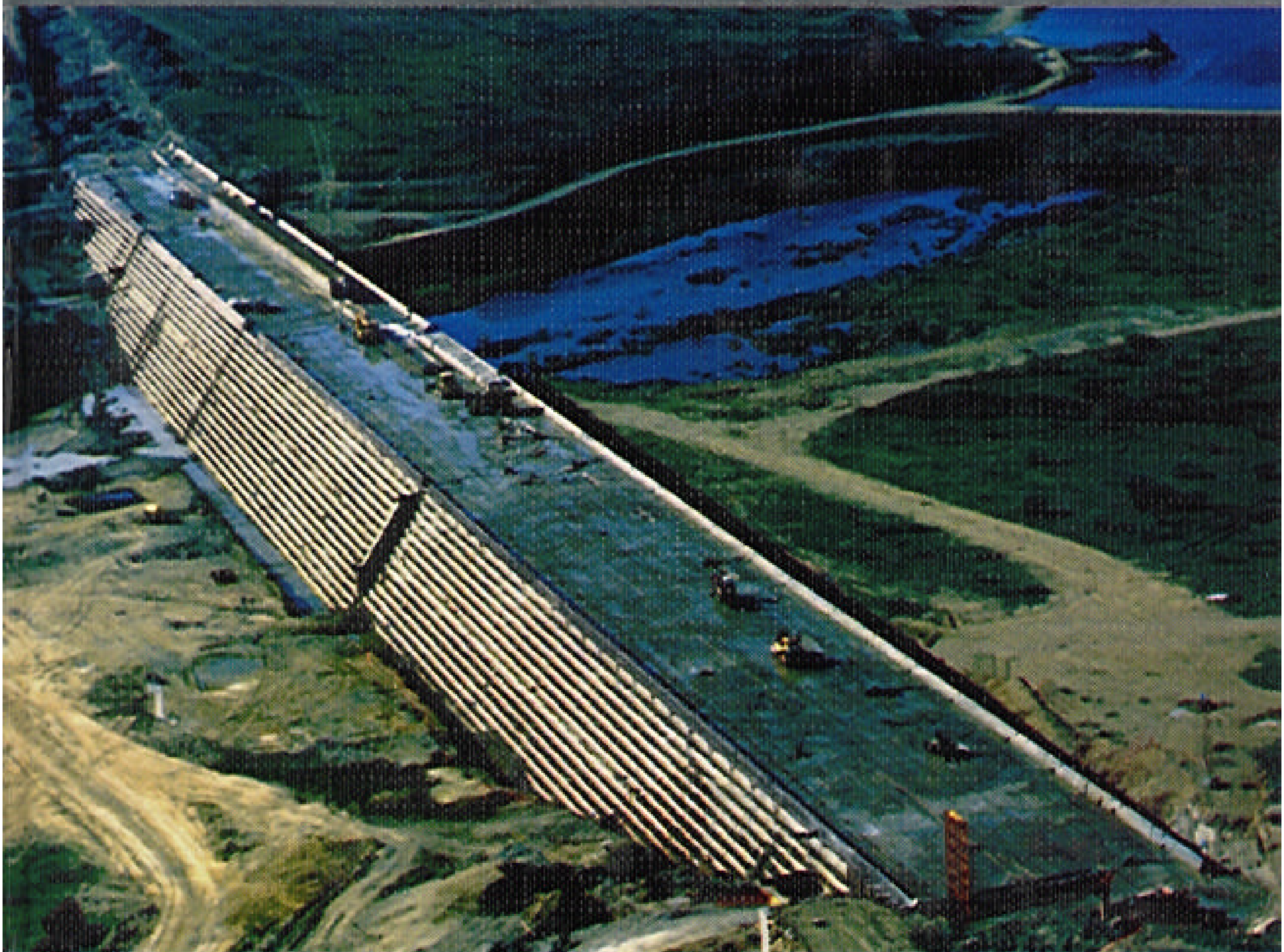
ROLLER COMPACTED CONCRETE DAMS

Proceedings of the International Symposium held in Santander, Spain, on 2 - 4 October 1995

