onBalance

Case History
#oB–00005D

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The (homeowner name) pool on (homeowner address) in Tracy California was built by Aqua Pool and Spa, and plastered by Burkett Pool Plastering. According to the records of Aqua Pools and Spas, the pool was built and plastered in September of 1997 and turned over to a service company, Aqua Chlor, who started the service on 9/11/97. On that first day of service, the service company already documented that the pool surface was mottled.

Litigation – This pool was involved in legal activity between the owner of Aqua Pools and Spas, and Aqua Chlor. The pool has subsequently been replastered, and the litigation is now completed. To summarize, the litigation involved a suit instigated by Aqua Chlor (plaintiff) on multiple counts, including breach of contract, trademark infringement, and slander issues. The slander issue included the contention by the builder and/or plasterer that the service company (Aqua Chlor) was responsible for the substandard, poor appearance of the pool surfaces. Aqua Chlor's position was that the statements constituted slander, especially in light of their contention that the damage to the pools was actually a result of construction defects.

Two years into the lawsuit, the owner of Aqua Pools and Spas counter-sued, contending that they were due damages based upon the damage they felt Aqua Chlor caused to a list of specific pools.

Aqua Chlor engaged onBalance as expert witnesses in the actions, and Aqua Pools and Spas engaged Rob Burkett (the plastering subcontractor) and Greg Garrett as expert witnesses.

The builder was required as part of the litigation to provide a list of plaster components. That listing declared that the pool plaster was composed of cement, aggregate, water, calcium chloride, and Davis dye. It was also brought out in deposition that the plastering crew used wet tools or wet finishing techniques, as well as engaging in hard troweling.

The resolution of the lawsuit and counter-suit were as follows:

- The counter-suit was dismissed on summary judgement, meaning that the court dismissed the Aqua Pools and Spas allegations without hearing evidence, determining that the legal action was without merit.
- The original suit was decided by a jury in favor of the plaintiff (Aqua Chlor), and monetary damages were awarded. Additionally, legal fees were paid by the defendant (i.e., the owner of Aqua Pools and Spas and/or his insurance company).

It is important to note that neither the judge nor the jury actually made a ruling as to specifically who was responsible for the condition of the pool plaster surfaces. The verdict rendered was a general verdict on all causes of action. However, the general verdict was for the plaintiff (Aqua Chlor), and against Richard Townsend, owner of Aqua Pools and Spas. No defendant in this case was awarded any monetary judgement, legal fees or costs.

Analysis – In preparation for the lawsuit, and in order to diagnose the reason for the white discolorations, Greg Garrett hired Dr. Donald H. Campbell of Campbell Petrographic Services for evaluation of the pool, and submitted two core samples, D-1 (from an area of the pool that was uniformly whitened at the surface) and D-2 (from an area that contained both white and dark grey on the surface). Garrett also supplied Dr.

Campbell with photographs and with at least some description of the plastering methodology (i.e., that the surface was hard-troweled). Dr. Campbell makes the following conclusions:

- “the uniformly light-colored, hard-troweled top surface of Core D-1” exhibits conditions “possibly suggesting a relatively high water-cement ratio (w/c).”
- “The paste under the dark areas of Core D-2” suggest “a somewhat lower w/c”
- “the paste of this plaster appears to have variable water–cement ratios throughout each core. A variable bleeding tendency is suggested..."
- “The locally striped pool walls are puzzling. Perhaps the bleed water before or after finishing was more or less channeled on the wall...”
- “Microcracks are unusually numerous... One crack was partially filled with coarsely crystalline calcium hydroxide, suggesting autogenous healing, a process that is only effective in wet paste in the early stages of chemical solidification and hardening.”
- “Chemical analysis of additional cores of the pigmented morter might provide a precise value for the water and cement contents. Perhaps Bob O’Neill could help in the chemistry... hydrate water content... chloride values... differences in water permeability...”
- “In the body of the mortar... voids with ettringite.”
- Microcracks are extremely abundant in the paste of the plaster; cracks are approximately 2 to 3 microns wide and open... The walls... do not appear sharp but are ragged, suggesting plastic or near-plastic deformation.”

Dr. Campbell felt that he would be more likely able to pin down a diagnosis of the problem if two additional pieces of information were available to him, both means of determining the reason(s) for the porosity and microcracking he found associated with the discolorations. Those additional pieces were the amount of calcium chloride used in the plaster mix, and the amount of water used where the porosity was greatest. He therefore suggests in his written evaluation that a chemist such as Robert O’Neal be engaged to test chloride content and to make evaluations of apparent water:cement ratio. Unfortunately, Mr. Garrett failed to take Dr. Campbell up on his advice at that time.

