# CONTRIBUTIONS OF TWO MINERAL ADDITIONS ON CONCRETE PERFORMANCES

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**ABSTRACT**

*This work consisted of studying the influence of two mineral additions on the properties of concretes in the fresh state and in the hardened state with or without the use of adjuvant. The study was based on laboratory tests and the additions used are, fine and granular limestone fillers, rice husk ashes for energy purposes and obtained by controlled calcination which are industrial waste. The results obtained show the effectiveness of these mineral additions substituted in optimal quantity to the binder used, in particular limestone fillers and the ball ash composed largely of amorphous silica. We have also determined the coefficient of consideration of each type of addition used and these coefficients that derive from their granular, physicochemical, pozzolanic properties or the combination of the three appear to be in agreement with the effects of additions on concrete properties.*

***Key words**: concrete, mineral additions, workability, manufacturing parameters, performances, proprieties, optimization.*

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## 1. INTRODUCTION

Concrete is a material whose composition has a great influence on its characteristics, but if the expected characteristics are mostly well defined, the development of this material proves more delicate; therefore, all structures made with this material benefit from concrete formulated to meet project data, site constraints and expected concrete properties.

Indeed, "formulating a concrete" means determining the proportions of the various elements that constitute it, namely the binder, the aggregates, the water and the other elements added to the composition to improve one or more of its properties. A large variety of concretes is obtained by varying one of these proportions, but only the best formula gives the optimal result, that is to say a concrete that is easy to implement in the fresh state and has good quality. Resistance and durability in the cured state. In all cases, the formulation is good if it takes into account all the parameters that can influence the characteristics of the concrete of which the most sought are workability and resistance.

Madagascar has both natural resources and exploitable industrial waste. In concrete, the exploitation of these resources promises us a future of construction quite advantageous and profitable. We will seek not only the quality but also the least possible expense; then we will seek to formulate a concrete with a good workability combined with the best resistance and a minimum production cost by using industrial waste and natural resources as fines for adding concrete.

The use of admixtures, in particular superplasticizers, makes it possible to optimize the composition of the concrete and to resolve conflicts in terms of its often contradictory properties.

### 2. MATERIALS AND METHODS

#### 2.1. Experimental materials

The different materials used for the experiment are as follows:

- **The cement**

The cement used is of the CEM I 42,5 N types from HOLCIM Madagascar, packaged in a 50 kg bag.

- **Aggregates**
  - Sand 0/5

The sand used is river sand from Ambohimanambola.

- **Gravel**

Hand-made crushed gravel (Antsobolo quarry)

- G1: 5 / 12,5
- G2: 12,5 / 25

- **Mineral additions**
  - **Limestone fillers**

These are cipolin from the quarry of Belobaka Mahajanga that we have reduced to powder.

We used two calcareous fillers obtained by grinding with two degrees of fineness:

- fine limestone filler (CAF);
- coarse limestone filler (CAG).

- **Ashes of rice husks**

We used two types of rice husk ash that differ in how they are obtained:

- Ash recovered from a terracotta brick kiln, using rice husk from the Anosizato rice mill as fuel, therefore used for energy purposes (CBE);
- Ash obtained by controlled calcination at about 650 ° C, to have a product that has pozzolanic characters (CBP).

- .**Adjuvants**

We used two adjuvants found commercially:

- **CHRYSO FLUID OPTIMA 100 (ADJ 1)**

Plasticizer water reducer with superplasticizing functions of new generation based on modified phosphonate.

- **SYKAMENT 90 MF (ADJ 2)**

It is a multifunction adjuvant water reducer.

- **The mixing water**

The water used for the mixing of concrete is the tap water of the JIRAMA, which is therefore drinkable.

**2.2. Materials used**

The materials used during our experiments are:

- Oven: This is a device used to dry the samples or materials used. Its temperature varies between ambient and 105 ° C.

- Crusher: The crusher used is a ball mill in the shape of a cylindrical box. It is used to grind the samples by transforming them into the state of powders which will then be sieved.

- Sieving: The series of standardized sieves makes it possible to determine the granular distribution of a sample, which is materialized by its granulometric curve.

- Hot plate: This is an electric plate that is used to heat the samples as a solution but also to evaporate the adsorbed water. It is thermostated and possibly coupled to a magnetic stirrer.

- Oven of calcination: It is a device which serves to calcine a sample. The oven used can go up to 950 ° C. The sample is always put in a refractory beaker resistant to a fairly high temperature.

- Precision balance: The scale will be used to evaluate the mass of the samples. The choice of scale used depends on the quantity of samples.

## 3. CHARACTERISTICS OF MATERIALS

### 3.1. Cement characteristics

3.1.1. Chemical characteristics

- **Chemical composition**

The chemical composition of the cement used is given in Table 1 below:

*Table 1: Chemical composition of cement CM I (in percentage by mass)*

| $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | CaO | MgO | $SO_3$ | $Na_2O + K_2O$ | $CaO_L$ | PF à 975°C | RI |
|---|---|---|---|---|---|---|---|---|---|
| 18,97 | 5,23 | 3,15 | 61,30 | 0,60 | 1,56 | 0,60 | 1,07 | 1,60 | 1,30 |

- **Hydraulic index**

The hydraulic index of a mineral binder is given by the formula:

$$h = \frac{(SiO_2 + Fe_2O_3 + Al_2O_3)}{(CaO + MgO)}$$

We have: h = 0,44

Like h < 1, then we have a binder with basic characters.

- **Modules and required values**

A cement is characterized by three quantities which are required values: the lime module MC, the silica module MS and the alumina module MA.

The modules of cement CEM I 42.5 N are given in Table 2 which follows:

*Table 2 : modules du CEM I 42,5 N*

| MC | MS | MA |
|---|---|---|
| 93,81 | 2,26 | 1,66 |

3.1.2. Potential mineralogical composition

As MA> 0,638 and 90 <MC <100, the mixture is normal. The potential mineral composition of the cement determined by the BUGUE formula is given in Table 3 which follows:

*Table 3: Potential Mineralogical Composition of CEM I cement*

| $C_3S$ | $C_2S$ | $C_3A$ | $C_4AF$ | $CaO_L$ |
|---|---|---|---|---|
| 56,68 | 11,94 | 8,54 | 9,58 | 1,07 |

3.1.3. Physical and mechanical properties

The physical and mechanical characteristics of the cement are given in Table 4 which follows:

*Table 4: Physical and Mechanical Characteristics of CEM I cement*

| | |
|---|---|
| Apparent density : ρ ($Kg/m^3$) | 1 010 |
| Specific mass : γ($Kg/m^3$) | 3 102 |
| Blaine specific surface area : SSB ($cm^2/g$) | 3 342 |
| Water of normal consistency (%) | 2 8,40 |

| | |
|---|---|
| Start of setting (mn) | 185 |
| End of setting (mn) | 275 |
| Color | Grise |
| True Class of Resistance (MPa) | 53,8 |

**3.2. Characteristics of aggregates**

3.2.1 Characteristics of the sand

- Geometric characteristics
  - granularity

The results of the sand particle size analysis 0/5 are given in Table 5 and give the grain size curve of Figure 1:

*Table 5 : Sand 0/5 size analysis results*

| d [mm] | 0,08 | 0,16 | 0,25 | 0,315 | 0,5 | 0,63 | 0,1 | 1,25 | 2 | 2,5 | 3,15 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AFNOR Module | 20 | 23 | 24 | 26 | 28 | 29 | 31 | 32 | 34 | 35 | 36 | 37 | 38 |
| Passing [%] | 5 | 12 | 14 | 20 | 30 | 42 | 75 | 85 | 93 | 96 | 98 | 99 | 100 |

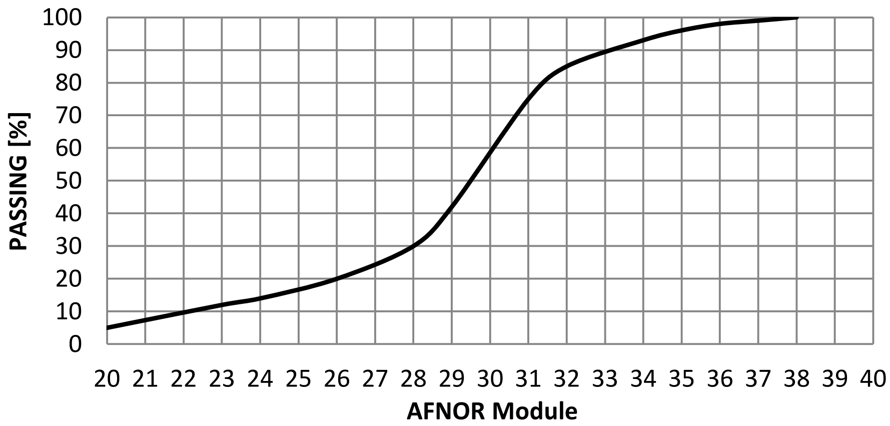


*Figure 1: Sand particle size curve 0/5*

- Finesse module

According to the calculation we have: Mf = 2,45

The sand has a modulus of finesse which is well suited to the manufacture of mortars and concretes.

(2,2 < Mf < 2,8).

- Physical properties

The physical properties of sand 0/5 are given in Table 6 which follows:

*Table 6: Physical properties of sand 0/5*

| | |
|---|---|
| Apparent density: $\rho_s$ (Kg/m$^3$) | 1.442 |
| Specific mass $\gamma_s$ (Kg/m$^3$) | 2 664 |
| ES Sand equivalent: | 91,2 |

From the results obtained, it can be deduced that the sand is clean and lends itself well to the manufacture of concrete.

3.2.2. Characteristics of chippings

- granularity

The results of the granulometric analysis of the chippings are given in Table 7, and give the particle size curves of Figure 2.

