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REPORT 22199/F/2

EFFECTS OF SWIMMING POOL WATER

ON CEMENTITIOUS GROUTS

LABORATORY TEST PROGRAMME

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This report comprises
10 pages of text
Tables 1 to 18 each of 1 sheet
Tables 19 and 20 each of 2 sheets
Table 21 of 1 sheet
Appendix A of 2 sheets

For the attention of Mr B Guthrie

1 July 2004

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EFFECTS OF SWIMMING POOL WATER

ON CEMENTITIOUS GROUTS

LABORATORY TEST PROGRAMME

Instructions: PWTAG letter dated 22 March 2001.

1. INTRODUCTION

Sandberg were engaged to carry out a study into the effects of swimming pool water on cementitious grouts on behalf of the Pool Water Treatment Advisory Group (PWTAG). The study comprised two parts:

(I) A literature review
(II) A programme of laboratory work

The Literature Review is presented in Sandberg Report 22199/X/01. The programme of laboratory work was designed in conjunction with PWTAG to examine the performance of tile grouts in different treated waters.

Following a meeting with PWTAG in August 2001 a preliminary trial was carried out to establish the effect on water composition of contact with the cementitious grout. A further meeting was then held with PWTAG on 20 November 2001 when details of the main laboratory test programme were agreed and finalised.

The main programme investigated four levels of calcium hardness by monitoring the change in length of grout prisms immersed in the test solutions. The prism specimens were monitored for six months. The results were then analysed and after further discussion with PWTAG an additional programme of work was carried out to assess the effect of sulphate levels in the water (at equal calcium hardness).

2. PRELIMINARY TRIAL

Prior to commencing with the main laboratory programme a preliminary trial was carried out to establish the effect on water composition of contact with the grout.

It was originally proposed that 50 x 50 x 200mm grout specimens would be used in the trials, however there was concern that there would be a much greater surface area of grout exposed to the test solution compared to the area of tile grout exposed to swimming pool water in a normal situation. Also the 50 x 50mm cross section is significantly larger than the standard joint size.

Assuming a 25m x 13m x 1.5m swimming pool and a tile joint thickness of 10mm the ratio of tile grout surface area to water is 47mm² to 1 litre. However as swimming pool water circulates through other areas (pipes, holding tanks) which may expose the water to other sources of alkalies (cementitious render or concrete) it is difficult to establish a definite ratio for trial purposes.

The preliminary trial was therefore intended to establish the smallest specimen size that could be manufactured and handled as well as monitoring the pH of the water. The effect of, periodically, changing the water was also to be investigated.

For the purposes of the preliminary trial Ardex's product Ardurit C2 was used. The grout used to prepare specimens for these preliminary trials and the subsequent main trials was all mixed in accordance with the manufacturers' instructions given in the product data sheet. Prism specimens 10mm x 20mm x 160mm were produced and demoulded at 24 hours. Two sets of 6 No. specimens were then placed in separate circulatory water baths at 30°C containing distilled water.

The pH of the solution were monitored regularly (hourly initially, reducing to daily).

The water was changed in one of the baths at regular intervals depending on the pH values found. By running two sets it was possible to assess how different intervals between changes affect the pH.

Bath 1 was left undisturbed for the full duration of the preliminary trial (35 days).

The water in Bath 2 was changed after 1 day, then after a further 4 days, 1 day, 1 day, 1 day and 4 days. At the time of the last water change 'lime' deposits were cleared from the prisms. After a further 14 a water sample was taken from each bath. The water in Bath 2 was then changed again and lime deposits again cleared from the specimens. Seven days later a second water sample was taken from each bath, the water in both baths stirred to agitate any deposits and then a third set of water samples taken.

The three water samples from each bath were then chemically analysed to determine calcium content, bicarbonate alkalinity, carbonate alkalinity and total alkalinity.

The test results are given in Tables 1 and 2.

Table 1: Data showing variation of water pH with time.
Table 2: Analysis of water samples.

A data sheet for Ardurit C2 grout is copied in Appendix A.

3. MAIN TRIAL

The main trial investigated four calcium levels. Typical pool water compositions are in the order of 20-800mg/L calcium hardness. In order to investigate the full range, four test solutions were prepared using calcium chloride as the source of calcium:

(I) 0ppm Calcium
(II) 75ppm Calcium
(III) 200ppm Calcium
(IV) 1000ppm Calcium

The test solutions were contained in circulating water baths at 30±2°C. Carbon dioxide was used to set the pH of the test solutions with a target pH of 7.3±1.

Twenty four 20 x 10 x 60mm grout prisms were prepared. The grout used was the same as that used in the preliminary trials - Ardex 'Ardurit C2'. This is the standard (not the chemical resistance) grade which, we understand, is most commonly used in swimming pools.

The specimens were air cured at 20±2°C for 7 days and then water cured in deionised water at 30±2°C for 14 days. The pH of the water was monitored. The specimens were weighed on completion of air curing and water curing.

Initial prism length datum readings were taken on the prisms prior to immersion in the test solutions. Six prisms were then immersed in each of the test solutions and supported in such a way that the test solution was free to circulate around all exposed surfaces.

Initial values for calcium content, alkalinity and chloride content were determined for each test solution. pH was monitored regularly at appropriate times.

At fortnightly intervals up to 2 months (and then 4 weekly) the prisms were measured for comparison with the datum readings. At the same time the test solutions were checked for calcium content, alkalinity and chloride content and the specimens were weighed.

The volume of each solution was maintained at about 40 litres. The solution was not replaced entirely during the test but was topped up if deemed necessary.

The test results are tabulated and presented graphically in Tables 3 to 6 with a summary in Table 7.

The water bath pH records are given in Table 8 and alkalinity, chloride and calcium content results are given in Tables 9 to 12.

The individual specimen weights are given in Table 19 and percent of weight change data is given in Table 20.

4. ADDITIONAL WORK TO ASSESS EFFECT OF SULPHATE

Following completion of the main programme an additional series of tests were carried out to assess the effect of sulphate content of pool water on tile grout.

Three of the water baths had their calcium hardness equalized at 75ppm calcium hardness.

The PWTAG considered 360mg/L was the level above which sulphate attacks grout sufficiently that sulphate-resistant Portland cement or epoxy grouts are specified.

British Standard BS 5385:Part 4[1] recommends that the sulphate concentration in swimming pool water should be kept below 300ppm (expressed as SO_3) or alternatively "where this level cannot be achieved, consideration should be given to the use of impermeable adhesives and grouting materials that are not affected by sulphates".

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[1] BS 5385:Part 4:1992 'Wall and Floor Tiling Code of Practice for Ceramic Tiling and Mosaic in Specific Conditions'.

BS 5328: Part 1: 1997[2] gives recommendations for concrete exposed to sulphate attack in terms of Classes 1 to 5. Recommended cement types and cement contents are given for sulphate concentrations in groundwater or fill for each class. Class 1 (which requires no special precautions) covers sulphate levels in groundwater of up to 400 mg/L as SO_4. Class 2 levels are 400 to 1400 mg/L. Ordinary Portland cement is still permitted although there are limits on the minimum cement content and water/cement ratio.

Although tile grouts in swimming pools cannot be compared directly with concrete and groundwater, the above is useful and suggests that a higher level of addition than 400 mg/L should be considered in this additional work to confirm the effect on tile grout.

Consequently sulphate concentrations of 200, 400 and 600mg/L were established in the three baths using sodium sulphate. The prisms were then monitored for length change and weight as before. A fourth bath (which contained Solution D - 1000ppm Ca) was also monitored as a reference. The test solutions were also checked for sulphate and calcium contents.

The test results are tabulated and presented graphically in Tables 13 to 16 with a summary in Table 17. The sulphate and calcium results are given in Table 18.

The specimen weights and weight change data is given in Tables 19 and 20.

5. COMPARATIVE HARDNESS TESTING

No visual disruption of the specimens was seen after completion of the monitoring periods (calcium hardness and sulphate).

A further brief trial was then carried out to assess the hardness of the specimens. A fresh sets of prism specimens was cast, air cured for 7 days at 20±2°C and then water cured at 30±2°C. No additional calcium was added. After two months the hardness of the specimen was assessed qualitatively by scratching with a steel point and quantitatively by scratching using a Moh's Hardness mineral set comprising the standard ten minerals[3].

Similar tests were carried out on specimens for the four solutions sets and a further set of specimens cast at the same time as the preliminary trial, water cured for 7 days and then air cured.

The test results are given in Table 21.

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[2] BS 5328:Part 1:1997 'Concrete - Guide to Specifying Concrete'.

[3] A method used in geology for recognition of minerals by hardness. Moh's scale has ten degrees of hardness which is represented by ten standard minerals ranging from 1- (soft - talc) to 10 (hard - diamond).

6. DISCUSSION

6.1 Preliminary Trial

The purpose of the preliminary trial was

1. to establish the smallest specimen size that could be manufactured and handled
2. to monitor the pH of the test solutions
3. to assess the effect of changing the water.

The 10mm x 10mm x 160mm specimens produced were fragile , however provided they were handled carefully they appeared to be sufficiently robust to withstand the programme of length change monitoring envisaged.

The pH of the test solutions was about 7.4 prior to the specimen immersion and immediately reached about 10.5 within a few hours. In bath 1 where the water was not changed the pH began to decrease after about 4 days, reducing to about 9.0 after 8 days and 8.2 after 14 days whereupon it remained reasonably constant.

Changing the solution in bath 2 caused drops in pH followed by a steep rise but overall the pH of the water dropped in a reasonably similar manner to bath 1. 'Lime' deposits built up on the specimens and removal of this resulted in a small increase in pH.

In both baths after about 14 days equilibrium was reached, as shown overleaf.

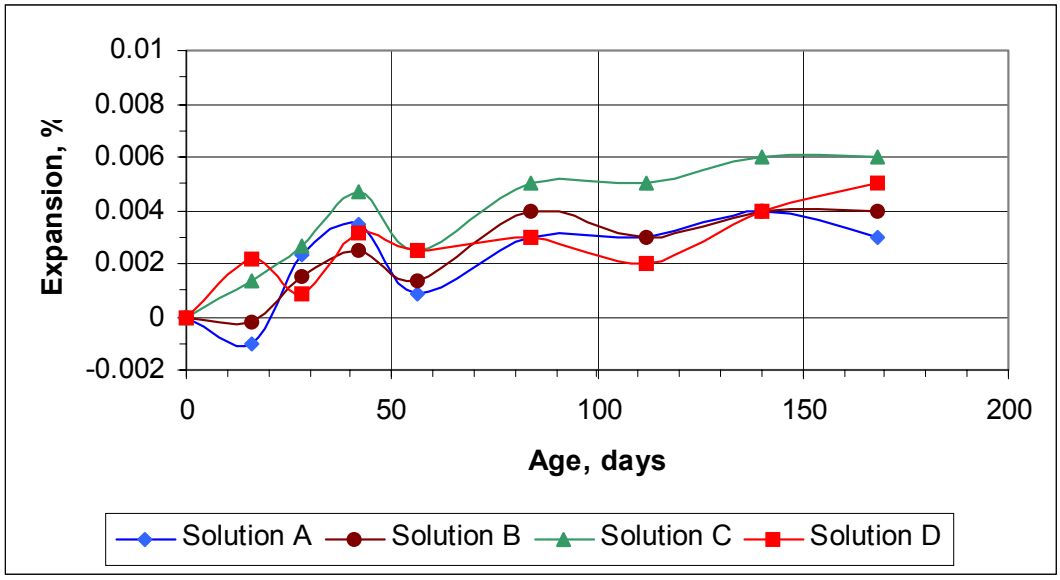
	Bath 1 Water Constant	Bat 2 Water Changed
	Water pH, over period 14 days - 35 days	
Average	8.11	8.19
Maximum	8.22	8.39
Minimum	7.95	8.05

Thus it was agreed that for the main trial the test specimens would be water cured in de-ionised water for 14 days prior to commencement of the test.

Monitoring of the temperature of the water bath during the trial indicated that a target temperature of $30 \pm 2°C$ could be maintained. The average temperature over the whole 35 day period was 30°C with a maximum of 30.8°C and minimum of 29.4°C.

6.2 Main Trial

The mean length change results for each solution are shown below.



