ROLLER COMPACTED CONCRETE DAMS

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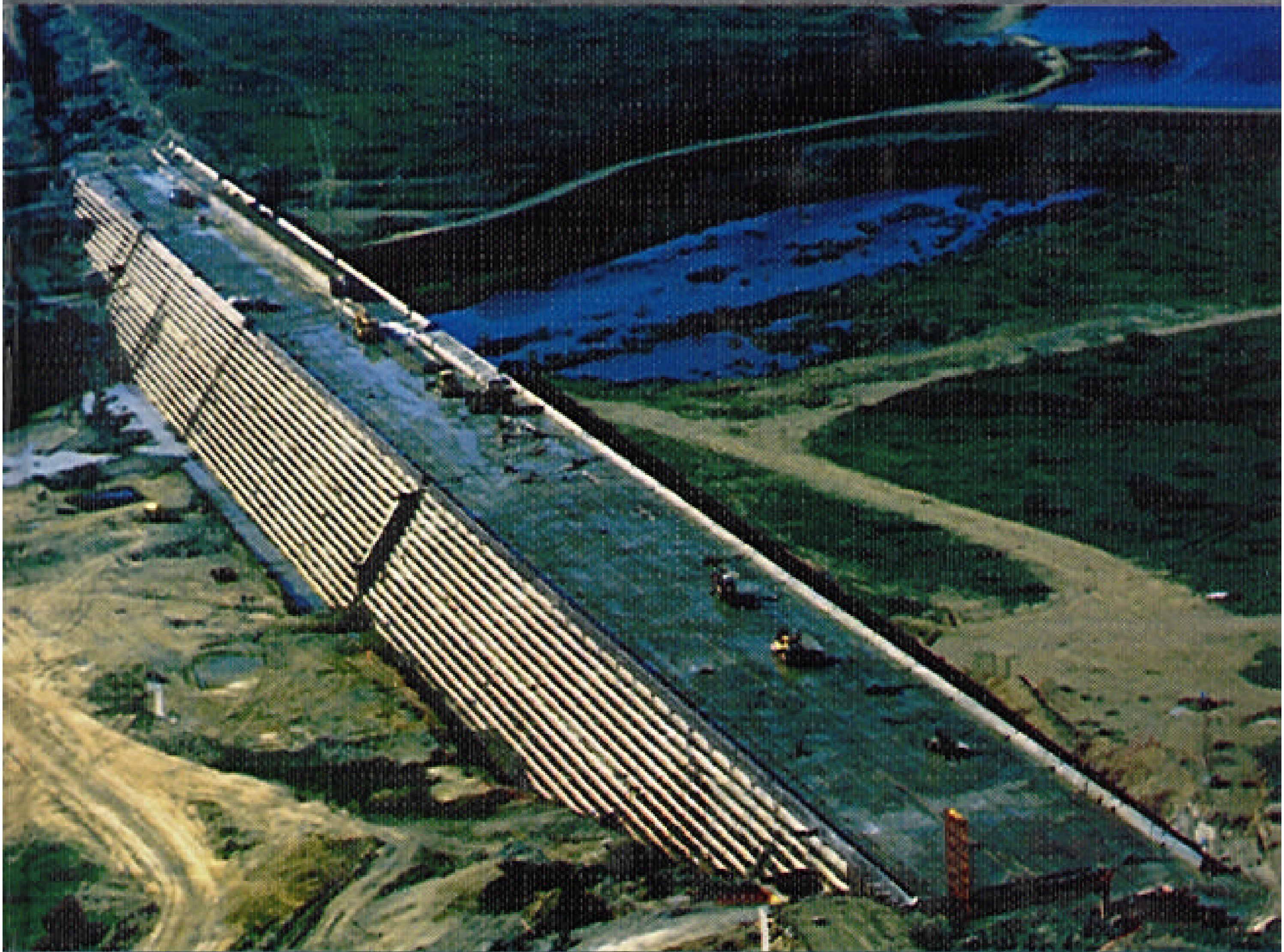
HIGH PASTE CONTENT AND LOW CEMENT CONTENT MIXES, FINELY CRUSHED ROCK, SPECIFIC GRAVITY, COMPACTING RATIO, LOW COST....DISCUSSIONS AND VALUES OBTAINED



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HIGH PASTE CONTENT AND LOW CEMENT CONTENT MIXES, FINELY CRUSHED ROCK, SPECIFIC GRAVITY, COMPACTING RATIO, LOW COST....DISCUSSIONS AND VALUES OBTAINED

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ABSTRACT

Presented in this report are the points of discussion regarding whether or not high cement content mixes are required to achieve a high degree of compacting, as is required in some specifications. The use of other non-traditional materials, with an adequate grain size make it possible to reach a Specific Gravity, on site, which is very close to the design mix content. The Degree of Compacting- COMPACTION RATIO in this method is higher than the 96% achieved with low cement content mixes.

Data are presented on mix studies, the execution of test fills and jobs confirming that a high degree of compacting can be obtained even with low cement content mixes, not only with high cement content mixes. Due to the use of high specific gravity aggregates, there has been a supplemental increase with respect to the degree of compacting chosen to comply with the minimum required in the design. In this way it is possible to reduce the cost of Roller Compacted Concrete for certain jobs.

