Improvement of the concrete behaviour to sulphate corrosion using fly ash admixture collected by wet process

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Abstract. For the concretes subjected to sulphate corrosion the use of the H II/A-S cement type is recommended. To improve the behaviour of these concretes to aggressive sulphate and magnesia corrosion, the use of the fly ash admixture collected by wet process for replacing the fine part of the aggregate is proposed. Because this type of corrosion is manifesting by expansion the analysis was conducted by measuring the dimensional modifications. In the Laboratory of the Faculty of Civil Engineering and Building Services of Iasi, an experimental program was conducted in order to assess the dimensional modification of the some samples prepared by concrete mixes based on belitic cements of type H II/A-S and embedding fly ash subjected to a combined sulphate and magnesia corrosion process using a mixed solution of Na2SO4 and MgSO4 having certain concentrations. The prismatic concrete samples were preserved in distilled water and in the combined solution, and then after 28 and 90 days their dimensions were measured by the Graff device. In this paper is presented the behaviour of the concretes in the first life time and, as further research other samples will be tested for longer time.

1. Introduction

Concrete durability continues to be a subject of challenges for design professionals, and specialists of concrete. The durability of concrete structures is affected by many environmental factors, the sulphate corrosion being one of the most frequent and detrimental processes [1].

The sulphate corrosion is characterised by the expansion of the cement stone due to the formation of crystallized products that are containing a great number of crystallization water molecules, which normally will lead to volume increase.

This type of corrosion is also produced by the sodium sulphate, which is a soluble sulphate, often encountered in practice. This is reacting with the calcium hydroxide from the cement stone forming another calcium sulphate. The calcium sulphate is combining with the calcium hydro aluminate giving a complex salt crystallized with 31 water molecules, called ettringite. This tendency of crystals formation leads that in a first stage to be observed an increase of the cement stone’s strength, an improve of the structural characteristics, so finally internal friction to appear, that in the end are leading to the decay of the concrete’s structure [2].
So, the sulphate corrosion supposes the formation of more hard soluble compounds, having a great molecular volume which will deposit in the concrete’s pores, capillaries and microcracks and can lead, in certain conditions to internal frictions appearance and concrete’s decay [3].

The formation of the compact and impermeable structure of the concrete represents a main condition, and supposes that in the conditions of the use of some cement type having high characteristic strengths to sulphate aggressiveness, the increase of the compactness to be realize not only through the cement dosage and the water / cement ratio, but with fly ash admixture, as well. In the case of using of some active ashes from chemical point of view, these will react with the calcium hydroxide resulted from the reaction with water of the cement’s mineralogical compounds, forming the calcium hydro silicates which are covering the ash granules favouring the formation of new gelic products. The previous researches highlighted favourable behaviour for the ash admixtures collected by wet process in proportions of 40% from the cement dosage [4].

The analysis of the concretes from the buildings main structures subjected to intense sulphate aggressive actions is conducted on concretes based on cement with high specific strengths to chemical aggressiveness, such as H II/A-S type cement, trying to highlight the favourable influence of the thermal power plant fly ash as compositional factor [5, 6].

The obtained concrete has to present high specific strengths to aggressive actions, because at least in the first stage, after the placing, when the concrete’s porosity is greater, the reaction between the aggressive solution and the cement stone’s compounds can lead to an intense corrosion process in the initial stage [7]. Also it has to be considered that the sulphate corrosion effect can occur by expansion of the affected structure and in this study are suggested two testing terms, at 28 and 90 days, in order to highlight the action of the aggressive agent.

Taking into account that the suggested cement for the research is of the type H II/A-S 32.5 composite cement, the evolution of the sulphate corrosion was studied on four concrete mixes containing this type of cement in different dosages and different thermal power plant dosages, using a high concentration of the aggressive agent (2% Na₂SO₄ and 1% MgSO₄).

2. Experimental program

In the Laboratory of the Faculty of Civil Engineering and Building Services of Iasi, an experimental program was conducted in order to assess the dimensional modification of the some samples prepared by concrete mixes based on belitic cements of type H II/A-S and embedding fly ash subjected to a combined sulphate and magnesia corrosion process using a mixed solution of Na₂SO₄ and MgSO₄ having certain concentrations.

The experimental program was conducted according to the requirements of the actual Standards (NE 012/1:2007 [8] and NE 012/2:2010) [9] referring at the realization of concretes in aggressive environments and that are requiring limits for the compositional factors and, in the same time, are recommending function of the exposure class of the concrete, even the cement type that is required for use. Taking into account the limitations imposed by the Standards four concrete mixes were realized.