Solution A Water at 30°C
Solution B 75ppm Calcium at 30°C
Solution C 200ppm Calcium at 30°C
Solution D 1000ppm Calcium at 30°C

The actual length changes recorded are very small over the whole of the monitoring period. Confidence limits for each reading would at best be ±0.002%. Thus there would appear to be no significant difference between any of the three test solutions B, C or D and solution A, the water reference. None of the solutions appear to have caused any disruption to the grout prisms either under visual assessment or by monitoring change of length.

The target pH of 7.3±0.1 proved extremely difficult to achieve. The actual pH ranges over the duration of the trial are summarised below.

Solution	pH		
	Average	Maximum	Minimum
Bath 1 - A water	7.91	8.46	7.40
Bath 2 - B 75ppm Calcium	7.63	8.25	7.24
Bath 3 - C 200ppm Calcium	7.51	7.89	7.12
Bath 4 - D 1000ppm Calcium	7.31	7.61	6.85

Only in solution D was the target achieved, but even then the range was greater than ±0.1.

The pH of the water in the baths will rise over time due to the dissolving of calcium hydroxide from the grout specimens placed within them. In the case of bath 1, which contains no salts, the calcium hydroxide will more readily dissolve into solution than in the case of the other three baths which each contain increasing quantities of dissolved salts making the rate of dissolving of the calcium hydroxide slower. This means that, given equal time intervals between monitoring, bath 1 will show on average a more rapid increase in pH than the other three baths, resulting in a higher maximum and average pH readings for the period of the monitoring exercise. The other three baths will show progressively lower pH readings with an increase in salt concentration.

Comparison of the calcium contents of the solutions is given below.

Solution A - Bath 1 - 0ppm Ca (water).

The calcium content increased above 0 due to the presence of the cementitious grout prisms. By 56 days the calcium content had equalised at about 30ppm Ca.

Solution B - Bath 2 - 75ppm Ca.

The calcium content was reasonably constant around a value of about 85ppm Ca.

Solution C - Bath C - 200ppm Ca.

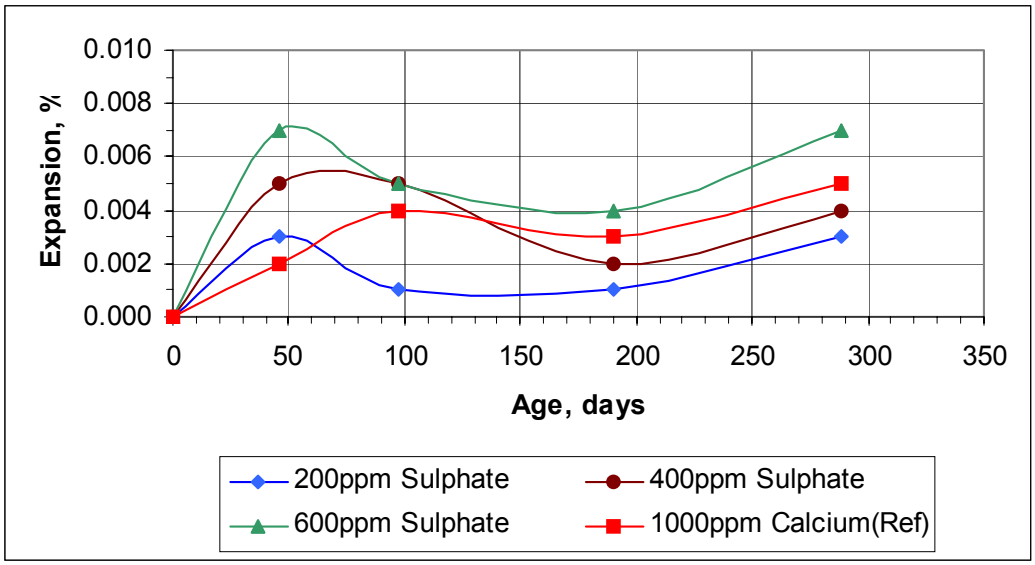
The calcium content was reasonably constant around a value of 190ppm Ca.

Solution D - Bath B - 1000ppm Ca.

The calcium content was initially about 960ppm Ca but then reduced to a value of about 850ppm Ca, possibly due to precipitation out of solution of calcium as calcium carbonate.

6.3 Effect of Sulphate

The mean results for each solution are shown below.

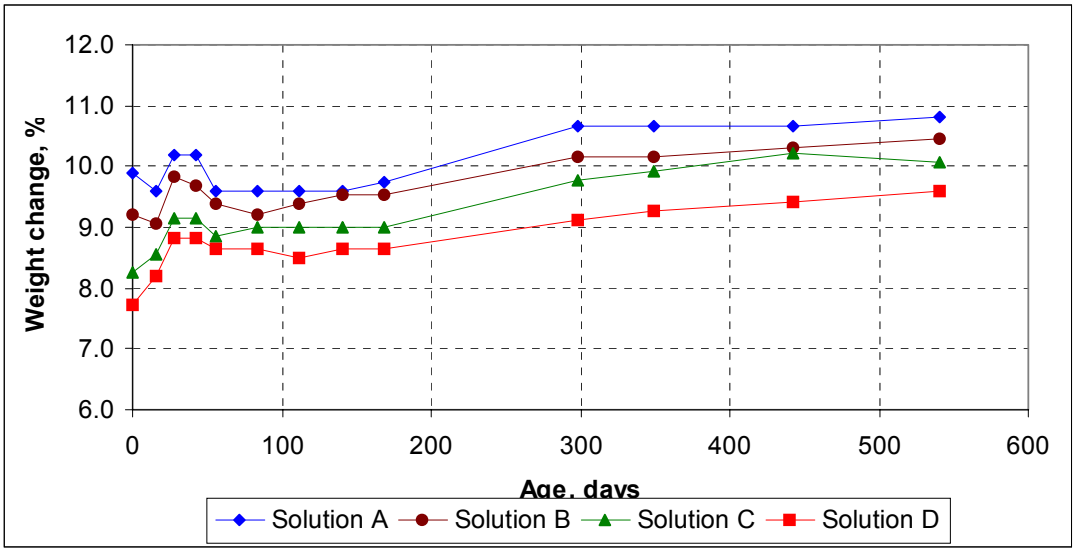


Allowing for confidence limits of ±0.002%, there is little evidence that sulphate at the addition rates under test, is having any significant effect on the stability of the cementitious grout. No visual deterioration of any of the prisms was apparent.

Analysis of the water confirmed the actual sulphate contents to be reasonably close to the nominal values and the calcium content was about 85ppm Ca in all three solutions.

6.4 Weight Change of Specimens

The mean results for each solution are shown below:



Test Solution A

Method of Storage:	Days 0 to 252	Water Control (Calcium approx 30ppm) at 30˚C
	Days 252 to 540	75ppm Calcium & 200ppm Sulphate at 30˚C

Test Solution B

Method of Storage:	Days 0 to 252	75ppm Calcium at 30˚C
	Days 252 to 540	75ppm Calcium & 400ppm Sulphate at 30˚C

Test Solution C

Method of Storage:	Days 0 to 252	200ppm Calcium at 30˚C
	Days 252 to 540	75ppm Calcium & 600ppm Sulphate at 30˚C

Test Solution D

Method of Storage:	Days 0 to 252	1000ppm Calcium at 30˚C
	Days 252 to 540	1000ppm Calcium & 0ppm Sulphate at 30˚C

The weight changes recorded are quite small compared to the initial water saturated weights. Confidence limits for each reading would be of the order of ±0.3% (0.2g).

The weight change recorded for the four solutions from water saturated (i.e. day 0) to end of test are given below.

	Solution A	Solution B	Solution C	Solution D
Specimen Weight (g) Change, %	+0.9 (+0.6)	+1.3 (+0.8)	+1.8 (+1.2)	+1.9 (+1.2)

This suggests there is a difference between solutions A & B and C & D. However the weight changes after 16 days in solution to end of test (given below) show very little difference.

	Solution A	Solution B	Solution C	Solution D
Specimen Weight (g) Change, %	+1.2 (+0.8)	+1.4 (0.9)	+1.5 (+1.0)	+1.4 (0.9)

This suggests that up to 16 days the weight change may be solution dependant but after 16 days it is probably not related to the solution type.

During the first 16 days specimens in Solutions A and B underwent a small loss in weight, possibly due to equalisation of the calcium content of these two 'low' calcium content solutions. Specimens in Solutions C and D, which had higher calcium content, did not show similar weight loss.

The peaks at 28 and 42 days have no clear causes, other than perhaps variations in operator measurement technique.

The overall trend over the whole duration of the test is for a small increase in weight. This is most likely the result of slight continuing absorption of water by the tile grout specimens.

6.5 Hardness of Specimens

The comparative tests revealed a variation in hardness from the air cured specimens, which were clearly the hardest, to the recently cast water cured, which were the softest. The results are summarised overleaf.

Solution	Moh's Hardness*
Preliminary - Air Cure only	9
A - 30ppm Ca then 75ppm Ca & 200ppm SO_3	6
B - 75ppm Ca then 75ppm Ca & 400ppm SO_3	6
C - 200ppm Ca then 75ppm Ca & 600ppm SO_3	7
D - 1000 ppm Ca	4
Extra - Water Cure (nominal 30ppm Ca)	2

* 1 - Soft to 10 - Hard

Visual examination of the specimens shows the variation in hardness is not due to surface deposits but appears to be related to a surface zone on the specimens 1-2mm visible when the specimen is broken in half and viewed in cross-section. Changes in sulphate concentration do not appear to be significant.

The 'extra' set of specimens was cast from a new batch of grout, however unless there has been a product formulation change, this should not have had an effect on the results.

7. SUMMARY

The purpose of this laboratory work was to investigate the effects of the swimming pool water on standard cementitious tile grout.

The effects of four levels of calcium hardness and three sulphate contents were assessed by monitoring changes in the length and weight of 10mm thick flat prism specimens.

After completion of the monitoring periods (6 months for the calcium hardness and 10 months for the sulphate) no significant expansion or change in weight of the specimens was found to have occurred either relative to each other or in total. No visual disruption of any of the specimens was seen.

The test programme was generally successful in achieving and maintaining the test solutions at the nominal calcium and sulphate levels required however it was not possible to achieve the target pH range consistently by simple addition of carbon dioxide. However we do not consider that this has significantly affected the overall findings.

The main findings can be summarised as follows:

(i) Initial leaching of lime compounds from the freshly prepared cementitious grout causes the pH of the water to rise significantly. As the cementitious grout cures the pH then decreases until a relatively stable pH is achieved.

(ii) If a 'standard' cementitious tile grout is correctly prepared, dried and cured, it is unaffected by the levels of calcium and sulphate found in typical swimming pool water at 30°C.

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for Sandberg LLP

Richard Rogerson
Department Manager

For the attention of Mr B Guthrie

CMD/RAR/tb

1 July 2004

LABORATORY PROGRAMME FOR THE DETERMINATION OF THE EFFECTS OF SWIMMING POOL WATER ON CEMENTITIOUS GROUTS PRELIMINARY TRIAL

Variation in ph of Water against Time

Date	Elapsed Time		Time	Ph of Water		Water
	Bath 1	Bath 2	Hours	Bath 1	Bath 2	Temp °C
27/09/2001	0	0	0.0	7.41	7.38	30.7
	5min	5min	0.1	9.58	9.60	30.5
	20min	20min	0.3	9.97	10.03	30.3
	1hr	1hr	1.0	10.23	10.35	30.4
	2hr	2hr	2.0	10.50	10.56	30.1
	3hr	3hr	3.0	10.59	10.66	30.2
28/09/2001	18hr	18hr	18.0	10.71	10.79	30.6
	19hr	19hr	19.0	10.70	10.75	30.0
	20hr	20hr	20.0	10.63	10.66	30.0
	21hr	1hr	21.0	10.53	9.66 *	29.8
	22hr	2hr	22.0	10.63	10.25	30.0
	23hr	3hr	23.0	10.61	10.36	30.0
	24hr	4hr	24.0	10.56	10.40	30.0
	25hr	5hr	25.0	10.56	10.37	29.8
	26hr	6hr	26.0	10.58	10.46	30.0
01/10/2001	4 days	4 days	90.7	10.58	10.45	30.8
	4 days	5min	92.7	10.52	9.44 *	29.4
	4 days	1hr	93.7	10.32	9.68	30.1
	4 days	4hr	96.7	10.08	9.87	29.6
	4 days	5hr	97.7	9.99	9.78	29.9
02/10/2001	5 days	1 day	115.1	9.78	9.77	29.9
	5 days	1 day	120.1	9.71	9.75	30.0
	5 days	5min	120.5	9.70	9.05 *	29.9
	5 days	1hr	121.1	9.69	9.54	29.9
03/10/2001	6 days	1 day	138.7	9.58	9.26	30.1
	6 days	1 day	139.7	9.56	9.23	29.8
	6 days	1 day	145.7	9.51	9.14	29.8
	6 days	5min	146.5	9.47	8.70 *	30.6
	6 days	20min	146.7	9.46	9.06	30.2
04/10/2001	7 days	16.5hr	163.1	9.38	8.97	30.1
	7 days	20hr	166.7	9.33	8.82	29.8
	7 days	23hr	169.7	9.36	8.75	30.1
	7 days	5min	170.1	9.34	7.97 *	29.8
	7 days	45min	170.7	9.28	8.22	30.0
05/10/2001	8 days	18hr	187.1	9.09	8.36	30.3
	8 days	20hr	189.1	9.04	8.31	29.9
	8 days	23hr	192.1	9.05	8.33	30.0
08/10/2001	11 days	4 days	259.7	8.80	8.17	29.8
	11 days	4 days	260.7	8.77	8.15	29.9
	11 days	5min	262.1	8.75	8.62 * #	30.4
	11 days	1hr	263.1	8.69	9.18	29.8
	11 days	3.5hr	265.7	8.65	9.16	29.6