1- INTRODUCTION

The basic objective of a design mix study is to establish a proportion between the "available" materials in order to obtain a concrete with the following characteristics:

- In its fresh state,
    - Does not segregate, maintaining uniformity;
    - Is reasonably stable under normal climatic conditions;

  - May be handled during a given period of time, without significantly altering its workability characteristics;

- After Hardening:

  - shall attend to the required properties;
  - shall be volumetrically stable (thermal and autogenous);
  - shall be durable;
  - shall attend the established density requisites;

- Shall be economical.

The design mix study must be well done, with quality and safety, and at a low cost, with the materials available in the proximities of the construction-site. When establishing that RCC must be used as mass concrete, the condition of attending to maximum density becomes relatively important, being an important parameter to be attended. On the other hand, attention is still given to economy. It is with the intent of attending to maximum density that discussions may occur. This text intends to establish a debate on the subject.

2- CONCEPTS

Some Technical Specifications, or some authors indicate the following:

..."Under a 0.35 (paste)/(mortar) relation, there will be an insufficient paste content to fill the void parts of the fine aggregates after compaction"...

..."*One can also observe that the RCCs theoretical maximum density is attended by the employment of fine aggregates that have a relation of voids of the 0.32 to 0.40 order in the compacted condition"...*

..."*for a 0.35 paste/mortar relation the RCC density, expressed as a compaction ratio related to the theoretical maximum density, may vary between 90% and 98%"...*

Following these postulations are the demands, or recommendations, of using "high paste" RCC, with the employment of a high content of cementitious material (cement - pozzolanic material).

In general, next follow the design mixes with a 40 to 100Kg/m3 cement consumption and pozzolanic material from 150 to 50 Kg/m3.

Questions may arise, such as:

- How to make RCC design mixes for works in regions, or even in countries, without the availability of pozzolanic materials?;
- What is the real amount of pozzolanic material, that is actually acting with the adequate Pozolanic activity, that is reacting with the elements liberated by cement hydration?
- Wouldn't a great portion of this pozzolanic material be being used simply as a "FILLER"? What about the resulting costs?
- How is this condition of adopting a high content of pozzolanic material considered, while using good pozzolanic cement, to take adequate advantage of the chemical components acting as the pozzolanic material already existent in the cement?
- What is the real need of having paste/mortar relation above 0.35?
- What are the considerations on the "Compactation Ratio"?
- Is there a need to emphasize “a few or eventual" differentiations between Rollcrete, RCC, High Paste RCC, Lean RCC, RCD?
- Are all these materials concrete?
- What is the similarity between these materials?

3- DATA AND INFORMATIONS

“ *The in situ density of concrete will depend to a great extent on the relative density of the aggregates to be used. In addition to this, the two most important factors are the void ratio of the fine aggregate and the paste/mortar ratio. The latter factor was introduced in the middle 1970s [1][2]. It is the ration of the volume of paste (i.e. cementitious content and water plus entrained air , if used) to the volume of mortar (i.e. paste and fine aggregate) [3].”*

In [3] there is an additional piece of information to that cited above:

“ *The densities are plotted against the paste/ mortar ratio of concretes where this defined as the ratio of the volume of paste (i.e. cement + fly ash or slag {if any} + entrained air {if any} to the volume of mortar (i.e. paste + fine aggregate - say the passing the 5-mm sieve)’* [4] (call attention for the Caps letter from these authors).

Reference [5] recommends:

“When using RCD Method, it is especially important to select a mix design with which compaction of concrete will be made easy on carrying out proportioning tests. Here, concretes were mixed with sand-aggregate ratio varied at several levels while maintaining unit binder content (unit cement-plus-fly ash content) and unit water content constant, and comparison studies were made on measuring the respective vibrating compaction (VC) values.

...... As is clearly shown ... there exists a s/a at which VC value will be a minimum. This s/a is the s/a of concrete at which compaction is most easily accomplished, and is in a range of 32% to 34%.”

On reference [6 note:

“The sand-aggregate ratio was selected to be 30% from the results of laboratory tests measuring Vc values varying the sand-aggregate ratio and...”

And on [7] note:

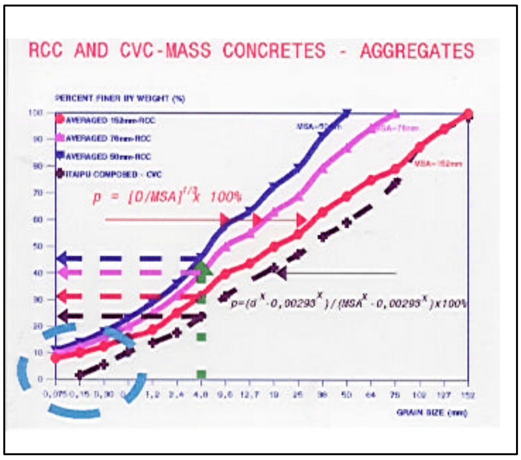
“According to the principles of mix design for RCD concrete, voids in compacted coarse aggregates must be filled up with mortar in compacted fine aggregates must be filled up with paste, but the AMOUNT OF PASTE MUST BE RESTRICTED TO A MINIMUM.” (call attention for the Caps letter from these authors).

