An Update on the Cause of Swimming Pool Plaster Efflorescence (Calcium Nodules)

Que Hales, Doug Latta and Kim Skinner - *onBalance*

Swimming pool plaster samples exhibiting calcium nodule growths have been analyzed by cement petrographers, and the findings are consistent with the model proposed by onBalance in a 1998 JSPSI article.

In 1998 we published an article titled "Calcium Nodules" in the Journal of the Swimming Pool and Spa Industry (Volume 3 Number 2 pp. 21-26). In that article we proposed a mechanical and chemical model for the occurrence of calcium nodules on swimming pool plaster. The primary characteristics of the phenomenon were described as water penetration into or through various types of flaws in the plaster, leaching calcium hydroxide from within the plaster paste; and then carbonation, or conversion into calcium carbonate as the exudate reacts with alkalinity in the pool water at the exterior plaster surface.

This reaction does not involve "aggressive" pool water as some in the industry were maintaining, and in fact the presence of aggressive water inhibits nodule formation by solubilizing the calcium (derived primarily from calcium hydroxide, but also from chloride) into soluble calcium bicarbonate.

Since that time the majority of the pool industry has accepted this understanding of pool plaster calcium nodules. However, there have been a few cases where there was still dispute. In those cases, samples of calcium nodules were obtained and presented for forensic analysis at petrographic laboratories. We are here presenting copies of those analyses, showing that the lab findings support and substantiate the model we presented.

Journal of the Swimming Pool and Spa Industry
Volume 6, Number 2, pages 20–26

Case Study oB-00015

This pool failed primarily by being extensively soft spotted. However, there were also some areas where nodule formation occurred. In one such area, a core sample was removed to acquire the nodule and we found complete bond failure between the gunite substrate and the plaster layer (see Figure 0B-00015a). Hairline cracking occurred in the plaster, allowing water to penetrate between the plaster and the gunite, and a nodule formed along the exterior crack line. A three-inch core was removed from the plaster, which including the nodule (see Figure oB-00015b). This core was sent to Dr. Boyd Clark, at the time a Senior Materials Scientist and petrographer at the RJ Lee Group (RJLG). An additional sample of the plaster (with soft spotting only, no nodule) was sent to Laura Powers, at the time a petrographer and Principal Microscopist at Construction Technology Laboratories (CTL), the subsidiary lab of the Portland Cement Association (PCA) for a second opinion.

Dr. Clark noted the bond failure:

No concrete, from the pool substrate, was observed on the opposite side (not shown), indicative of plaster delamination from the shotcrete substrate. [RJLG p. 1]

Although referred to as "efflorescence" in the cement/concrete industry, he associated it with the pool term "nodule":

Relief is observed, in figure 2, decorating the length of the crack due to efflorescence, indicative of a calcium rich material. From our discussions, this phenomenon seems to be generally termed nodular growth in the swimming pool industry. [RJLG p. 2]

He also said the pool plaster surface was not etched from aggressive water:

The stereo optical images do not show evidence of "disrupted" paste indicative of an aggressive solution (surface attack due to acidic water conditions.) [RJLG p. 2]

He further notes that:

The chloride content in the paste (observed in the SEM) indicates that calcium chloride has been added to the plaster at a concentration greater than 2 Wt.%. [RJLG p. 3]

Note that two weight percent chloride-to-cement as dihydrate is a recognized high-end limit and that this limit was substantially exceeded in this pool. In fact, Dr. Clark's determination of acid soluble chloride in bulk plaster was 1.04 Wt.%, which converts to around 5% calcium chloride to cement as flake calcium chloride dihydrate [RJLG p. 3]. This substantial defect disrupted the paste, filled void spaces with Friedel's salt, and created stresses resulting in the lifting separation and craze cracking upon which the nodule formed:

This addition has resulted in extensive shrinkage cracking throughout the plaster paste. This cracking also appears to predate the formation of the affected region, highly porous paste follows the crack and calcium rich material has moved from the porous regions into the crack. [RJLG p. 3]

Powers, in her peer review report, concurred that the surface had not been etched by aggressive water:

The outer surface of the marble does not exhibit evidence of dissolution or etching. (CTL p. 2)

She calculated the calcium chloride addition in her sample at 1.06 Wt.% (CTL p. 4), comparable to the RJLG value, and also commented on the paste distress, including the attendant Friedel's salt deposits (CTL p. 2).

This calcium nodule perfectly illustrates the bond failure-related type of formation.