Crushed Powder Filler - The Use on RCC and the Reduction of Expansion due to the Alkali - Aggregate Reaction



IECA Spanish Institute of Cement and its Applications (IECA)

Spanish National Committee on Large Dams (CNEGP)

Crushed Powder Filler - The Use on RCC and the Reduction of Expansion due to the Alkali - Aggregate Reaction

Oliveira, Paulo José

CESP - Companhia Energética de São Paulo - Brazil

Salles, Flavio Moreira

CESP - Companhia Energética de São Paulo - Brazil

Andriolo, Francisco Rodrigues

Consulting Engineer-São Paulo- Brazil

ABSTRACT

The data from the study of mixes with the use of Crushed Powder Filler from basaltic rocks are presented. The studies carried out in the laboratory of Companhia Energética de São Paulo - CESP, in Ilha Solteira, demonstrate the advantages of this material in reducing expansion resulting from the Alkali-Silica Reaction. The test data on the mortar bars are presented with various contents of this material in combination with high alkali cement contents.

1- INTRODUCTION

Crushed sand has been regularly used combined with natural sand, for correction of the fineness module or as substitute when no natural sand deposits are available near the worksite. Fine materials (less than # 200 -0,075mm mesh opening) have been considered unsuitable for use with conventional concrete, and their maximum limits are set forth in the specifications. However, the use of this material on RCC has resulted beneficial to the extent that it has increased strength and reduced permeability. Due to this, studies have been carried out by Companhia Energética de São Paulo at their laboratory in Ilha Solteira, in order to determine the effects of filler originating from crushed rock materials on conventional concretes and RCC, and to evaluate also the pozzolanic activity of these fines and their action as regards alkalis aggregate reaction.

The purpose of this work is to demonstrate that it is not necessary to wash these aggregates after crushing of sound material and to point out the benefits from these fines to conventional concretes and RCC and to reduction of expansion resulting from alkali aggregates reaction.

2- CONCEPT

Crushed sands originated from crushed rock can be obtained with "Impactor" type crushers which produce round grains and fine contents of about 12% to 16%, or with recrushers for fines "Hydrofine" or "Very Fine Crusher" types, producing sand with fine content of about 8% to 14%. This material, when obtained from sound rock does not contain clay fractions and has no cohesive characteristics. However, Technical Specifications consistently require that aggregates be washed, in order to eliminate these fines.

3- MATERIALS

3.1- Aggregates

Crushed sand produced from crushed basalt, laboratory classified in grade ranges determined and added of fines produced by recrushing. Coarse aggregates also obtained from crushed basalt.

3.2- Agglomerates

- Common Portland Cement with addition, ABNT-NBR-(BRAZIL) -CP-II-F type.
- Common Portland Cement with high alkalis content - CP-II-E type.
- Common Portland Cement without addition - CP-I-S type.
- Fly Ash

4- MATERIAL PREPARATION

4.1- Crushed Sand

Crushed sand was laboratory made in order to comply with grading and content ranges as indicated in Figure 1.

MATERIAL	SIZE GROUP	SIEVE SIZE mm	%
CRUSHED SAND	A	4,8 - 2,4	10
	B	2,4 - 1,2	20
	C	1,2 - 0,6	30
	D	0,6 - 0,3	20
	E	0,3 - 0,15	15
	F	0,15 - 0,075	5
	G- FILLER	< 0,075	VARIABLE

FIGURE 1- GRADING RANGES SANDS

CRUSHED SAND	% OF G FILLER
AAP	0
AAP - 2	2
AAP - 4	4
AAP - 6	6
AAP - 8	8
AAP - 10	10
AAP - 15	15
FILLER G	100

FIGURE 2- FINE CONTENTS IN COMPOUND SANDS

The sand, thus composed was named AAP - Standard Crushed Sand. Following this, other crushed sands were produced with increased fine contents as shown in Figure 2.

4.2- Coarse Aggregates

Coarse aggregates were obtained from crushed basalt with Maximum Size Aggregate of Coarse 1=19mm, Coarse 2=38mm, Coarse 3=50mm.