Another batching orientation may be observed [8]:

“Fine and coarse aggregate should be proportioned to create a well-graded combined aggregate.... ....The addition of material finer than the 0,075mm (No. 200) sieve may be necessary to supplement fine aggregate in order to reduce the volume of voids within the fine aggregate and to produce a more cohesive mixture. This supplemental fine material may consist of fly ash, natural pozzolan, ground granulated blast-furnace slag (GGBF slag), or natural fine sand. The use of fly ash, natural pozzolan, or GGBF slag as supplemental fine material may provide added benefits as a result of reduced overall water demand, lower water to cementitious material ratio, and higher ultimate strength.”

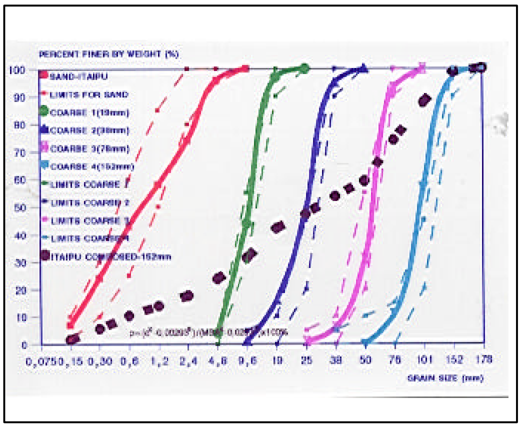
The grading/distribution curve recommended in [8] is similar to a cubic type curve, that has also been preconized and adopted by various authors and designs [9 to 24, 40 to 42]. One of the characteristics of the cubic type curve is that of requiring a certain amount of dimension material below 0.075mm (No. 200 sieve). This amount is about 8% to 12% of the total aggregates in the mixture, as illustrated in Figure 1.

FIGURE 1- CUBIC TYPE GRADING CURVE, ADOPTED IN VARIOUS DESIGNS AND A AGGREGATE COMBINATION CURVE FOR CONVENTIONAL MASS CONCRETE (CVC)



Another characteristic approached by the cubic type curve is the reduction of the coarsest part of the aggregates, which usually causes segregation. This may be seen comparatively in Figure 1, while observing the curves in Figure 1 and of the combination of aggregates, normally used for conventional mass concretes, also shown on Figures 2 (and 1).

FIGURE 2 - CURVES OF THE INDIVIDUAL FRACTIONS OF EACH AGGREGATE AND THE CURVE COMPOSED FOR MASS CONCRETE (ITAIPU)



Observing the previous citations, the following basic recommendations to attend maximum density and the maximum compaction ratio stand out:

- Paste/mortar relation not inferior to 0.35;
- The Paste must contain Fly Ash or Slag;
- Sand/aggregate relation with a total not inferior to 0.3.

Note that the citation of the (paste)/(mortar) relation not being inferior, conflicts with citation [7], of reducing the paste content to the minimum.

Figure 3 presents a set of RCC(or HPC-RCC, or RCD or Lean RCC) design mix data used in various dams or studies.

From this set one can observe that various mixes have reached a compaction ratio superior to 96%, of which attention should be given to the design mixes used on the Dams Nova Olinda (Order 14, Figure 3), Uruguai (21-A and 21-B), Capanda (23), CESP studies (24-K and 24-L), Jordão (25-A, 25-B and 26), Jequitai (28-A, 28-B; 28-E; 28-F) and Canoas (29) on which Fly Ash or Escoria were not used and the paste/mortar relation is inferior to 0.35, being that a compaction ratio of 96% to 100% was reached. On the other hand, Yantan mixes (18-A to 18-D) with a 0.35 paste/mortar relation presented a Compaction Ratio around 92% to 96%.

The (sand)/(total aggregate) relation normally considered in the conventional mass concrete studies varies for each aggregate set, considering that it reduces with the increase of MSA, as illustrated in Figure 4 [38 and 39]. The same may be observed for the RCC when using the cubic type curve, as illustrated in Figure 1.

One can observe, in Figure 1, when comparing the cubic curves adopted for RCC and those of the composed aggregates, that there is a greater RCC over mortared to CVC. From this observation, one may verify that the recommendation that the sand/aggregate relation not inferior to 0.3, is generically attended.

The data on Figure 4 shows, on the other hand, that the paste/mortar relations are normally superior to 0.35%, for the conventional mass concrete, but the majority does not attend to the sand/total aggregate surpassing 0.3.

Where, then, does the basic difference lie?

In comparing the water content of the RCC and CVC of the same dams (see Figure 5), one will observe that the RCC values are around 10% to 35% smaller, with around 30% predominance, for the RCC, which means approximately 30 liters/m3.

If this void is filled by Fly Ash or Escoria, with an absolute specific gravity around 2.2t/m3 to 2.9t/m3, this signifies about 70 Kg/m3 to 90Kg/m3 more material in RCC. If the addition of Fly Ash or Escoria is not employed, however using aggregates with an absolute specific gravity of 2.65t/m3 to 2.95t/m3, this signifies around 80Kg/m3 to 90Kg/m3 more material in RCC.

In reducing the cement content, even more, in the Lean RCC mixtures, the corresponding voids will need to be filled by Fly Ash, Escoria or, again, by aggregates (or by aggregate Fillers).

