SPECIAL SELF-COMPACTING CONCRETES

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ABSTRACT. The paper presents experimental investigations on the special self-compacting concretes, in different compositions. Also, in this paper highlights the influence of super plasticizers additives use upon the mechanical, structural and chemical properties of self-compacting concretes improving. During these laboratory investigations were made samples of self-compacting concrete with different compositions, on which were performed workability and mechanical tests (compressive strength), as well as, structural attempts (microscopy, density, porosity tests).

Keywords: Self-compacting concretes, Superplasticizers additives, Workability, Compression strength, Structural investigations.

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INTRODUCTION

Self-compacting concrete (SCC) is an innovative concrete that does not requires vibration for placing and compaction. It is able to flow under its own weight, completely filling formwork and achieving full compaction, even in the presence of congested reinforcement. The hardened concrete is dense, homogeneous and has the same mechanical properties and durability as traditional vibrated concrete. SCC has many advantages such as the followings:

a) from the contractors point of view costly labor operations are avoided improving the efficiency of the building site;
b) the concrete workers avoid manual vibration which is a huge benefit for their working environment;
c) when vibration is omitted from casting operations the workers experience a less strenuous work with significantly less noise and vibration exposure;
d) SCC is believed to increase the durability relatively to vibrated concrete (this is due to the lack of damage to the internal structure, which is normally associated with vibration) [1].

With the advent of superplasticizers, flowing concretes with slump level up to 290 mm were manufactured, provided that an adequate cement factor was used, that is at least 300 kg/m^3. The most important basic principle for flowing and unsegregable concretes including SCCs is the use of superplasticizer combined with a relatively high content of powder materials in terms of portland cement and fly ash. A partial replacement of Portland cement by fly ash was soon realized to be the best compromise in terms of rheological properties, resistance to segregation and strength level.

POLYCARBOXYLATE-BASED SUPERPLASTICIZERS

The family of chemical compounds referred to a High-Range Water- Reducers, or Superplasticizers, comprises a variety of synthetic water soluble polymers, taken from a broader group of compounds, generically labeled `polymeric dispersants`. For nearly half a century, the superplasticizers group comprised mostrly two types of polymers, derived respectively from sulfonated naphthalene and sulfonated melamine. In the past decade, however, the introduction of acrylic- type polymers has considerably broadened the group, which now includes dozens of different carboxylated polymers, these are often referred to as Polycarboxy superplasticizers`.

In self-compacting concrete (SCC) mixture design, employment of polycarboxylate-based superplasticizers (PC-based SPs) usually guarantees the initial workability. However, depending on the type of PC-based SPs, workability loss of SCC sometimes appears to be a problem at least for ready-mixed concrete industry. On the contrary, early setting and early strength gaining properties are more important, whereas workability retention may be less important to precasters.

From chemistry point of view, polycarboxylate based superplasticizer is the third generation superplasticizer which is developed from the first type water reducing agent that represented by Ligno Sulphonate Calcium and Naphthalene Sulfonate. In table 1, below are presented the technical data for this types of additives [2]:

Table 1 Technical data for polycarboxylate based superplasticizer

Appearance:	liquid: brown
Water Content (Powder) (%):	＜2
Solid Content (Liquid) (%):	20%,40%
pH Value (20℃) (20% Liquid):	5~8
Alkali Content (%):	<5
CI Content (%):	<0.03
Surface Tension(mn/m):	71.5~72
Dosage Recommendation(%): in relation of weight of cement	/
	liquid:0.5~1% (20% solid content)

MATERIALS USED AND EXPERIMENTAL WORKS

Polycarboxylate Additives Used

In present study are used two types of polycarboxylate based superplasticizer, more exactly polycarboxylate ether additives. First used is the superplasticizer produced by BASF, known commercially as Glenium Sky 617. In table 2 are presented the technical data and the chemistry of this superplasticizer.

Acording to the manufacturer the recommended dosage is aprox 1.5 kg per 100 kg of cement and in special situations is 1.7 kg per 100 kg of cement.