5- TESTS

5.1- Materials Characterization

5.1.1- Cements- Cements were characterized as shown in Figure 3.

5.1.2- Fly Ash- Fly Ash was characterized as shown in Figure 3.

5.1.3- Coarse and fine aggregates - were characterized as shown in Figure 4.

5.1.4- Fines (Filler G)- Were tested as if being pozzolanic material with the following adjustments:

- Alkali reactivity (ASTM-C-441) -tested above the content specified in test methodology (25% in volume) with Filler G contents of 37,5% e 50% as cement replacement;
- Pozzolanic Activity (ASTM-C-305 and ASTM-C-311)- -tested above the content specified in test methodology (35% in volume) with Filler G contents of 30% e 40% as cement replacement;
- Activity with Lime (ASTM-C-311) - without changes.

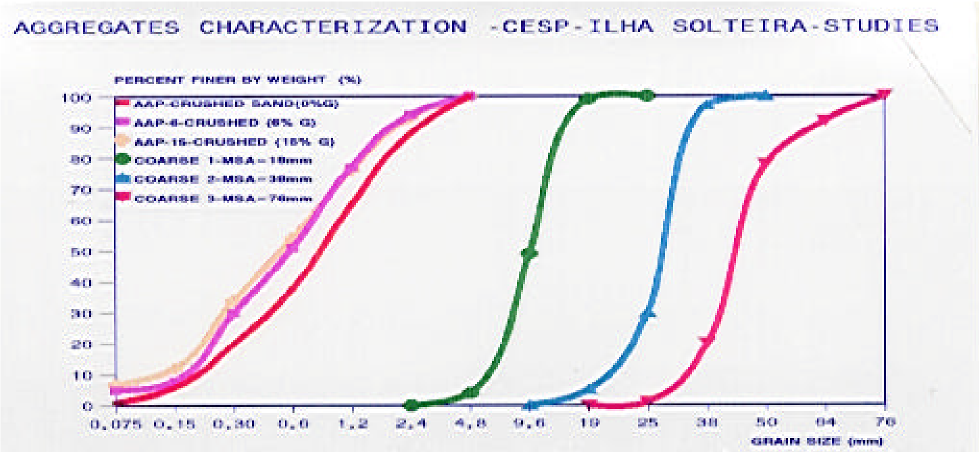
Values obtained are shown in Figure 5. It should be pointed out that “Filler G” presented a Specific Blaine Surface Fineness between 1700 cm2/g and 2000cm2/g.

TEST	FILLER G % (VOLUME)	AAP FILLER G	FLY ASH
MORTAR EXPANSION - %	25	0,004	0,022
	37 5	0,002	
	50	0,005	
REDUCTION OF EXPANSION - %	25	68 3	78 6
	37 5	75,2	
	50	97,9	
WATER REQUIREMENT - %	30	104	
	35	104,8	118
	40	108	
ACTIVITY INDEX WITH CEMENT - %	30	55 5	
	35	48,7	52,7
	40	42 5	
ACTIVITY INDEX WITH LIME- MPa		0 4	3 9