(In a later instance, Mr. Robert O’Neill actually was engaged to analyse plaster from a different pool with almost identical symptoms, and associated with the same builder, plasterer, and service company – see case history oB-00005E. Although Mr. O’Neill reports having been provided “several reports, photographs, and documents” with his sample (presumably including Dr. Campbell’s report and recommendation?), he failed to analyze the plaster for water:cement ratio or to make any statements at all relative to the excess porosity that other researchers (i.e., onBalance, RJ Lee, and CTL) have tied directly to water-related finishing techniques and excess chloride. As far as chloride analysis was concerned, O’Neill found 2% calcium chloride dihydrate by weight to cement, which is the industry upper limit for white plaster. However, since calcium chloride is incompatible with the color admixture used in both pools, *none at all should have been used* – see references from Davis Color.)

Attachment A	Written report by onBalance
Attachment B	List of citations regarding colored plaster and wet finishing, and regarding colored plaster and calcium chloride
Attachment C	Photographs of pool captured from video
Attachment D	Photograph and caption from Davis-written article
Attachment E	Report from Dr. Campbell
Attachment F	Scanned image of the Davis Color Chart (note injunctions against wet finishing and

overworking, and the statement that the use of calcium chloride is the only known incompatibility, which causes blotching and discoloration)

Attachment G	Photograph of a Davis Powder Color tint package (note injunctions against wet finishing, overworking, and use of calcium chloride)
Attachment H	Photograph of a Davis Liquid Color tint package (note injunctions against wet finishing, overworking, and use of calcium chloride)

onBalance

Swimming Pool Chemistry and Plaster Consulting

Mr. Jerry Wallace
General Manager, Aqua Chlor

Re: onBalance Project oB-00005D

Mr. Wallace:

You engaged onBalance to diagnose the cause(s) for discolorations on the surface of the swimming pool plaster located at [homeowner's address] in Tracy California, at the residence of [homeowner's name]. You provided us with video footage, your chemical start-up and treatment records, discovery documents from the builder/plasterer, and Dr. Campbell's written analysis of pool core samples. The following are our observations and opinions of those documents.

Observations

Document Review
onBalance performed a review of start-up and weekly chemical maintenance records maintained for this pool. The chemical ranges were maintained within accepted industry standards, and the documentation does not show any incidences of aggressive water conditions.

Video Review
Video footage provided was studied. The video includes footage of the pool both filled with water and when drained.

The grey plaster pool exhibits an extreme discoloration pattern, very similar to those of the [oB-00005M] pool. As in that case, the patterns coincide with fan patterns from troweling, and also a significant amount of discolored, smeared plaster up onto the surface tile grout.

Discovery Document Review
Documents provided by the builder/plasterer show that, although the cement:aggregate ratio and cement:water ratios are reported to have been within normal ranges, the presence of both calcium chloride and Davis color admixtures violates Davis Color's specific, repeated directions and warnings. These warnings include the specific statement that "the only known incompatibility [with Davis Color admixture] is with calcium chloride set accelerator which causes blotching and discoloration." They also specifiy "don't wet finishing tools", and in an article written by a Davis employee they provide a picture of white surface discoloration caused by wet finishing a colored surface with a broom. Using calcium chloride and wet troweling colored plaster is prevelent in the pool plastering industry, even thopugh both practices are known to cause white discoloration – the specific cause of complaint in this pool.

Report Review

Quotes and comments:

- “the analytical data suggest "a relatively high water–cement ratio (w/c).” *Parts of the pool were constituted or finished with excess water.*
- "the paste of this plaster appears to have variable water–cement ratios throughout each core. A variable bleeding tendency is suggested..." *This can be caused by poor mixing, improper placement, wet finishing, etc. – but happens before the pool is filled!*
- "early craze cracking of the tread surfaces of the steps formed fissures through which CO_2–bearing pool water could enter a few hours after placement. One can reasonable assume carbonation beginning from time of placement and continuing during immersion." *i.e., the problems began before the pool was filled, and continued thereafter.*
- "Perhaps the bleed water before or after finishing was more or less channeled on the wall..." *Again, by contractor admission, these walls were wet-trowelled. Also, Dr. Campbell specifically notes artifacts of hydration that show the problem happened before the pool was filled.*
- "Microcracks are unusually numerous..." *A normal consequence of both chloride use and added water to the surface.*
- "One crack... [exhibited] a process that is only effective in wet paste in the early stages of chemical solidification and hardening." *In other words, while the pool was still firming up and being worked – again, before the pool was filled.*