*Table7: Results of granulometric analysis of chippings (Passing %)*

| d [mm] | 3,15 | 4 | 5 | 6,3 | 8 | 10 | 12,5 | 16 | 20 | 25 | 31,5 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Module | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 |
| $G_1$ 5/12,5 | 0 | 3 | 8 | 20 | 52 | 82 | 95 | 100 | | | |
| $G_2$ 12,5/25 | | | | | 0 | 0 | 10 | 46 | 82 | 95 | 100 |

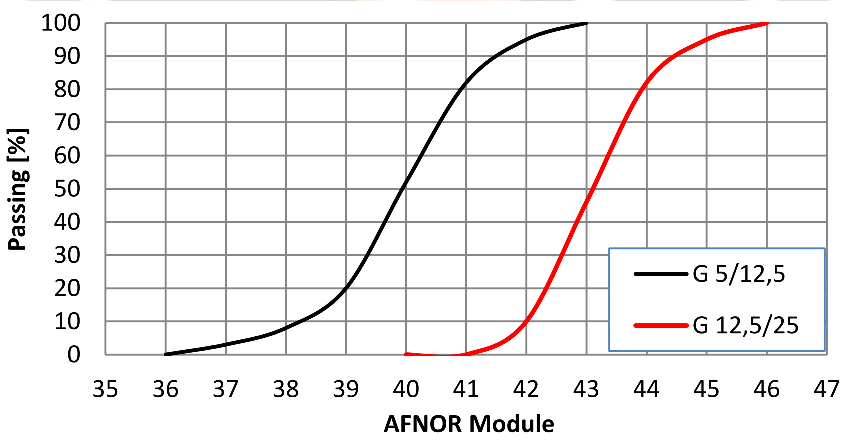


*Figure 2: Particle size curves of chippings*

- Physical characteristics

The physical properties of chippings are given in Table 8 which follows:

*Table 8 : Physical properties of shippings*

| Propriétés | $G_1$ 5/12,5 | $G_2$ 12,5/25 |
|---|---|---|
| Apparent density : ρ (Kg/m$^3$) | 1 498 | 1 535 |
| Specific mass : γ(Kg/m$^3$) | 2 685 | 2 682 |
| Volume coefficient CV | 0,2 | 0,44 |
| Coefficient of flattening CA | 24 | 30 |

The gravel, by their specific masses very close, are of the same origin. They are of standard quality.

**3.3. Characteristics of mineral additions**

3.3.1 Characteristics of calcareous fillers

- Chemical composition

Cipolin contains a large amount of calcium carbonate. The two fillers have the same chemical composition; it is given in Table 9 below:

*Table 9: Chemical composition of the two limestone fillers*

| Constituents | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | CaO | MgO | $CO_2$ | N.D. |
|---|---|---|---|---|---|---|---|
| %Content | 0,50 | 1,64 | 0,16 | 45,10 | 0,21 | 33,40 | 1,55 |

Cipolin contains about 76% $CaCO_3$

- Physical properties

The physical properties of calcareous fillers are given in Table 10 which follows:

*Table 10: Physical properties off the two calcareous fillers*

| Fillers | CAF | CAG |
|---|---|---|
| Apparent density : $\rho_s$ ($Kg/m^3$) | 746 | 1 002 |
| Specific mass: $\gamma_s$ ($Kg/m^3$) | 2 841 | 2 838 |
| Blaine Specific Surface area: SSB ($cm^2/g$) | 11 362 | 3 426 |

- Activity

The results of the determination of limestone fillers activity are given in the table 11 below:

*Table 11: Activity of calcareous fillers*

| Fillers | CAF | CAG |
|---|---|---|
| Rc28 (100% Cement) [Mpa] | 53,8 | 53,8 |
| Rc28 (75% Cement + 25% Ajout) [Mpa] | 42,7 | 39,9 |
| Activity index i | 0,794 | 0,742 |
| Coefficient of taking into account k | 0,382 | 0,226 |

3.3.2. Characteristics of rice husk ashes

- Chemical composition

The chemical composition of the rice husk ash is given in Table 12 below:

*Table 12: Chemical composition of rice Ball Ash*

| Constituents | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | CaO | MgO | $Na_2O$ | $K_2O$ | PF |
|---|---|---|---|---|---|---|---|---|
| % content | 91,10 | 01,59 | 00,15 | 00,44 | 00,42 | 00,04 | 02,93 | 01,93 |

- Physical properties

The physical properties of rice husk ash are given in Table 13 which follows:

*Table13: Physical Properties of Rice Ball Ash*

| Rice Ball Ash | CBE | CBP |
|---|---|---|
| Apparent density : ρs ($Kg/m^3$) | 561 | 558 |
| Specific mass : ϒs ($Kg/m^3$) | 1 936 | 1 941 |
| Blaine Specific Surface area : SSB ($cm^2/g$) | 8 967 | 9 665 |

- Activity

The results of the determination of the activity of rice husk ash are given in Table 14:

*Table14: Activity of Rice Ball Ashes*

| Fillers | CBE | CBP |
|---|---|---|
| Rc28(100% cement) [Mpa] | 53,8 | 53,8 |
| Rc28 (75% cement + 25% filler) [Mpa] | 34,4 | 46,1 |
| Activity index i | 0,639 | 0,856 |
| Coefficient of taking account k | 0 | 0,568 |

In general, the characteristics of the two ashes are identical, which is normal since they are obtained from rice husks of the same origin.

The difference in their activities is explained by their different methods of obtaining: energy end for one and controlled cooking for the other.

**3.4. Characteristics of adjuvants**

3.4.1. Characteristics of Chryso fluid optima 100

The characteristics of Chryso fluid optima 100 are given in Table 15 which follows:

*Table15: Characteristics of CHRYSO FLUID OPTIMA 100*

| | |
|---|---|
| Presentation | Liquid |
| Density | 1,06 ± 0,01 |
| Color | white-yellow slightly milky |
| pH | 4 ± 0,5 |
| Freezing point | -3°C |
| $Cl^{-}$content | ≤ 0,01% |
| $Na_2O$ equivalent | ≤ 0,3% |
| Dry extract (EN 480-8) | 31 ± 1,5 % |
| Life time | 9 months |
| Assay range | 0,3 à 5 % of the cement mass |

This product meets the regulatory requirements of the CE marking, which conforms to the NFO 85 certification standard whose technical specifications are those of the non-harmonized part of the NF EN 934-2 standard.

**3.4.2 Characteristics of Sykament 90 MF**

The specifications of SYKAMENT 90 MF which is a water-reducing adjuvant are given in Table 16 which follows:

*Table16: Characteristics of SYKAMENT 90 MF*

| | |
|---|---|
| Presentation | Liquid |
| Density | 1,21 ± 0,03 |
| Color | Brown |
| pH | 5,5 ± 0,5 |
| Freezing point | - |
| $Cl^{-}$content | ≤ 0,1% |
| $Na_2O$ equivalent | ≤ 2,5 % |
| Dry extract (EN 480-8) | 31 ± 1,5 % |
| Life time | 3 years in original packaging |
| Assay range | 0,3 à 2 % of the cement mass |

The SYKAMENT 90 MF complies with the NF EN 934-2 standard. It meets the regulatory requirements of CE marking.

### 4.5. Characteristics of mixing water

The water characteristics of JIRAMA, used for mixing concrete, are given in Table 17 below with the corresponding limit specifications:

*Tableau 17: Water Analysis Result and Limit Specifications*

| Specification | Parameter | Value |
|---|---|---|
| Suspended material | 0 mg/L | < 200 mg/L |
| Dissolvied subtances | 7 mg/L | < 15 mg/L |
| Organic material | 2,24 mg/L | < 5 mg/L |
| Alkaline Carbonate | 0 mg/L | < 20 mg/L |
| Sulfate to $SO_3$ | 6 mg/L | < 10 mg/L |
| Sulfate to $SO_4^{2-}$ | 0 mg/L | < 2 mg/L |
| Phosphate | 0 mg/L | - |
| $Ca^{2+}$ | 0 mg/L | < 20 mg/L |
| $Mg^{2+}$ | 0 mg/L | < 20 mg/L |
| Acidity : pH à 20°C | 6 | 5 à 12 pour CEM I |
| Humique acid | No brownish coloring | - |
| Chloride | 4,5 mg/L | < 250 mg/L |
| $CO_2$ | 0 mg/L | < 250 mg/L |

The water of JIRAMA lends itself well to the manufacture of concrete, it respects all the specifications required by the standards. The relatively high content of chloride ions certainly comes from the treatment agents.

## 5. PREPARATION

### 5.1. Drying

Drying is used to remove moisture from the raw materials to facilitate the grinding operation. The duration of this step is usually 4 days in the sun, or 6 hours in an oven with a drying temperature of 105 ° C.

### 5.2. Grinding

This operation consists in reducing the granulometry of a material. Grinding is carried out by successive fragmentation of the grains to increase the reactivity of the raw materials by increasing their specific surface area.

### 5.3. Sieving

After grinding, the products are sieved to obtain granulometries less than or equal to 80 µm. It is also used to determine the granularity of aggregates used for the manufacture of concrete.

### 5.4. Weighing

This operation consists in weighing the different constituents to compose the different necessary mixtures.

### 5.5. Mixing

This is the most important step to obtain, from the various constituents, a homogeneous mixture. The operation is carried out manually or with a laboratory mixer and the quality of the mixture is estimated visually.

**6. CONCRETE FORMULATION**

To see the influence of additions on concretes with different cement contents, we opted to experiment with two types of concrete: concrete with high cement content (BS); less dosed cleanliness concrete (BP).

## 6.1. Non adjuvant control concrete

The formulation of the control concretes is done using the Dreux-Gorisse method.