FIGURE 5- CHARACTERIZATION OF "FILLER G" AND POZZOLANIC MATERIAL

MATERIAL			CEMENT-CP-II-F	CEMENT-CP-I-S	FLY ASH
IDENTIFICATION			21210	21055	5260
% RETAINED ON SIEVE # 200			3.3	2 4	
% RETAINED ON SIEVE # 325			19 3	16 1	55 1
FINENESS SPECIFIC SURFACE - BLAINE - cm2/g			3325	3496	2511
AVERAGED DIAMETER - micron					11 4
APPARENT SPECIFIC GRAVITY - g/cm3			1 06	1 11	0 69
ABSOLUT SPECIFIC GRAVITY - g/cm3			3.06	3 15	2 09
REACTIVITY WITH ALKALIES	REDUCTION OF EXPANSION - %				0 22
	MORTAR EXPANSION - %				78 6
POZZOLANIC ACTIVITY INDEX	WATER	REQUIREMENT-%			118 5
	WITH	CEMENT - %			52 7
	WITH	LIME - MPa			3 9
WATER FOR	CONSISTENCY	grams	125	130	
FLOW		%	25	26	
DRYING SHRINKAGE - %					-0 003
TIME OF SETTING h m			2 16	2 48	
COMPRESSIVE STRENGTH CYLINDERS 50x100mm	3 DAYS	MPa	24 6	24 9	
	7 DAYS	MPa	29 1	27 5	
	28 DAYS	MPa	39,4	32 1	
	90 DAYS	MPa	41,6	33 8	
HEAT	HYDRATION	7 DAYS		80	
	cal/g	28 DAYS		87	
MOISTURE - %					0 4
CHEMICAL ANALYSIS %	LOSS ON	IGNITION	5,64	2 6	5 33
	INSOLUBLE	RESIDUE	1 64	0 55	
	SiO2		18,24	18 23	53 8
	Fe2O3		2,63	3 55	7 43
	Al2O3		6.05	4 71	28 03
	CaO		61,97	61 6	
	MgO		1,11	4,56	0 12
	SO3		2,4	2,95	0,26
	Na2O		0,23	0,15	
	K2O		0,43	0,67	
	Al2O3 + Fe2O3				35 46
	Al2O3+Fe2O3+SiO2				86,26
	ALKALIES Eq		0,51	0 59	
	FREE LIME AS CaO		1,07	1 47	
	C3S			61 11	
	C2S			6 19	
	C3A			6 47	
	C4AF			10 8	

FIGURE 3- CHARACTERIZATION OF CEMENTS AND FLY ASH



AGGREGATE	CRUSHED SAND-AAP	CRUSHED SAND APP-6	CRUSHED SAND APP-15	COARSE 1	COARSE 2	COARSE 3
M.S.A (mm)	4,8	4,8	4,8	19	38	76
ABSOLUTE SPECIFIC GRAVITY (t/m3)	2,654	2,475	2,477	2,949	2,957	2,96
APPARENT SPECIFIC GRAVITY (t/m3)				1,514	1,471	1,426
ABSORPTION (%)	2,25	1,87	2,25	1,43	1,05	0,75

FIGURE 4- CHARACTERIZATION OF AGGREGATES USED FOR STUDIES

5.2- Lime Fixation- Lime (Ca[OH]2)- calcium hydroxide fixation is a method for evaluating the pozzolanic properties of materials. It is accepted that 100g of sand can adsorb in its surface 30mg of $Ca(OH)_2$ in a 1N solution, after 28 days suspension period.

Lime fixation test was executed by placing the material under study (fine aggregate or Fly Ash) in contact with a saturated Ca(OH)2 solution of 10g/l and the Ca(OH)2 content was fixed after aging periods of 7,14, 21, 60, and 90 days, in an aliquot of the supernatant solution. A "white" (standard) aliquot was used as reference. Evaluations were made for sands in Figure 2 and for Fly Ash, and for fixation values in Figure 6.