Conclusions

The presence of calcium chloride is associated with discoloration in cementitious products. Industry-accepted documentation from the Portland Cement Association, the American Concrete Institute, and other authorities indicate that even low levels of calcium chloride (<2%) will cause discoloration. The accepted standard is to not exceed 2% dihydrate to the weight of the cement. However, there is also a provision in the standard that all admixtures must be compatible. Calcium chloride and color plaster admixtures are not compatible. The contractor has admitted to using both Davis Color and calcium chloride in this pool. Attached is a copy of Davis’ color chart, stating that there is a known incompatibility with calcium chloride. Also attached are copies of the Davis color powder and liquid packaging which includes the statement of incompatibility. It is our opinion that this breach constitutes a latent manufacturing defect in the pool directly attributable to a State-licensed contractor.

There are indications that the plaster surface was finished with wet tools, or that water was applied to the surface during finishing. This is a poor finishing practice which is prohibited by ACI and PCA. Davis Color also indicates on the attached color chart and on the packaging that water should not be used in finishing. The included picture from an article written by a Davis Color employee shows what can happen when a wet broom is applied to a concrete surface containing color admixture. The striped walls of the pool, along with chatter marks, is a direct analog in a pool application – water was applied to the finished surface and/or tools and then hard troweled into the surface. This produces both the “local striping” that Dr. Campbell found so curious, and also the apparent higher water:cement ratio in those areas.

There is a specific causal chain of events evidenced in this pool, which includes the use of incompatible admixtures, prohibited finishing practices, and an overall disregard for professional workmanship practices which, in this pool, led to the severe discoloration seen on the pool surface. In spite of statements by the plastering contractor and his expert witness, it is not permissible to violate manufacturers recommendations even if the contractor believes they do not apply.

The “discolored grout” claimed by the plastering contractor as evidence that the plaster was not at fault is actually discolored plaster which was pulled up over the grout by the plastering crew, and not cleaned off (see attached photograph oB-00005Eb).

The pool has not undergone an aggressive chemical attack. None of the accepted hallmarks of aggressive attack (such as surface cement paste dissolution and etching of the surface-exposed aggregate) are evident. This is consistent with the chemical history documentation provided onBalance and with the analysis undertaken by onBalance.

Many factors are usually associated with spot discolorations, including excess calcium chloride, wet finishing, and overworking the surface. All of these factors appear to have been contributory to the problems seen in this pool.

Sincerely,
Partner – onBalance Consulting

List of citations which clarify positions or statements:

Colored Plaster and Water

"Even though the same portland cement is used, a difference in color can result through a variation in the water–cement ratio. A cement paste having a low water–cement ratio will be darker than a cement having a high water–cement ratio. Any construction practice that tends to produce variations in the water cement ratios produce variations in color." (*Concrete Inspection Procedures*, Portland Cement Association, New York:John Wiley & Sons, Inc. 1975 p. 95)

"avoid any finishing operation when free water is present." (*Concrete Inspection Procedures*, Portland Cement Association, New York:John Wiley & Sons, Inc. 1975 p. 113)

"The following rules should be followed to avoid scaling. (1) Use concrete with an optimum air content. (2) Maintain proper water–cement ratio. (3) Thoroughly consolidate the concrete. (4) Don't add water at the job site. (5) Avoid starting the finishing operations too soon..." (*Concrete Inspection Procedures*, Portland Cement Association, New York:John Wiley & Sons, Inc. 1975 p. 113–114)

"One of the most common errors encountered in trying to correct poor workability is to add more water. Adding water upsets the water–cement ratio, reduces the strength of the hardened concrete, and can cause other serious problems. The water content of a plastic [i.e., unset] concrete mixture should be altered *only* if the water–cement ratio designed for this mix is maintained." (italics original) (*Concrete Inspection Procedures*, Portland Cement Association, New York:John Wiley & Sons, Inc. 1975 p.)