6.1.1. Concrete of non-additive control structure BSTN

For the concrete of non-additive control structure BSTN we have: Rbk = 35 MPa; A = 6 cm

- Determination of the composition of the binder paste
  - Maximum diameter: D = 25 mm
  - Targeted resistance:

  Rb = 1,15*Rbk

  Rb = 40,25 MPa

- Granular coefficient: G = 0,5

The Bolomey formula gives: $\frac{C}{E} = 2$

Which gives for a plastic consistency (slump A = 6 cm), an approximate cement dosage: C = 400 Kg / $m^3$.We deduce the water dosage: E = 200 L

- Determination of aggregates dosages
  According to the OAB reference curve (optimal compactness) of Figure 3:
- Origin O: (0.08mm, 0%), in modulus (20, 0%)
- Limit point B: (25mm; 100%), in module (46; 100%)
- Breaking point A: (XA; YA)
  D> 20 mm

$$X_A = \frac{38 + 46}{2} = 42$$

$$y_A = 50 - \sqrt{1{,}25\ D} + K + K_s$$

Normal vibration, concrete dosage 400 Kg / $m^3$ and rolled sand and crushed gravel: $K = -1$
Sand fineness module: Mf = 2,45: $K_s = -0{,}3$

$Y_A$= 43.7

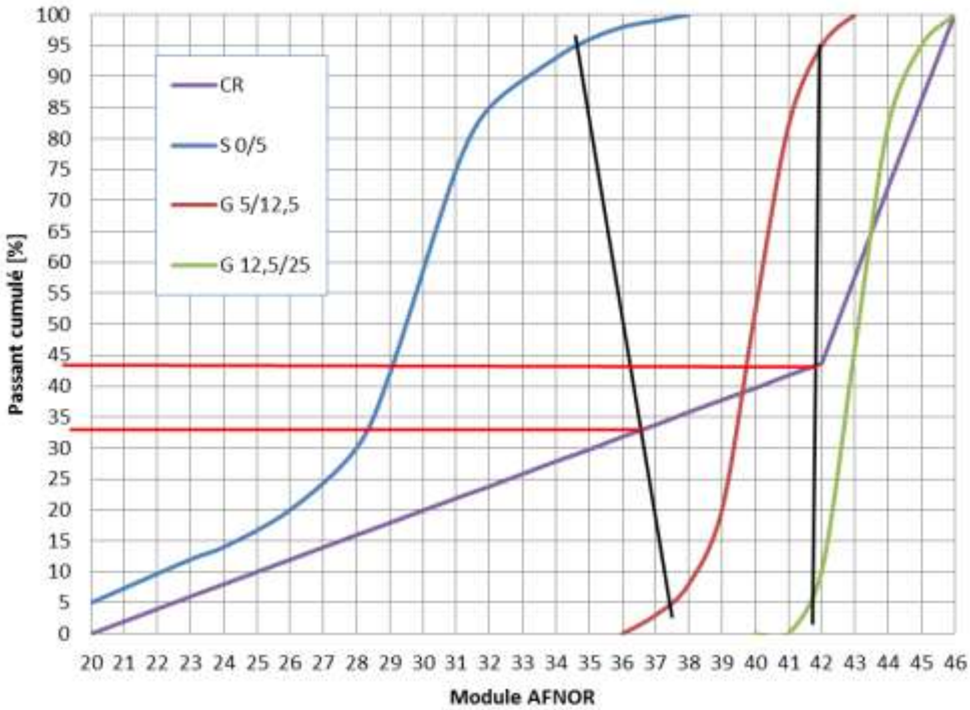


*Figure 3: Determination of the proportions of aggregates*

Absolute volume proportion of aggregates: s = 33%; $g_1$= 10%; $g_2$= 57%

• Coefficient of compactness: Γ = 0,81

• Volume of solids in 1 $m^3$: Vsol = 810 L

• Volume of cement: Vc = 129 L

• Volume of aggregates: Vgr = Vsol - Vc = 681 L

Vs = Vgr * s = 224,7 L

$Vg_1$ = Vgr * $g_1$= 68,1 L

$Vg_2$ = Vgr * $g_2$= 388,2 L

Mass dosage of aggregates:

S = Vs * $\gamma_s$= 597 Kg

$G_1$5 / 12.5 = $Vg_1$ *$\gamma_{g_1}$ = 183 Kg

$G_2$12.5 / 25 = $Vg_2$ * $\gamma_{g_2}$= 1041 Kg

The composition, by mass, for 1 $m^3$ of BSTN is given in Table 18:

*Table 18: Composition of non-adjuvanted structural concrete BSTN*

| Dosage in Kg/$m^3$ | | | | | Density Δo [Kg/$m^3$] |
|---|---|---|---|---|---|
| C | S | $G_1$ | $G_2$ | E | |
| 400 | 597 | 183 | 1 041 | 200 | 2,421 |

6.1.2. Non-additive control clean concrete BPTN

For the non-additive control cleanness concrete BPTN we have: Rbk = 15 MPa; A = cm; D = 25 mm; Normal vibration.

With the same method as above, there is the composition of the non-additive control clean concrete BPTN described in Table 19 which follow:

*Table 19: Composition of non-additive control clean concrete BPTN*

| Dosage in Kg/m$^3$ | | | | | Density Δo [Kg/m$^3$] |
|---|---|---|---|---|---|
| C | S | $G_1$ | $G_2$ | E | |
| 227 | 756 | 247 | 968 | 199 | 2,397 |

We notice an increase in the proportions of small and medium aggregates (S and G1). This is explained by the decrease in the dosage of cement: to have the same consistency, with almost the same dosage of water, it requires more fine and medium elements to compensate for the decrease in the dosage of cement.

**6.2. Adjuvanted control concrete**

The adjuvanted control concretes are obtained from those non-adjuvanted in which a superplasticizing adjuvant was added for a dosage of 1% by weight (in dry extract) of the cement dosage.The amount of mixing water necessary to obtain the plastic consistency corresponds to a slump A = 6 cm.

**6.2.1. Concrete of adjoining control structure BSTA**

- With CHRYSO FLUID OPTIMA 100 (ADJ1): Rbk = 35 MPa; ADJ1 = 1%; A = 6 cm.

The composition for 1m$^3$ of 1BSTA (in Kg) is given in Table 20 below:

*Table 20: Composition of the adjoining control structure concrete 1 BSTA (in Kg/m$^3$)*

| C | S | $G_1$ | $G_2$ | ADJ1 | E |
|---|---|---|---|---|---|
| 400 | 597 | 183 | 1041 | 12,9 | 107 |

- With SYKAMENT 90 MF (ADJ2): Rbk = 35 MPa; ADJ2 = 1%; A = 6 cm.

The composition for 1m$^3$ of 2 BSTA (in Kg) is given in Table 21:

*Table 21: Composition of the adjoining control structure concrete 2 BSTA (in Kg/m$^3$)*

| C | S | $G_1$ | $G_2$ | ADJ2 | E |
|---|---|---|---|---|---|
| 400 | 597 | 183 | 1 041 | 12,9 | 152 |

6.2.2. Adjunctive control clean-up concrete BPTA:

Only the most effective adjuvant was used: Rbk = 15 MPa; ADJ1: 1%; A = 6 cm.

The Composition for 1m$^3$ of BPTA (in Kg) is described in Table 22 which follows:

*Table 22: Composition of the adjoining control concrete BPTA (in Kg/m$^3$)*

| C | S | $G_1$ | $G_2$ | ADJ1 | E |
|---|---|---|---|---|---|
| 227 | 756 | 247 | 968 | 7,4 | 105 |

**6.3. Concretes with additions**

The principle adopted is to start from the composition of the control concretes and to substitute an absolute volume of cement by the same absolute volume of addition.

The formulations have been adopted to help understand the influence of mineral additions on different properties of concrete, both fresh and hardened, the main ones being:

- effects on consistency;
- effects on water demand;
- effects on resistance;
- effects on adjuvant demand;
- effects on porosity.

The additions used are summarized in Table 23, with their names:

*Table 23: Mineral additions used and added names*

| ADDITIONS | ADDED NAMES |
|---|---|
| Fine limestone filler | CAF |
| Coarse calcareous filler | CAG |
| Rice husk ash (energy end) | CBE |
| Rice bean ash (controlled calcination) | CBP |

6.3.1. Concrete structure

- Non-adjuvanted structural concretes
- Non-adjuvanted structural concrete with the same amount of water
  The principle is as follows:
- Volume substitution of cement by additions: 5 - 10 - 15 - 20 - 25%;
- Keep the water dosage of the control concrete;
- Define the consistency of fresh concrete and the ease of implementation.

The different corresponding formulas are obtained with their denominations (Table 24). The compositions of non-adjuvanted structural concretes with the same amount of water are indicated in Table 25.

*Table 24: Cement substitution rate and denomination of non-adjuvanted structural concretes*

| ADDITIONS | PROPORTION IN VOLUME (%) | | VOLUME ABSOLUTE (L) | | ADDED NAMES |
|---|---|---|---|---|---|
| | ADDITION | CEMENT | ADDITON | CEMENT | |
| | 0 | 100 | 0,00 | 129,00 | BSTN |
| CAF | 5 | 95 | 6,45 | 122,55 | BSNCAF5 |
| | 10 | 90 | 12,90 | 116,10 | BSNCAF10 |
| | 15 | 85 | 19,35 | 109,65 | BSNCAF15 |
| | 20 | 80 | 25,80 | 103,20 | BSNCAF20 |
| | 25 | 75 | 32,25 | 96,75 | BSNCAF25 |
| CAG | 5 | 95 | 6,45 | 122,55 | BSNCAG5 |
| | 10 | 90 | 12,90 | 116,10 | BSNCAG10 |
| | 15 | 85 | 19,35 | 109,65 | BSNCAG15 |
| | 20 | 80 | 25,80 | 103,20 | BSNCAG20 |
| | 25 | 75 | 32,25 | 96,75 | BSNCAG25 |
| CBE | 5 | 95 | 6,45 | 122,55 | BSNCBE5 |
| | 10 | 90 | 12,90 | 116,10 | BSNCBE10 |
| | 15 | 85 | 19,35 | 109,65 | BSNCBE15 |
| | 20 | 80 | 25,80 | 103,20 | BSNCBE20 |
| | 25 | 75 | 32,25 | 96,75 | BSNCBE25 |
| CBP | 5 | 95 | 6,45 | 122,55 | BSNCBP5 |
| | 10 | 90 | 12,90 | 116,10 | BSNCBP10 |

