International Journal of ChemTech Research
CODEN (USA): IJCRGG, ISSN: 0974-4290, ISSN(Online):2455-9555
Vol.11 No.01, pp 01-06, 2018

Characterization of Cementitious Polymer Mortar – Polyethylene Composites

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Abstract : The aim of this study is the design, fabrication and experimentally characterization of polymer mortar (PM) such as polyethylene (PE). PE is used in packaging like plastic bag, plastic films, geomembranes, containers including bottles, etc, but rarely used in a composite or concrete. In this paper polyethylene has been very successfully applied to forming polymer mortar due to its good specific strength and low density. A series of laboratory experiments were investigated in the cement manufacturer in Morocco: LafargeHolcim Oujda. So In this study a portion of cement was replaced by polyethylene powder, with three different dosages (5%, 10%, 15% and 20%).During the first phase, physical and mechanical properties of these blended cements were determined (e.g. water demand, expansion and mechanical performance).The second phase included mechanical tests concerning the specimens of these blended cements in a temperature ranging from 25 up to130 °C.The results showed that thermal cycle increased and enhanced strength potential of the polymer mortar.
Keywords : polymer mortar, polyethylene, thermal cycle, strength potential.

Introduction and Experimental:

Researchers are more focused on the compressive and bending strengths of a Polymer Cement PC. The use of polymer as partial replacement for Portland cement in blended cements and concrete has become almost unavoidable due to energy-saving concerns and other environmental considerations [1-2]. Thermoset composites present a three-dimensional intertwined structure that complicates the recovery of the initial materials through conventional methods, as the reaction is not reversible. They present optimal behavior in terms of corrosion and wear, and electrical insulation properties [2-3-4]. Prominent among its disadvantages are its difficulty to be recycled and its poor flame-retardant properties [3-4]. The optimum formulation of the PC depends of the homogeneity of polymer with cement. At present, they are considered embryonic technologies in need of further technological development. In fact, it is necessary to validate the extrapolation of the laboratory results on an industrial scale, before these innovative products may be considered real alternative treatments [5-6].

Polyethylene is a lightweight, a viscoelastic and a thermoplastic material[7]. There are many different kinds of polyethylene, usually called polythene, and abbreviated to PE. Its chemical formula is $(C_2H_4)_n$.So it is a polymer of ethene, with a variable value of n, which can be low or extremely high (millions), producing solid materials at room temperature, with various physical properties[8].

Common PE is a mixture of such polymers. They are all classified as being thermoplastics, because, if they are heated steadily, they become soft and capable of plastic deformation, before they melt. On cooling they become hard again. The temperature at which this happens depends upon the value of n, and their average chain length, and also upon their molecular structure - whether they are amorphous, crystalline or semi-crystalline[9].

Polyethylene is usually classified into groups according to their density which can theoretically range from855 to 1000 kg/m^3. Each of these polyethylene groups has its own performance characteristics with different thermal, physical and rheological properties[10].Itstypical applications are containers, film, appliances, packaging, household goods,automotive,electrical, electronic and industrial applications. It is resistant to concentrated acids, alkalis and many organic solvents[9-10].

The objective of this investigation is to study the influence of adding PE on the properties of cement. Moreover the Effect of thermal cycle on the mechanical strengths of the PC was tested.

Research of utilization of PE as a partial cement replacement in CEM 42,5 N was used on reparing of 4 experimental mixturesby adding to CEM 42,5 N thepolyethylenepowder as shown in fig.1 up (5%, 10%, 15% and 20%).The chemical and physical properties of PE used are determinate in table1. The four different cements were tested in pastes and mortars according to European Norm to determine their physical and mechanical characteristics.

Fig 1: polyethylene powder

Table 1: chemical and physical properties of PE used

composition	$[C_2H_4]_n$contains traces of antioxidants
appearance	Natural, slightly white powder
particle size	<500µ
solubility	Insoluble in water
density	938 Kg / m³ (Solid)
bulk density	0.37 g/cm³
melting point	130 °C
boiling point	300 °C
Tensile strength at yield	10 MPa
Flexural modulus	750MPa

Standard consistency and setting times of cements were determined using aVicat apparatus according to the European standard EN 196-3[11]. The expansion was measured according to the LeChatelier method. Compressive strength measurements were conducted at the ages of 2, 7, and 28 days on mortar specimens (dimensions 40×40×160mm) prepared and tested in accordance with the European standard EN 196-1[12].