"...the quality of the paste is of primary consideration. This is controlled by the water–cement ratio... Where prolonged exposure to water is expected, a low water content paste must be provided to reduce permeability, absorption, and the effect of leaching." (*ACI Manual of Concrete Inspection*, American Concrete Institute, Detroit:ACI 1981 p. 113)

"Some of the constituents of the hardened paste are water–soluble, and the rate of leaching of those soluble constituents is greatly diminished with more dense paste. Hence, it is desirable that the paste be dense and have a low water–cement ratio when the concrete is to have prolonged contact with soft water or with water that contains chlorides, sulfates, acids, or other aggressive chemicals. The strength and density of the paste depend primarily on the water–cement ratio (see Figure 5–2) and on the extent to which the cement becomes hydrated. " (*ACI Manual of Concrete Inspection*, American Concrete Institute, Detroit:ACI 1981 p. 94)

"The use of additional water applied to the surface by dashing with a brush, sprinkling, or spraying during finishing or edging operations should not be permitted." (*ACI Manual of Concrete Inspection*, American Concrete Institute, Detroit:ACI 1981 p. 250)

"AT THE JOB SITE – Water should not be added to the mix, into pumps, onto the fresh surface, or onto finishing tools or brooms. This will cause surface to pale or discolor. (Davis Colors Brochure "Color Standards for the Concrete Industry" April 1996)

"Do not use calcium chloride set accelerators with concrete colors since discoloration can result." (Arizona Oxides, LLC., "Colors for Concrete" http://www.arizonaoxides.com/concolor.htm 11/08/01)

"Bear in mind, water/cement ratio needs to be consistent throughout the entire project. Once placing has begun, do not add more water as it will affect color. After placing and floating, no further finishing should be performed until bleed water has evaporated, after which final finishing can take place... Water should never be added to the surface as it will weaken and discolor it... Finishing techniques must be consistent. Differing finishing techniques will change the appearance of color."

(Butterfield Color “Technical Data Specification Guides” http://www.butterfieldcolor.com/links/technical.html 11/08/01)

“FINISHING: Over troweling should be avoided. No dusting of cement or sprinkling of water should be used when finishing colored concrete.” (Lambert Southwest – www.LambertSW.com)

“Do not add water to the concrete while placing or finishing, or overtrowel as this will cause discoloration.” “Do not add water to the surface during finishing operations. Added water may create a blotchy surface.” (Lambert Corporation - Lambco Color Product Description – Lambert Southwest – www.LambertSW.com)

“Excess water should be removed from broomed surface before contact is made with fresh cement. Inconsistencies in concrete mix, water cement ratio, batch to batch slump, job site conditions, finishing practices, and curing methods may produce variations in the color of the finished product. CAUTION: Variation of color can occur when the actual job-site materials and individual finishing methods are applied. Changes on the water to cement ratio or water added at the job site will affect the final color of the concrete.” (Decosup Intregal Colors - www.decosup.com)

“The crew should avoid adding water during finishing and avoid making too many troweling passes.” (“Controlling Integral Color Uniformity in Concrete” Concrete Producer, March 1999)

Colored Plaster and Calcium Chloride

“Calcium chloride and other accelerators should not be used indiscriminately, and they should never be used unless absolutely necessary.” (*ACI Manual of Concrete Inspection*, American Concrete Institute, Detroit:ACI 1981 p. 218)

“Calcium chloride set accelerator should not be used. Calcium chloride represents the only known incompatibility with this product. (Davis Colors Brochure “Color Standards for the Concrete Industry” 2001)

“MIX DESIGN – DON’TS – Don’t use calcium chloride or any admixture containing calcium chloride.” (L.M. Schofield Company “Chromix Admixtures for Color-Conditioned Concrete”)

“Colored concrete requires control of water and mixing procedures used. Excess water can cause the color to look pale and weak.” (Arizona Oxides, LLC., “Colors for Concrete” http://www.arizonaoxides.com/concolor.htm 11/08/01)

“Calcium chloride – admixture used to accelerate the hydration process, not for colored concrete. (The Stamp Store “Glossary of Industry Terms” http://www.thestampstore.com/glossary.htm 11/01/01)

“Absolutely nothing containing calcium chloride is permitted in the mix.” (Concrete Concepts of New Jersey “Specifications and General Data” http://www.concreteconcepts.com/cicspecs.html)

“Our integral colors are made from the finest blended pigments in the industry with color stability and pure color tone. Colors are sunfast, lime proof, weather resistant, and packaged to insure consistent color mixing. They are compatible with most admixtures except calcium chloride.” (Murray Supply Decorative Concrete “Decorative Concrete Supply, Inc. – Contractors Page” http://murrayconcrete.com/index2.html)