The second superplasticizer used is also produced by BASF and is known from commercially point of view as Glenium Sky 526. The manufacturer recommend the dosage to be 0.4 – 1.0 kg per 100 kg of cement. For this superplasticizer additive the technical data and the chemistry are also presented in Table 2:

Table 2 Technical data and chemistry for Glenium 617 and Glenium Sky 526 [3]

TECHNICAL DATA AND CHEMISTRY	GLENIUM SKY 617	GLENIUM SKY 526
Primary function	Superplasticizer / high range water reducer	Superplasticizer / high range water reducer
Secondary function	Curring Accelerator	Curring Accelerator
CE mark	Second NP EN 934-2	Second NP EN 934-2
Aspect	Líquid, brown	Líquid, brown
Relativ density (20ºC):	1,05 ± 0,02 g/cm³	1,07 ± 0,02 g/cm
pH, 20ºC:	7 ± 1	5 ± 1
Viscosity (20ºC):	< 100 cps	< 100 cps
Clor content:	≤ 0,1 %	≤ 0,1 %
Alkali content	≤ 2.5 % (EN 934-1 / 2008)	≤ 2.5 % (EN 934-1 / 2008)

Characteristics and advantages of this two superplasticizers:

- beneficial effect on coezitivity, facilitates mixture pumping and minimizing the risk of segregation,
- improved dimensional stability and reduce the risk of shrinkage cracks,
- maintaining the consistency, to ensure that the concrete as the same characteristics as that specified and ordered from the batching plant
- obtaining a concrete with low viscosity, easy to be compacted and finished,
- obtaining a concrete with high stability under variation of material characteristics.

Cement

Cement paste mixtures were prepared with a CEM I 42.5R type cement with Blaine specific surface area (SSA) of 380 m²/kg and density of 3.12g/cm³. The same cement was also used in concrete mixtures. In table 3 is shown the mineral composition of this type of cement.

Table 3 The chemical properties of cement (CEM I 42.5 R)

TYPE OF OXIDE	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	SO_3	Cl	L.O.I.
COMPOS - ITION (%)	19.30	5.57	3.46	63.56	0.86	0.13	0.80	2.91	0.013	2.78

Fly Ash

The fly ash used in this study is a classe N fly ash with a fineness of ≤40 % that passes on the sieve 0.045 mm accordind with **EN 451 – 2*.** Its density and Blaine SSA were 2.2g/cm³ and 290 m²/kg, respectively. The oxide composition of the fly ash is shown in table 4.

Table 4 Oxide composition of fly ash

OXIDE (%)	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	TiO_2	L.O.I.
FLY ASH	59.94	22.87	4.67	3.08	1.55	0.35	0.62	2.19	0.94	3.34

Also in figure 1 it can be seen the sferic sheaps of the fly ash particles made by microscopic analisys method.

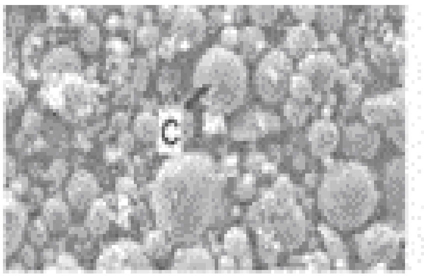

Figure 1 The geometrical form of the fly ash particles [4]

Fine and Coarse Aggregates

In this study were used granite aggregates. Fine aggregates was within the granulometric range of 0-4 mm, and coarse aggregates in granulometric range of 4-8 mm. We determined the density of the aggregates (table 5), according with European Standard EN 1097-6 and granulomertrice curves were drawn in accordance with European Standard **EN 933-1** (figure 2 and 3).

