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The effect of nature the granulate on the evolution of the thermal conductivity of an resin concrete exposed to high temperatures

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Abstract. *The knowledge of the thermal conductivity properties of concrete is essential in studying the behavior of concrete at high temperatures. This knowledge is so essential to feed the thermal behavior patterns and correctly simulate the temperature field developing in a concrete element in any type of heating. In this context, this work aims to follow the influence of the nature of the granulate on the evolution of the thermal conductivity of epoxy-based concretes. The experimental results obtained show that the mineralogical nature of the granulate great affects the conductivity of the concrete.*

Key words: resin concrete, the granulate, high temperature, thermal conductivity

1. Introducere

With a world production concrete is the most widely used material particularly in construction buildings hospitals roads industrial plants producing power plants this means that today would be unable to meet the needs of construction without concrete to a simple question of availability of raw materials on the planet[1].

It is essential that all concrete must continue to perform its intended function, that is to say, keep its desired strength and functionality during the lifetime specified service. It follows that the concrete is to be capable of resisting the physico-chemical deterioration process to which is estimated to be exposed. Thus, a concrete that offers a remarkable resistance to aggression when properly dosed and implemented is said to be durable. The durability of the materials used in civil engineering, is the discount in a question by the ageing of these materials, ageing provoked by the climatic constraints, pollution, etc [2].

To overcome to some disadvantages of hydraulic concretes, the use of the composites concrete-polymer the material, proves very interesting on everything that these "new materials" arouse renewed interest [3] thanks to their remarkable quality compared to conventional building materials [4] in the field of civil engineering. Indeed, the incorporation of the polymers in concretes and mortars obviously produces materials similar to ordinary cementitious concretes but with superior characteristics [5].

The cementitious matrix can be replaced in part or in whole by an organic matrix, a resin, and by the consolidation of the cementitious binder hydrated by these resins [6]. The resulting concrete is known as the Anglo-Saxon denominnation" Concrete-Composite Polymer." These concretes are also known under the name of "concrete-polymer" generally classified into three classes [7]. Among these classes, only the concrete known as "resin concrete» (PC Concrete Polymer) will be investigated in this study. The Resin concrete is a composite whose binder consists entirely of a synthetic organic polymer sometimes thermoplastic but generalement thermosetting and whose skeleton consists of mineral filler (granulate).

The behaviour at the high temperatures and fire the resin concrete is very important when used as facing material or for interior decoration. Although, the polymer element is flammable concrete products do not burn easily, because they contain a strong mineral charge. At the moment the bad resistance to fire and high temperatures of resin concretes and their relatively high cost compared to that of hydraulic concretes constitute the brake major on their development [7].

The first objective of this study is then to optimize the constituents of the concrete studied to meet mechanical criteria of use in service at high temperature and under aggressive environment. In order to improve the fine resins concrete at high temperatures, adding additions to the development of flame retardants or flame retardants may be beneficial while ensuring reasonable mechanical performance. By themselves so the second goal of this work is to analyze the influence of the nature of the aggregates on the evolution of the thermal conductivity at high temperatures.

2. Experimental procedure

2.1. Used materials

The choice of materials in general and the resin in particular is a very important step to be able to develop a resinous concrete, which responds to the constraints among which is figure the need to have an almost complete polymerization at ambient temperature between the basic components (pre-polymer and hardener) which must be sufficiently reactive in this temperature range (generally between 05 ° C and 35 ° C). Other conditions such that the consistency of the resin, the polymer properties after crosslinking and their compatibilities.

Three types of gravel (G_1, G_2 and G_3) and a sand rolled siliceous single (S), common to all formulations studied concretes, and differing in their mineralogical nature were tested. (Figure 1 and 2) corresponds to the diffractograms obtained by X-ray diffraction of a powder of sand and gravel aggregates respectively. The siliceous granulats (S and G_1), havemineralogies similar, being off from the same quarry.They consist mainly of quartz in the close proportions (between 52% and 59%) and feldspar (36% to 38%) then side element (micas and chlorites). Granite is distinguished by an upper amount of feldspar (48%) relative to quartz. It also contains more mica (11%) and chlorites than relative to granulate siliceous. Limestone granulats are materials enclosing carbonates unlike granite and siliceous ones.