References:

Boyd Clark "RJ Lee Group Project Number MAH304128" 07-08-2003 (http://www.poolhelp.com/wp-content/uploads/2023/03/oB-00015_RJLG-MAH304128.pdf)

L. J. Powers "Evaluation of Surface Discoloration – Swimming Pool Plaster" Construction Technology Laboratories Project #154801, 08-14-2003 (http://www.poolhelp.com/wp-content/uploads/2023/03/oB-00015_CTL-154801.pdf)

Figure oB-00015a – Bond Failure and Cavity Behind Crack and Nodule

Figure oB-00015b – Front of Core with Crack and Nodule Following Crack

Case Study oB-00045

This pool failed by accumulating hundreds of small white calcium nodules on craze lines throughout the pool and spa plaster surface after about a year from plastering. The pool was drained, polished (wet sanded) and re-filled multiple times. Each time new nodules formed on the craze cracks.

A sample of the plaster with a nodule was cored (see Figure oB-00045) and sent to Laura Powers, at the time an Associate Principal Microscopist at Wiss, Janney, Elstner Associates.

In this case, Ms. Powers notes that there was no bond failure:

> *...the plaster is tightly adhered to the shotcrete. [p. 2].*

Ms. Powers noted that the plaster in this pool was also significantly over-accelerated with calcium chloride:

> *If the assumed proportions of cement and sand are 1 part to 1-1/2 parts, the percentage of calcium chloride dihydrate by mass of cement is 4.81 at a water-cement ratio of 0.5 and 4.47 percent at a water-cement ratio of 0.3. [p. 2]*

She associated the problem – both cracks and nodules – with the plastering workmanship:

> *The elongated white nodule appears to be an extrusion at the outside end of a low-angle (approximately 10 degrees) crack that intersects the exterior surface of the plaster (Figure 4)... The crack passes around crushed marble aggregate particles suggesting that it formed fairly early, probably during finishing operations. [p. 2]*
>
> *The general characteristics of the crack suggest that it was caused by finishing operations. [p. 3]*

This calcium nodule, then, perfectly illustrates the craze crack-related type of formation.

Reference:

L. J. Powers "Analysis of Nodules on Pool Plaster" WJE No. 2011.0741 (http://www.poolhelp.com/wp-content/uploads/2023/03/oB-00045_WJE-2011-0741.pdf)

Figure oB-00045 – Front of Core with Craze Nodules Following Cracks

Case Study oB-00058

This pool plaster failed in a way that was visually similar to the previous pool, but which actually had bond failure similar to the first (Figure oB-00058). The plaster had been re-peatedly re-polished (wet sanded), yet small calcium nodules on craze lines repeatedly reappeared.

Cores 2 and 4, referenced in the report, are depicted in Figure 1 [p. 6] and Figure 2 [p. 7] of the report. The nodules on the surfaces and the bond failure of both cores are shown.

When analyzed by Laura Powers (at this time back at CTL Group), the plaster was determined to not have an intact bond with the substrate, which in this case was a combination of gunite and left-over white plaster from the previous coating:

> *Remnants of an older white plaster (Figs. 5 and 6) and patches of gray concrete substrate are adhered to the bottom surface of Core 2 Floor and to the back surface of the Core 4 Wall. [p. 2]*

The actual nodule on Core 4 is associated with:

> *The delamination crack may be an artifact of troweling operations. Microcracks are*

common in the surface region of Core 4 Wall (Fig. 14). The cause of microcracking is not apparent. Possible causes include finishing and curing operations. [p. 3]

The chloride content in the bulk paste is listed at 0.768 weight percent [p. 3], which is 4.4% as calcium chloride dihydrate to cement. Again, this is more than double the commonly accepted maximum dose.

These calcium nodules, then, are of interest because visually they appear to be craze nodules, but when the pool plaster is cored, it was found that each nodule was on a small crack over a bond-failed area.

Reference:

L. J. Powers "Petrographic Examination of Swimming Pool Plaster Cores from Gilbert AZ" Construction Technology Laboratories Project #150389, 04-30-2020 (http://www.poolhelp.com/wp-content/uploads/2023/03/oB-00058_CTL-150389.pdf)

Figure oB-00058 – Core 4 with Nodule Following Crack and Bond Failure

Case Study oB-00060

As a point of interest, although this pool has yet to be replastered or core sampled, it was covered with small nodules similar to the previous two pools. Again, the plastering contractor assumed that the nodules were craze nodules, and he was under the impression that craze nodules were the result of pool water maintenance failures. However, when the pool was drained, it was found that each nodule was located on a small, almost invisible crack which led to a sub-surface reservoir of contained water. These, then, were bond-failure nodules and are being addressed by the contractor.