Table 5 Specific gravity of fine and coarse aggregates

AGGREGATES	VALUE OF DENSITY (g/cm^3)
Fine aggregates	2,66
Coarse aggregates	2,62

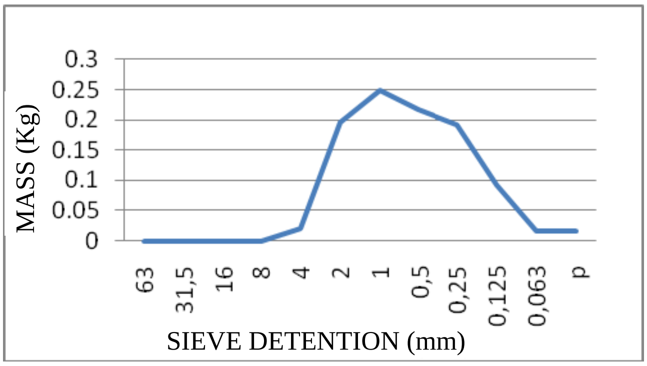

Figure 2 Granulometric curve on the fine aggregates

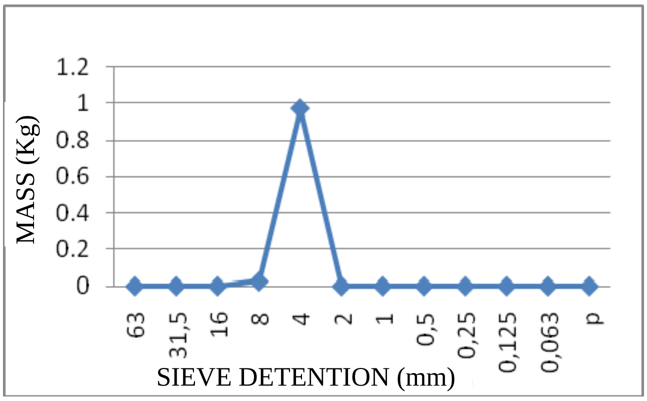

Figure 3 Granulometric analysis curve on the coarse aggregates

CONCRETE COMPOSITIONS

This study was designed 10 concrete compositions. Some had good features of self-compacting concrete, especially compositions C3 and C8. The other compositions showed a low degree of segregation (C1, C4, C5, C6, C9). C2 and C10 compositions had encountered problems of workability, thus cannot be considered self - compacting concretes, especially composition C2. C7 composition presented severe problems due to excess segregation, probably due to a high amount of fly ash. All these data can and studied in Table 6. Slump tests were conducted according to the **EN 12 350 – 8 / 2010**, standard norm.

Table 6 Concrete compositions

COMPO-SITION NO.	CEMENT Kg/m³	FLY ASH Kg/m³	FINE AGG. Kg/m³	COARSE AGG. Kg/m³	WATER Kg/m³	TYPE, % OF SP	W/C RATIO	W/B RATIO	SLUMP TEST T500 (sec)	SLUMP TEST D (mm)	SLUMP TEST H (mm)
C1	477	-	1100	616	199	Glenium Sky 617 – 3%	0.42	-	1.81	735	253
C2	477	-	1200	600	167	Glenium Sky 617 – 3%	0.35	-	Not recorded	395	255
C3	477	-	1155	645	167	Glenium Sky 526 – 3%	0.35	-	11.30	787.5	290
C4	477	-	1155	645	167	Glenium Sky 526 – 2%	0.35	-	17.15	665	273
C5	477	-	1155	645	167	Glenium Sky 526 – 2,5%	0.35	-	10.45	710	282.5
C6	477	-	1155	645	167	Glenium Sky 617 – 9%	0.35	-	2.65	765	284.5
C 7	330	330	1000	500	194	Glenium Sky 526 – 1.5%	0.58	0.29	2.67	800	290
C8	300	177	1260	645	102	Glenium Sky 526 – 2%	0.34	0.21	6.87	735	286.5
C 9	300	177	1260	645	102	Glenium Sky 526 - 1.5%	0.34	0.21	20.21	600	271.5
C 10	300	177	1260	645	102	Glenium Sky 526 – 1%	0.34	0.21	24.3	520	252

After the concrete compositions and the slump tests were made, the concrete from each mixture, was cast in molds (50 mm cubes), to obtain samples, that were subjected, furthermore, to mechanical tests of compressive strength. Casting and compressive strength tests, were conducted according to European Norms, **EN 12390-2/2003** and **EN 12390-2/2003**, respectively. In table 7 are presented the compressive strength values, obtained for each composition from this study. The samples were held in water until the day of the test. The tests presented in the table were made at 1, 3 , 7, 14 and 28 days from curing.

Table 7 Compressive strength values after 1,3,7,14 and 28 days of free hardening

COMPOSITION NO.	1 DAY (MPa)	3 DAYS (MPa)	7 DAYS (MPa)	14 DAYS (MPa)	28 DAYS (MPa)
C1	11.99	36.7	45.7	56.2	62.2
C2	16.4	36.7	43.4	57.1	61.8
C3	31	46.6	52.3	63.7	73.8
C4	23.6	47.2	59.3	63.8	70.6
C5	23.5	42.6	60.4	66.3	74.5
C6	7.6	36.2	49.9	59.2	65.8
C7	10.2	16	26.5	36.4	45.2
C8	10.2	19.8	29.3	51.2	61.5
C 9	15.2	31.5	40.7	47.5	60.3
C 10	12.4	26.7	34.5	42.8	54.4

Following the compressive strength values (table 7) and apparent porosity values from table 8, it can be said that the compressive strength for this compositions is clearly, inversely proportional with the values of the apparent porosity obtained for the same compositions.