***** Bath 2 water changed # 'lime' deposits cleaned from prisms

Each bath contains 6 No 160x20x10mm grout prisms in 4.5l of deionised water

sandberg

Table 1/2

LABORATORY PROGRAMME FOR THE DETERMINATION OF THE EFFECTS OF SWIMMING POOL WATER ON CEMENTITIOUS GROUTS PRELIMINARY TRIAL

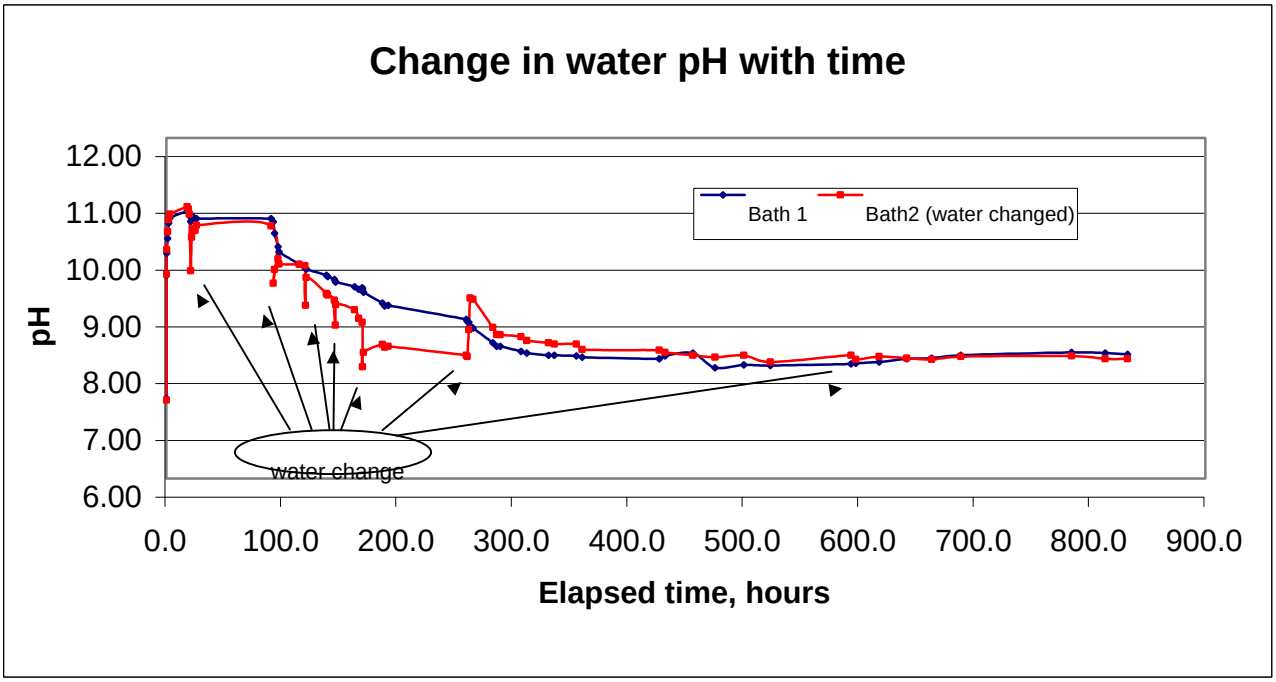
Variation in ph of Water against Time

Date	Elapsed Time		Time	Ph of Water		Water
	Bath 1	Bath 2	Hours	Bath 1	Bath 2	Temp °C
09/10/2001	12 days	20.5hr	282.7	8.39	8.66	29.9
	12 days	1 day	286.1	8.33	8.54	29.8
	12 days	1 day	289.1	8.33	8.53	29.9
10/10/2001	13 days	2 days	307.1	8.24	8.50	30.1
	13 days	2 days	312.1	8.21	8.43	29.8
11/10/2001	14 days	3 days	331.1	8.17	8.39	30.2
	14 days	3 days	336.1	8.17	8.37	30.0
12/10/2001	15 days	4 days	355.1	8.16	8.37	30.0
	15 days	4 days	360.1	8.14	8.27	29.9
15/10/2001	18 days	7 days	427.1	8.11	8.26	30.3
	18 days	7 days	432.1	8.16	8.22	29.9
16/10/2001	19 days	8 days	456.2	8.21	8.17	29.8
17/10/2001	20 days	9 days	475.2	7.95	8.14	29.8
18/10/2001	21 days	10 days	500.2	8.00	8.17	29.7
19/10/2001	22 days	11 days	523.2	7.99	8.05	30.0
22/10/2001	25 days	14 days	593.2	8.02	8.17	29.8
	25 days	5 min	597.2	8.03	8.10 ***#$**	29.8
23/10/2001	26 days	1 day	617.6	8.05	8.15	29.9
24/10/2001	27 days	2 days	641.2	8.11	8.12	29.7
25/10/2001	28 days	3 days	663.0	8.12	8.10	30.1
26/10/2001	29 days	4 days	688.1	8.17	8.15	29.8
30/10/2001	33 days	8 days	784.1	8.22	8.16 **$**	29.9
31/10/2001	34 days	9 days	813.1	8.21	8.11	30.0
01/11/2001	35 days	10 days	832.6	8.19	8.11	30.0

***** Bath 2 water changed # 'lime' deposits cleaned from prisms

$ Water sample taken from Baths 1 & 2

Each bath contains 6 No 160x20x10mm grout prisms in 4.5l of deionised water



LABORATORY PROGRAMME FOR THE DETERMINATION OF THE EFFECTS OF SWIMMING POOL WATER ON CEMENTITIOUS GROUTS PRELIMINARY TRIAL

Analysis of Water Samples

	Bath 1				Bath 2			
Constituent, mg/L	Calcium, Ca	Bicarbonate Alkalinity	Carbonate Alkalinity	Total Alkalinity*	Calcium, Ca	Bicarbonate Alkalinity	Carbonate Alkalinity	Total Alkalinity*
Date								
22/10/2001	26	65	10	75	53	85	20	105
29/10/2001	26	65	20	85	26	70	10	80
29/10/2001 (stirred)	24	55	30	85	28	70	10	80

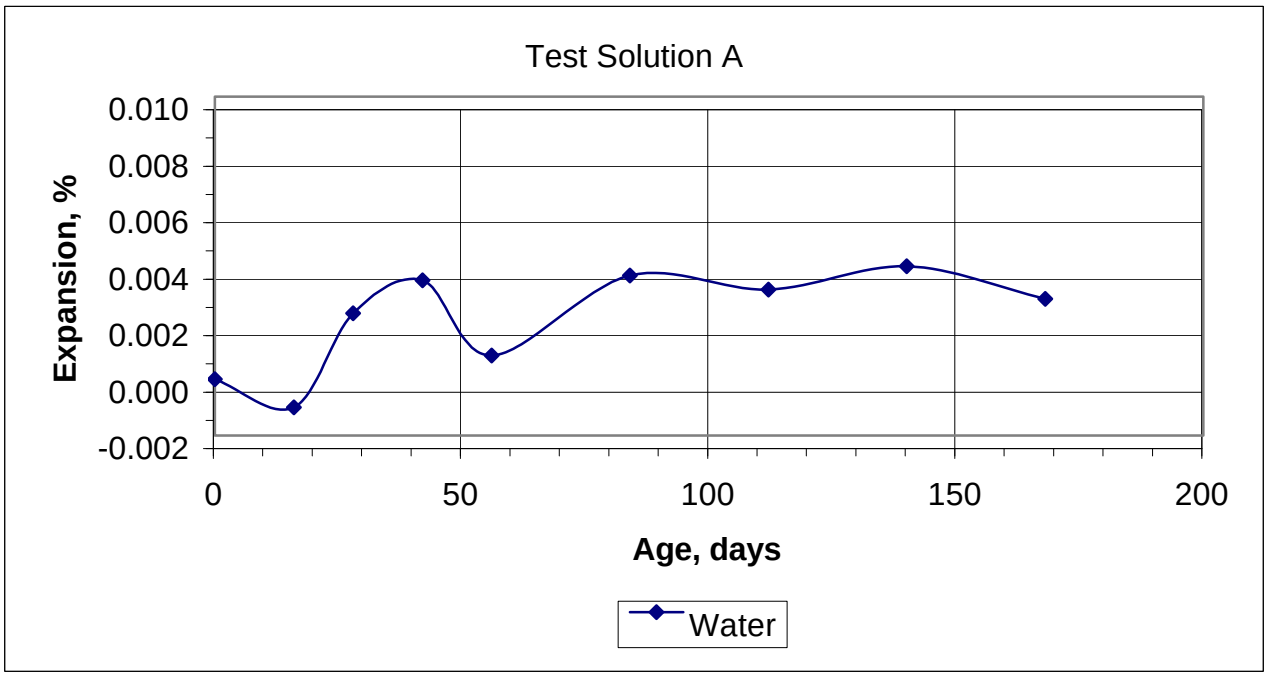
* as calcium carbonate

LABORATORY PROGRAMME FOR THE DETERMINATION OF THE EFFECTS OF SWIMMING POOL WATER ON CEMENTITIOUS GROUTS

Test Solution A

Method of Storage: Water Control at 30 °C

Sample Reference		7958	7959	7960	7961	7962	7963	Mean
Date	Age, days	Expansion,%						
05/02/2002	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000
21/02/2002	16	0.000	0.001	-0.002	-0.001	-0.002	-0.002	-0.001
05/03/2002	28	0.003	0.006	0.002	0.002	0.001	0.000	0.002
19/03/2002	42	0.006	0.006	0.002	0.003	0.002	0.002	0.004
02/04/2002	56	0.002	0.004	0.000	-0.001	0.000	0.000	0.001
30/04/2002	84	0.003	0.006	0.002	0.002	0.004	0.005	0.004
28/04/2002	112	0.003	0.006	0.002	0.001	0.003	0.004	0.003
25/06/2002	140	0.005	0.006	0.003	0.002	0.004	0.004	0.004
23/07/2002	168	0.003	0.006	0.003	0.001	0.002	0.002	0.003