The spectra show the presence of the peaks relative to the calcium carbonate element (CaO_3) and the absence of the peaks characterizing the silica (SiO_2), an absence which can be attributed to the small proportion of this element present in the setting of trial. It is constituted nearly only of carbonates, mainly of calcite 94% and a small proportion of dolomite, 6%.We note some traces of quartz and micasOnly one type of cement was used in this study. It is a Portland cement CEM I 52.5N of medium setting.Tensile tests [EN 196-3] and mechanical compressive strength were also performed on the cement paste and on the standardized mortar [EN 196-1] in order to check the quality of the cement used [EN 196 -3].

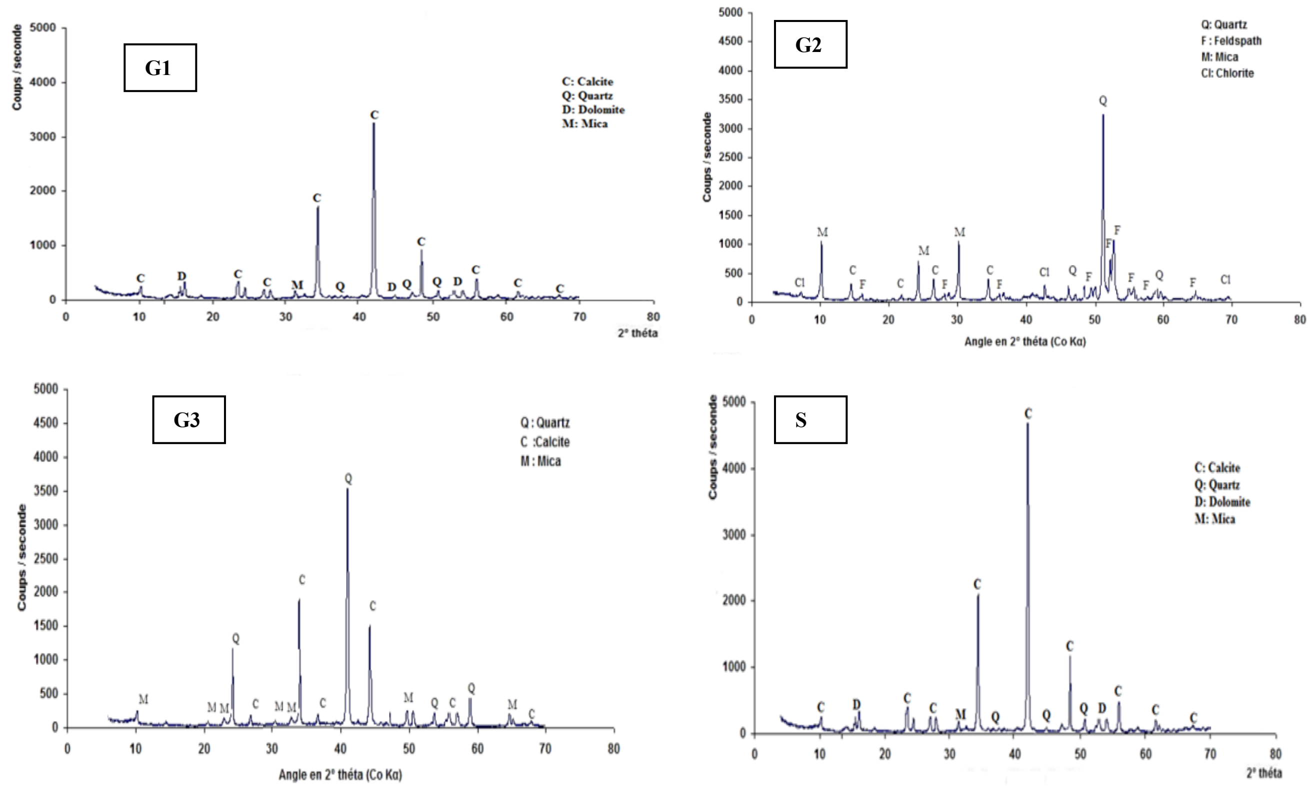

Fig.1: Diffractometer diagram of aggregate used.