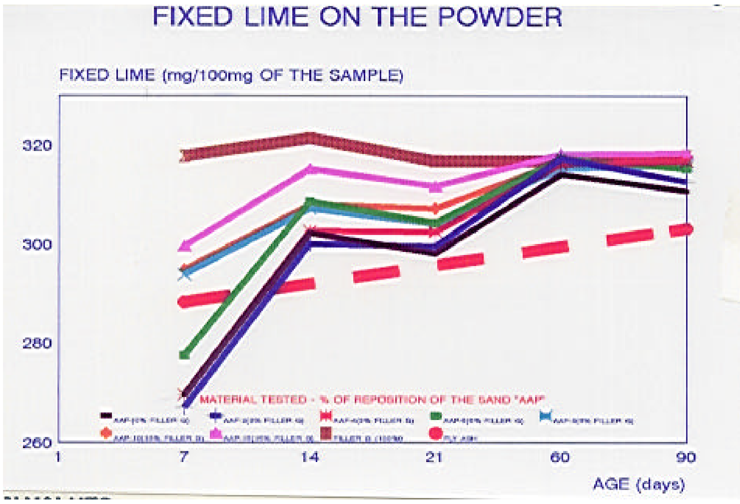


FIGURE 6- LIME FIXATION VALUES

5.3- Potential Reactivity - N.B.R.I.-Method -South Africa

This test was carried out according to methodology of the NBRI- “National Building Research Institute” from South Africa. Samples of basalt and Pyrex glass were selected with 0,52% soluble alkali content cement mixes. Mortar bars were molded according to NBRI methodology, with 100% cement and mortar with replacement of cement (in weight) with 10%, 20% e 30% of Filler G (fraction below 0,075mm). For comparison purposes , the same aggregates (Pyrex and basalt) were tested with mortar with replacement of cement with 10%, 20% e 30% of Fly Ash. The figures obtained are shown in Figure 7.