*Table 25: Compositions of non-adjuvanted structural concretes with the same amount of water*

| ADDED NAMES | DOSAGE IN MASS FOR $1m^3$ OF CONCRETE (Kg) | | | | | |
|---|---|---|---|---|---|---|
| | ADDITION | CIMENT | S | $G_1$ | $G_2$ | E |
| BSTN | 0 | 400 | 597 | 183 | 1 041 | 200 |
| BSNCAF5 | 18 | 380 | 597 | 183 | 1 041 | 200 |
| BSNCAF10 | 37 | 360 | 597 | 183 | 1 041 | 200 |
| BSNCAF15 | 55 | 340 | 597 | 183 | 1 041 | 200 |
| BSNCAF20 | 73 | 320 | 597 | 183 | 1 041 | 200 |
| BSNCAF25 | 92 | 300 | 597 | 183 | 1 041 | 200 |
| BSNCAG5 | 18 | 380 | 597 | 183 | 1 041 | 200 |
| BSNCAG10 | 37 | 360 | 597 | 183 | 1 041 | 200 |
| BSNCAG15 | 55 | 340 | 597 | 183 | 1 041 | 200 |
| BSNCAG20 | 73 | 320 | 597 | 183 | 1 041 | 200 |
| BSNCAG25 | 92 | 300 | 597 | 183 | 1 041 | 200 |
| BSNCBE5 | 12 | 380 | 597 | 183 | 1 041 | 200 |
| BSNCBE10 | 25 | 360 | 597 | 183 | 1 041 | 200 |
| BSNCBE15 | 37 | 340 | 597 | 183 | 1 041 | 200 |
| BSNCBE20 | 50 | 320 | 597 | 183 | 1 041 | 200 |
| BSNCBE25 | 62 | 300 | 597 | 183 | 1 041 | 200 |
| BSNCBP5 | 12 | 380 | 597 | 183 | 1 041 | 200 |
| BSNCBP10 | 25 | 360 | 597 | 183 | 1 041 | 200 |
| BSNCBP15 | 37 | 340 | 597 | 183 | 1 041 | 200 |
| BSNCBP20 | 50 | 320 | 597 | 183 | 1 041 | 200 |
| BSNCBP25 | 62 | 300 | 597 | 183 | 1 041 | 200 |

The quantity of mixing water of the control concrete did not make it possible to obtain the same consistency. Mixing and processing are very difficult for some mixtures. It was therefore necessary to correct the water dosage to obtain, approximately, the same consistency for all the mixtures.

- Non-adjuvanted structural concretes with the same consistency

The principle is as follows:

- Volume substitution of cement by additions: 5 - 10 - 15 - 20 - 25%;
- Correction of the amount of mixing water to have the same consistency (A = 6 cm).

Corrected compositions of non-adjuvanted structural concretes are shown in Table 26.

We note that in general, to obtain the desired consistency (A = 6 cm), the additive mixtures actually require a greater amount of mixing water than the control. This phenomenon is the more marked that the dosage in mineral addition increases; it is certainly due to greater finesse of the additions.

This phenomenon is not actually observed with the coarse calcareous filler, which has a fineness equivalent to that of cement.

On the other hand, the ashes of rice husks require a quantity of excessive water which their only fineness of grinding does not explain.

*Tableau 26: Corrected compositions of non-adjuvanted structural concretes with the same consistency*

| ADDED NAMES | DOSAGE IN MASS FOR $1m^3$ OF CONCRETE (Kg) | | | | | |
|---|---|---|---|---|---|---|
| | AJOUT | CIMENT | S | $G_1$ | $G_2$ | E |
| BSTN | 0 | 400 | 597 | 183 | 1041 | 200 |
| BSNCAF5C | 18 | 380 | 597 | 183 | 1041 | 205 |

| | | | | | | |
|---|---|---|---|---|---|---|
| BSNCAF10C | 37 | 360 | 597 | 183 | 1041 | 210 |
| BSNCAF15C | 55 | 340 | 597 | 183 | 1041 | 216 |
| BSNCAF20C | 73 | 320 | 597 | 183 | 1041 | 225 |
| BSNCAF25C | 92 | 300 | 597 | 183 | 1041 | 239 |
| BSNCAG5C | 18 | 380 | 597 | 183 | 1041 | 199 |
| BSNCAG10C | 37 | 360 | 597 | 183 | 1041 | 198 |
| BSNCAG15C | 55 | 340 | 597 | 183 | 1041 | 196 |
| BSNCAG20C | 73 | 320 | 597 | 183 | 1041 | 194 |
| BSNCAG25C | 92 | 300 | 597 | 183 | 1041 | 191 |
| BSNCBE5C | 12 | 380 | 597 | 183 | 1041 | 210 |
| BSNCBE10C | 25 | 360 | 597 | 183 | 1041 | 228 |
| BSNCBE15C | 37 | 340 | 597 | 183 | 1041 | 252 |
| BSNCBE20C | 50 | 320 | 597 | 183 | 1041 | 281 |
| BSNCBE25C | 62 | 300 | 597 | 183 | 1041 | 312 |

- Adjuvant structural concrete

We start from the composition of the adjuvanted control concretes and we replace a part of the cement by the additions. The substitution rates are 5; 15 and 25%. We believe that non-adjuvanted mixtures can already give an idea of the influence of the substitution rate.

- Adjuvanted structural concretes with the same adjuvant dosage

The principle is as follows: for each composition, define the quantity of water necessary to obtain the desired consistency (A = 6 cm), with the adjuvant dosage of the control concrete.

- Use of CHRYSO FLUID OPTIMA 100 (ADJ1)

The compositions of the adjuvanted structural concretes with the same consistency and ADJ1 adjuvant dosage obtained are indicated in the following Table 27:

*Table 27: Compositions of adjuvanted structural concretes with the same consistency and adjuvant ADJ1*

| | ADDITION (%) | DOSAGE IN MASS FOR 1m$^3$ OF CONCRETE (Kg) | | | | | | | ADDED NAMES |
|---|---|---|---|---|---|---|---|---|---|
| | | ADDITION | C | S | $G_1$ | $G_2$ | ADJ1 | E | |
| | 0 | 0 | 400 | 597 | 183 | 1 041 | 12,9 | 107 | BSTA |
| CAF | 5 | 18 | 380 | 597 | 183 | 1 041 | 12,9 | 117 | BSACAF5C |
| | 15 | 55 | 340 | 597 | 183 | 1 041 | 12,9 | 140 | BSACAF15C |
| | 25 | 92 | 300 | 597 | 183 | 1 041 | 12,9 | 169 | BSACAF25C |
| CAG | 25 | 92 | 300 | 597 | 183 | 1 041 | 12,9 | 102 | BSACAG25C |
| CBE | 5 | 12 | 380 | 597 | 183 | 1 041 | 12,9 | 124 | BSACBE5C |
| | 15 | 37 | 340 | 597 | 183 | 1 041 | 12,9 | 185 | BSACBE15C |
| | 25 | 62 | 300 | 597 | 183 | 1 041 | 12,9 | 263 | BSACBE25C |
| CBP | 5 | 12 | 380 | 597 | 183 | 1 041 | 12,9 | 128 | BSACBP5C |
| | 15 | 37 | 340 | 597 | 183 | 1 041 | 12,9 | 191 | BSACBP15C |
| | 25 | 62 | 300 | 597 | 183 | 1 041 | 12,9 | 270 | BSACBP25C |

- Using the SYKAMENT 90 MF (ADJ2)

By noting the relative lesser effectiveness of this adjuvant compared to the other in the formulation of the control concretes, we will only use two types of additions: the fine CAF limestone and the CBE rice husk ash.

Thus, the compositions of the adjuvanted structural concretes with the same consistency and ADJ2 adjuvant dosage are given in Table 28.

*Table 28: Compositions of adjuvanted structural concretes with the same consistency and adjuvant ADJ2*

| | ADDITION (%) | DOSAGE IN MASS FOR 1m$^3$ OF CONCRETE (Kg) | | | | | | | ADDED NAMES |
|---|---|---|---|---|---|---|---|---|---|
| | | ADDITION | C | S | $G_1$ | $G_2$ | ADJ2 | E | |
| | 0 | 0 | 400 | 597 | 183 | 1 041 | 12,9 | 152 | 2BSTA |
| CAF | 5 | 18 | 380 | 597 | 183 | 1 041 | 12,9 | 158 | 2BSACAF5C |
| | 15 | 55 | 340 | 597 | 183 | 1 041 | 12,9 | 176 | 2BSACAF15C |
| | 25 | 92 | 300 | 597 | 183 | 1 041 | 12,9 | 202 | 2BSACAF25C |
| CBE | 5 | 12 | 380 | 597 | 183 | 1 041 | 12,9 | 165 | 2BSACBE5C |
| | 15 | 37 | 340 | 597 | 183 | 1 041 | 12,9 | 223 | 2BSACBE15C |
| | 25 | 62 | 300 | 597 | 183 | 1 041 | 12,9 | 288 | 2BSACBE25C |

- Adjuvanted structural concretes with the same water dosage

The principle is to add, for each composition and for the quantity of water of the reference concrete, the amount of adjuvant necessary to obtain the desired consistency (A = 6 cm).

The compositions of structural concretes adjuvanted with ADJ1, with the same consistency and water dosage are summarized in Table 29 which follows:

*Table 29: Compositions of adjuvanted structural concretes with the same consistency and water dosage - ADJ1*

| | ADDITION (%) | DOSAGE IN MASS FOR 1m$^3$ OF CONCRETE (Kg) | | | | | | | ADDED NAMES |
|---|---|---|---|---|---|---|---|---|---|
| | | ADDITION | C | S | $G_1$ | $G_2$ | ADJ1 | E | |
| | 0 | 0 | 400 | 597 | 183 | 1 041 | 12,9 | 107 | BSTA |
| CAF | 5 | 18 | 380 | 597 | 183 | 1 041 | 13,8 | 107 | BSACAF5E |
| | 15 | 55 | 340 | 597 | 183 | 1 041 | 16 | 107 | BSACAF15E |
| | 25 | 92 | 300 | 597 | 183 | 1 041 | 19,1 | 107 | BSACAF25E |
| CAG | 25 | 92 | 300 | 597 | 183 | 1 041 | 11,7 | 107 | BSACAG25E |
| CBE | 5 | 12 | 380 | 597 | 183 | 1 041 | 14,5 | 107 | BSACBE5E |
| | 15 | 37 | 340 | 597 | 183 | 1 041 | 19,1 | 107 | BSACBE15E |
| | 25 | 62 | 300 | 597 | 183 | 1 041 | 28,4 | 107 | BSACBE25E |

6.3.2. Concretes of cleanliness

The purpose of this stage of our work is to know the influence of mineral additions on other types of concretes, in particular a low cement concrete.