The epoxy resin used in this study is issue a mixture of Eponal 371V1 resin and hardener of the same denomination. A super-plasticizer type Cimfluid 3020, based on modified plycaboxylates, was used to ensure satisfactory plasticity of the different formulations without varying the amount of binder paste relative to that of the granular skeleton. This adjuvant, in accordance with the standard [EN 206-1], has a density of 1078 kg / m^3, a dry extract of 30.81% [NF EN 480-8] and a viscosity of 59 cps at 25 ° C. The recommended dosage varies from 0.2 to 2.5 kg per 100 kg of cement a mineral flame retardant was used the pure polymer concrete fireproofing.

2.2. Formulation and implementation of concrete

Before proceeding with the actual manufacture proper of the resin concrete, preliminaries steps are necessary to obtain a product identical to itself and to minimize the effect of the elements related to the state and the quality of the incoming materials. in the composition of the resin concrete to be manufactured and as well also to the method of manufacture

The constituents must therefore be stored under favorable conditions according to the instructions of the manufacturer or the rules of the state of the art .Indeed, granulats should be dried at 105 °C, for more; 24 hours and the resin must be stored in the room at temperature-controlled.

The measurements were performed on samples 7x7x28 cm^3 dimensions. The prismatic moulds were filled on three layers, and each layer received 40 shots with a metal bar. This phase is moving by the levelling of the upper surface of the specimens, with a rule according to saw movement Demolding of the samples are conserved in the room controlled at temperature and humidity (25 ° C and 50% RH), until a maturity of the experimental tests. The surfaces of the samples have been rectified with a diamond disc, to get two surfaces enough that were sufficiently level so that there was as little air as possible between the probe and the samples.

2.3. Thermal cycle

In this study, we applied a hot heating cycle the ambient temperature to 25°C until exposure temperatures (bearing) equal to 105 ° C, 150 ° C, 200 ° C and 250 ° by means of an oven. These exposure temperatures are defined from DSC and TGA analysis of virgin polymer, the component most sensitive to temperature compared to other components.

The specimens were placed in an oven in a way allowing the heat to be distributed homogeneously in the enclosure with a ventilation system. A K type thermocouple is placed in contact with the surface of a control sample and another is embedded in the center in order to determine changes in temperature. Measurements of thermal conductivity of concrete studies were performed according to the following steps:

- ✓ Measurement of the thermal conductivity at room temperature. The measurement was performed three times with a regular time interval of 45 min.
- ✓ Heating the specimen at a rate of 1 ° C / min, until the next measurement temperature
- ✓ Maintenance of the temperature measurement for 15 h to ensure the heat and water homogeneity of the sample.
- ✓ Each measurement of thermal conductivity was carried out 3 times with a time interval of 45 min.
- ✓ Heating the specimen to the next temperature and repeating the cycle until the last temperature measurement (250 °C).

2.4. Experimental methodology

One of the most accurate and most convenient techniques to study the thermal conductivity method Source Transient Plane (Transient Plane Source) (TPS). It is a modern technique for determining the thermal conductivity per unit volume of the material studied.

The method is based on the use of a planar probe with transient heating and best-known adaptation is the "Hot Disk" (Thermal Constants Analyzer). Hot Disk the probe is in the form of a double spiral of electrically conductive material which has been obtained by etching a thin layer of metal (nickel). This spiral is encapsulated between two thin sheets of insulating material: kapton (polymer film), for test temperatures below 227 ° C or mica for test temperatures between 227° C and 727° C. The Hot Disk system can measure the thermal conductivity of materials from 0.01 to 400 W/mK using highly sensitive material. It detects temperature rises lower than 0.1 mK,

The basic principle of the system is to apply a constant power for a time defined in an initially isothermal sample through a Hot Disk probe and monitor the sample temperature changing using the probe as a thermometer resistive [8]. Increasing the temperature directly related to the increase in resistance of the sensor, is recorded precisely and analyzed for conductivity and the thermal diffusivity in a single transient recording. If the material has good insulating properties (low thermal diffusivity), the temperature in the disk rapidly increases under application of an electric current pulse. Conversely, if the material is a good thermal conductivity (high thermal diffusivity), increasing the temperature in the probe will be less in response to the same electrical stress.