Furthermore, given that porosity is a factor of durability, for concrete constructions, were made also, determinations of apparent porosity by water absorption method. Since the apparent porosity is calculated in percentage, density values were determined for each concrete composition, for a better understanding and analysis of the percentage of apparent porosity. Apparent porosity and density were determinated in accordance with European Standards, **EN 1097-6/ 2001** and **EN 12390-7/2003**, respectively. These values of apparent porosity, can be considered satisfactory in comparison with existing data in the literature, which states that the value of apparent porosity should have a maxim value of 10 percentage [5]. In table 8 are presented the data for density and apparent porosity.

Table 8: Density and apparent porosity

MIXTURE NO.	SPECIFIC MASS (DENSITY,) kg/m^3	APPARENT POROSITY %
C1	2343.84	7.47
C2	2386.42	7.12
C3	2434.13	5.42
C4	2427.56	5.85
C5	2442.59	6.21
C6	2380.51	7.72
C7	2328.12	7.49
C8	2380.06	6.90
C9	2340.54	6.46
C10	2375.38	5.78

Furthermore in table 8, it can be seen that the calculated apparent porosity is inversely proportional to the density of these mixtures, if the apparent porosity is lower the density is higher, aspect which is required for concretes with high durability.

MICROSCOPYC ANALYSIS

Microscopic analysis were performed with the microscope SEM (scanning electron microscopy), on samples of hardened cement paste and concrete. Analyzed compositions are also simple (cement and water, in case of cement pastes with w / c ratio of 0.35; and cement, water and aggregates,in case of concretes with a ratio w / c 0.35) and additivates, like superplasticizers additives and/ or fly ash. Figure 4 presents a possible unadsorb superplasticizer in the proces of hydration, like a bridge between concrete particles. Some authors [6,7,8] have found that ettringite that crystallizes in the presence of a superplasticizer loses its needle-like shape to form rather small crystals without the definite characteristical shape ettringite. A neddle sharp form of ettringite is presented in the microscopic analisys of figure 5. The composition is without superplasticizer additives and it is form on the surface of fly ash particle.

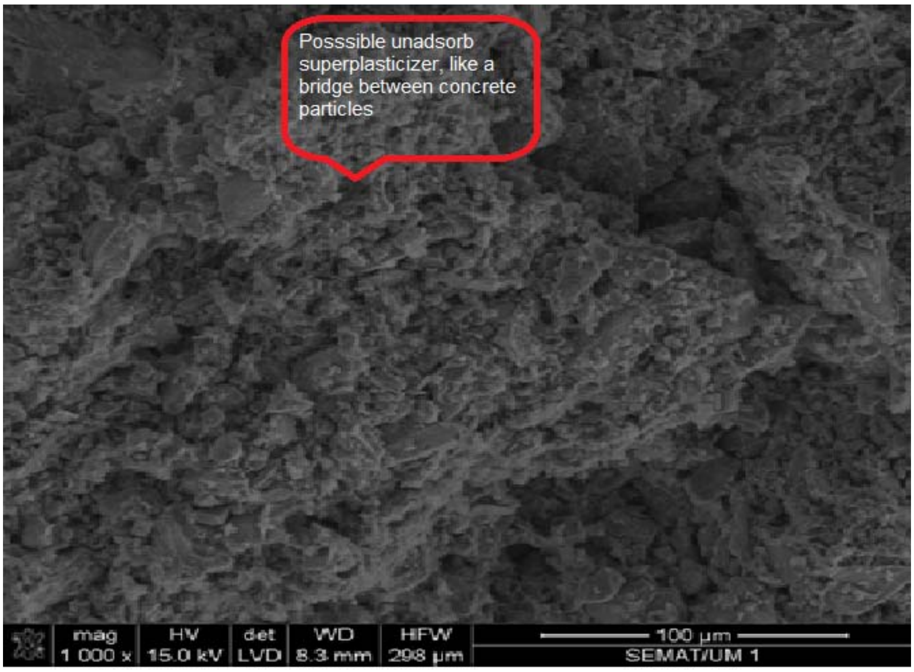

Figure 4 Possible left over of superplasticizer additive
that was not adsorb in the process of hydration