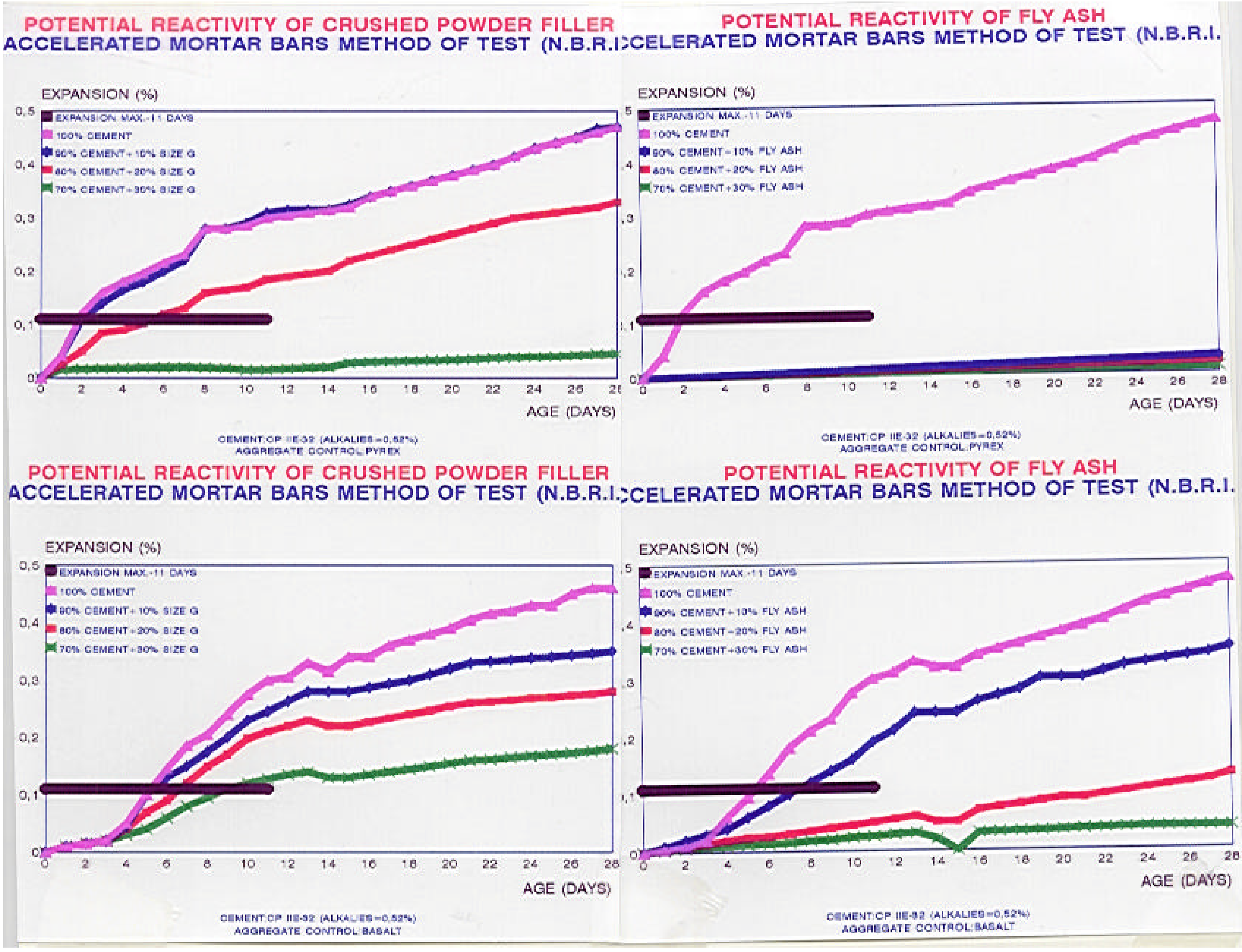


FIGURE 7- “FILLER G” EFFECT ON EXPANSION REDUCTION (ALKALIS REACTION)

5.4- Tests with Concrete

5.4.1- RCC- Roller Compacted Concrete

Crushed sand AAP-15 (with 15% Filler G) and common cement without addition (CP-I-S) have been used for these concrete mixes . RCC mixes which have been tested were composed of Coarse 1, 2 e 3, combined so as to obtain the lowest void index, based on a cubic curve type $p = (d/MSA)^{1/3}$ x100%. A time interval of 25+/- 5 seconds was established in the VeBe modified test to determine consistency. After establishing optimum content of mix water, three mixes were prepared with cement consumption of 60, 90 and 120 Kg/m3, and whole cylindrical test specimens (25x50cm), were molded for simple axial compression resistance tests at 28 and 90 days. Characteristics and values obtained are shown in Figure 8. Mix efficiency (compressive strength/cementitious content) are shown in Figure 9

5.4.2- Conventional Concrete

Crushed aggregates as mentioned before and crushed sand AAP (standard without fines) AAP-6 (with 6% Filler G) and AAP-15 (with 15% Filler G). were used for these concrete mixes, Binder used was common Portland cement with additions (CP-II-F). Characteristics and values obtained are shown in Figures 8 and 9.

PROPORTIONIG MIX - CVC AND RCC CONCRETES WITH POWDER FILLER

IDENTIFICATION		UNIT	19 AAP	19AAP6	19AAP15	38AAP	38APP6	38AAP15	50APP	50APP6	50APP15	RCC-60	RCC-90	RCC120
SIZE OF AGGREGATE mm		mm	19	19	19	38	38	38	50	50	50	50	50	50
SAND CONTENT	WEIGHT	Kg												
	SOLID VOLUME	%	45	45	45	42	42	42	34	34	34	43	43	43
MATERIALS Kg/m3	CEMENT	Kg/m3	250	250	250	200	200	200	150	150	150	60	90	120