It is at this point that the fine fraction of the cubic curve becomes important, for the fine fractions (inferior to 0.075mm) recommended in contents around 8% to 12%, serve to fill the voids previously mentioned, allowing to reach an adequate compaction ratio and consistency.

There are, however, options for the filling of these voids, the use of Fly Ash or Escoria, but there is also the option of adopting the Filler following the aggregate/crushing, or of a silt.
The authors of this work are of the opinion that the material to be used should be that which offers the greatest benefits at a lesser cost. The following may be observed from this:

- In using a great quantity of Fly Ash or Escoria, or another pozzolanic material, how much of this would really be acting with Pozolanic Activity, reacting with hydroxides available in the cement? Or, would a part be acting only as an inert Filler? At what cost would it be worth transporting this amount of Pozolanic material?

- In using the fine fractions derived from the crushing (on the construction-site itself, with site materials) or a silt, would these materials have any pozzolanic action?

It is, therefore, necessary to make a technical/economic balance for the optimization of the use of the materials.

NUMBER OF ORDER	DAM OR STUDY	COUNTRY	MAXIMUM AGGREGATE SIZE(mm)	CEMENT Kg/m3	POZ MATERIAL Kg/m3	TOTAL CEMENTITIOUS Kg/m3	WATER Kg/m3	PASTE (l)	SAND Kg/m3	MORTAR (l)	PASTE/MORTAR 0,35	COARSE Kg/m3	SAND / AGGREGATES 0,3	SPECIFIC GRAVITY (Kg/m3) THEORETICAL	LABORATORY	FIELD CONTROL	COMPACTION RATIO %
1	TAMAGAWA	JAPAN	150	91	39	130	95	142,9	657	390,9	0,37	1544	0,30	2426		2390	98 5
2	MONKSVILLE	USA	76	63		63	136	156,3	1376	675,6	0,23	890	0,61	2465		2283	92,6
3	TEST	ECHOSLOVA	125	110		110	100	135,5	990	509,1	0,27	1210	0,45	2410		2197	*91,2*
4--A	MIDDLE FORK	USA	76	66		66	95	116,3	1166	556,3	0,21	777	0,60	2104		1930	*91,7*
4--B	MIDDLE FORK	USA	76	66		66	95	116,3	1166	556,3	0,21	777	0,60	2104		2000	**95,1**
4--C	MIDDLE FORK	USA	76	66		66	95	116,3	1166	556,3	0,21	777	0,60	2104		2006	**95,3**
4--D	MIDDLE FORK	USA	76	66		66	95	116,3	1166	556,3	0,21	777	0,60	2104		2100	**99,8**
4--E	MIDDLE FORK	USA	76	66		66	95	116,3	1166	556,3	0,21	777	0,60	2104		2120	**100,8**
5	ITAIPU TEST & BACKFILL	BRAZIL	76	91	26	117	71	112,7	804	399,9	0,28	1625	0,33	2617	2446	2511	***95,9***
6	TUCURUI	BRAZIL	76	51	30	81	60	90,7	750	373,8	0,24	1670	0,31	2561		2461	**96,1**
7	SHIMAJIGAWA	JAPAN	80	84	36	120	105	149,2	755	434,1	0,34	1476	0,34	2456		2440	99,3
8--A	STUDY	JAPAN	80	84	36	120	100	144,2	711	412,5	0,35	1518	0,32	2449	2440		99,6
8--B	STUDY	JAPAN	80	84	36	120	95	139,2	768	429,1	0,32	1438	0,35	2421		2392	98,8
9	GALESVILLE	USA	76	44	30	74	103	131,5	866	458,3	0,29	1560	0,36	2603		2510	**96,4**
10	UPPER STILLWATER	USA	38	80	173	253	95	203,2	728	477,9	0,43	1291	0,36	2367		2339	98,8
11	LOWER CHASE CREEK	USA	76	63		63	108	128,3	712	397,0	0,32	1542	0,32	2425		2280	94,0
12--A	ELK CREEK	USA	76	70	33	103	125	163,3						2371		2347	99,0
12--B	ELK CREEK	USA	76	70	33	103	125	163,3						2371		2340	98,7
12--C	ELK CREEK	USA	76	70	33	103	125	163,3						2371		2341	98,7
12--D	ELK CREEK	USA	76	70	33	103	125	163,3						2371		2336	98,5
13	LES OLLIVETES	FRANCE	63	81	54	135	125	176,8				2250		2510		2450	97,6
14	SACO NOVA OLINDA	BRAZIL	70	75		75	142	166,2	1632	782,0	0,21	532	0,75	2381		2371	**99,6**
15	OKAWA	JAPAN	80	96	24	120	100	142,4	694	404,3	0,35	1481	0,32	2395		2390	99,8
16	BELLEFONTE	USA		44	165	209	83	175,8	734	452,7	0,39	1488	0,33	2514		2474	**98,4**
17--A	CASTILBLANCO ARROYOS	SPAIN	40	102	86	188	96	169,9	674	424,2	0,40	1454	0,32	2412		2310	*95,8*
17--B	CASTILBLANCO ARROYOS	SPAIN	40	87	94	181	66	138,8	670	391,7	0,35	1445	0,32	2362		2300	97,4