Specimens are preparedaccording to dimensions40×40×160 mmin Fig.2.After 28days,the specimens were exposed to the thermal cycle: 25°C to 70°Cfor 1 h and 70°C to 130°Cfor 3 h.The temperature stability over time for the cooling system is 10°C/min and for the heating system is 5°C/min. The compressive tests are immediately carried out after removing the specimens from the chamber by the experimental procedure.

Fig 2: mortar specimens (dimensions 40× 40 ×160 mm) prepared to test mechanical strength

Results and Discussion

1- Effect on water demand and setting times:

As presented in table 2for all blended cements, the water consistency increased with the percentages of replacement of PE, it could attributed to the high specific area of blended cements and the very small PE particles, which has been suggested as the cause of the increase of water consumption. However, the initial and final setting times were shorter with the percentages of replacement of PE; it could be attributed to the insolubility of PE powders in water whichfavors the drying of the paste of cement.

Table 2: water demand and setting times of cements mixtures

Cement	WD (%)	Initial setting time (min)	Final setting time (min)
C1(0% PE)	25	145	245
C2(5% PE)	25,3	140	240
C3(10% PE)	25,7	134	235
C4(15% PE)	26.3	130	230
C5(20% PE)	26.8	126	220

Table 3: expansion tests

Cement	Exp (mm)
C_1(0% PE)	2.65
C_2(5% PE)	2,18
C_3(10% PE)	1.7
C_4(15% PE)	1,3
C_5(20% PE)	0.3

2-Effect on LeChatelier expansion:

We noticed, as presented in table 3the expansiondidn't increase with the increase of PE rate.

The soundness and expansion tests are well correlated with the free lime content of clinker.So free lime (fCaO) reacts with water, and releases a rapid increase of volume (about 1,8 times) due to the formation of Ca $(OH)_2$ which is accompanied with an effective expansion. [13-14-15].Thus conclude that contents of below 20% of PE over total weight caused no expansive reaction at all.

3-Effect on compressive strength:

The compressive strength of Portland cement is the main property characterizing its classification and influencing its quality[16-17-18-19].

Hydration of cement is a sequence of overlapping chemical reactions between clinkercomponents, mineral additives, calcium sulphate and water, leading to continuous cementpaste stiffening and hardening[20-21-22-23].

According to the results of tests in compressive strength in table 4, we noticed that adding 5% of PE to the cement had no significant development of strength but a replacement of 10%of PE had a decrease of 16% of strength at 28days.A 35% decrease in compressive strength was noted with a replacement of 15%of PE, and it reduced by 66% with a substitution of 20% of PE.

It could supposed that the grains of cement of an incompatible combination with PE see their movement decreased and that their displacement to the others grains during the hydration is difficult because of strengths of friction created by the grains of PE.Thus the grains of cement are relatively too much taken away from each other to influence really the rheology of the paste and it is necessary to wait for some time so that the first products of hydration begin to interfere with the free movement of the grains of cement.