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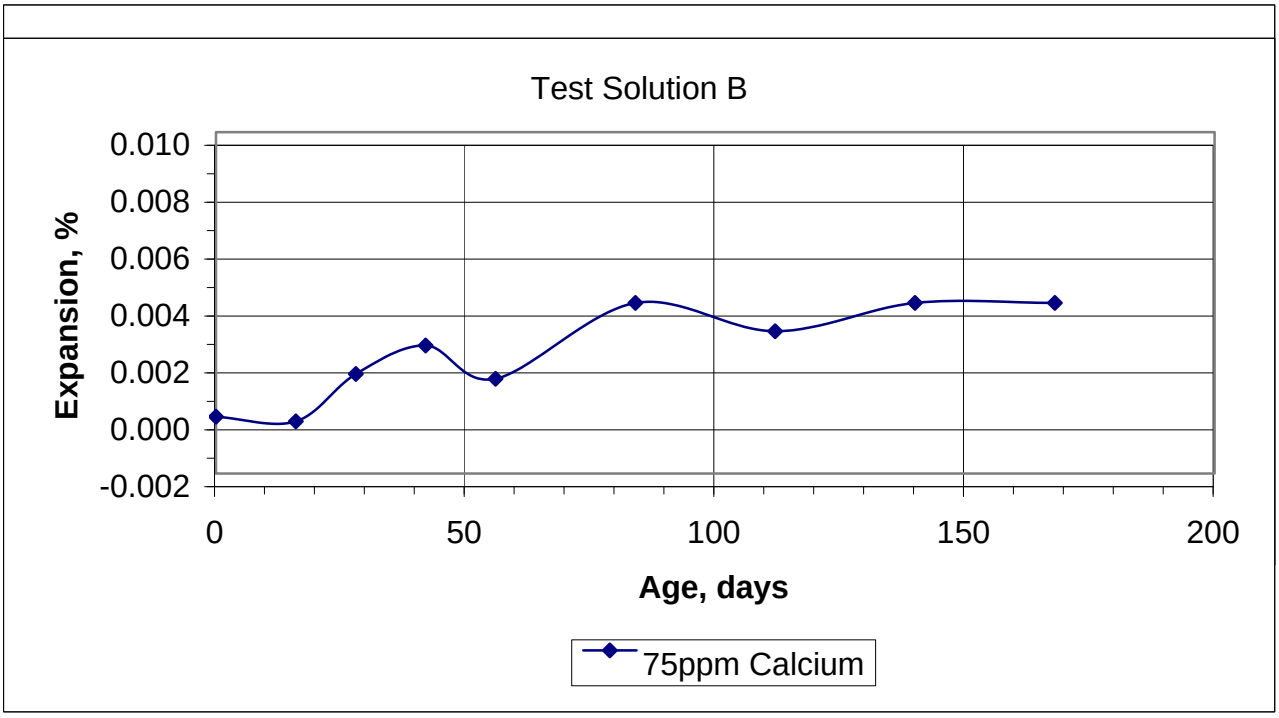
LABORATORY PROGRAMME FOR THE DETERMINATION OF THE EFFECTS OF SWIMMING POOL WATER ON CEMENTITIOUS GROUTS

Test Solution B

Method of Storage: 75ppm Calcium at 30 °C

Sample Reference		7964	7965	7966	7967	7968	7969	Mean
Date	Age, days	Expansion,%						
05/02/2002	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000
21/02/2002	16	-0.002	-0.001	-0.001	0.001	0.002	0.000	0.000
05/03/2002	28	-0.001	0.002	-0.001	0.004	0.003	0.002	0.002
19/03/2002	42	0.001	0.003	0.001	0.003	0.005	0.002	0.003
02/04/2002	56	0.001	0.001	-0.001	0.003	0.003	0.001	0.001
30/04/2002	84	0.006	0.002	0.001	0.006	0.006	0.005	0.004
28/04/2002	112	0.002	0.002	0.000	0.005	0.005	0.004	0.003
25/06/2002	140	0.002	0.004	0.002	0.005	0.006	0.004	0.004
23/07/2002	168	0.002	0.006	0.001	0.007	0.006	0.004	0.004

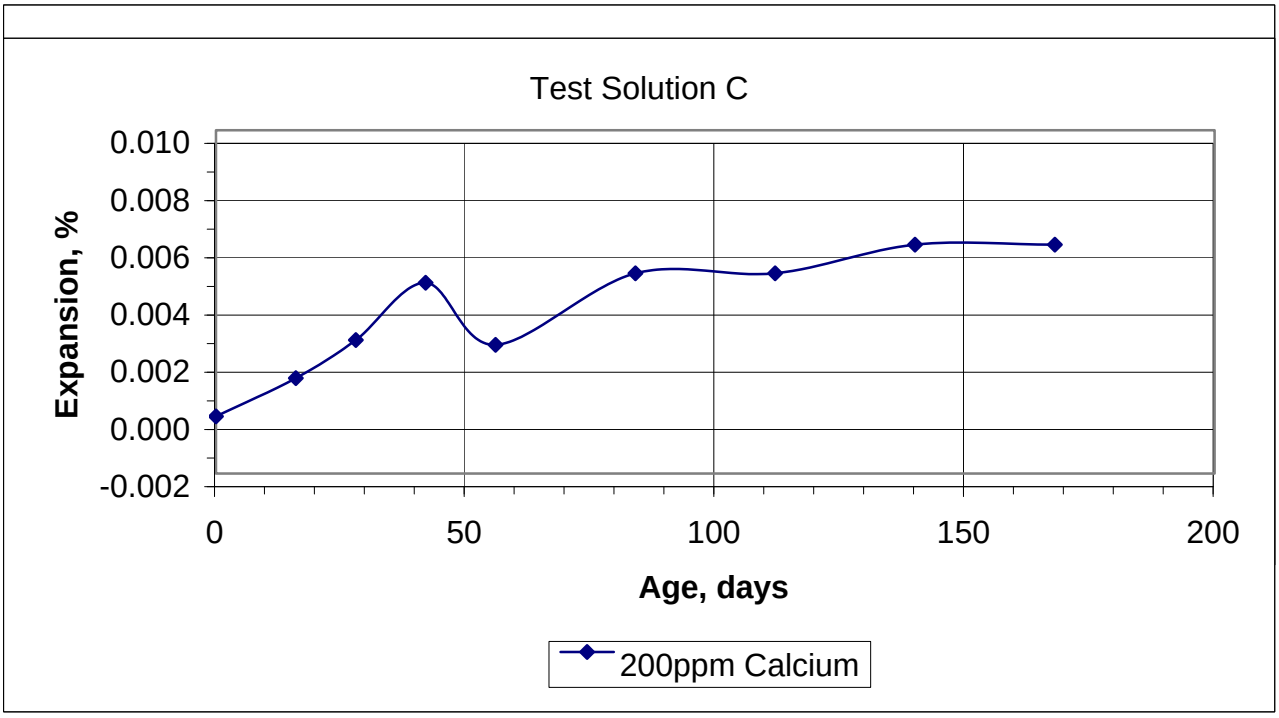


LABORATORY PROGRAMME FOR THE DETERMINATION OF THE EFFECTS OF SWIMMING POOL WATER ON CEMENTITIOUS GROUTS

Test Solution C

Method of Storage: 200ppm Calcium at 30 °C

Sample Reference		7970	7971	7972	7973	7974	7975	Mean
Date	Age, days	Expansion,%						
05/02/2002	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000
21/02/2002	16	0.001	0.000	0.004	0.000	0.001	0.002	0.001
05/03/2002	28	0.004	0.003	0.003	0.003	0.002	0.001	0.003
19/03/2002	42	0.004	0.003	0.005	0.005	0.007	0.004	0.005
02/04/2002	56	0.004	0.002	0.004	0.002	0.002	0.001	0.003
30/04/2002	84	0.006	0.004	0.006	0.006	0.004	0.003	0.005
28/04/2002	112	0.006	0.003	0.006	0.005	0.005	0.003	0.005
25/06/2002	140	0.006	0.004	0.007	0.006	0.006	0.004	0.006
23/06/2002	168	0.006	0.004	0.007	0.006	0.006	0.004	0.006



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LABORATORY PROGRAMME FOR THE DETERMINATION OF THE EFFECTS OF SWIMMING POOL WATER ON CEMENTITIOUS GROUTS

Test Solution D

Method of Storage: 1000ppm Calcium at 30 °C

Sample Reference		7976	7977	7978	7979	7980	7981	Mean
Date	Age, days	Expansion,%						
05/02/2002	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000
21/02/2002	16	0.001	0.002	0.002	0.003	0.002	0.003	0.002
05/03/2002	28	0.001	-0.001	0.002	0.001	0.001	0.001	0.001
19/03/2002	42	0.003	0.001	0.005	0.005	0.002	0.003	0.003
02/04/2002	56	0.003	-0.001	0.003	0.004	0.003	0.003	0.003
30/04/2002	84	0.005	-0.001	0.003	0.005	0.005	0.003	0.003
28/04/2002	112	0.003	-0.002	0.003	0.003	0.003	0.003	0.002
25/06/2002	140	0.005	-0.001	0.005	0.004	0.003	0.005	0.004
23/07/2002	168	0.006	-0.001	0.006	0.005	0.004	0.005	0.005

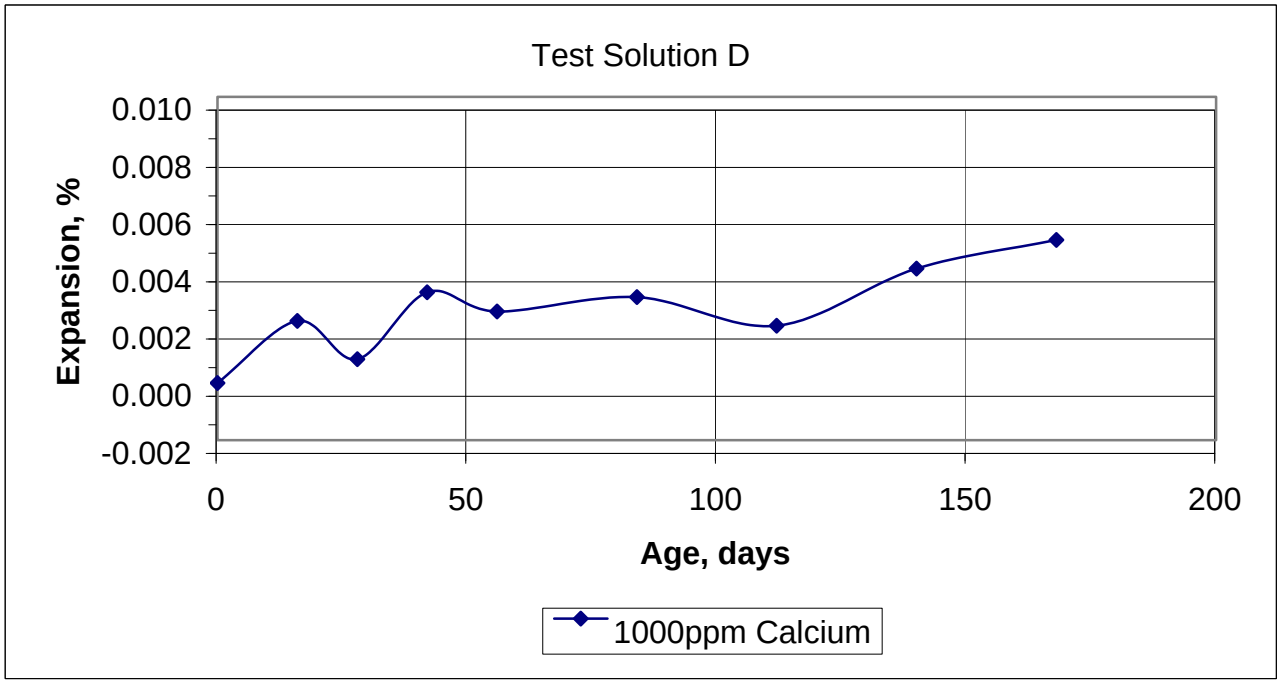

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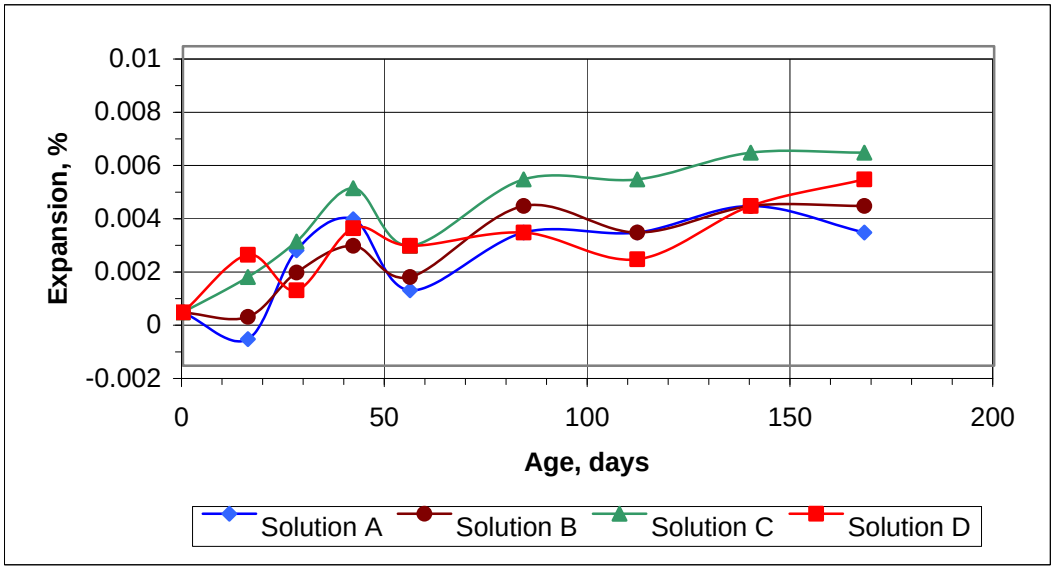
Table 7