18--A	YANTAN	CHINA		55	104	159	90	157,3	759	443,7	0,35	1490	0,34	2498		2459	98,4
18--B	YANTAN	CHINA		55	104	159	90	157,3	759	443,7	0,35	1490	0,34	2498		2302	*92,2*
18--C	YANTAN	CHINA		55	104	159	90	157,3	759	443,7	0,35	1490	0,34	2498		2358	*94,4*
18--D	YANTAN	CHINA		55	104	159	90	157,3	759	443,7	0,35	1490	0,34	2498		2395	*95,9*
18--E	YANTAN	CHINA		55	104	159	90	157,3	759	443,7	0,35	1490	0,34	2498		2422	97,0
19--A	SHUIKOU	CHINA	76	60	60	120	84	131,9	651	377,6	0,35	1634	0,28	2489		2412	96,9
18--B	SHUIKOU	CHINA	76	50,4	75,6	126	82	134,3	649	379,2	0,35	1632	0,28	2489		2413	96,9
20	YANTAN	CHINA		55	104	159	90	157,3	759	443,7	0,35	1490	0,34	2498		2422	97,0
21--A	URUGUA-I	ARGENTINE	76	60		60	100	119,4	1247	589,9	0,20	1298	0,49	2705		2632	**97,3**
21--B	URUGUA-I	ARGENTINE	76	90		90	105	134,0	1226	596,7	0,22	1275	0,49	2696		2648	**98,2**
22	SERRA MESA-COF DAM	BRAZIL	38	60	140	200	133	219,0	876	549,6	0,40	1210	0,42	2419		2352	97,2
23	CAPANDA	ANGOLA	64	70		70	102	124,6	1085	534,0	0,23	1190	0,48	2447		2412	98,6
24--A	CESP-STUDIES- I	BRAZIL	76	50	15	65	107	130,3	938	484,2	0,27	1410	0,40	2520		2447	97,1
24--B	CESP-STUDIES- I	BRAZIL	76	80	20	100	107	142,3	926	491,8	0,29	1393	0,40	2526		2454	97,1
24--C	CESP-STUDIES- I	BRAZIL	76	50	15	65	125	148,3	1081	556,2	0,27	1269	0,46	2540		2391	*94,1*
24--D	CESP-STUDIES- I	BRAZIL	76	80	20	100	107	142,3	926	491,8	0,29	1393	0,40	2526		2511	99,4
24--E	CESP-STUDIES- I	BRAZIL	76	80	20	100	120	155,3	1067	558,0	0,28	1253	0,46	2540		2444	96,2
24--F	CESP-STUDIES- I	BRAZIL	76	50	150	200	137	224,6	871	553,2	0,41	1308	0,40	2516		2462	97,9
24--G	CESP-STUDIES- I	BRAZIL	76	50	150	200	137	224,6	871	553,2	0,41	1308	0,40	2516		2444	97,1
24--H	CESP-STUDIES- I	BRAZIL	76	50	150	200	140	227,6	989	600,8	0,38	1161	0,46	2490		2420	97,2
24--I	CESP-STUDIES- I	BRAZIL	76	80	30	110	117	157,1	919	503,9	0,31	1381	0,40	2527		2499	98,9
24--J	CESP-STUDIES- I	BRAZIL	76	80	30	110	117	157,1	919	503,9	0,31	1381	0,40	2527		2499	98,9
24--K	CESP-STUDIES- II	BRAZIL	76	60		60	75	94,4	1047	489,4	0,19	1389	0,43	2571	2531		**98,4**
24--L	CESP-STUDIES- II	BRAZIL	76	90		90	85	114,0	1047	509,1	0,22	1389	0,43	2611	2510		**96,1**
24--M	CESP-STUDIES- II	BRAZIL	76	120		120	95	133,7	1047	528,8	0,25	1389	0,43	2651	2510		94,7
25--A	JORDÃO - COPEL - STUDIES	BRAZIL	50	75		75	100	124,2	1400	652,5	0,19	1130	0,55	2705	2640		**97,6**
25--B	JORDÃO - COPEL -TESTFILL	BRAZIL	50	75		75	100	124,2	1400	652,5	0,19	1130	0,55	2705		2583	**95,5**
26	JORDÃO - DAM CONTROL	BRAZIL	50	75		75	90	114,2	1400	597,0	0,19	1130	0,55	2695		2622	**97,3**
27-A	ITAIPU FOR OTHERS	BRAZIL	50	130	100	230	125	214,6	730	490,0	0,44	1440	0,34	2525			
27-B	ITAIPU FOR OTHERS	BRAZIL	50	130	100	230	122	211,6	730	487,0	0,43	1440	0,34	2522			
27-C	ITAIPU FOR OTHERS	BRAZIL	50	110	100	210	115	198,1	1200	650,9	0,30	1130	0,52	2655			
28-A	JEQUITAI - STUDIES	BRAZIL	50	60		60	125	144,4	839	461,0	0,31	1340	0,39	2364	2328		**98,5**
28-B	JEQUITAI - STUDIES	BRAZIL	50	80		80	130	155,8	813	462,6	0,34	1337	0,38	2360	2351		**99,6**
28-C	JEQUITAI - STUDIES	BRAZIL	50	100		100	129	161,3	797	462,0	0,35	1340	0,37	2366	2333		**98,6**
28-D	JEQUITAI - STUDIES	BRAZIL	50	120		120	128	166,7	784	462,6	0,36	1341	0,37	2373	2382		**100,4**
28-E	JEQUITAI - STUDIES	BRAZIL	50	60		60	123	142,4	840	459,3	0,31	1347	0,38	2370	2345		**98,9**
28-F	JEQUITAI - STUDIES	BRAZIL	50	80		80	133	158,8	813	465,6	0,34	1333	0,38	2359	2352		**99,7**
28-G	JEQUITAI - STUDIES	BRAZIL	50	100		100	129	161,3	797	462,0	0,35	1340	0,37	2366	2364		**99,9**
28-H	JEQUITAI - STUDIES	BRAZIL	50	120		120	124	162,7	783	458,2	0,36	1351	0,37	2378	2351		**98,9**
29	CANOAS-CEARA	BRAZIL	76	80		80	123	148,8	839	465,4	0,32	1329	0,39	2371		2315	**97,6**