The composition principle is exactly the same as for structural concretes, only the target strength and, consequently, the cement dosage varies.

In this step we will study more than the addition which seems to us to be able to give us even more information: the limestone filler finely ground CAF.

- Non-adjuvanted cleanliness concrete with the same water dosage

The principle is as follows:

- Substitution of cement by CAF: 5 - 10 - 15 - 20 - 25%;
- Keep the water dosage of the control concrete;
- Define the consistency of fresh concrete and the ease of implementation.

*Table 30: Compositions of non-additive concretes with the same dosage of water*

| CAF (%) | DOSAGE IN MASS FOR 1m$^3$ OF CONCRETE (Kg) | | | | | | ADDED NAMES |
|---|---|---|---|---|---|---|---|
| | CAF | C | S | $G_1$ | $G_2$ | E | |
| 0 | 0 | 227 | 756 | 247 | 968 | 199 | BPTN |
| 5 | 10 | 215 | 756 | 247 | 968 | 199 | BPNCAF5 |
| 15 | 31 | 193 | 756 | 247 | 968 | 199 | BPNCAF15 |
| 25 | 52 | 170 | 756 | 247 | 968 | 199 | BPNCAF25 |

➢ Adjuvant cleanliness concrete with the same consistency and adjuvant dosage

The principle is, for each composition, to define the quantity of water necessary to obtain the desired consistency (A = 6 cm), with the adjuvant dosage of the control concrete.

The compositions of the adjuvanted cleanliness concretes with the same consistency and adjuvant dosage are given in Table 31 which follows:

*Table 31: Compositions of adjuvanted cleaners with the same consistency and adjuvant dosage*

| CAF (%) | DOSAGE IN MASSE FOR 1m$^3$ OF CONCRETE (Kg) | | | | | | | ADDED NAMES |
|---|---|---|---|---|---|---|---|---|
| | CAF | C | S | $G_1$ | $G_2$ | ADJ1 | E | |
| 0 | 0 | 227 | 756 | 247 | 968 | 7,4 | 105 | BPTA |
| 5 | 10 | 215 | 756 | 247 | 968 | 7,4 | 110 | BPACAF5C |
| 15 | 31 | 193 | 756 | 247 | 968 | 7,4 | 122 | BPACAF15C |
| 25 | 52 | 170 | 756 | 247 | 968 | 7,4 | 146 | BPACAF25C |

➢ Adjuvant cleanliness concrete with the same consistency and water dosage

The principle is, for each composition and for the quantity of water of the reference concrete, add the amount of adjuvant necessary to obtain the desired consistency (A = 6 cm).

The compositions of the adjuvanted cleaners with the same consistency and water dosage are given in Table 32 which follows:

*Table 32: Compositions of adjuvanted cleaners with the same consistency and water dosage*

| CAF (%) | DOSAGE IN MASSE FOR 1m$^3$ OF CONCRETE (Kg) | | | | | | | ADDED NAMES |
|---|---|---|---|---|---|---|---|---|
| | CAF | C | S | $G_1$ | $G_2$ | ADJ1 | E | |
| 0 | 0 | 227 | 756 | 247 | 968 | 7,4 | 105 | BPTA |
| 5 | 10 | 215 | 756 | 247 | 968 | 7,6 | 110 | BPACAF5C |
| 15 | 31 | 193 | 756 | 247 | 968 | 8,4 | 122 | BPACAF15C |
| 25 | 52 | 170 | 756 | 247 | 968 | 10,5 | 146 | BPACAF25C |

## 7. CHARACTERISTICS OF CONCRETE ADDITIONS

### 7.1. Characteristics of fresh concretes

7.1.1. Consistency

The consistency of the mixtures is evaluated by measuring the cone collapse of ABRAMS.

This test was performed:

- On non-adjuvanted mixtures with the water dosing of control concretes;
- On all mixtures to check that they all have the desired consistency (A = 6 cm).

The results of the measurements are presented in Table 33.

*Table 33: ABRAMS cone collapse of concretes with additions*

| STRUCTURAL CONCRETE | | | | CLEANLINESS CONCRETE | |
|---|---|---|---|---|---|
| ADDED NAMES | A (cm) | ADDED NAMES | A (cm) | ADDED NAMES | A (cm) |
| BSTN | 6 | BSTN | 6 | BPTN | 6 |
| BSNCAF5 | 5,7 | BSNCBE5 | 5,4 | BPNCAF5 | 5,8 |
| BSNCAF10 | 5,3 | BSNCBE10 | 4,8 | BPNCAF15 | 5,1 |
| BSNCAF15 | 4,8 | BSNCBE15 | 4,1 | BPNCAF25 | 3,9 |
| BSNCAF20 | 4,2 | BSNCBE20 | 3,2 | | |
| BSNCAF25 | 3,6 | BSNCBE25 | 2,1 | | |
| BSNCAG5 | 6,05 | BSNCBP5 | 5,3 | | |
| BSNCAG10 | 6,1 | BSNCBP10 | 4,6 | | |
| BSNCAG15 | 6,2 | BSNCBP15 | 3,8 | | |
| BSNCAG20 | 6,4 | BSNCBP20 | 3,0 | | |
| BSNCAG25 | 6,6 | BSNCBP25 | 2,0 | | |

7.1.2. Density of fresh concrete

The principle is to measure the mass of fresh concrete in the mold and bring it back to the volume of the latter. Average values were taken for each type of addition and for each type of concrete (structural or clean), relative to that of the control concretes.

The results are reported in the following Table 34:

*Table 34: Volume masses of fresh concrete in Kg / $m^3$*

| | BSN | BSA | BPN | BPA |
|---|---|---|---|---|
| WITNESSES | 2 421 | 2 481 | 2 399 | 2 434 |
| CAF | 2 407 | 2 492 | 2 370 | 2 448 |
| CAG | 2 431 | 2 485 | - | - |
| CBE | 2 387 | 2 447 | - | - |
| CBP | 2 384 | 2 442 | - | - |

The densities of non-adjuvanted concretes with addition should, in general, be lower than those of control concretes since the cement is heavier than the additions. However, the calcareous fillers CAF and CAG make it possible to obtain a greater density.

These findings allow us to conclude that the respective density of the different constituents of the concrete is not the only parameter to be taken into account for the evaluation of its density. In all cases, an increase in the density is the result of an improvement in the compactness of the mixture. Any phenomenon that leads to this improvement must therefore be taken into account, such as:

- a better arrangement of the granular skeleton,
- the formation of more compact compounds ...

Another remark can be made: for the same cement dosage, the added concrete has a higher density. This is the consequence of a lower demand for water, accompanied by an increase in the compactness of the mixture.

**7.2. Characteristics of concrete in the hardened state**

7.2.1. Resistance in simple compression

➢ Non-adjuvanted concrete

The 28-day compressive strengths, as a function of the degree of substitution, of the non-adjuvanted concretes are given in Table 35 which follows:

*Table 35: Compressive strength at 28 days of non-adjuvanted concretes according to the degree of substitution (in MPa)*

| STRUCTURAL CONCRETE | | | | | CLEANLINESS CONCRETE | |
|---|---|---|---|---|---|---|
| ADDITION [%] | BSNCAF | BSNCAG | BSNCBE | BSNCBP | ADDITION [%] | BPNCAF |
| 0 | 36,8 | 36,8 | 36,8 | 36,8 | 0 | 15,4 |
| 5 | 37,2 | 37,8 | 32,1 | 37,6 | 5 | 15,8 |
| 10 | 36,2 | 38,2 | 28,9 | 38,5 | 15 | 13,3 |
| 15 | 35,3 | 36,1 | 26,8 | 36,4 | 25 | 11,9 |
| 20 | 34,2 | 34,5 | 25,1 | 34,7 | | |
| 25 | 33,1 | 33,4 | 23,4 | 33,5 | | |

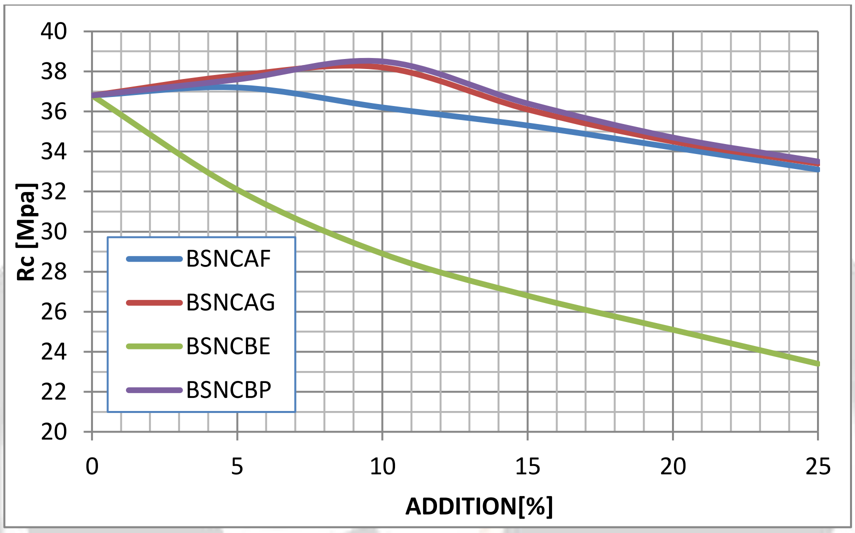


*Figure 4: Evolution of the compressive strength according to the rate of addition – Non-adjuvanted structural concretes*

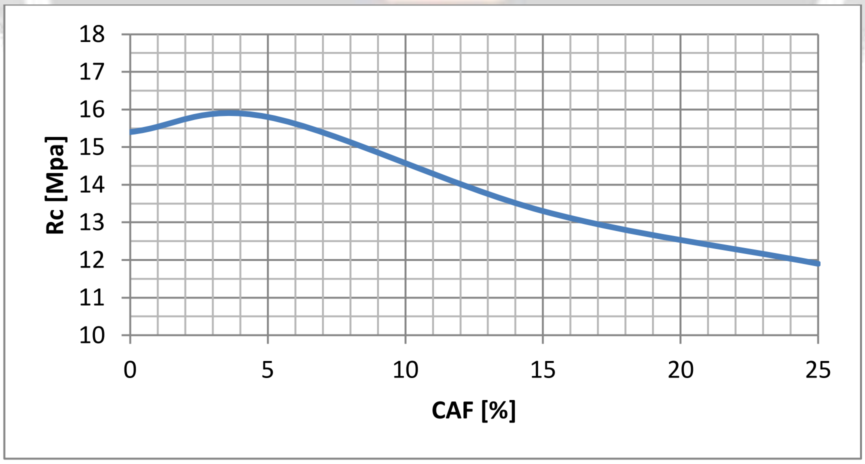


*Figure 5: Evolution of the compressive strength according to the rate of CAF –Non-adjuvanted cleanliness concretes*

In general, for non-adjuvanted concretes, the effect of increasing the degree of substitution, of the cement by an addition, on the value of the resistance is as follows:

- at first the resistance increases,
- and after reaching a maximum it tends to decrease.