“Incompatibility (Materials to Avoid): Calcium Chloride” (Concrete Chemicals, Manufacturer of LiquiBlack “LiquiBlack Material Safety Sheet” http://www.liquiblack.com/materialssafety.htm 11/08/01)

“In hot weather the use of a set retarder should be considered. In cold weather when set accelerant is needed choose a non–chloride accelerant. Never use calcium chloride.” (Butterfield Color “Technical Data Specification Guides” http://www.butterfieldcolor.com/links/technical.html 11/08/01)

“No admixtures containing calcium chloride are permitted.” (Bomanate of New Jersey “Bomanate/Bomacron Specifications” http://www.patternconcrete.com/Bomaspec.html 11/08/01)

"The concrete mix must not contain any admixture or additive that contains calcium chloride." (Matcrete "Questions/Answers" http://www.matcrete.com/questions.htm 11/08/01)

"Chloride admixtures may produce mottling (to colored concrete surfaces...)." (Ramachandran, V.S. "Concrete Admixtures Handbook – Properties, Science and Technology" Noyes Publications, Park Ridge:New Jersey, p. 982)

"(Chloride) compatibility with other admixtures may also need trials and the manufacturer's recommendation should be followed." (Ramachandran, V.S. "Concrete Admixtures Handbook – Properties, Science and Technology" Noyes Publications, Park Ridge:New Jersey, p. 971

"Chemical admixtures should be checked for their influence on color by making test samples. To avoid mottled discoloration, calcium chloride should not be used in white or colored concrete." (Portland Cement Association, "White Cement Concrete and Colored Concrete Construction", Concrete Technology Today, November 1999 p. 2)

"One word of warning: Accelerators can contain calcium chloride, but Fritz-Pak's Ojeda warns décor contractors to stay away from the calcium chloride ones. They can cause corrosion problems if exposed to water, react negatively with integral colors, and promote efflorescence, a drawback to aesthetics, he says." ("Using Admixtures in Décor Work" in Concrete Décor, April/May 2002 p. 35)

"ADMIXTURES: Avoid the use of calcium chloride or other admixtures that will contribute to efflorescence. Do not use any admixtures that contain calcium chloride. Calcium Chloride will cause uneven color, discoloration, and salt deposits." "Avoid the use of calcium chloride accelerator as it will affect the uniformity of color." (Lambert Corporation - Lambco Color Product Description – Lambert Southwest – www.LambertSW.com)

"Do not use with concrete mixes containing calcium chloride. No admixtures containing calcium chloride shall be permitted." (Bomanite Corporation - www.bomanite.com)

"It's common practice to use calcium chloride to speed setting in cold weather. But you shouldn't add it to concrete that's getting integral color because chloride-based accelerators can discolor the slab or cause efflorescence. If you need to pour in cold weather, ask your supplier to use hot water or to increase the cement content of the mix. Other options include using a more expensive nonchloride accelerator or concrete containing fast-setting type III cement." (The Journal of Light Construction, "Decorative concrete: add color and texture to make concrete look like more expensive materials or to create unique effects." Jan, 2003, by David Frane)

"It's common practice to use calcium chloride to reduce setting time in cold weather, but don't add it to colored concrete because chloride-based accelerators can discolor the finished slab." ("Fancy Flatwork 2: more trade secrets for decorative concrete." Tools of the Trade, March-April, 2004, by David Frane)

"Calcium Chloride accelerator should not be used with any pigment. The use of Calcium Chloride may result in uneven coloring and spots (bleached-out areas)." (Decosup Intregal Colors - www.decosup.com)

"No calcium chloride is permitted in the mix. This product can cause discoloration in the form of light and dark areas in the finished product." (Symons Corporation - Info@symons.com, www.symons.com)

"Avoid admixtures that contain calcium chloride since it can cause discoloration." ("Controlling Integral Color Uniformity in Concrete" Concrete Producer, March 1999)

"The use of calcium chloride accelerators are not recommended in Color-Conditioned Concrete." (L. M. Scofield Company, a Strategic Partner of Master Builders, Inc.).