FIGURE 3 - DESIGN MIXES DATA, THEORETICAL SPECIFIC GRAVITY AND OBTAINED DURING THE CONTROL, AND COMPACTION RATIO OF VARIOUS DAMS OR STUDIES

	DAM OR STUDY	COUNTRY	MAXIMUM AGGREGATE SIZE(mm)	CEMENT Kg/m3	POZZOLANIC MATERIAL Kg/m3	TOTAL CEMENTITIOUS Kg/m3	WATER Kg/m3	PASTE (l)	SAND Kg/m3	MORTAR (l)	PASTE / MORTAR 0,35	COARSE Kg/m3	SAND / AGGREGATES 0,30	SPECIFIC GRAVITY (Kg/m3) THEORETICAL	LABORATORY	FIELD CONTROL	COMPACTION RATIO %
101-A	ITAIPU	BRAZIL	152	108	13	121	85	126,0	579	344,5	0,37	1837	0,24	2622		2283	87,1
101-B			76	113	16	129	94	138,1	559	349,0	0,40	1837	0,23	2619			
102-A	ILHA SOLTEIRA	BRAZIL	152	63	21	84	82	112,3	424	272,3	0,41	1881	0,18	2471			
102-B			76	111	37	148	98	151,4	490	336,3	0,45	1642	0,23	2378			
103-A	TUCURUI	BRAZIL	152	73	22	95	64	118,0	568	332,4	0,36	1731	0,25	2478			
103-B			76	94	28	122	90	133,7	665	384,6	0,35	1581	0,30	2458			
104	SHIMAJIGAWA	JAPAN	80	126	54	180	137	203,4	667	462,6	0,44	1353	0,34	2357			
105	TAMAGAWA	JAPAN	150	126	54	180	108	174,4	497	361,9	0,48	1587	0,24	2372			
106	SAKAIGAWA	JAPAN	80	126	54	180	123	189,4	639	430,5	0,44	1466	0,30	2408			
107	MYAGASE	JAPAN	150	151	65	216	108	187,7	537	390,3	0,48	1535	0,26	2396			
108	URAYAMA	JAPAN	150	147	63	210	94	171,4	552	379,7	0,45	1594	0,26	2450			
109	HOOVER	USA	229	225		225	130	202,6	552	410,9	0,49	1589	0,26	2496			
110	GRAND COULEE	USA	152	224		224	134	206,3	582	425,9	0,48	1523	0,28	2483			
111	GLEN CANYON	USA	152	111	56	167	91	153,5	461	327,4	0,47	1651	0,22	2370			
112	JOHN DAY	USA	152	88	30	118	80	122,7	554	331,7	0,37	1761	0,24	2513			
113	CAPANDA	ANGOLA	76	180		180	136	194,1	660	443,1	0,44	1370	0,33	2346			
114	SEGREDO	BRAZIL	76	179		179	128	185,7	890	521,6	0,36	1278	0,41	2475			
115	JORDÃO	BRAZIL	50	186		186	142	202,0	1167	642,4	0,31	1052	0,53	2547	2530		99,3

FIGURE 4 - CONVENTIONAL MASS CONCRETE MIXES DATA OF VARIOUS DAMS [38-39]