Except for rice husk ash for energy purposes, for which resistance decreases more and more as the rate of addition increases.

The optimum value of the substitution rate for obtaining the maximum resistance is between 5 and 10%.

- Age-dependent compressive strength for the best compositions and for the 25% addition (in MPa) mixtures of BSN

The compressive strengths as a function of age for the best compositions and for the 25% admixtures of non-additive structural concretes are given in Table 36 which follows:

*Table 36: Age-Dependent Compressive Strength for Best Compositions and 25% Addition Mixtures (in MPa) - BSN*

| AGE | 2d | 7d | 14d | 28d |
|---|---|---|---|---|
| BSTN | 8,4 | 23,5 | 30,2 | 36,8 |
| BSNCAF5 | 7 | 19,1 | 26,5 | 36,7 |
| BSNCAF25 | 4,5 | 14,2 | 22,1 | 33,1 |
| BSNCAG10 | 7,9 | 20,9 | 28,1 | 38,2 |
| BSNCAG25 | 5,8 | 16,2 | 22,6 | 33,4 |
| BSNCBE5 | 4,5 | 15,4 | 23,2 | 32,1 |
| BSNCBE25 | 3,1 | 10,8 | 17,6 | 23,4 |
| BSNCBP10 | 7,8 | 19,8 | 30,7 | 38,5 |
| BSNCBP25 | 3,4 | 15,3 | 22,9 | 33,5 |

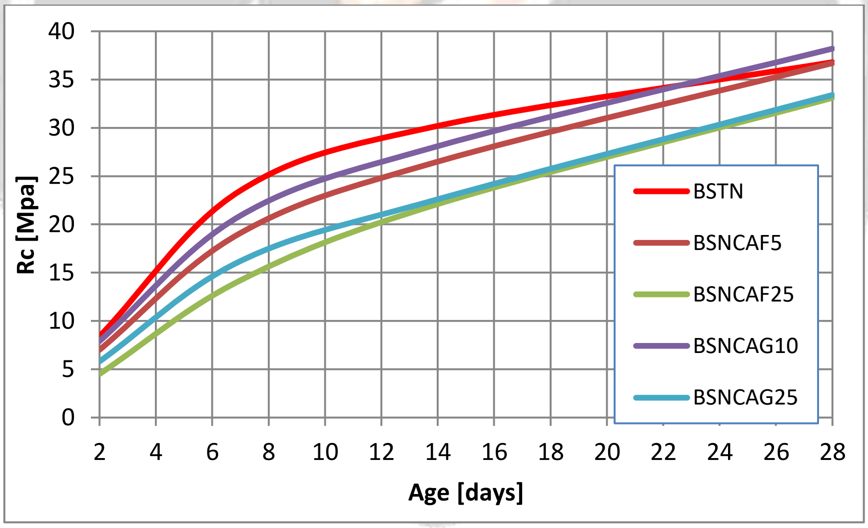


*Figure 6: Evolution of compressive strength of concretes with non-additive limestone additions as a function of age*

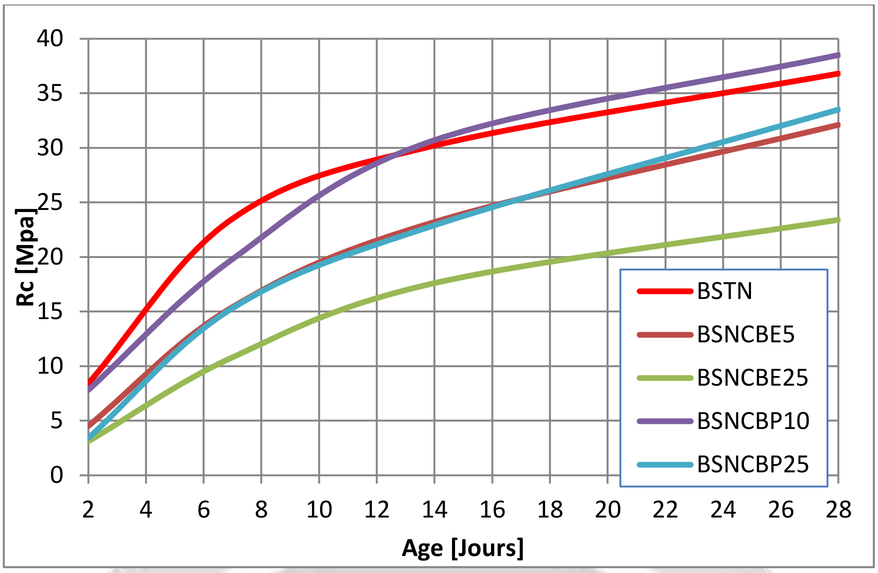


*Figure 7: Evolution of the compressive strength of concretes with additions of non-adjuvanted CBR as a function of age*

- Adjuvanted concretes
  - Structural concrete - BSA
    - Compressive strength at 28 days as a function of the degree of substitution in addition of the adjuvanted structural concretes (in MPa)

The compressive strengths at 28 days as a function of the degree of substitution in addition of the adjuvanted structural concretes (in MPa) are given in Table 37 which follows and illustrated in Figure 8.

***Table 37:*** *Resistance to compression at 28 days as a function of the substitution rate in addition of the BSA (in MPa)*

| Addition % | BSACAFC | BSACBEC |
|---|---|---|
| 0 | 48,2 | 48,2 |
| 5 | 49,4 | 38,7 |
| 15 | 47,2 | 34,2 |
| 25 | 37,9 | 31,2 |

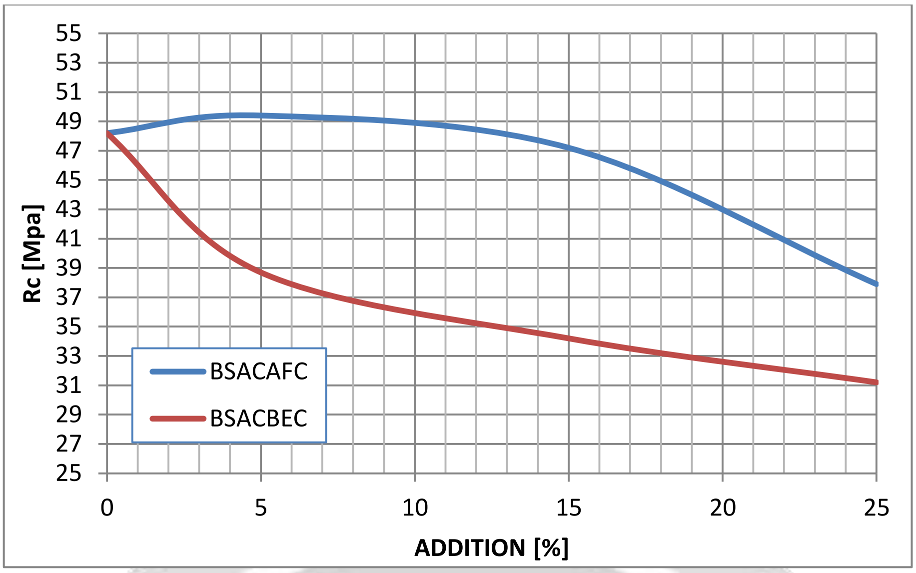


*Figure 8: Compressive strength at 28 days depending on the substitution rate of BSA (in MPa)*

- Compressive strength as a function of age for the best compositions and for the 25% additive mixtures of adjuvanted structural concrete

The compressive strengths as a function of age for the best compositions and for the 25% additions mixtures of the adjuvanted structural concretes are given in Table 38 and illustrated in Figure 9:

*Table 38: Age-Dependent Compressive Strength for Best Compositions and Blends at 25% addition in MPa - BSA*

| ADDITION | 2d | 7d | 14d | 28d |
|---|---|---|---|---|
| BSTA | 11,5 | 29,5 | 37,8 | 48,2 |
| BSACAF5C | 9,2 | 24,2 | 35,2 | 49,4 |
| BSACAF25C | 6,2 | 17,4 | 26,2 | 37,9 |
| BSACBE5C | 5,6 | 18,4 | 28 | 38,7 |
| BSACBE25C | 4,2 | 13,4 | 21 | 31,2 |

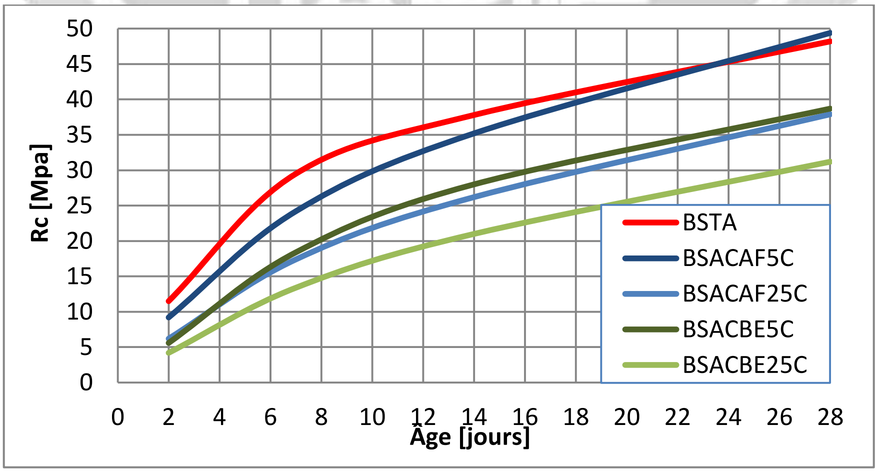


*Figure 9: Evolution of the compressive strength of the adjuvanted structural concretes according to age (in MPa)*

- Cleanliness Concretes - BPACAFC

The compressive strengths at 28 days as a function of the degree of substitution (CAF) of the adjuvanted cleaners (in MPa) are given in Table 39 which follows and illustrated by Figure 10.