LABORATORY PROGRAMME FOR THE DETERMINATION OF THE EFFECTS OF SWIMMING POOL WATER ON CEMENTITIOUS GROUTS

SUMMARY OF RESULTS

Solution Reference		A	B	C	D
Date	Age, days	Expansion,%			
05/02/2002	0	0	0	0	0
21/02/2002	16	-0.001	0.000	0.001	0.002
05/03/2002	28	0.002	0.002	0.003	0.001
19/03/2002	42	0.004	0.003	0.005	0.003
02/04/2002	56	0.001	0.001	0.003	0.003
30/04/2002	84	0.003	0.004	0.005	0.003
28/04/2002	112	0.003	0.003	0.005	0.002
25/06/2002	140	0.004	0.004	0.006	0.004
23/07/2002	168	0.003	0.004	0.006	0.005



Solution A Water at 30 °C
Solution B 75ppm Calcium at 30°C
Solution C 200ppm Calcium at 30°C
Solution D 1000ppm Calcium at 30°C

LABORATORY PROGRAMME FOR THE DETERMINATION OF THE EFFECTS OF SWIMMING POOL WATER ON CEMENTITIOUS GROUTS

Ph of Water

40 litre baths of solution
6no 160 x 20 x 10 in each bath

Bath	Specimen Refs	Solution
1	7958-63	Water
2	7964-69	75ppm Calcium
3	7970-75	200ppm Calcium
4	7976-82	1000ppm Calcium

Date	Elapsed Time	pH of water			
		Bath 1	Bath 2	Bath 3	Bath 4
05/02/2002	0	7.71	7.25	7.08	7.14
05/02/2002	0.04	8.68	7.31	7.28	7.18
06/02/2002	0.75	8.67	8.67	8.03	7.93
06/06/2002	1	8.8	7.63	7.66	7.29
07/02/2002	2	8.31	7.54	7.69	7.42
08/02/2002	3	8.15	7.57	7.63	7.37
12/02/2002	7	7.84	7.39	7.55	7.3
13/02/2002	8	7.73	7.37	7.44	7.29
14/02/2002	9	7.72	7.42	7.48	7.37
15/02/2002	10	7.64	7.53	7.51	7.34
19/02/2002	14	7.9	7.58	7.51	7.38
21/02/2002	16	8.12	7.42	7.52	7.44
22/02/2002	17	7.74	7.47	7.52	7.44
04/03/2002	27	7.79	7.24	7.14	6.86
06/03/2003	29	8.23	8.1	7.84	7.45
08/03/2002	31	8.44	8.09	7.85	7.46
13/03/2002	36	7.77	7.44	7.27	6.99
19/03/2002	42	7.65	7.33	7.16	6.89
21/03/2002	44	7.4	7.26	7.12	6.85
22/03/2002	45	7.64	7.48	7.36	7.46
26/03/2002	49	7.86	7.5	7.32	7.46
02/04/2002	56	7.76	7.64	7.48	7.34
05/04/2002	59	7.84	7.51	7.45	7.28
12/04/2002	66	7.89	7.54	7.36	7.31
19/04/2002	73	7.81	7.52	7.45	7.28
26/04/2002	80	7.88	7.61	7.43	7.34
30/04/2002	84	7.88	7.85	7.59	7.35
20/05/2002	105	7.83	7.62	7.49	7.4
28/05/2002	112	7.86	7.82	7.54	7.28
05/06/2002	120	7.85	7.66	7.46	7.2
12/06/2002	127	8.3	8.08	7.79	7.4
21/06/2002	136	7.79	7.56	7.46	7.26
25/06/2002	140	7.82	7.8	7.6	7.2
09/07/2002	154	8.11	7.84	7.62	7.41
17/07/2002	162	8.46	8.25	7.89	7.61
22/07/2002	167	8.2	7.92	7.8	7.38
23/07/2002	168	7.89	7.86	7.6	7.26

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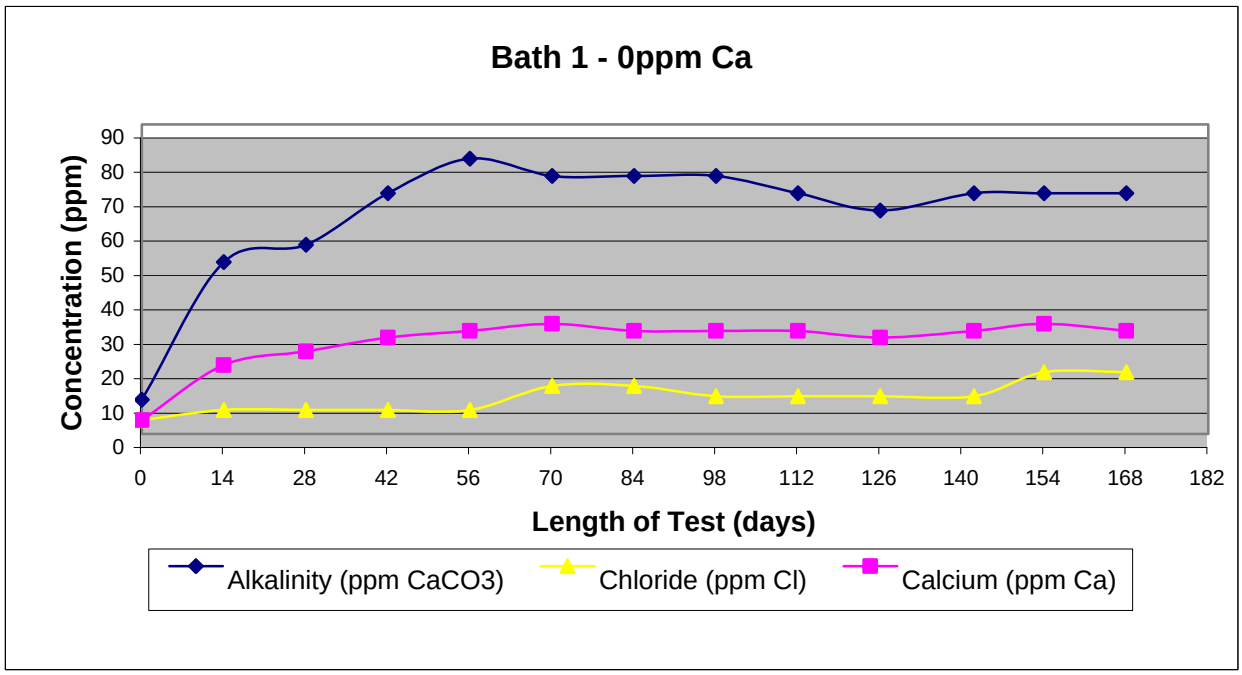
LABORATORY PROGRAMME FOR THE DETERMINATION OF THE EFFECTS OF SWIMMING POOL WATER ON GROUTS SOLUTION STRENGTH DATA

Bath 1 - 0ppm Ca

length of test (days)	Alkalinity (as ppm CaCO3)	Chloride (as ppm Cl)	Calcium (as ppm Ca)
0	10	4	4
14	50	7	20
28	55	7	24
42	70	7	28
56	80	7	30
70	75	14	32
84	75	14	30
98	75	11	30
112	70	11	30
126	65	11	28
142	70	11	30
154	70	18	32
168	70	18	30



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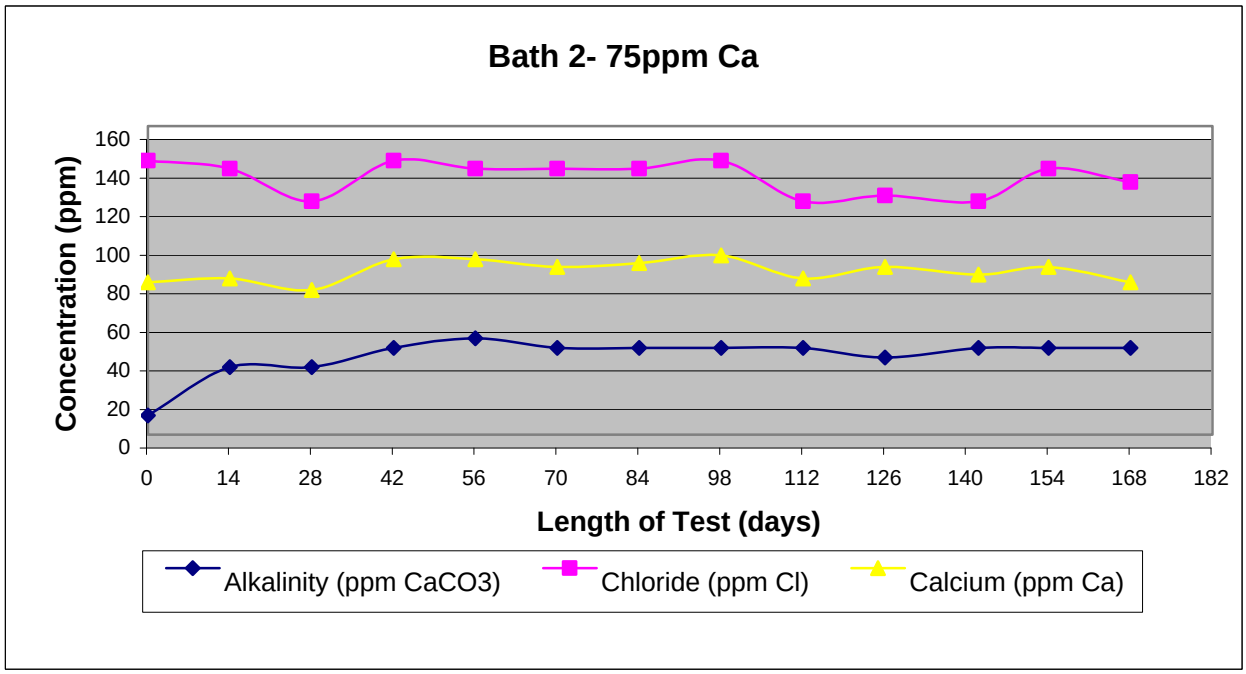
LABORATORY PROGRAMME FOR THE DETERMINATION OF THE EFFECTS OF SWIMMING POOL WATER ON GROUTS SOLUTION STRENGTH DATA

Bath 2- 75ppm Ca

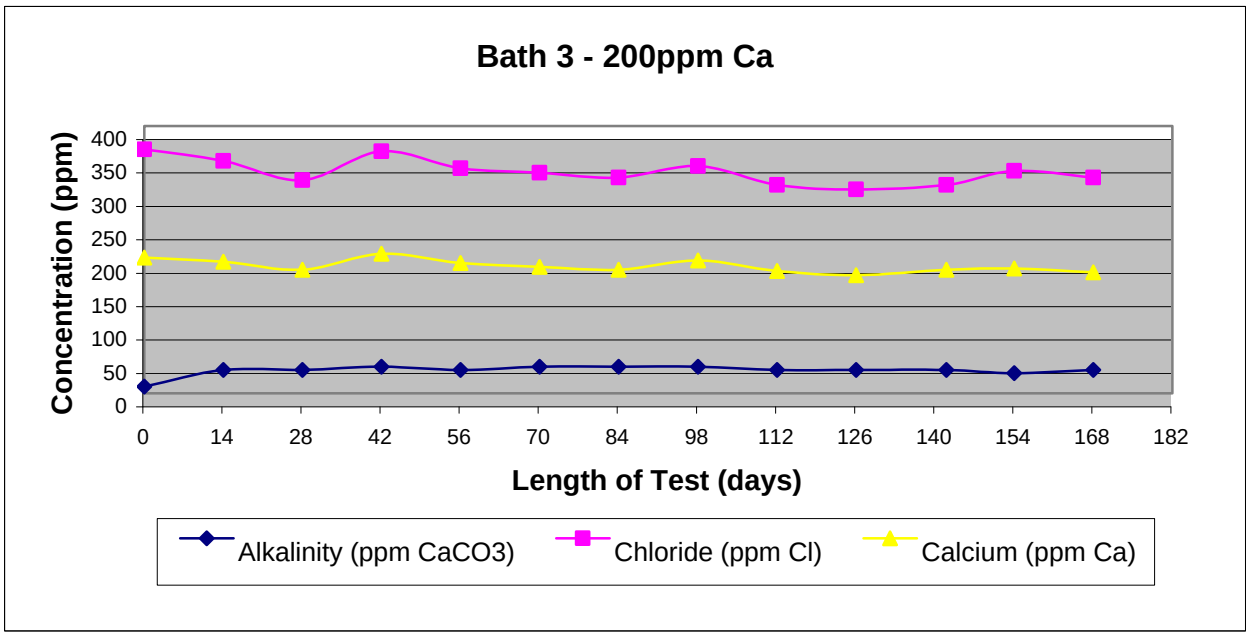
length of test (days)	Alkalinity (as ppm CaCO3)	Chloride (as ppm Cl)	Calcium (as ppm Ca)
0	10	142	79
14	35	138	81
28	35	121	75
42	45	142	91
56	50	138	91
70	45	138	87
84	45	138	89
98	45	142	93
112	45	121	81
126	40	124	87
142	45	121	83
154	45	138	87
168	45	131	79