"Calcium chloride is not permitted in ready-mix concrete with integral color because it can create discoloration." (Symons Corporation - 200 E. Touhy Avenue, Des Plaines, IL 60018)

“With any color agents you should never use calcium chloride, because it can have an adverse effect, cause uneven drying and promote color streaking.” (Clark Branum, July/98, Greater Seattle Concrete)

“Do not use calcium chloride set accelerators with concrete colors since discoloration can result.” (Arizona Oxides L.L.C. 1999)

“Chemical admixtures should be evaluated for their effect on color control of the concrete as some chemical admixtures have agents that can cause surface discolorations. It is recommended to check with the admixture supplier regarding use. Do not use calcium chloride (CaCl2) as it can affect color and set consistency.” (“Guide for Specifying White and Colored Concrete” Portland Cement Association - Internet: www.portcement.org)

“Calcium Chlorides can cause *“mottleing”* or discolorations of pigments. It’s recommended to use non-chlorides if using pigments for colored concrete products.” (*Butler Enterprises* – Post Falls, ID)

“Chrome-crete should not be used with any admixture that contains calcium chloride as calcium chloride can cause non-uniform color. Do not use calcium chloride or calcium chloride-based products in colored concrete.” (Chrome-crete Integral Colors - Specialty Concrete Products, Inc.)

“Do not use calcium chloride-based admixtures when using QC ColorTech-E.” (QC ColorTech-E: Product Information Bulletin 22.102, Concrete Impressions LLP)

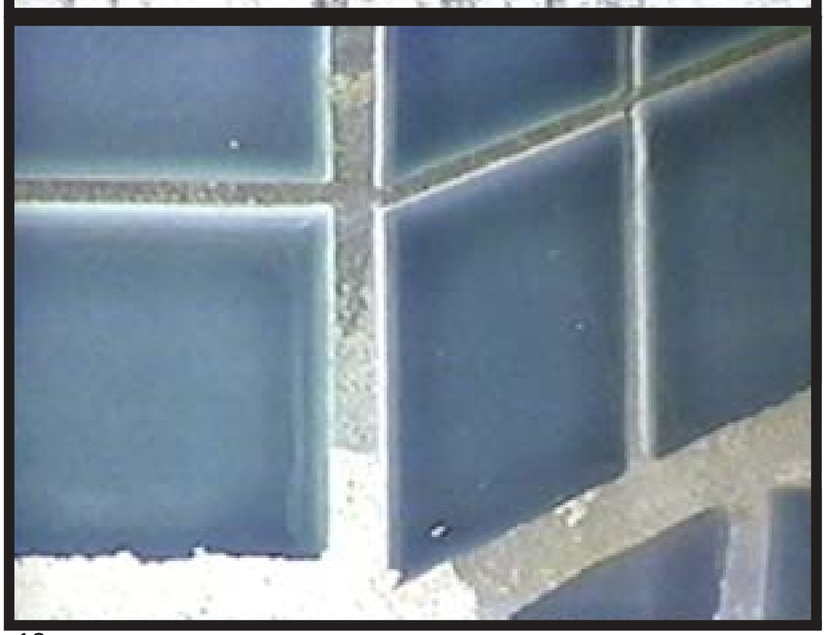
“Calcium Chloride has been frequently used as a concrete set accelerator because it is cheap and speeds up set times. However, major problems with Calcium Chloride have become troublesome to the industry. You can’t use it with colored concrete, because uneven coloration results.” (Non-Choride Accelerator Uses in Decorative Concrete – Fritz-Pak NCA)

“The concrete mix must not contain any admixture or additive that contains calcium chloride.” (Pavecrete Interactive Developers S.A.R.L.)

“Do not use calcium chloride or calcium chloride based products in colored concrete.” (The Construction Specifications Institute)

oB-00005Da – Sloppy cleanup – whitened plaster over grout below water level plus discolored wall

oB-00005Db – Sloppy cleanup – whitened plaster over grout below water level



oB-00005Dc – Sloppy cleanup – whitened plaster over grout below water level

oB-00005Dd – Multiple acid applications etch surface until aggregate shows

oB-00005De – Discoloration on steps

oB-00005Df – Walls showing “locally striped areas” (see Dr. Campbell’s report). Note right-handed troweler pattern – pulling trowel over plaster from lower left to upper right

oB-00005Dg – Horizontal water lines and bottom-to-top trowel pattern

oB-00005Dh – View of deep end walls

oB-00005Di – Wall view

oB-00005Dj – Discoloration by skimmer throat

oB-00005Dk – Discoloration

oB-00005Dl – Discoloration by rocks

oB-00005Dm – Wall discoloration

oB-00005Dn – Discoloration around fitting

oB-00005Do – Drip lines on wall

“The pale broom mark, which is permanent, shows the first broom stroke after the broom was wetted.” *Ensuring the Quality of Colored Concrete Finishes* – by Nick Paris [Davis Color] and Michael Chusid in The Construction Specifier, December 1998

Picture and Caption from Article Written by Davis Color Employee

CAMPBELL PETROGRAPHIC SERVICES, INC.