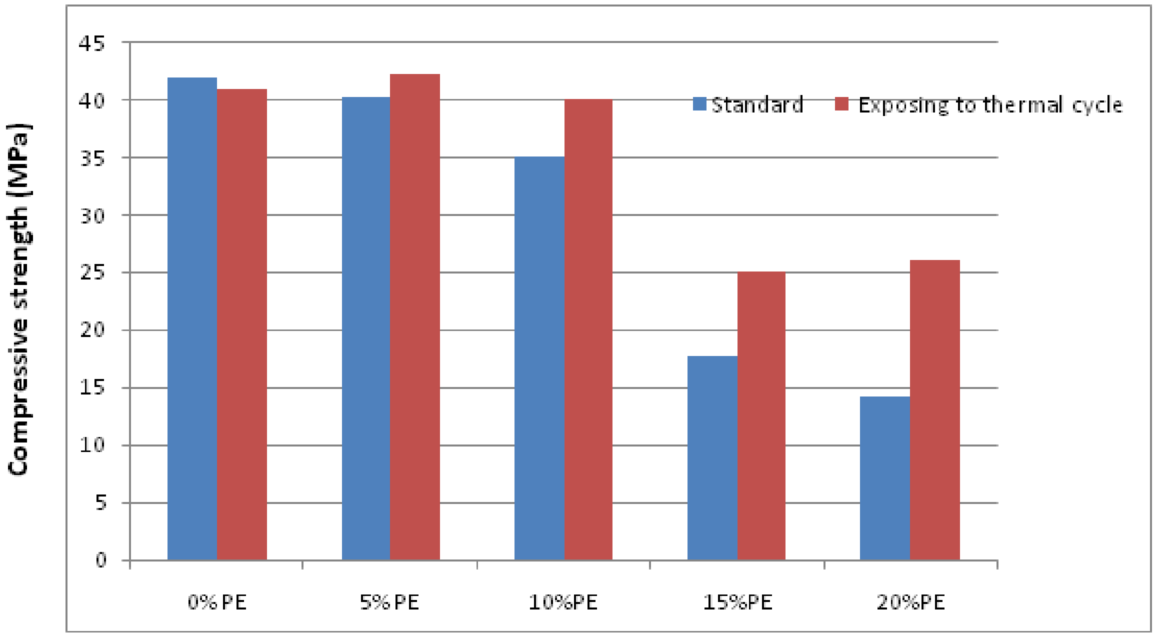

Fig 3: Effect of thermal cycle on compressive strength of blended cements

Table 4: compressive strength

Cement	compressive strength (MPa) at 2 days	compressive strength (MPa) at 7 days	compressive strength (MPa) at 28 days
C_1(0% PE)	22.53	33.31	41.91
C_2(5% PE)	21,7	32	40.3
C_3(10% PE)	16.6	26.59	35.16
C_4(15% PE)	7.46	11.5	17.69
C_5(20% PE)	5.54	8.11	14.26

Table 5: compressive strength after thermal cycle

Cement	compressive strength (MPa) at 28 days
C_1(0% PE)	41.02
C_2(5% PE)	42.3
C_3(10% PE)	40.16
C_4(15% PE)	25.13
C_5(20% PE)	26.06

As shown in tables4 and 5 and fig .3,exposing to thermal cyclehad no significant influence on the strength of the reference cement,while compressive strengths of the proposed formulation rise neatly as the temperature increases.

This is due to thermoplastic property of polyethylene which significantly changes with increasing the temperature up to the melting point. As the temperature was raised, PE forms a layer after the evaporation of the water and the melting by coalescence of the particles of polymer. The layer acts as an organic binder, to be adhered as thermoplastic with diverse substrates of mortar, and contributes to development of the strengths of the structure of mortar and favor an excellent adhesion to cement.

Conclusion:

The laboratory investigation described in this paper focused on the effects of polymer PE as an additive for cement. The analysis was divided into two main phases: the first one was dedicated to the evaluation of the effects of different dosages of polymer PE on the corresponding mixtures by using physical and mechanical characteristics tests. The second one aimed at evaluating the effects of thermal cycle on polymer mortarby increasing temperature environments in order to benefit from its total potential in strength.

Based on the results reported in this paper, the following conclusions can be drawn:

- The addition of low dosage (e.g. 5%) of polymer PE does not significantly affect themechanical strength but with medium and high dosages (e.g. 10 % and 15%) show a rise of water demand and a reduction in compressive strength.
- Mechanical performance is reduced neatly with very high rate of polymer PE (20%).
- The reference cement (without polymers) specimens look their stress quite similar after thermal cycle.Increasing the temperature does not result in this yield point because the mobility of dislocations is already compromised to begin with.
- The thermoplastic and viscoelastic properties of PE which significantly appear with increasing the temperature up to the melting point,thus,PEguaranteed same benefits in strength.

Acknowledgements:

The authors would like to thank the personnel of quality control department of LafargeHolcim Oujda - Morocco for the technical assistance.

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