LABORATORY PROGRAMME FOR THE DETERMINATION OF THE EFFECTS OF SWIMMING POOL WATER ON GROUTS SOLUTION STRENGTH DATA

Bath 3 - 200ppm Ca

length of test (days)	Alkalinity (as ppm CaCO3)	Chloride (as ppm Cl)	Calcium (as ppm Ca)
0	10	365	203
14	35	348	197
28	35	319	185
42	40	362	209
56	35	337	195
70	40	330	189
84	40	323	185
98	40	340	199
112	35	312	183
126	35	305	177
142	35	312	185
154	30	333	187
168	35	323	181



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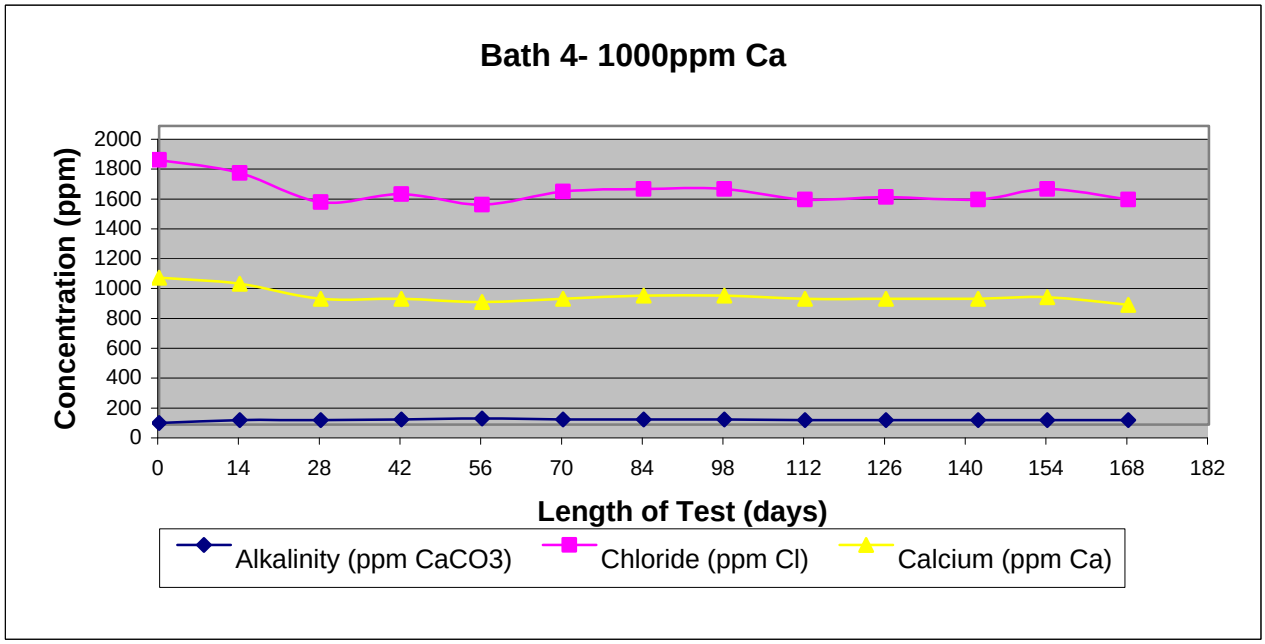
LABORATORY PROGRAMME FOR THE DETERMINATION OF THE EFFECTS OF SWIMMING POOL WATER ON GROUTS SOLUTION STRENGTH DATA

Solution D - 1000ppm Ca

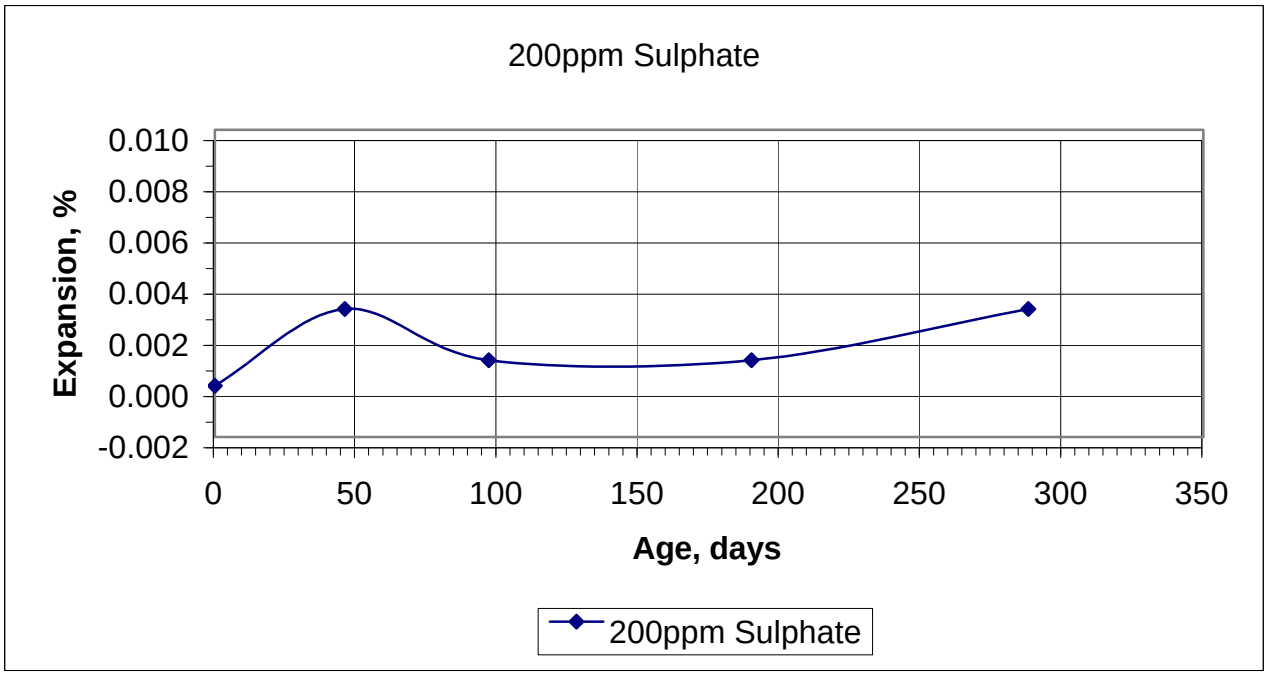
length of test (days)	Alkalinity (ppm CaCO3)	Chloride (ppm Cl)	Calcium (ppm Ca)
0	10	1773	984
14	30	1684	944
28	30	1489	843
42	35	1543	843
56	40	1472	822
70	35	1560	843
84	35	1578	863
98	35	1578	863
112	30	1507	843
126	30	1525	843
142	30	1507	843
154	30	1578	853
168	30	1507	802



LABORATORY PROGRAMME FOR THE DETERMINATION OF THE EFFECTS OF SWIMMING POOL WATER ON CEMENTITIOUS GROUTS - SULPHATE SOLUTIONS

Method of Storage: 75ppm Calcium at 30 °C
200ppm Sulphate

Sample Reference		7958	7959	7960	7961	7962	7963	Mean
Date	Age, days	Expansion,%						
22/11/2002	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000
07/01/2003	46	0.004	0.005	0.002	0.001	0.004	0.002	0.003
26/02/2003	97	0.001	0.003	0.000	-0.001	0.001	0.000	0.001
30/05/2003	190	0.001	0.003	0.000	0.001	0.000	0.001	0.001
05/09/2003	288	0.004	0.006	0.003	0.002	0.003	0.002	0.003



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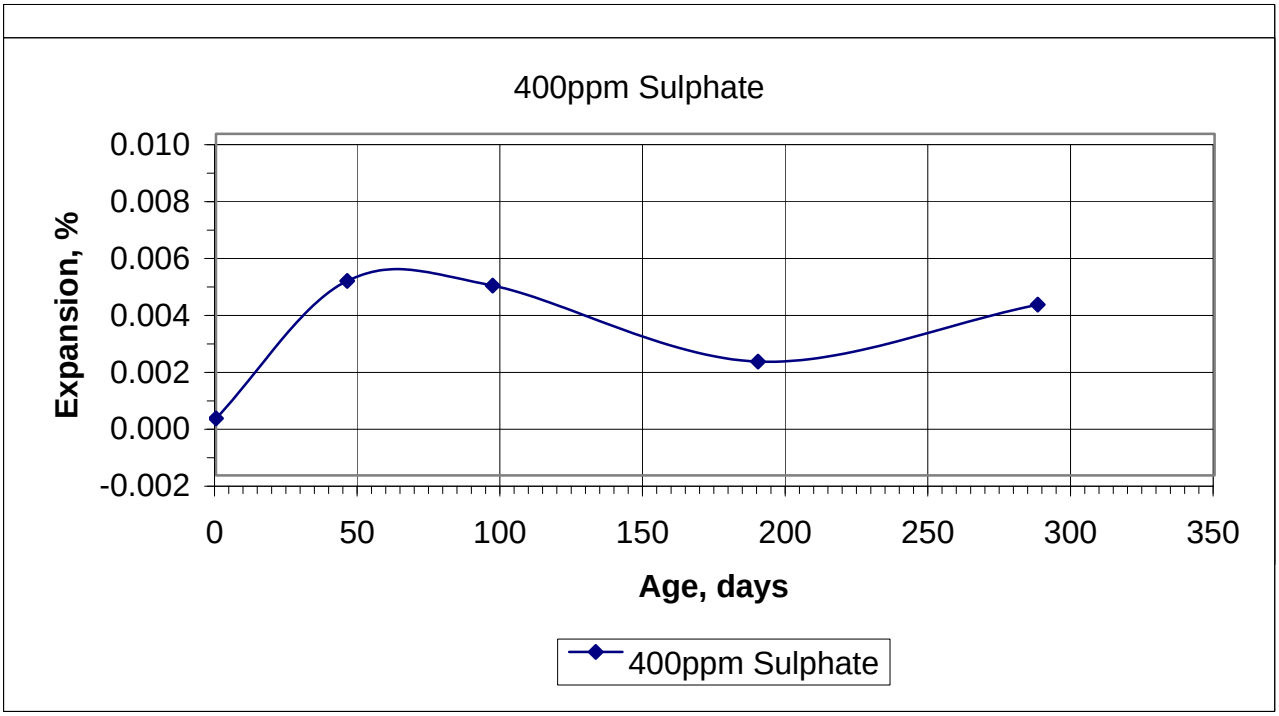
LABORATORY PROGRAMME FOR THE DETERMINATION OF THE EFFECTS OF SWIMMING POOL WATER ON CEMENTITIOUS GROUTS - SULPHATE SOLUTIONS

Method of Storage: 75ppm Calcium at 30 °C
400ppm Sulphate

Sample Reference		7964	7965	7966	7967	7968	7969	Mean
Date	Age, days	Expansion,%						
22/11/2002	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000
07/01/2003	46	0.002	0.006	0.002	0.007	0.006	0.006	0.005
26/02/2003	97	0.004	0.004	0.002	0.007	0.006	0.005	0.005
30/05/2003	190	0.002	0.001	-0.001	0.005	0.005	0.003	0.002
05/09/2003	288	0.003	0.004	0.001	0.006	0.006	0.005	0.004