Figure oB-00060a – Pool Floor with Nodules Over Cracks and Sub-Surface Trapped Water

Figure oB-00060b – Close-up of Nodule on Microcrack With Leaking Water

Garrett – Nodules on Fiberglass

In March of 1993 a calcium nodule report was written based on an analysis by Timothy S. Folks of Riverside Cement Company on behalf of Greg Garrett, who was at the time with Shasta Pools in Phoenix. The calcium nodule is described as being on a "fiberglass resurfaced pool sample."

Photographs of this calcium nodule (see for example Figure A – Garrett) were used in Mr. Garrett's pool industry presentations to insinuate that calcium nodules must be precipitated from dissolved calcium in the pool water, rather than from the pool plaster and/or cementitious substrate, since there was no pool plaster involved (see, for example, a video of Mr. Garrett making such claims here: https://www.youtube.com/watch?v=4cY-oWNq-PKo).

However, the lab analysis, dating previous to Mr. Garrett's presentations, shows that the defective fiberglass coating (see Figure B – Garrett) was apparently compromised with a path, in this report referred to as a "pin hole," through which water could penetrate to the previous plaster and/or the gunite substrate behind the fiberglass coating:

> *There is some evidence of an actual pin hole through the surface to the plaster backing. [p. 1]*

It was also noted that there were other sites on the surface that could become similar nodules because of the poor quality of the fiberglass coating.

A second report was written in April of 1993, this time by Ed Holdsworth of SEM/TEC Laboratories. It is unknown whether this calcium nodule on a fiberglass surface was from the same swimming pool as that analyzed by Mr. Folks, or if it came from a different pool.

The findings are essentially the same: a calcium nodule on a fiberglass-coated plaster pool. Mr. Holdsworth found:

> *…the plaster had been covered with resin/fiberglass which should preclude the pool water reaching the plaster. [p. 1]*
>
> *Removal of the glass showed several sites where the dye had reached the plaster layer. One spot corresponded to the location of the nodule… [p. 1]*
>
> *…nodules can form on "glass" surfaces, but probably only when there exists a pathway from the surface down to the base plaster. [p. 2]*
>
> *The carbonate that forms the nodule derives from the plaster and not the water… [p. 2]*

Any statements made by Mr. Garrett insinuating that a calcium nodule on a fiberglass pool surface does not involve plaster should therefore have been known by Mr. Garrett to contradict his lab reports at the time he made them. This information, and the reports were of course not disclosed to the industry in the mid- to late-1990s when the photographs were first being used.

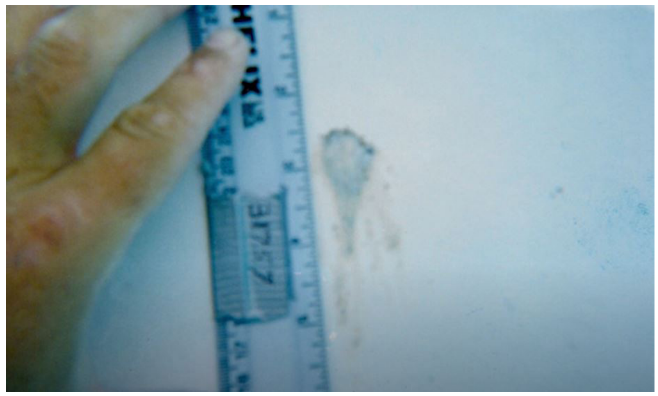

Figure A – Screenshot From Garrett Video

Figure B – Screenshot From Garrett Video

References:

Timothy S. Folks "Composition of Calcium Nodule" Riverside Cement Company RLA 93022701 (http://www.poolhelp.com/wp-content/uploads/2023/03/Riverside_93022701.pdf)

Ed Holdsworth "Examination of surface

and subsurface portions of wall nodule" SEM/TEC Laboratories 11666A (http://www.pool-help.com/wp-content/uploads/2023/03/Sem-tec_11666A.pdf)

Case Study oB-00042 [NAGC/NPC Coupon 3]

In 1999 the National Plasterers Council and the National Association of Gas Chlorinators collaborated on a project that involved creating 12" diameter pool plaster coupons for experimentation (see Figure oB-00042a). Two matching sets of sixteen coupons – one set in Tucson AZ and another in Livermore CA – were placed in water of four different chemical (alkalinity) qualities (40, 80, 120, and 160 ppm TA), exposing both the troweled and the molded sides of each plaster coupon to the four different waters. After a few months, small calcium nodules appeared on all four quartered slices/chunks of that one coupon (out of 16) at Tucson and the same matching coupon at Livermore in all four chemistries. The other 15 coupons did not form any nodules at all although they were submerged in the same four waters (see Figure oB-00042b). Interestingly, the calcium nodules only appeared on the troweled sides, not the molded sides (see Figure oB-00042c).

