-mechanical properties of Polymer Modified Mortar

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ABSTRACT

This paper presents the results of an experimental program devoted to the study of Polymer Modified Mortars' (PMM) thermal conductivity, thermal diffusivity and calorific capacity at different temperatures and compressive and flexural strengths at room-temperature. For this purpose, Ordinary Mortar (OM) and PMM samples with different contents and through partial substitution of Portland cement were prepared. A real improvement of the PMM thermal properties was observed in comparison with those of OM despite the decrease of mechanical strength. X-rays Diffract Meter (XDM), Differential Scanning Calorimetry (DSC) and Scanning Electron Microscope (SEM) were also conducted to show the interaction of the polymer material considered.

1. Introduction

Amongst all the materials used in construction, concrete using Ordinary Portland Cement (OPC) still the most largely used material in the world and since the early 18th century, and the second after water [1]. Cement is largely used in the preparation of concrete and the demand of this material is in continuous growth to meet the needs of society in terms of housing and buildings construction. The popularity of concrete using OPC can be attributed to its simplicity in preparation and its easy availability. However, the cost of cement is in continuous growth despite the danger it causes to public health and environment. To cope with this problem, plastic wastes such as High Density Poly-Ethylene (HDPE) can be used as partial substitutes to OPC and considered as sustainable building material. Incorporating polymers in mortar and concrete has contributed to propose new structural materials such as Polymer Modified Mortars (PMMs) and Polymer Modified Concrete (PMC) [2]. Several studies were conducted to describe the potential of using polymers in the concrete technology. The use of PMM and PMC in specific applications such as damaged concrete, protecting constructions can, to some extent and by their versatile applications, contribute to this excessive demand.

In the past, researchers used industrial or plastic wastes such as glass [3] or fiber [4] in the preparation of self-consolidating concrete. Nowadays, the re-use of PET wastes seems to be an appropriate solution in the development of new formulations of building materials such as concrete. PET wastes were extensively used in laboratory programs. During the last two decades, studies on the use of PET wastes in concrete technology and construction materials [5] were largely undertaken. In line with this research, Albano et al. [6] and Benosman [7] studied the use of PET in composite polymers. In those studies, Albano investigated the mechanical behaviour of recycled concrete using PET and varying W/C ratio (W/C = 0.5 and 0.6). On his side, Benosman added several percentage of PET by partial substitution to Portland cement. He studied the mechanical effects and the durability of modified mortars. Many researchers were concerned with industrial products such as silica fume [8–10] and nano-silica [11–13] but others rather studied thermal conductivity and mechanical strength [14–19]. Among those researchers, Xing et al. [15] concluded that it is within the cement paste that the main phenomena of dehydration and expulsion of moisture took place and lead to concrete deterioration. They reported that, at high temperatures, the behaviour of concrete or cement is strongly dependent upon the properties of cement paste.

Many experimental programs were conducted on polymers in the world. However, none of those studies (to the authors' knowledge) were concerned with thermal conductivity, capacity and diffusivity effects on PMM and PMC. Also, Algeria is one of the countries in the world in which the quantity of household wastes is about 8.5 million tons per year (0.75 kg per inhabitant and per

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year) and is in continuous increase. In the city of Algiers this reaches 1 kg per inhabitant and per year. In Algeria and all over the world, the use of packed products has induced an increase in dumped plastic wastes and a difficulty of their removal from grounds. In addition, in this country, polymer materials are hardly used as construction materials and in both research and applications of PMM and PMC, Algeria is still far behind most countries. It was therefore an opportunity for the authors to initiate research in the field of these types of polymer-based concretes.