*Table 39: Compressive strength at 28 days as a function of the CAF substitution rate of BPA (in MPa)*

| CAF [%] | 0 | 5 | 15 | 25 |
|---|---|---|---|---|
| $Rc_{28}$ [MPa] | 21,7 | 25,4 | 20,3 | 17,6 |

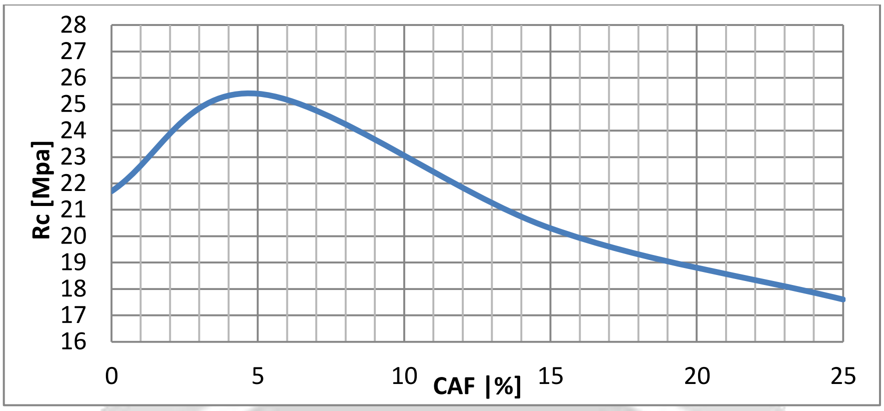


*Figure 10: Evolution of compressive strength at 28 days as a function of rate of CIF substitution of BPA (in MPa)*

The age-dependent compressive strengths for the additive BPACAF5C concrete are given in Table 40 and illustrated in Figure 11:

*Table 40: Compressive strength at 28 days as a function of the age of BPACAF5C (in MPa)*

| *Age* | *2d* | *7d* | *14d* | *28d* |
|---|---|---|---|---|
| $Rc_{28}$ [MPa] | 5,5 | 12,0 | 17,5 | 25,4 |

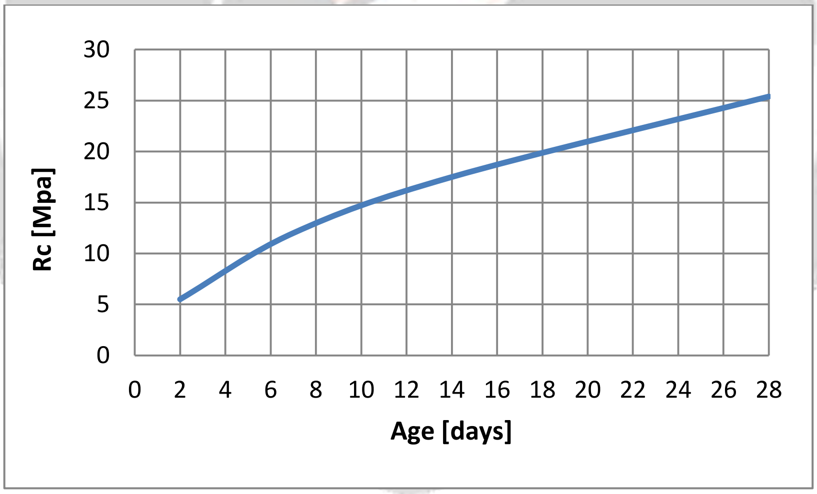


*Figure 11: Evolution of the compressive strength of BPACAF5C clean concrete according to age*

7.2.2. Open porosity of concretes

The following Table 41 and Figure 12 illustrate the variation of the open porosity depending on the type of concrete and the type of addition.

*Table 41: Open Porosity by Concrete Type and Addition Type (%)*

| ADITION | BSN | BSA | BPN | BPA |
|---|---|---|---|---|
| WITNESSES | 9,4 | 4,1 | 11,3 | 8,2 |
| CAF | 10,6 | 3,2 | 13,4 | 6,9 |
| CAG | 8,5 | 3,8 | - | - |
| CBE | 12,3 | 7,1 | - | - |

| | | | | |
|---|---|---|---|---|
| CBP | 12,1 | 6,8 | - | - |

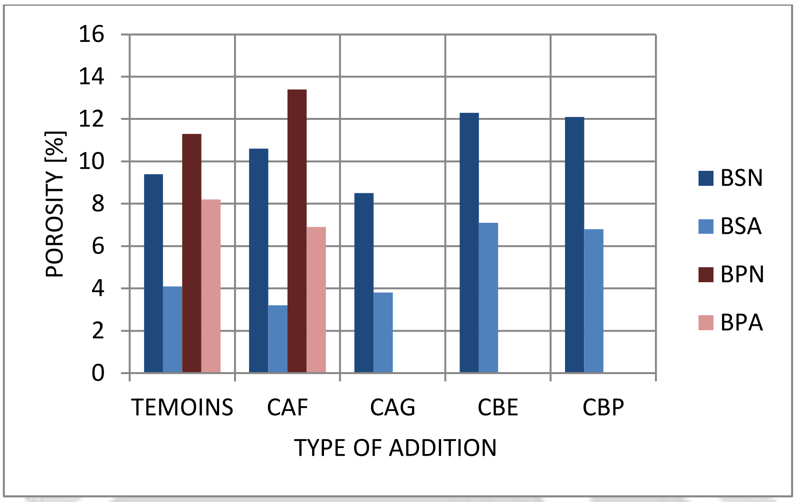


*Figure 12: Variation in porosity depending on the type of addition and type of concrete*

## 8. INFLUENCES OF EACH TYPE OF ADDITION

In this part of the study, we will study only the effects of each type of addition on the two most important properties of concrete: the consistency of fresh concrete, that is to say its workability, and the mechanical strength of hardened concrete.

The principle is to present the relative difference of the concrete parameter to the additions compared to that of the corresponding control concrete.

### 8.1. Limestone fillers - CAF and CAG

8.1.1. Effects on consistency

Figure 13, which follows, shows the evolution of the variation of the consistency of the concretes with the additions compared to the witnesses concrete, as a function of the rate of substitution of fine calcareous filler CAF and coarse AGC and according to the type of concrete BS or BP.

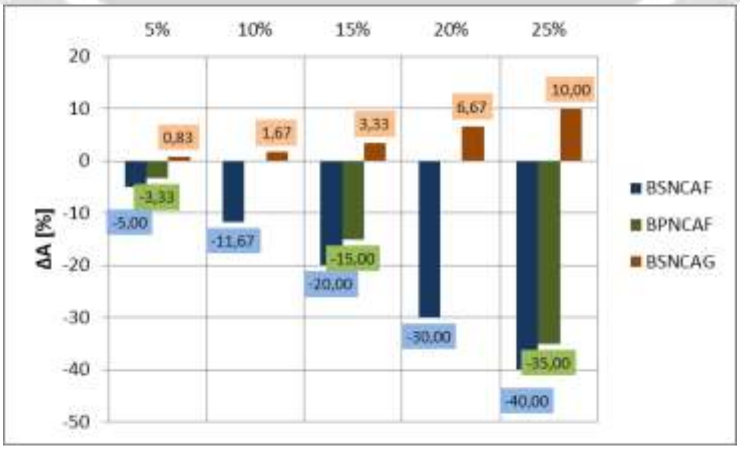


*Figure 13: Variation of settling of concretes to additions compared to control concrete, according to the degree of substitution of CAF and CAG and according to the type of concrete BS or BP*

Compared to the control, in the case of the fine filler, the sag decreases as the substitution rate increases. The phenomenon is more and more marked:

- when increasing the amount of the addition in the mixture;
- for structural concretes (compared to concrete concretes):

- For structural concretes: the decrease compared to the control is 5% for a rate of 5% and 40% for a rate of 25%;
- For concrete cleaners: the decrease compared to the control is 3,33% for a rate of 5% and 35% for a rate of 25%.

Concretes with coarse filler additions, for their part, have a greater ease of implementation than the control concrete. The intensity of this phenomenon decreases when the rate of substitution is increased; the increase in sag is:

- 10% for a rate of 5%;
- 0,83% for a rate of 25%.

8.1.2. Effects on strength

The following figure 14 shows the evolution of the compressive strength of concretes at the additions compared to the control concrete, as a function of the degree of substitution of fine calcareous filler CAF and coarse AGC, in the case of non-additive concretes and according to the type BSN or BPN concrete.