4001 Berg Road
Dodgeville, WI 53533-8508
Tel: (608) 623-2387
Fax: (608) 623-2594

03 January 2000

Re: Petrographic Examination
Delegeane Residence
Tracy, California

Mr. Greg Garrett
Director of Operations/Research
Mason Mart
2619 West McDowell Road
Phoenix, Arizona 85009

Mr. Garrett:

Two cores, labeled D-1 and D-2, respectively, were received in early December 1999, for microscopical examination relating to a generally discolored surfaces of the walls, love seat (Core D-1), walkways, and steps (Core D-2). Core D-1 is from an area showing a white finished surface. Core D-2 is from a love seat showing a strong mottling of white and dark gray. Epoxy resin had been placed on top of the coring locations prior to drilling the core to preserve any water-soluble materials in place. Photographs received with the cores show large areas of mottling on the pool wall, bowl, love seat, steps, and elsewhere. The original pool plaster surface was reported to have been hard troweled to a uniform dark gray.

Method of Sample Preparation

The cores were examined, as received, under a stereomicroscope at magnifications up to 50X. The tops of each of the cores were cut off at a depth of approximately 22 mm (0.9 inch) and multiple sections (sawcuts) were made on each top with the metallographic saw. Up to 4 sections were made per core, lapped, and examined. Selected sections, representing each of the two cores, were impregnated/encapsulated with epoxy resin, lapped with diamond paste, cleaned with a sonic device in isopropyl alcohol, studied with the stereomicroscope, and placed on a glass microscope slides with epoxy for thin sectioning. The thin sections extend up to 40 mm along the diameter of the cores. A polished, fluorescent-epoxy impregnated section was studied of Core D-1. Thus the total area of thin-section and polished surfaces is approximately 6200 mm^2.

The sections were reduced to a maximum thickness of approximately 15 to 30 microns and examined with a petrographic microscope at magnifications up to 500X in transmitted light to determine paste and aggregate mineralogy and microstructure. Percentages of calcium hydroxide (CH) and unhydrated portland cement clinker particles (UPC's) are estimated by volume of paste in areas of the thin sections which are approximately 15 microns thick. Optical characteristics were used to determine the depth of carbonation in thin sections. Procedures followed are given in ASTM C 856, "Petrographic Examination of Hardened Concrete."

Findings and Conclusions

In thin section, the uniformly light-colored, hard-trowled top surface of Core D-1 is intensely carbonated to an average depth of approximately 1.5 mm, contains relatively few unhydrated portland cement clinker particles (UPC's), possibly suggesting a relatively high water-cement ratio (w/c). The paste under the dark areas of Core D-2 contains less carbonation, more

UPC's, and a brown coloring agent tentatively identified as extremely finely ground iron oxide-hydroxide; a somewhat lower w/c is suggested.

Patches of pigment-rich paste were observed in both cores, the patches appearing to have a relative abundance of UPC's and becoming larger toward the base of the plaster. Distribution of the pigment, therefore, is not uniform, however, its relation to the discoloration is not clear.

Within the dimensions of the cores, the paste of this plaster appears to have variable water-cement ratios throughout each core. A variable bleeding tendency is suggested, and thus variable susceptibility to carbonation (high intensity of carbonation over the areas with relatively high w/c). Early craze cracking of the tread surfaces of the steps formed fissures through which CO_2-bearing pool water could enter a few hours after placement, the upper step showing the most cracking and being the last to be immersed. One can reasonably assume carbonation beginning from time of placement and continuing during immersion. Petrographic study of mottled areas of the bowl and wall might be helpful.

The locally striped pool walls are puzzling. Perhaps the bleed water during or after finishing was more or less channeled on the wall, leading to variations in w/c and carbonation rates.