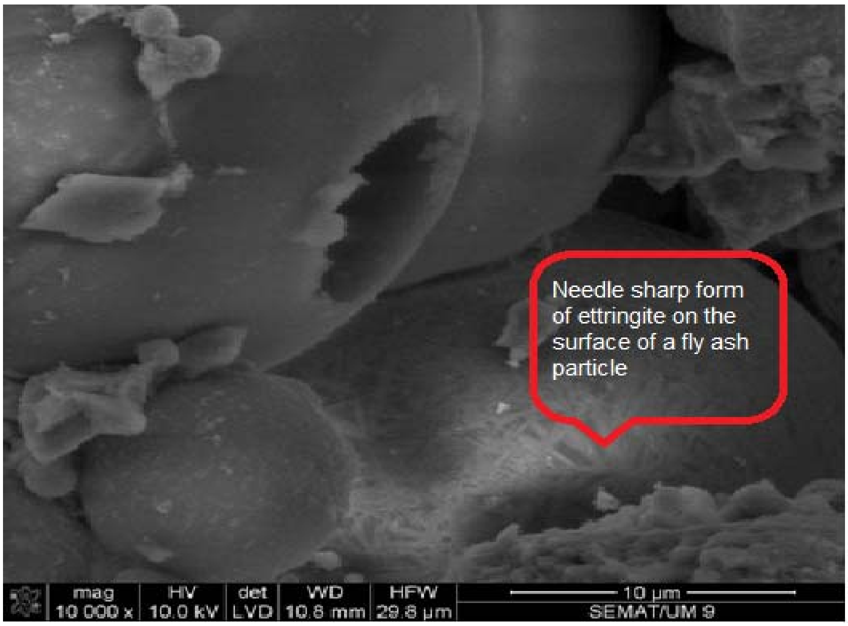

Figure 5 Neddle – sharp form of ettringite in concrete without superplasticizers, after 1 h from hydration

In figure 4 it can be seen, in the left part of the center, of the microscopyc image, a fraction that appears to be a unadsorb superplasticizer additive. Also, in this figure it can be seen the geometry of hydration products form in the presente od superplasticizers. Figure 5 shows the geometry of hydration products, like sharp needles, form in concretes compositions without superplasticizers additives.

In figures 6 and 7, are illustrated by microscopic analisys the mixture C3, C8, respectively. On them it can be seen the small crystals of hydration products, without the normal characteristics of this hydration product, obtained in the absence of superplasticizer additives.