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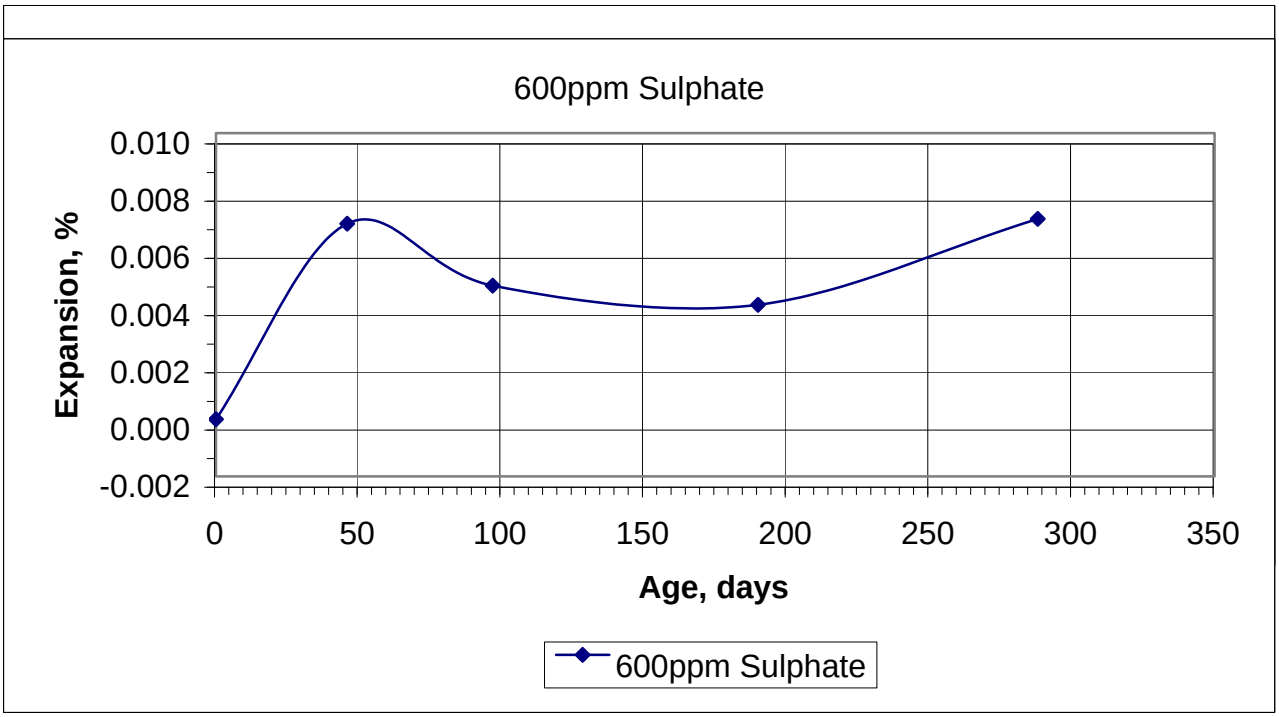
LABORATORY PROGRAMME FOR THE DETERMINATION OF THE EFFECTS OF SWIMMING POOL WATER ON CEMENTITIOUS GROUTS - SULPHATE SOLUTIONS

Method of Storage: 75ppm Calcium at 30 °C
600ppm Sulphate

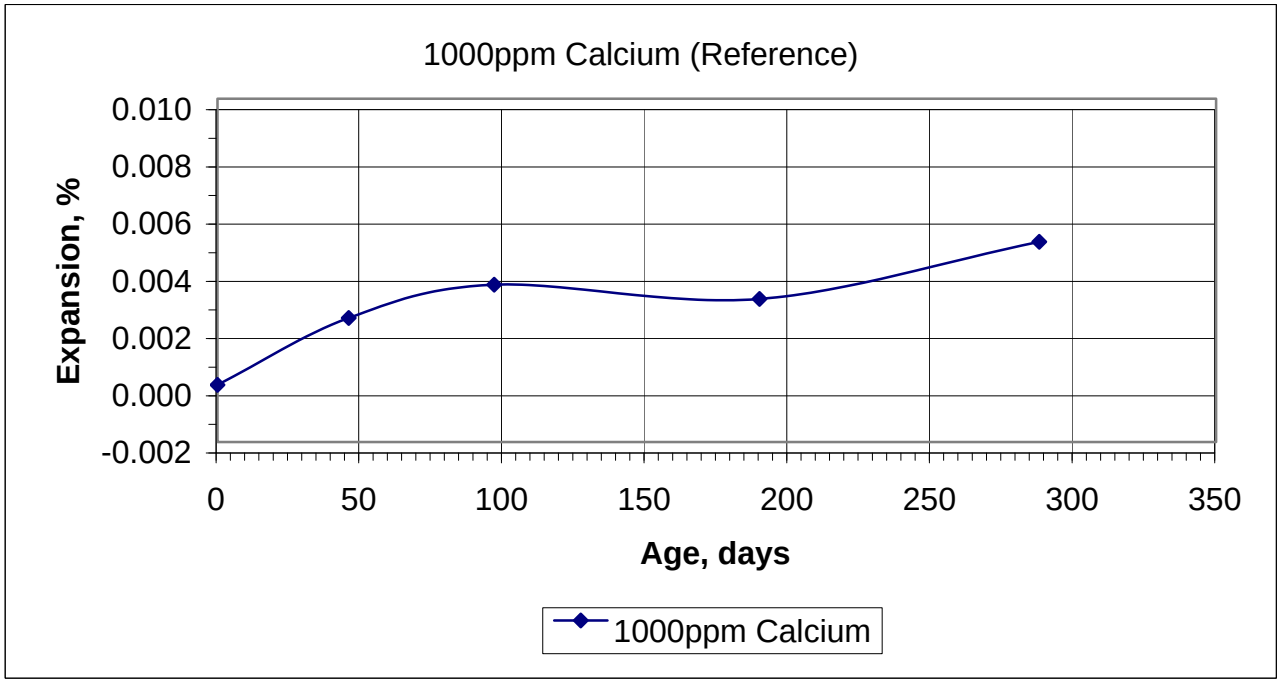
Sample Reference		7970	7971	7972	7973	7974	7975	Mean
Date	Age, days	Expansion,%						
22/11/2002	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000
07/01/2003	46	0.008	0.005	0.008	0.008	0.006	0.006	0.007
26/02/2003	97	0.005	0.003	0.006	0.005	0.004	0.005	0.005
30/05/2003	190	0.005	0.002	0.006	0.004	0.004	0.005	0.004
05/09/2003	288	0.006	0.005	0.009	0.007	0.007	0.006	0.007



LABORATORY PROGRAMME FOR THE DETERMINATION OF THE EFFECTS OF SWIMMING POOL WATER ON CEMENTITIOUS GROUTS - SULPHATE SOLUTIONS

Method of Storage: 1000ppm Calcium Reference at 30 °C

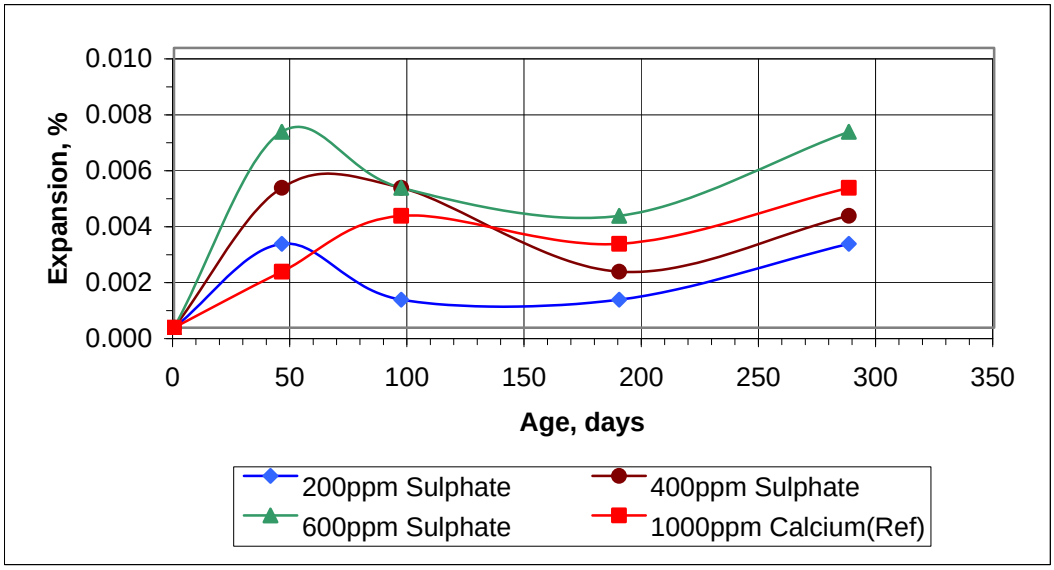
Sample Reference		7976	7977	7978	7979	7980	7981	Mean
Date	Age, days	Expansion,%						
22/11/2002	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000
07/01/2003	46	0.004	-0.003	0.005	0.003	0.003	0.002	0.002
26/02/2003	97	0.004	-0.001	0.005	0.004	0.004	0.005	0.004
30/05/2003	190	0.004	-0.003	0.004	0.003	0.004	0.004	0.003
05/09/2003	288	0.006	0.000	0.007	0.005	0.005	0.005	0.005



LABORATORY PROGRAMME FOR THE DETERMINATION OF THE EFFECTS OF SWIMMING POOL WATER ON CEMENTITIOUS GROUTS - SULPHATE SOLUTIONS

SUMMARY OF RESULTS

Sample Reference		200ppm SO4	400ppm SO4	600ppm SO4	1000ppm Ca
Date	Age, days	Expansion,%			
22/11/2002	0	0.000	0.000	0.000	0.000
07/01/2003	46	0.003	0.005	0.007	0.002
26/02/2003	97	0.001	0.005	0.005	0.004
30/05/2003	190	0.001	0.002	0.004	0.003
05/09/2003	288	0.003	0.004	0.007	0.005



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CONSULTING, INSPECTING
AND TESTING ENGINEERS

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Table
18

Date of Test
25/11/02-29/8/03

ANALYSIS OF WATER
DETERMINATION OF CALCIUM AND SULPHATE

Internal method 51.1

Solution Strength (nominal ppm SO_4)	Date of sampling	Sulphate		Calcium ppm
		ppm SO_3	ppm SO_4	
200	25/11/02	165	197	85
	24/02/03	180	216	85
	29/08/03	182	218	83
400	25/11/02	322	387	81
	24/02/03	331	397	85
	29/08/03	310	372	87
600	25/11/02	504	605	81
	24/02/03	494	593	87
	29/08/03	490	589	89

LABORATORY PROGRAMME FOR THE DETERMINATION OF THE EFFECTS OF SWIMMING POOL WATER ON CEMENTITIOUS GROUTS

SAMPLE WEIGHTS

Test Solution A

Method of Storage: Days 0 to 252 Water Control at 30°C
Days 252 to 540 75ppm Calcium & 200ppm Sulphate at 30°C

Sample Reference		7958	7959	7960	7961	7962	7963	Mean
Date	Age, days	Weight, g						
16/01/2002	-20	64.2	63.0	68.1	65.8	63.8	63.4	64.7
05/02/2002	0	71.0	69.1	74.3	72.2	70.0	69.9	71.1
21/02/2002	16	70.9	68.9	74.2	72.1	69.8	69.7	70.9
05/03/2002	28	71.4	69.4	74.6	72.3	70.1	70.1	71.3
19/03/2002	42	71.0	69.3	74.7	72.5	70.2	70.0	71.3
02/04/2002	56	70.9	68.9	74.2	72.0	69.8	69.7	70.9
30/04/2002	84	70.8	68.9	74.2	72.0	69.9	69.7	70.9
28/04/2002	112	70.8	69.0	74.2	72.0	69.9	69.7	70.9
25/06/2002	140	70.8	69.0	74.1	72.0	69.8	69.7	70.9
23/07/2002	168	70.8	69.0	74.1	72.1	69.9	69.8	71.0
07/01/2003	298	71.5	69.7	74.8	72.9	70.4	70.5	71.6
26/02/2003	349	71.4	69.8	75.0	72.8	70.5	70.3	71.6
30/05/2003	442	71.4	69.7	74.9	72.8	70.6	70.4	71.6
05/09/2003	540	71.5	69.8	75.0	72.9	70.7	70.5	71.7