- ✓ To perform the measurements of the conductivity and thermal diffusivity, the following principle was defined:
- ✓ Insert a probe between samples kapton symmetrical surface sufficiently flat (surfaced panels): the probe is selected according to the test temperature, the dimensions of the sample and the nature of the material.

- ✓ Define the following handling parameters: outdoor temperature, depth of penetration of the probe (based on sample dimensions), power and heating time).
- ✓ Start the test: Application of electrical power and acquisition start

3. Experimental results

The results of the thermal conductivity tests are presented below (Figure 2 and 3). The values presented below are the average of three measurements on the same sample at the same temperature. Table 1 shows the experimental results obtained.

Table I

Evolution of the thermal conductivity with the rise of the temperature of concrete studies

Temperature (° C)		thermal conductivity (W / mK)	relative thermal conductivity ** (%)	*** Ecart (%)
BR1	* 25	2764	100.00	00.00
	105	2481	90.08	09.92
	150	2038	73.73	26.27
	200	1857	67.18	32.82
	250	1734	62.73	37.27
BR2	* 25	2067	100.00	00.00
	105	1932	93.46	06.54
	150	1,785	86.35	13.65
	200	1584	76.63	23.37
	250	1342	64.92	35.08
BR31	* 25	1826	100.00	00.00
	105	1748	95.72	04.28
	150	1424	77.98	22.02
	200	1.114	61.00	39.00
	250	1.017	55.69	44.31

NB:

(*) Temperature 25°C is considered as the reference temperature (ambient temperature).

(**) thermal conductivity relative represents the percentage ratio between the recorded thermal conductivity at a given temperature with respect to that reference.

(***) Difference which is the percentage increase or decrease in thermal conductivity recorded at a temperature with respect to that reference.

Determination of thermal conductivity and its evolution with temperature were followed for all investigated concrete compositions. The values of thermal conductivity and curves of the variation of the conductivity difference are plotted on the Figure 2 and 3 respectively.

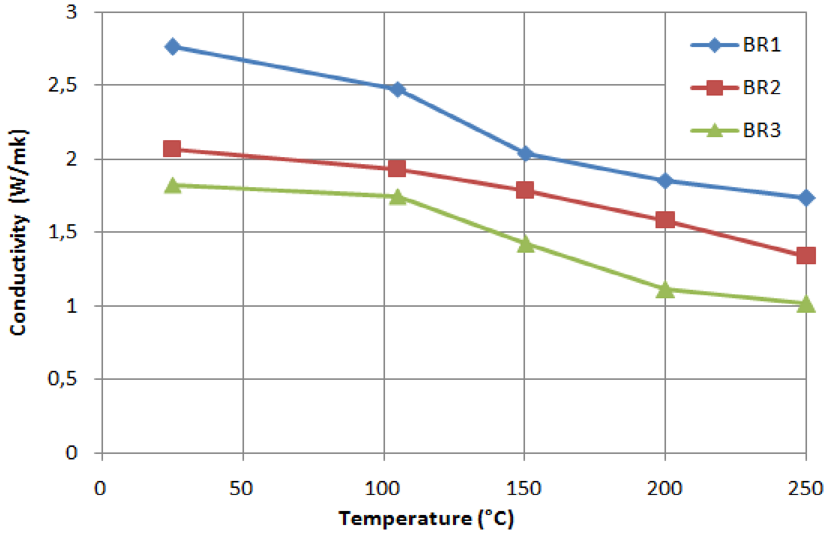

Fig. 2. Evolution of the thermal conductivity of concretes tested as a function of temperature