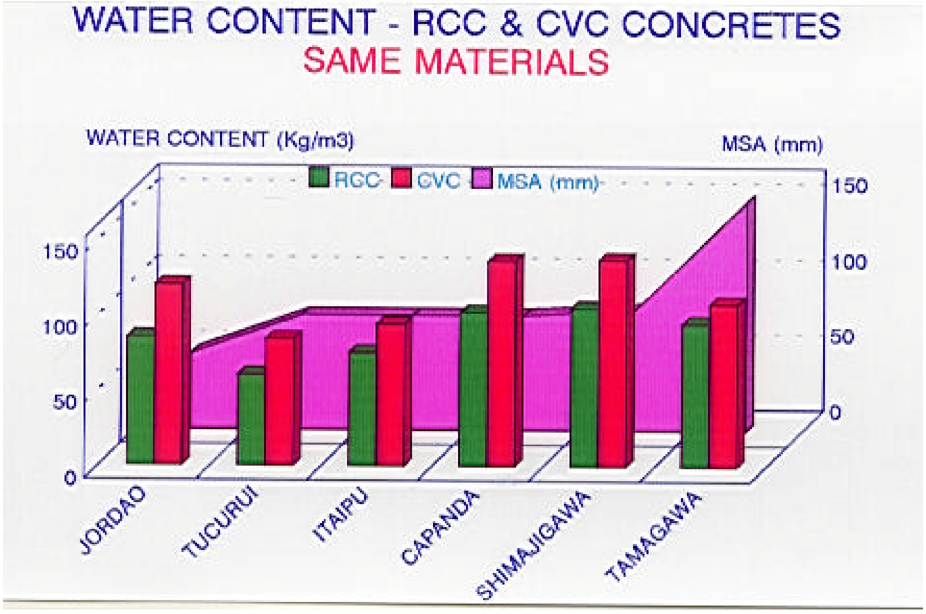


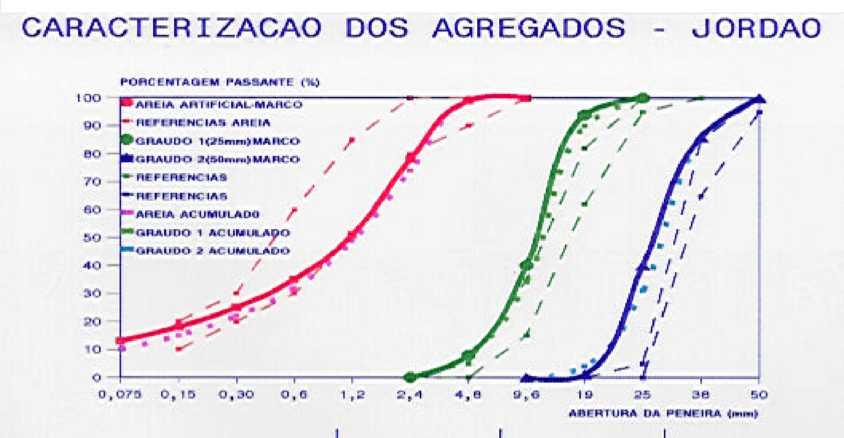
FIGURE 5 - CONVENTIONAL MASS CONCRETE AND RCC WATER CONTENT, OF THE SAME JOBS

4 - COMPLEMENTARY EVALUATIONS AND STUDIES

With the intention obtaining a comparison of the various RCC "types", a design mix study was done considering the mixtures cited in Figure 6, as well as the characterized aggregates in Figure 7.

MIX		E - 90	E - 91	E - 102	E - 103	E - 104	E - 105	E - 106	E - 107	E - 108	E - 109
MSA (mm)		50	50	50	50	50	50	50	50	50	50
PROPORTIONING	CEMENT	89	88	71	52	74	89	70	50	89	91
	FLY ASH						168	200	219	30	30
	FILLER	216	215	263	310						100
	TOTAL CEMENTITIOUS	*89*	*88*	*71*	*52*	*74*	*257*	*270*	*269*	*119*	*121*
MIX	WATER	116	95	107	102	132	95	95	95	137	92
	CRUSHED SAND	1248	1271	1251	1245	1360	1285	1266	1258	1320	1331
(Kg/m3)	COARSE CRUSHED 1 (25-4,8)mm	490	495	488	485	531	501	494	491	516	520
	COARSE CRUSHED 2 (50 -25)mm	493	495	488	485	531	501	494	491	516	520
THEORETICAL SPECIFIC GRAVITY (Kg/m3)		2652	2659	2668	2679	2628	2639	2619	2604	2608	2684
TEST ON	SPECIFIC GRAVITY (Kg/m3)	2554	2564	2653	2580	2540	2585	2550	2600	2575	2603
FRESH	VeBe (sec)	18	26	25	30	25	20	20	19	25	30
RCC	COMPACTION RATIO (%)	96,3	96,4	99,4	96,3	96,7	98,0	97,4	99,8	98,7	97,0
PARAMETERS	PASTE (L)	144,71	123,39	129,9	118,77	155,87	190,91	197,58	198,73	177,71	133,3548
	MORTAR (L)	575,05	561,66	561,28	548,08	624,84	634,01	634,13	632,52	632,88	592,3204
	PASTE / MORTAR RATIO	0,2516	0,2197	0,2314	0,2167	0,2495	0,3011	0,3116	0,3142	0,2808	0,22514
	SAND	1464	1486	1514	1555	1360	1285	1266	1258	1320	1431
	TOTAL AGGREGATES	2447	2476	2490	2525	2422	2287	2254	2240	2352	2471
	SAND / AGGREGATES RATIO	0,60	0,60	0,61	0,62	0,56	0,56	0,56	0,56	0,56	0,58
COMPRESSIVE	7 (Days)	3,3	4,9	3,4	2,7	1,4	5,4	5	4	2	4,5
STRENGTH	28(Days)	4,7	8,9	5,1	2,8	TO BE INFORMED DURING SYMPOSIUM MEETING					
(MPa)	90(Days)		TO BE INFORMED DURING SYMPOSIUM MEETING								
MIX	7(Days)	0,04	0,06	0,05	0,05	0,02	0,02	0,02	0,01	0,02	0,04
EFFICIENCY	28(Days)	0,05	0,10	0,07	0,05						
(Kgf/cm2)/(Kg/m3)	90(Days)										