Test Solution B

Method of Storage: Days 0 to 252 75ppm Calcium at 30°C
Days 252 to 540 75ppm Calcium & 400ppm Sulphate at 30°C

Sample Reference		7964	7965	7966	7967	7968	7969	Mean
Date	Age, days	Weight, g						
16/01/2002	-20	62.9	65.0	66.5	61.7	60.4	67.7	64.0
05/02/2002	0	69.4	71.1	72.0	66.8	65.5	74.3	69.9
21/02/2002	16	69.2	71.0	71.7	66.8	65.5	74.4	69.8
05/03/2002	28	69.7	71.5	72.4	67.3	65.9	74.8	70.3
19/03/2002	42	69.7	71.3	72.0	67.3	65.9	74.7	70.2
02/04/2002	56	69.5	71.1	71.9	67.0	65.7	74.5	70.0
30/04/2002	84	69.4	71.1	72.0	67.0	65.6	74.4	69.9
28/04/2002	112	69.4	71.2	71.9	67.1	65.7	74.5	70.0
25/06/2002	140	69.4	71.3	72.0	67.2	65.8	74.6	70.1
23/07/2002	168	69.4	71.2	72.0	67.2	65.9	74.6	70.1
07/01/2003	298	69.7	71.7	72.5	67.7	66.4	74.9	70.5
26/02/2003	349	69.7	71.7	72.6	67.7	66.4	74.8	70.5
30/05/2003	442	69.7	71.7	72.6	67.9	66.5	74.9	70.6
05/09/2003	540	69.8	71.8	72.7	68.0	66.6	75.0	70.7

LABORATORY PROGRAMME FOR THE DETERMINATION OF THE EFFECTS OF SWIMMING POOL WATER ON CEMENTITIOUS GROUTS

SAMPLE WEIGHTS

Test Solution C

Method of Storage: Days 0 to 252 200ppm Calcium at 30°C
Days 252 to 540 75ppm Calcium & 600ppm Sulphate at 30°C

Sample Reference		7970	7971	7972	7973	7974	7975	Mean
Date	Age, days	Weight, g						
16/01/2002	-20	68.6	67.3	64.4	65.3	65.9	68.1	66.6
05/02/2002	0	75.3	72.4	69.7	70.3	71.4	73.2	72.1
21/02/2002	16	75.5	72.6	70.0	70.5	71.5	73.5	72.3
05/03/2002	28	75.7	73.0	70.5	71.1	72.0	74.1	72.7
19/03/2002	42	75.7	73.0	70.4	70.9	71.8	74.1	72.7
02/04/2002	56	75.6	72.8	70.2	70.8	71.7	73.8	72.5
30/04/2002	84	75.8	72.8	70.3	71.0	71.7	73.8	72.6
28/04/2002	112	75.8	72.8	70.3	71.0	71.7	73.9	72.6
25/06/2002	140	75.8	72.7	70.3	71.0	71.7	73.9	72.6
23/07/2002	168	75.8	72.7	70.3	71.1	71.8	74.0	72.6
07/01/2003	298	76.5	73.0	70.7	71.6	72.4	74.5	73.1
26/02/2003	349	76.5	73.2	70.8	71.7	72.4	74.6	73.2
30/05/2003	442	76.6	73.3	70.9	71.9	72.6	74.8	73.4
05/09/2003	540	76.6	73.3	71.0	71.9	72.4	74.8	73.3

Test Solution D

Method of Storage: Days 0 to 252 1000ppm Calcium at 30°C
Days 252 to 540 1000ppm Calcium & 0ppm Sulphate at 30°C

Sample Reference		7976	7977	7978	7979	7980	7981	Mean
Date	Age, days	Weight, g						
16/01/2002	-20	66.0	64.4	62.1	67.1	64.7	63.7	64.7
05/02/2002	0	71.7	69.1	66.7	71.8	69.5	69.1	69.7
21/02/2002	16	72.0	69.4	67.0	72.1	69.8	69.4	70.0
05/03/2002	28	72.6	69.7	67.4	72.6	70.1	69.7	70.4
19/03/2002	42	72.4	69.9	67.6	72.4	70.2	70.0	70.4
02/04/2002	56	72.3	69.9	67.4	72.3	69.9	69.8	70.3
30/04/2002	84	72.3	69.8	67.4	72.3	69.9	69.8	70.3
28/04/2002	112	72.2	69.8	67.3	72.3	70.0	69.7	70.2
25/06/2002	140	72.3	69.9	67.4	72.4	70.0	69.7	70.3
23/07/2002	168	72.3	69.9	67.5	72.4	70.0	69.7	70.3
07/01/2003	298	72.8	70.2	67.8	72.5	70.3	70.0	70.6
26/02/2003	349	72.8	70.3	67.9	72.6	70.4	70.1	70.7
30/05/2003	442	72.9	70.5	68.1	72.7	70.4	70.3	70.8
05/09/2003	540	73.0	70.6	68.2	72.8	70.4	70.4	70.9

LABORATORY PROGRAMME FOR THE DETERMINATION OF THE EFFECTS OF SWIMMING POOL WATER ON CEMENTITIOUS GROUTS

SAMPLE WEIGHTS

SUMMARY OF RESULTS

Solution Reference		A	B	C	D	Remarks
Date	Age, days	Weight, g				
16/01/2002	-20	64.7	64.0	66.6	64.7	Dry
05/02/2002	0	71.1	69.9	72.1	69.7	Water saturated
21/02/2002	16	70.9	69.8	72.3	70.0	Solution Saturated
05/03/2002	28	71.3	70.3	72.7	70.4	Solution Saturated
19/03/2002	42	71.3	70.2	72.7	70.4	Solution Saturated
02/04/2002	56	70.9	70.0	72.5	70.3	Solution Saturated
30/04/2002	84	70.9	69.9	72.6	70.3	Solution Saturated
28/04/2002	112	70.9	70.0	72.6	70.2	Solution Saturated
25/06/2002	140	70.9	70.1	72.6	70.3	Solution Saturated
23/07/2002	168	71.0	70.1	72.6	70.3	Solution Saturated
07/01/2003	298	71.6	70.5	73.1	70.6	Solution Saturated (Sulphate)
26/02/2003	349	71.6	70.5	73.2	70.7	Solution Saturated (Sulphate)
30/05/2003	442	71.6	70.6	73.4	70.8	Solution Saturated (Sulphate)
05/09/2003	540	71.7	70.7	73.3	70.9	Solution Saturated (Sulphate)

Test Solution A

Method of Storage:	Days 0 to 252	Water Control (Calcium approx 30ppm) at 30°C
	Days 252 to 540	75ppm Calcium & 200ppm Sulphate at 30°C

Test Solution B

Method of Storage:	Days 0 to 252	75ppm Calcium at 30°C
	Days 252 to 540	75ppm Calcium & 400ppm Sulphate at 30°C

Test Solution C

Method of Storage:	Days 0 to 252	200ppm Calcium at 30°C
	Days 252 to 540	75ppm Calcium & 600ppm Sulphate at 30°C

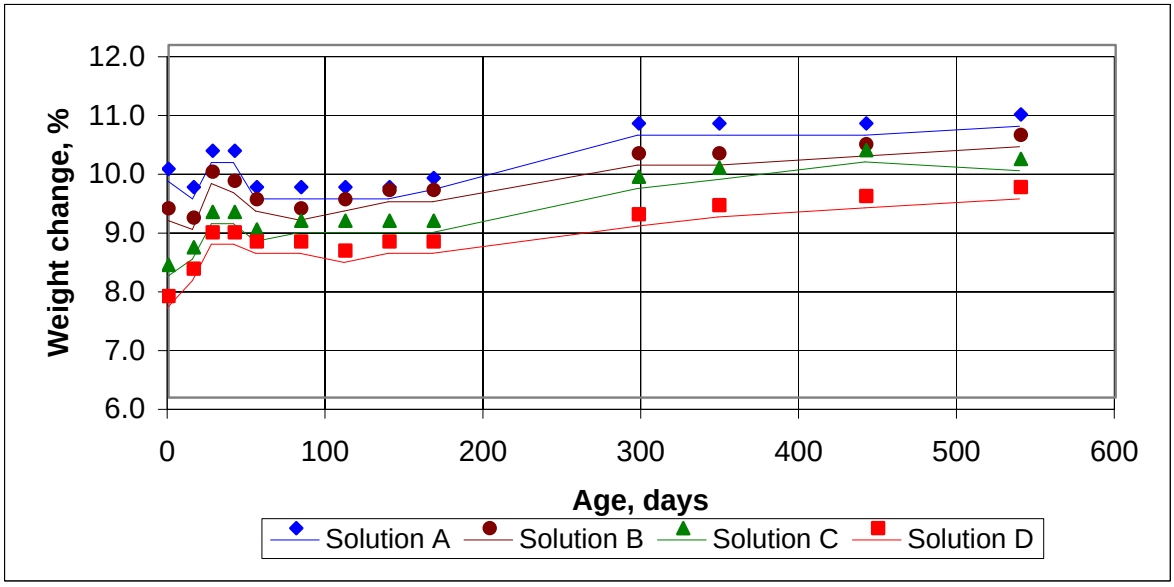
Test Solution D

Method of Storage:	Days 0 to 252	1000ppm Calcium at 30°C
	Days 252 to 540	1000ppm Calcium & 0ppm Sulphate at 30°C

LABORATORY PROGRAMME FOR THE DETERMINATION OF THE EFFECTS OF SWIMMING POOL WATER ON CEMENTITIOUS GROUTS

SAMPLE WEIGHT CHANGE AS PERCENTAGE

Solution Reference / Age, days	A	B	C	D	Remarks
	Weight change, %				
0	9.9	9.2	8.3	7.7	Dry to Water saturated as a percent of Dry weight
16	9.6	9.1	8.6	8.2	Dry to Solution saturated as a percent of Dry weight
28	10.2	9.8	9.2	8.8	
42	10.2	9.7	9.2	8.8	
56	9.6	9.4	8.9	8.7	
84	9.6	9.2	9.0	8.7	
112	9.6	9.4	9.0	8.5	
140	9.6	9.5	9.0	8.7	
168	9.7	9.5	9.0	8.7	
298	10.7	10.2	9.8	9.1	
349	10.7	10.2	9.9	9.3	
442	10.7	10.3	10.2	9.4	
540	10.8	10.5	10.1	9.6	



Test Solution A

Method of Storage:	Days 0 to 252	Water Control (Calcium approx 30ppm) at 30°C
	Days 252 to 540	75ppm Calcium & 200ppm Sulphate at 30°C

Test Solution B

Method of Storage:	Days 0 to 252	75ppm Calcium at 30°C
	Days 252 to 540	75ppm Calcium & 400ppm Sulphate at 30°C

Test Solution C

Method of Storage:	Days 0 to 252	200ppm Calcium at 30°C
	Days 252 to 540	75ppm Calcium & 600ppm Sulphate at 30°C

Test Solution D

Method of Storage:	Days 0 to 252	1000ppm Calcium at 30°C
	Days 252 to 540	1000ppm Calcium & 0ppm Sulphate at 30°C

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0262

Set Ref.	Date Cast	Storage Conditions	Comparative Hardness	Moh's Hardness
Preliminary	Sep 2001	Air Cure (never in solution)	Hard	9
A	Jan 2002	Days 0 to 252 - Water Control (Calcium approx 30ppm) at 30°C then - 75ppm Calcium & 200ppm Sulphate at 30°C	Hard	6
B	Jan 2002	Days 0 to 252 - 75ppm Calcium at 30°C then - 75ppm Calcium & 400ppm Sulphate at 30°C	Hard	6
C	Jan 2002	Days 0 to 252 - 200ppm Calcium at 30°C then - 75ppm Calcium & 600ppm Sulphate at 30°C	Hard	7
D	Jan 2002	Days 0 to 252 - 1000ppm Calcium at 30°C then - 1000ppm Calcium & Oppm Sulphate at 30°C	Can be scratched with a steel point	4
Extra	Dec 2003	7 days air cure then water at 30°C	Can be easily scratched with a steel point	2

LABORATORY PROGRAMME FOR THE DETERMINATION OF THE EFFECTS OF SWIMMING POOL WATER ON GROUTS
COMPARATIVE HARDNESS

Table 21

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