A sample from each location was sent to Dr. Boyd Clark of the RJ Lee Group for analysis, one from the Tucson batch and one from the Livermore batch. In the report, they are labelled "Que's Sample" and "Kim's Sample."

As with other plaster samples described in this paper, these plaster samples were overdosed with calcium chloride. In this case, the chloride in bulk sample value was as high as 10%. Note that this is much higher than one would likely ever see in a swimming pool, but it was possible because of the "mix a small batch in a bucket" atmosphere at the trade show in question.

The conclusions found on page four of the report include:

The nodule growth on the top surface of the coupons is calcium carbonate

Shrinkage cracking of the coupons and leaching of calcium from the paste was promoted by calcium chloride content, apparent from the distinctive map crack pattern developed in high (10 Wt. %) calcium chloride content standard plaster.

Figure oB-00042a – Forming the Coupons

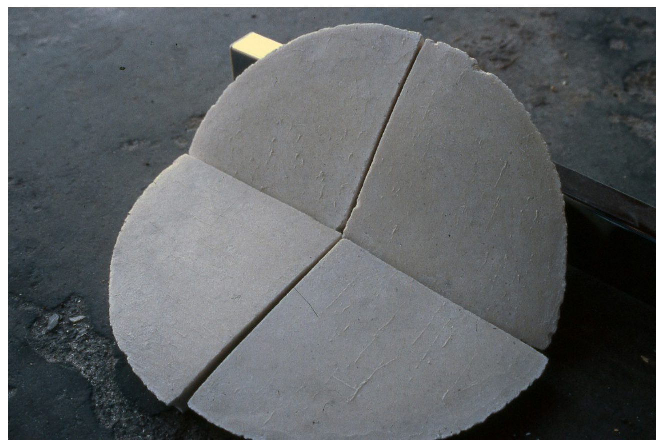

Figure oB-00042b – Nodules on Plaster Surface

Figure oB-00042c – Absence of Nodules on Molded "Backside" of Plaster Surface

Reference:

Boyd Clark "RJ Lee Group Project Number MAH011437" 03-19-2001 (http://www.poolhelp.com/wp-content/uploads/2023/03/oB-NPC-03_RJLG-MAH011437.pdf)

Conclusions

In every case of which we are aware, when pool plaster exhibiting efflorescence, or nodule growth is sent to a competent forensic petrography laboratory, the same conclusions are reached – that:

- the nodules are formed using material from the cement-based plaster
- the material is calcium ydroxide
- the hydroxide carbonates in reaction with alkalinity
- the material is leached from the cement paste by ionic movement, not by etching, or aggressive attack
- the leaching occurs through cracks, pinholes, or other defects in the surface
- nodules are often associated with over-acceleration of the paste using calcium chloride
- nodules that appear to be on craze cracks may actually be associated with bond failure, although draining or even coring may be required to find the cause
- both bond-failure and craze nodules are the result of a plaster failure and not a result of the quality of chemical maintenance of the pool water

About the Authors

J. Que Hales has been the manager of the Tucson branch office of Pool Chlor for the past 38 years. He is an active author, researcher, lecturer and publisher. He is the past president of the National Association of Gas Chlorinators, the Southern Arizona Chapter of the NSPI, and is the editor of the *Journal of the Swimming Pool and Spa Industry*.

Doug Latta is the president of the Latta Consulting Group based in Northridge, California and has been involved in the swimming pool industry for 48 years. He is an active consultant in the swimming pool industry. He was the president of Aqua Clear Pools, Inc which provided weekly service and repair as well as remodeling and new swimming pool construction in Southern California.

Kim Skinner is the co-owner of Pool Chlor. After working for Skinner Swim Pool Plastering in the Los Angeles area, he has been with Pool Chlor for over four decades. As a partner in onBalance, he is involved in research, education and publication in the areas of pool water chemistry as well as inter-reactions with interior pool surfaces.