	WATER	Kg/m3	200	200	200	172	172	172	138	138	138	75	85	90
	CRUSHED SAND	Kg/m3	872	879	879	867	874	874	746	751	752	1047	1047	1047
	FILLER G	Kg/m3		53	131		52	130		45	113			
	COARSE 19mm	Kg/m3	1102	1102	1102	558	558	558	419	419	419	417	417	417
	COARSE 38mm	Kg/m3				681	681	681	510	510	510	558	558	558
	COARSE 50mm	Kg/m3							571	571	571	414	414	414
	AIR ENTRAINING	%	0 07	0 09	0 12	0 09	0 11	0 13	0 16	0,24	0 48			
	REATARDER	%	0.2	0,2	0 2	0,2	0,2	0,2	0,2	0,2	0,2			
	A/C or A/Ceq		0 8	0 8	0,8	0 86	0 86	0 86	0 92	0 92	0 92	1 25	0 9444	0 75
THEORETICAL SPECIFIC GRAVITY		Kg/m3	2424	2484	2562	2478	2537	2615	2534	2584	2653	2571	2611	2646
TESTS ON FRESH CONCRETE	SPECIFIC GRAVITY	Kg/m3										2531	2510	2510
	COMPACTION RATIO	%										0,98	0.96	0,95
	SLUMP	cm	5–7	5–7	5–7	4–6	4–6	4–6	3–5	3–5	3–5			
	VEBE-MODIFIED	SEC										20–30	20–30	20–30
STRENGTH	7 DAYS - WET SCREENED	MPa							8 1	8 4	9			
	28 DAYS - WET SCREENED	MPa							10 5	11.6	12 5			
	90 DAYS - WET SCREENED	MPa							13 4	14,3	15 8			
	7 DAYS FULL MASS MIX	MPa	14,7	14 9	16 7	11,3	13 6	12 3	7 6	7 7	7 8			
	28 DAYS FULL MASS MIX	MPa	18 9	19,8	22,9	14 8	17 4	17 1	9 4	10 3	10 6	7,7	11 3	16 6
	90 DAYS FULL MASS MIX	MPa	22 3	24 7	27	17	20 8	20	11	12.8	12 6	8 8	10 6	19 9
MIX EFFICIENCY MPa/(Kg/m3)	7 DAYS - WET SCREENED								0,054	0.056	0 060			
	28 DAYS - WET SCREENED								0.070	0 077	0 083			
	90 DAYS - WET SCREENED								0,089	0 095	0 105			
	7 DAYS FULL MASS MIX		0 059	0.060	0 067	0 057	0 068	0 062	0 051	0 051	0 052			
	28 DAYS FULL MASS MIX		0 076	0.079	0,092	0,074	0 087	0 086	0 063	0,069	0 071	0 128	0.126	0 138
	90 DAYS FULL MASS MIX		0.089	0.099	0 108	0 085	0.104	0 100	0 073	0 085	0 084	0 147	0 118	0 166