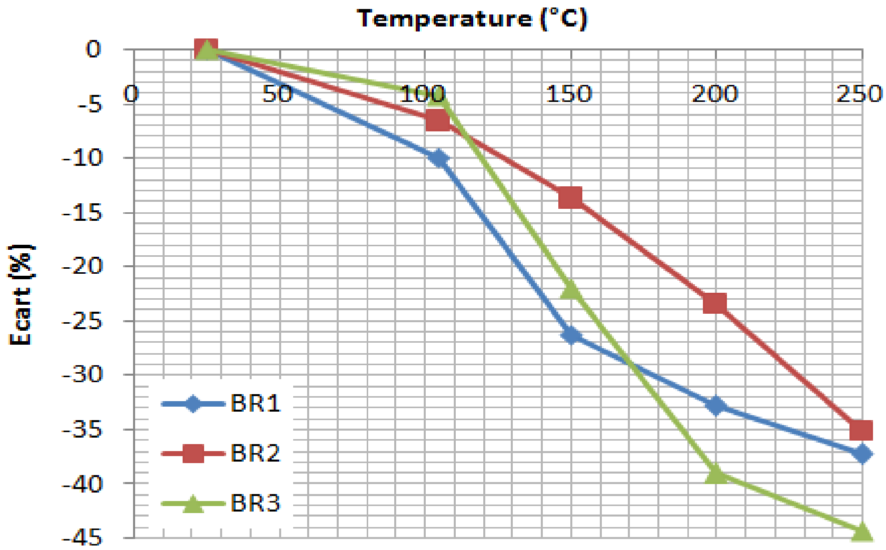

Fig. 3. Evolution of the ecart of thermal conductivity of concretes tested as a function of temperature

From these figures, we mainly notice that the thermal conductivity, for all types of concretes tested, varies according to the temperature. We can distinguish two phases consecutive in the evolution the thermal conductivity with the rise of the temperature:

Phase (I) (from 25° C to 105° C): in this first phase, the thermal conductivity of different concretes is significantly less than that recorded at room temperature. At this temperature, the resulting values are between 1.8 and 2.7 W/mK. These values are commonly found in the literature [9,10]. Thermal conductivity values decrease with increasing temperature to obtain results between 1.7 and 2.1 W/mK at 105° C. This decrease can be explained by the departure of the water by drying. Water with a high thermal conductivity, its departure causes a significant decrease in conductivity of the material.

Phase II (ranging from 105° C to 250° C): In this range of temperatures, various evolutions of thermal conductivity as a function of temperature appeared. Both concrete mixtures BR1 and BR2 have a small decrease of 105° C to 150° C and then an equivalent decrease from 200° C to 250° C. On the other hand, BR3 concrete shows a strong decrease in conductivity, reaching values below 1.1 W/m.K, when it is heated to 250° C. At this temperature, the conductivity becomes sensitive to the temperature gradient and the decrease is important.

It appears that the thermal conductivity of concrete depends on the aggregates used: in particular concretes with aggregates containing quartz (quartzite or siliceous aggregates) have a thermal conductivity largest as concrete with limestone aggregates. Usually the thermal conductivity of concrete decreases with increasing temperature. This is due to the importance of heat transfer by radiation through the pores [9]. This behavior highlights the deterioration of the microstructure which is manifested by the creation and propagation of microcracks (a consequence of the increase in porosity and pore size during exposure) and the loss of cohesion between the matrix resinous and reinforcements which limits the heat transfers[10,11]. Other factors, controlling the evolution of the thermal conductivity of concrete as a function of the exposure temperature are the thermal conductivity of each of its components, the proportions of the mixture [12,13] and the manufacturing process [14,15].

The type of aggregate, also has a significant influence on the conductivity of the concrete. This reinforces the idea that the thermal conductivity does not only depend on porosity and pore size but also on the exposure temperature and the nature of the aggregates. thermal conductivity of a material is a very complex phenomenon that can not be studied therefore considering only one parameter and ignoring the contribution of other features. It can be seen from these results that the nature of aggregates has an influence on the thermal conductivity of concrete. The presence of impact on the conductivity can be explained by the creation of voids (increase of the pore size and cracking at several scales) which constitute good thermal insulators and at the beginning progressive water (in all its forms) which is a good thermal conductor.

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