FIGURE 6 - COPEL COMPLEMENTARY MIXES STUDIES AND THE OBTAINED DATA



AGREGADO	AREIA ARTIFICIAL	GRAUDO 1(25mm)	GRAUDO 2(50mm)
Diametro Maximo (mm)	4,8	25	50
Densidade Absoluta (t/m3)	2,92	2,88	2,88
Densidade Aparente (t/m3)	1,61	1,46	1,42
Absorcao (%)	3	0,72	0,45
Modulo de Finura	2,93	6,68	8,10
Material Inferior a 0,075mm (%) em Peso	17,44	1,29	0,78

FIGURE 7 - AGGREGATES USED IN THE COMPLEMENTARY STUDY

5 - OBTAINED RESULTS

The complementary study allowed for the obtention of the data presented in Figure 6. The design mixes were established to attend a 25 +/- 5 second consistency (VeBe). Five RCC of Lean types were simulated (without fine fractions - E-104 design mix); Lean (with variable fine fractions - E-90 design mix; E-91; E-102; E-103); High Paste (E-105 to E-107); RCD (without fine fractions E-108) and RCD (with fine fractions E-109).

The values obtained show that the compaction ratio of all the mixtures surpassed 96%

6 - COMMENTS

From the reported data:

- The adoption of fine fractions in the RCC, is extremely valuable for the improvement of the properties, as already mentioned [8,13,14,21,22,23,43,44] ;
- The fine fractions used do not necessarily need to be Fly Ash or Escoria, but may be a sub-product of the aggregate beneficiary (CRUSHED POWDER) [21,43 and 44] or a silt [24,40,41];
- Considering that for gravity dams, the compression resistance is not always the most important requirement, it is convenient and prudent, to search for the low cost use of fine fractions;
- The complementary studies developed by COPEL, give greater importance to the use of fine fractions than the paste/mortar relation .
- The use of RCC, of low cement content attending to the granulometric composition, also provides a better termogenic condition to the mass structure;
- The behavior of the construction joint with low cement content RCC must be analyzed and solved in order to attend to the Design requirements, with the use of adequate treatment, to guarantee the necessary Cohesion (being that the friction hardly alters with the variation of cement consumption);
- The Coefficient of Permeability of the RCC with fine fractions is decreased [45] offering the structure greater waterthigness, not being potentially fissurable because of the increase of cement material content;
- Figure 8 indicates, through RCC compaction control statistic data of various sites, that the obtained specific gravities practically surpass the required minimum (with the exception of only one, with 1% inferior to the required minimum);
- The compaction ratio, which reflects the Quality Control performance rate, practically surpasses 96%, (the lowest statistical value of the average most probable value interval) even on constructions-sites

where the addition of Fly Ash or Escoria was not employed (Nova Olinda; Uruguay; Capanda; Jordão; Canoas-Ceará);

- The obtained and supplied data do not justify the need to dogmatize differences between the various design mixes practiced by the RCC (or RCD or Lean or High Paste), unless characterizing a Registered Trade-Mark!

DAM	SPECIFIC GRAVITY Kg/m3 STATISTICAL ELEMENTS						CONFIDENCE INTERVAL OF				LOW VALUE AND REQUIRED DENSITY RATIO
	MINIMUM REQUIRED	THEORETICAL	AVERAGE IN CONTROL	NUMBER OF SAMPLES	STANDARD DEVIATION S (Kg/m3)	COEFFICIENT OF VARIATION CV (%)	AVERAGE VALU FROM Kg/m3	TO Kg/m3	COMPACTION RATIO FROM %	TO %	
SACO N. OLINDA	2300	2381	**2371**	200	47	2	2362	2380	99,22	99,94	1,03
URUGUA-I		2705	**2632**	2678	33	1,2	2630	2634	97,24	97,36	
CAPANDA	2400 .	2447	**2412**	5240	12	0,5	2412	2412	98,55	98,59	1,00
JORDÃO	***2550***	***2705***	***2622***	***249***	***92,15***	***3,5***	*2607*	*2637*	96,38	97,49	1,02
SHUIKOU	2400	2510	**2380**	615	37,5	1,6	2376	2384	94,67	94,98	0,99
YANTAN	2400	2500	**2459**	537	28	1,14	2456	2462	98,24	98,48	1,02
KENGKOU	2320	2406	**2355**	191	28,1	1,19	2350	2360	97,66	98,10	1,01
CANOAS-CEARA		2371	**2315**	97	22	*1,0*	2309	2321	97,40	97,88	
LONGMENTAN	2330	2361	**2336**	147	36	1,58	2328	2344	98,62	99,27	1,00

FIGURE 8 - COMPACTION CONTROL SPECIFIC DATA OF VARIOUS DAMS [19; 21; 24; 33; 34; 35; 36; 42]

7 - RECOMMENDATIONS

The authors strongly recommend caution in searching for granulometric compositions that offer "closed" mixtures and cohesiveness, giving special attention to the content of fine fractions.

The fine fraction type to be used will depend on the availability for each worksite, however, it is important to remember that the choice be made on a technical-economic basis.

The Compaction Ratio parameter is a Quality Control Performance evaluation element and must be used as a warning, even in cases where the minimum required Specific Gravity is “very inferior” to the theoretical value of the mixture.

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