FIGURE 8- DATA ON THE STUDIED CVC AND RCC MIXES

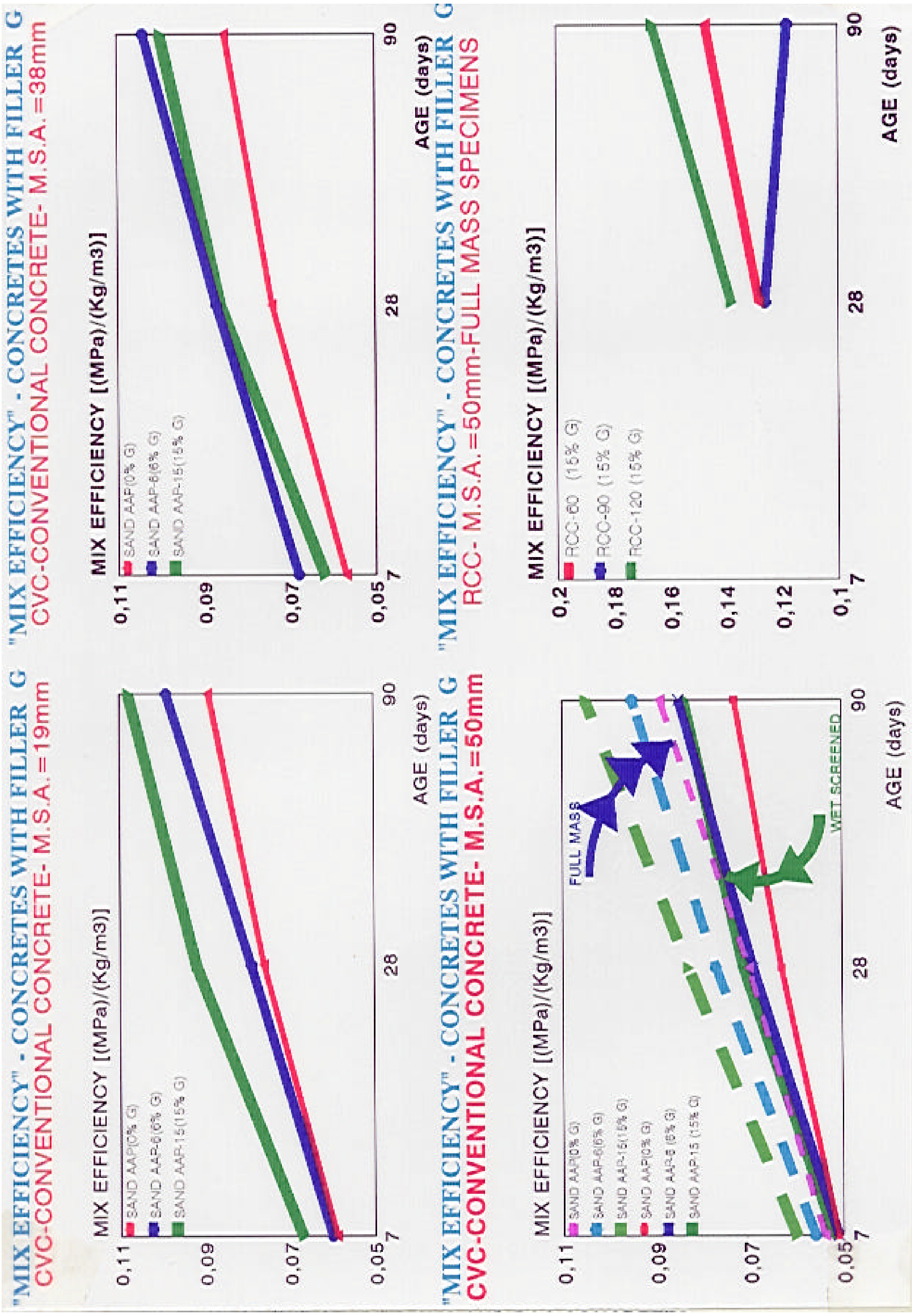


FIGURE 9- MIX EFFICIENCY OF THE STUDIED CVC AND RCC CONCRETES

6- COMMENTS

Basalt fines obtained by crushing and normally disregarded in Technical Specifications and characterized as “Filler G “ in this study, have shown:

- A pozzolanic activity as regards cement hydroxides reaction which should not be discarded although Lime Activity value was low denoting the possibility of implementing resistance, in combination with cement;
- Ca(OH)2 fixation, similar to reactions with Hydroxides available in the cement shows values analog to those for pozzolanic materials which is represented here by a Fly Ash as shown in Figure 6;
- Another pozzolanic action, as concerns minimization of expansion effects due to alkali reaction with the aggregates, as shown in Figure 7, demonstrates a supplementary advantage of “Filler G”;
- Data obtained through testing of CVC and RCC concretes, demonstrate through mix efficiency registered, that the use of this type of Filler, in the RCC as well as and even more in conventional concretes, increases its strength;
- Improved resistance obtained with the use of Filler on the CVC, plus the improvement observed in reduction of the RCC permeability [1, 2, 3, 4] prove that the use of this material is worthwhile.;
- These improvements lead to reviewing the parameters set in Technical Specifications for the Conventional Concretes as regards allowing the use of fines, provided these do not have cohesive characteristics (argillaceous) as practiced for the RCC.

7- REFERENCES

[1]- Braga, J.A; Lacerda, S.S.; Duarte, J.D.C.; Rosário, L.C.- “Utilização de Finos- Sub-Produto de Britagem nos Concretos Rolado e Convencional”- (“Use of Fines- A Crushing By-Product For RCC And Conventional Concrete”) XVIII S.N.G.B - Foz do Iguaçu- Brazil-1989

[2]- Andriolo, F.R.; Braga,J.A.; Zaleski, J.M.; Zanella, M.R.- “Uso do Concreto Rolado- Projeto Capanda (Angola)- Ensaios Especiais”- (“Use of RCC Concrete- Capanda Project-Angola)- Special Tests”- XIX SNGB- Aracaju-Brazil-1991

[3] - Tavares,M; Schmidt; Resende,F.; Fontoura, P.T.; Andriolo, F.R.- “Capanda-Angola Hydroelectric Development- Quality Control of Materials and Conventional and Roller Compacted Concrete”- Simposio Internacional Sobre Presas de hormigón Compactado- Spain-1995

[4]- Andriolo, F.R.- “RCC Properties”- Simposio Internacional Sobre Presas de Hormigón Compactado- Spain-1995