2.1. Materials

To realize the concrete mixes, for different values of the compounds dosages, the following materials were used:

- river aggregate – the maxim dimension;
- distillate water;
- cement – type H II/A-S 32.5;
- thermal power plant fly ash collected by wet process according to SR EN 450-1:2012 [10];
- solutions of Na₂SO₄ and MgSO₄ with concentration of 1000 mg/dm³, SO₄²⁻ ions.

2.2. Concrete mixes

For different values of the component dosages the following compositions were realized and are presented in table 1.
Table 1. Concrete mixes.

| Concrete mixes | Aggregates (kg/m³) | Cement (kg/m³) | Ash (kg/m³) | Water (l/m³) | W/C+Ash | Slump (cm) |
|----------------|--------------------|----------------|-------------|--------------|---------|------------|
| R1             | 1800               | 250            | 125         | 210          | 0.56    | S3 (7.0)   |
| R2             | 1800               | 100            | 200         | 223          | 0.74    | S3 (8.5)   |
| R3             | 1800               | 200            | 200         | 215          | 0.55    | S3 (8.5)   |
| R4             | 1800               | 300            | 150         | 216          | 0.49    | S3 (8.5)   |

2.3. Experimental set up
Prismatic samples having 7x7x28 cm sizes were prepared. Three of each concrete mix were immersed and preserved in water up to the testing moment as witness samples.

The other three samples of each concrete mix were immersed in a 2% concentration Na₂SO₄ solution mixed with a 1% concentration MgSO₄ solution for 28 and 90 days as shown in figure 1.

Figure 1. Samples preservation.

After the preserving time the dimensional modifications were measured.

The determination expansion due to the corrosion phenomenon was realized according to the SR EN 2833-2009. This standard establishes the test methods for the determination of hardened concrete volume changes of and of the strains during the determination constant humidity and temperature conditions using the micro dial gauge and the Graff equipment [11]. The Graff equipment is illustrated in figure 2.

Figure 2. Graff equipment.

3. Experimental results and discussions
According to the compositional characteristics of the four concrete mixes, after the samples were subjected to corrosion the following results were registered.

The results are presented in the table 2.
Table 2. Registered results.

| Concrete mixes | Aggressive environment, concentration (%) | W/(C+Ash) ratio | Expansion mm/m 28 days | Expansion mm/m 90 days |
|----------------|------------------------------------------|-----------------|------------------------|------------------------|
| R1             | 2% Na₂SO₄ + 1% MgSO₄                     | 0.56            | 0.000                  | 0.000                  |
| R2             |                                          | 0.74            | 0.070                  | 0.070                  |
| R3             | 1% MgSO₄                                 | 0.55            | 0.035                  | 0.035                  |
| R4             |                                          | 0.49            | 0.035                  | 0.035                  |

The following graphic representation, figure 3, shows a clearer appreciation of the concrete’s behavior to sulphate corrosion.

![Figure 3: Expansion variation of the four receipts in conditions of combined sulphate and magnesia corrosion.](image)

Figure 3. Expansion variation of the four receipts in conditions of combined sulphate and magnesia corrosion.

Analyzing the experimental results completed by the graphic illustration can be concluded the following:

- the mix 1 presents the best behaviour for an ash proportion of 50% from the cement dosage C=250 kg/m³;
- mixes 3 and 4 present for the both testing terms a favourable behaviour because the expansion values are very low due to the fact that the cement presents strength besides the action of SO₄²⁻ ions, phenomenon which is due to the reduced contain of aluminates from the cement and the compactness is greater determined by the ash admixture in proportions that are shown in the research;
- mix 2 presents a weaker behaviour but under the accepted limit for the expansion and is due the reduced cement contain, which represents the main element regarding the sulphate chemical attack;
- it can be considered that the mix 1 presents the best behaviour in the conditions of the experimental program because the values of the expansion in intense concentration conditions are presenting values below the accepted limits for the mentioned exposure times.
4. Conclusions

The use of the fly ash collected by wet process is improving the concretes behaviour to sulphate corrosion by processes which are increasing the compactness and decreasing the permeability.

The use of the fly ash collected by wet process which is improving the concretes behaviour to sulphate corrosion has many economic effects by ashes recycling and replacing the fine part of the aggregate.

The first experimental results are showing the favourable behaviour of the concretes based on fly ash to sulphate aggressive actions in the first part of life.

A further testing will highlight the favourable behaviour of the concretes based on fly ash subjected to sulphate corrosion for a longer life time.

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