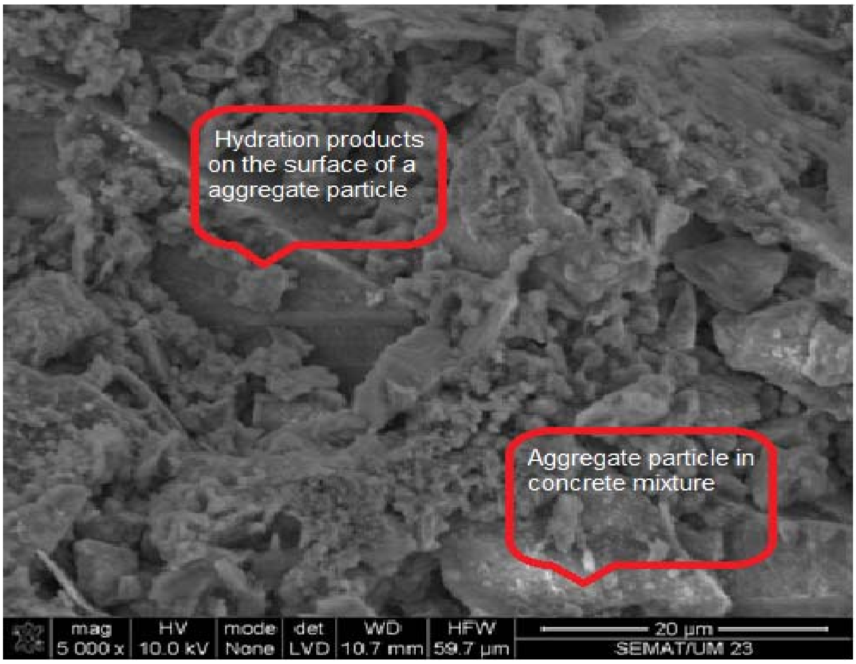

Figure 6 Microscopic analysis of mixture C3. Composition without fly ash

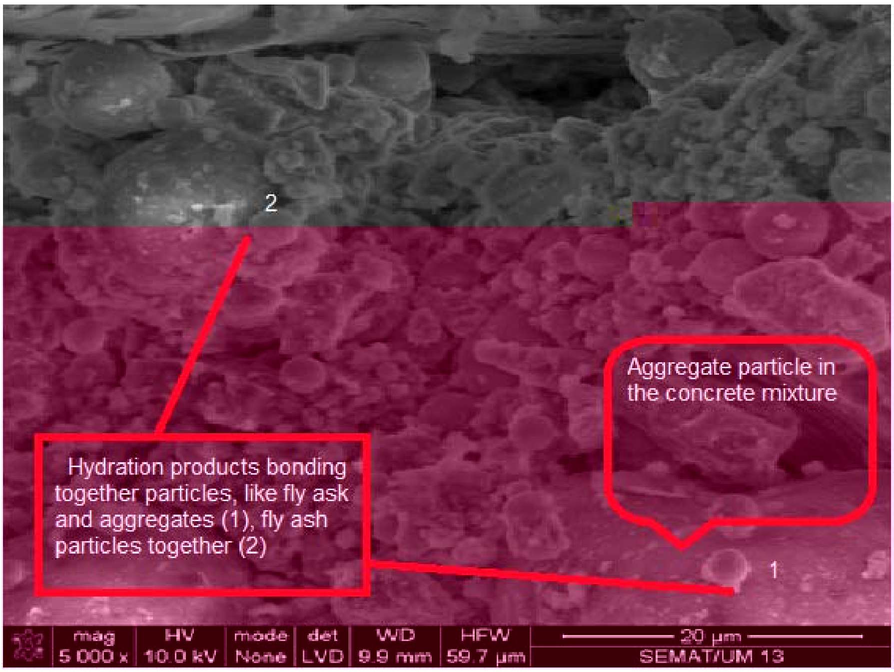

Figure 7 Microscopic analysis of mixture C8. Composition with fly ash

CONCLUSIONS

1. - the use of superplasticizers is a very important aspect to obtain a good workability and in the same time good mechanical streangth;
2. - the study shown that the Glenium Sky 526 aditiv has much more impact on good workability than the Glenium Sky 617, in therm of procentage use for the same mix of concrete;

3. - in this reserch were obtained 2 compositions of self-compacting concrete with good workability (one is simple and the other incorporates fly ash);

4. – this study follows the evolution of compressive strength for 10 concrete compositions up to 28 days of free hardening, thus were obtain concrete compositions with good mechanical properties;

5 - it was shown that the density of concrete compositions that varies within a small interval, may entail a considerable variation of porosity;

6 - the use of aggregates with small granulometrie (0-4mm for fine aggregates and 4-8mm for coarse aggregates) does not mean that it can be obtain self-compacting concretes with good performances. Good performances, workability, the most important, are obtained by a proper use of all the fractions (kg/m^3) in the mixture;

7 – microscopyc analysis showed the distribution of the mixture components and also the ways in which hydration products "link together" the aggregates, fly ash and other additives.

REFERENCES

1. IUREŞ LAND BOB C, The Future Concrete: Self-Compacting Concrete, `Buletinul Institutului Politehnic` from IAŞI , Technical University Gheorghe Asachi from Iaşi Tomul LVI (LX), Fasc. 2, 2010.
2. RIXOM R AND MAILVAGANAM N, Chemical Admixtures for Concrete, E & FN Spon Publication, III EditioN
3. www.basfromania.com
4. ABHISEK DAS, Dept. of Mining Technology, National Institute of Technology, Rourkela – 769008, Li Yujin, Zhou Shiquiong, Yin Jian, and Gao Yingli 2008.
5. NEVILLE A, Concrete properties, Dundee University, Scotland, 1975, pp 324.
6. MASSAZZA F AND COSTA U, Effect of superplasticizers on the C3A hydration, Proceedings of the 7th International Congress on the Chemistry of Cement, Paris 4 (1980) 529– 534.
7. BASSANT J B, Nouvelles me´thodes d’e´tude de la formulation d’hydrates des ciments. Applications a` l’analyse de l’effet d’adjuvants organiques, PhD Thesis No. 156, Universite´ de Franche Comte´, Besanc¸on, France, 1994.
8. FERNON V, Caracte´risation de produits d’interaction adjuvants/hydrates du ciment, Journe´e technique Adjuvants—Les Technodes, Guerville, France, 1994.