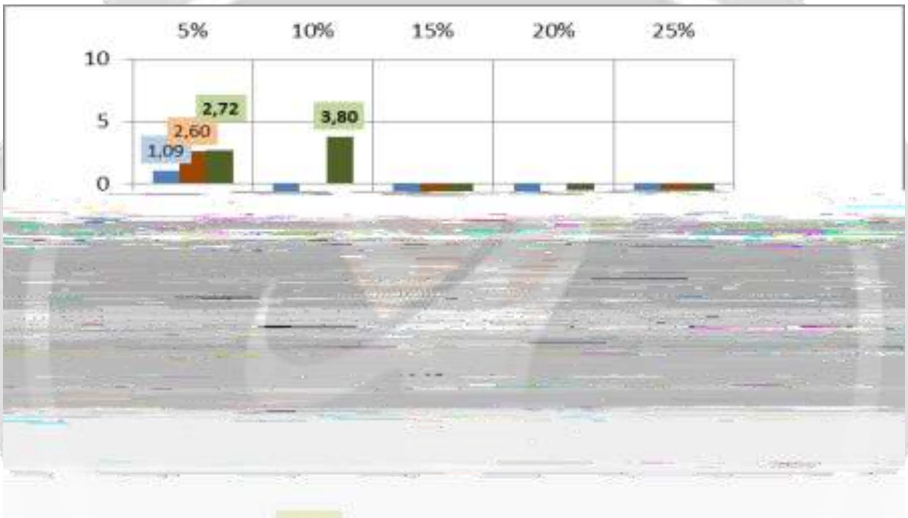


*Figure 14: Variation of the compressive strength of concretes to additions compared to control concrete, according to the substitution rate of CAF and CAG, case of non-additive concretes and according to concrete type*

The figure 15 shows the evolution of the compressive strength of the concretes at the additions compared to the control concrete, as a function of the degree of substitution of fine calcareous filler CAF, in the case of the use of adjuvant and according to the type of BSA or BPA concrete.

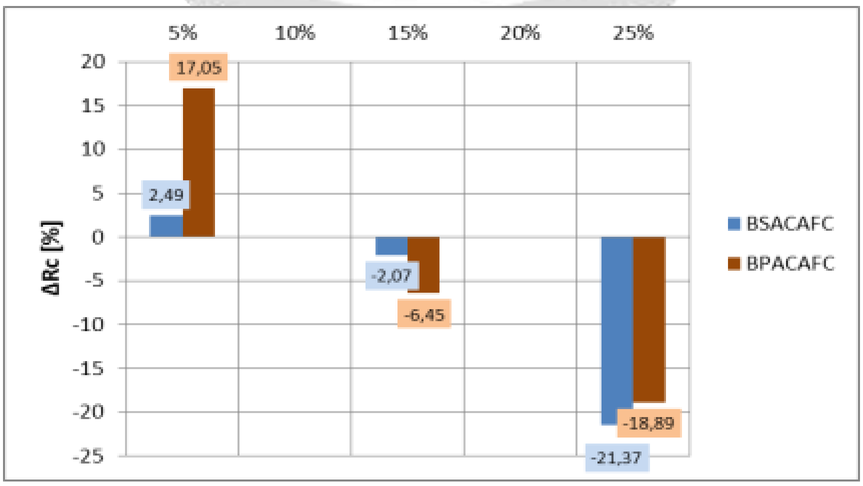

*Figure 15: Variation of the compressive strength of concretes with the additions of CAF,adjuvanted compared to control concretes*

***Case of non-adjuvanted concretes***:

The high strengths of cement (BSN) are not compatible with fine fillers (CAF), their use causes a gradual decrease in strength with the increase of the substitution rate.

On the other hand, for the BPN, the 5% CAF mixture is slightly more efficient than the control concrete ($\Delta Rc$ = -2,6%). Beyond this value, the resistance decreases with the substitution rate:

- 13,6% for a rate of 15%,
- 22,7% for a rate of 25%.

The use of CAG limestone filler, of fineness equivalent to that of cement, makes it possible to have concretes that perform better than the control. The optimum dosage is 10%.

***Case of adjuvanted concretes***:

Two concretes, BSACAF5 and BPACAF5, are more efficient than the control with the use of adjuvant for a rate of 5%. The phenomenon already observed with the CAF fine calcareous filler for non-adjuvanted concretes is amplified ($\Delta Rc$ = -17,1%).

With regard to the activities, for fine calcareous fillers, the coefficient of taking into account is k = 0,382, while k = 0,226 for coarse calcareous fillers (against k = 0,25 for the data of the standard) . These values show the performance of the mixture at 5% of the CAF compared to the control concrete. On the other hand, the coarse filler activity does not in itself explain the strength gain of the concretes based on this addition.

**8.2. The ashes of rice husks - CBE and CBP**

8.2.1. Effects on consistency

The following figure 16 shows the evolution of the relative variation of the slump, with respect to the control concrete, as a function of the substitution rate of ground CBR rice ash in the case of structural concretes.

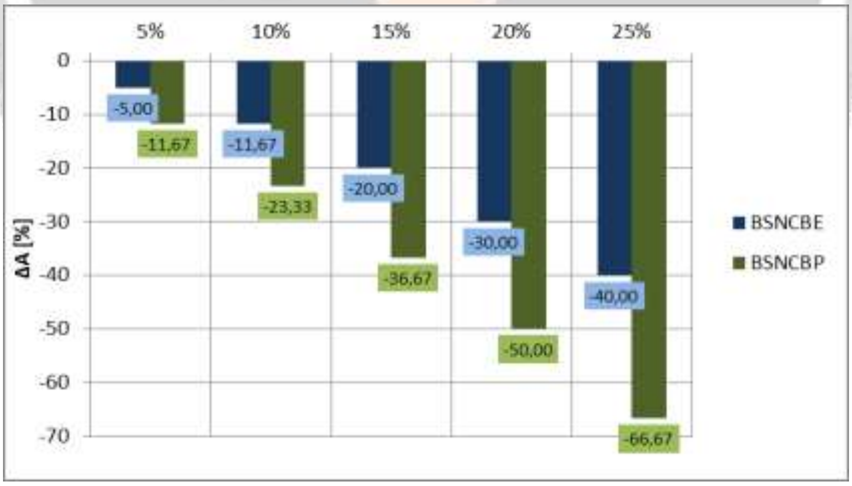


*Figure 16: Relative variation of subsidence, versus control concrete, based on CBR substitution rate- case of non-additive structural concretes*

Concretes with additions of rice husk ash were the most difficult to implement. Compared to the control, the slump decreases dramatically when ash is added to the mixture. The phenomenon is more and more marked when increasing the amount of the addition:

- 11,67% (CBE) and 23,33% (CBP) for a rate of 10%;
- 40% (CBE) and 66.67% (CBP) for a rate of 25%.

This phenomenon is attributable to the grain structure of the rice husk ash which is porous. This is in keeping with the excessive water demand observed for mixing rice husk ash mixtures.

8.2.2. Effects on strength

Figure17 shows the relative variation of the strength , with respect to the control concrete, as a function of the substitution rate of CBR ground rice husk ash in the case of structural concretes, whether or not they are adjuvanted.

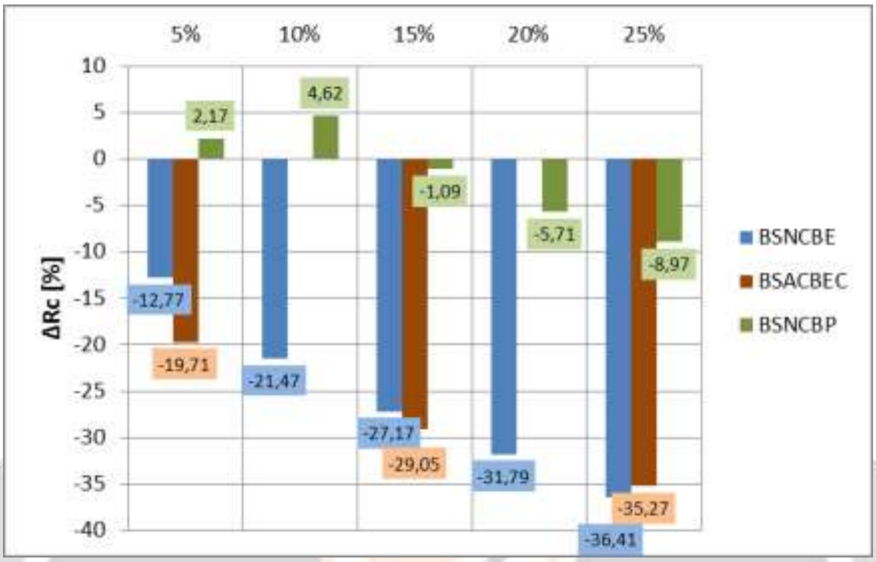


*Figure 17: Relative Change in Strength, versus Control Concrete, by Substitution Rate of CBR rice husk ash - case of structural concretes with or without adjuvanted*

The results obtained show the importance of the method of obtaining the ashes of rice husks:

Whether or not an adjuvant is used, rice husk ash for energy purposes gives poor results. The resistance drops to about 35.2% for a 25% substitution rate.

This fact can be explained by the very porous morphology of this type of addition, which causes a demand for excessive water.

Another explanation can be made: rice husks have been used for energy purposes and do not have the expected properties, pozzolanicity among others, due to the more or less partial reorganization of the product structure.

On the other hand, for the ash obtained by controlled calcination, it has an amorphous structure which is one that offers properties of high pozzolanicity. This explains the resistances that happen, for some determined substitution rates, to surpass that of the witness.

For rice husk ash, the coefficient of taking into account is zero for ash intended for energy purposes and k = 0,568 for that obtained by controlled calcination.

The very low resistance obtained with CBE shows that it is an inert type I addition.

The results obtained with controlled calcination of rice husks are explained by pozzolanic properties marked by ash.

**9. CONCLUSION**

The results of the tests carried out on two types of concrete, structural concrete and concrete cleanliness make it possible to determine the influence of each type of additions according to the importance of the cement dosage of the concretes and to determine the coefficient of taking into account each addition used.

In general, compared to control concrete, subsidence at Abrams cones decreases as the substitution rate of additions increases. This is observed on the various types of additions but the difficulty of implementing the concrete or the workability is solved by the use of superplasticizing admixtures in moderate amounts.

Concerning the coefficients of taking into account, $k = 0{,}382$ for the fine calcareous filler CAF and $k = 0{,}226$ for the coarse calcareous filler CAG, with or without adjuvant. With the rice bean ash for energy purposes CBE the coefficient of taking into account is zero but if the rice husk ash is obtained by controlled calcination CBP, it has marked pozzolanic properties and the value of the coefficient of taking into account becomes $k = 0{,}568$.

Finally, we can say that the effects of mineral additions on concrete are either granular, physico-chemical or pozzolanic, or the combination of the three effects. Moreover these coefficients of taking into account are in agreement with the concept of equivalent binder.