The study presented in this has a two-fold purpose: (i) to study the thermal and mechanical properties of the different PMM samples under different temperatures; (ii) to show the interaction of polymer matrix using X-rays Diffract Meter (XDM), Differential Scanning Calorimetry (DSC) and Scanning Electron Microscope (SEM). For both purposes, the Poly-Ethylene used was ground and partially substituted to Portland cement. The behaviour of PMM samples at various temperatures and the evolution of thermal properties under temperature increase were undertaken and measurement of conductivity, calorific capacity and thermal diffusivity were performed using the Quickline-30 equipment which is described below. For the mechanical properties of the PMM samples, compressive and flexural test were also performed at room-temperature (20 °C).

2. Materials

2.1. Polyethylene

The HDPE used is a powder ground grains type provided by EQUATE Petrochemical Company (5KSCC) of Koweit with a diameter less than 0.5 mm, as shown in Fig. 1. It is used for fabrication of plastic bags. The main properties of this HDPE are reported in Table 1 and the Differential Scanning Calorimetry (DSC) is shown in Fig. 2.

In order to show the degradation of HDPE under the effect of temperature, DSC analysis is considered. DSC analysis is carried out using a NETZSCH DSC-204F1 apparatus. The HDPE sample is placed in an aluminum crucible and is considered as a reference to aluminum. The values are recorded under a helium atmosphere and a speed rate of 5 °C/min. For this material, the melting point occurred at 124.9 °C as shown by the endogenous peak on Fig. 2. One can also see that deterioration begins at 300 °C. Also, to evaluate the conductivity, capacity and thermal diffusivity, under the effect of temperature and according to HDPE thermogramme, temperatures of 20 °C, 140 °C, 250 °C and 350 °C were considered.

Fig. 1. Photograph of an amount of HDPE passed through a 0.5 mm sieve.

Table 1
Chemical and physical properties of HDPE.

Shape	Powder
Melting temperature (°C)	118–138
Ignition temperature (°C)	349
Density at 20 °C (g/cm^3)	0.94–0.97
Solubility in water	Insoluble
Thermal conductivity at 23 °C (W m^{-1} K^{-1})	0.33

2.2. Adjuvant

The blending agent used is AETERNUM-3 superplasticiser coming from a TECKNACHEM company in Sidi Belabbes (west of Algeria). This adjuvant is mainly made of carbon, silicate and new powder generations infused in active nano-micro silicates. This type of adjuvant connects with a high pouzzolanic activity of the nano-micro silicates and assures rheology, fluidity with no segregation and permeability. 3% of AETERNUM-3 is added to the cement weight. This addition allows the preparation of mortars and concretes with reduced W/C ratios. The physical and chemical properties of this AETERNUM-3 superplasticiser are reported in Tables 2 and 3, respectively.

2.3. Cement

Portland cement type (CEM I/42.5) was used for the preparation of samples. This type of cement resists to sulfates and the chemical

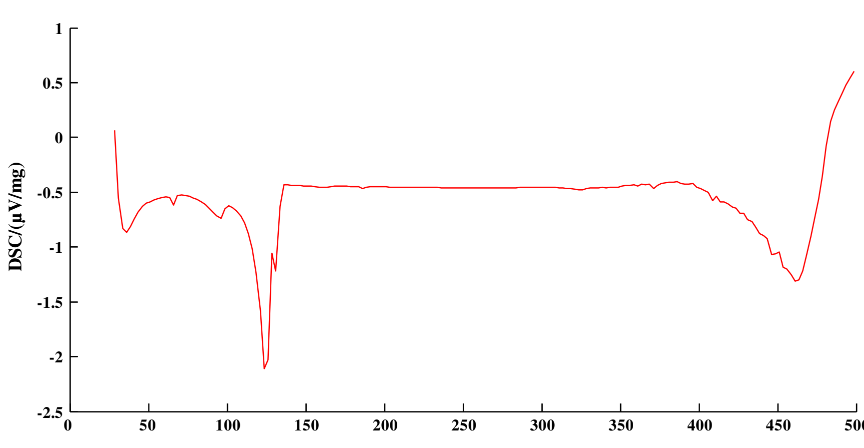

Fig. 2. Differential Scanning Calorimetry (DSC) of HDPE.