Microracks are unusually numerous in the plaster of both cores, the thin cracks typically abuting aggregates and probably representing autogenous shrinkage of the abundant paste (30 to 35%). One crack in *Core D-2* was partially filled with coarsely crystalline CH, suggesting autogenous healing, a process that is only effective in wet paste in the early stages of chemical solidification and hardening.

Chemical analysis of additional cores of the pigmented morta[illegible] [illegible]ght provide a precise value for the water and cement contents. Perhaps, Bob O'Neill could help in the chemistry. However, the hydrate water content would probably be today's value, not the original content as placed, as would chloride values. Nevertheless, differences in water permeability might be suggested.

Attached are photomicrographs illustrating various microscopical observations. Additional details are given in the data form also attached. The samples will be retained for six (6) months, then discarded, unless I hear otherwise from you. Thank you for the opportunity to examine this material.

Best wishes,

Donald H. Campbell

Donald H. Campbell, Ph.D.
Project 2056

PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE, ASTM C 856

Campbell Petrographic Services
4001 Berg Road, Dodgeville, Wisconsin 53533

Project No.: 2056 **Date:** 21 December 1999

Client: Mason Mart **Reported Problem:** Discoloration

Structure: Plastered Swimming Pool Coating **Examined By:** D. H. Campbell

Location: Delegeane Residence, Tracy, California

Sample Description

Identifications: Cores D-1 (love seat,white top surface) and D-2 (top step, strongly mottled dark and light).

Dimensions: 56-mm diameter cores, with lengths of 31 and 52 mm, respectively, for cores D-1 and D-2. Each core with plastered mortar on substrate shotcrete.

Cross Section Descriptions

Core D-1--Cross sections generally show a plastered mortar (10 mm thick) firmly bonded to the substrate shotcrete. A thin coating of secondary calcite (approximately 6 microns thick) covers the top surface. Paste volume is approximately 30%. The plaster mortar in Core D-1 can be divided into three zones: Stale

0.5mm Zone 1 The hard-trowled paste in the upper 0.5 mm is relatively uniformly white in reflected light, clear to translucent in thin section, generally carbonated, and contains an comparatively high volume (10%)* of small irregular air voids with diameters ranging from submicron to 6 microns. The paste in this zone has a relative scarcity of unhydrated white portland cement clinker particles (*UPC's*), estimated at *2 to 3%**. Calcium hydroxide (CH) in this upper zone is largely absent due to carbonation.

Brown pigment-rich paste, forming lenses and pods, are common in Core D-1 throughout its thickness, except at the top surface; the pigment appears to have concentrated in small paste patches, each patch containing UPC's and hydration products, the patches ranging in size from a few tens of microns to 0.5 mm, becoming larger with depth in the plaster to the point at the base where the paste is pigmented in mm-size patches, some large enough to contain the marble aggregates.

0.5mm Zone 2 In the next 0.5 mm a zone of partial leaching occurs in which the CH and perhaps some of the calcium silicate hydrate (CSH) has been leached. Zone 2 locally extends upward to the top surface.

Zone 3 In the body of the mortar, largely unaltered, UPC's are seen to be roughly 3 to 5%, increasing to 5 to 8% at the base of the plaster, and calcium hydroxide comprises approximately 8 to 10% of the paste by volume, occuring as irregular fine to coarsely crystalline masses in the paste and as coarse blade-form crystals in the voids with ettringite. Sub-micron particles (pigment) were detected in the plaster paste, some areas containing more pigment than others. At the base of the plaster mortar, where the UPC's increase to 7 to 10%, the paste shows patchy coloration. In the UPC-rich areas the paste is definitely pigmented in patchy manner. Open microcracks are common in the paste in all zones, the cracks abuting aggregates more or less perpendicularly.

Zone 3 rests on a carbonated "primer coat?" of gray cement (UPC-rich) mortar, containing aggregate particles much like those in the shotcrete. The primer coat(?) overlies the bulk shotcrete which also exhibits a carbonated top surface. The relatively porous and poorly consolidated primer(?), and bulk shotcrete contain a ferrite-rich cement, but with relatively few remaining silicates in the latter (presumably from in-service hydration). ?? Scratch coat multi coat

Core D-2--Cross sections show plastered mortar (17 mm thick) firmly bonded to substrate shotcrete. The secondary calcite layer (like that described above) is only 2 microns thick and discontinuous. Scaled thinner, mottly

Zone 1--The paste at the top surface under the light-colored areas is translucent in thin section, intensely carbonated, and has a relative scarcity of unhydrated portland cement clinker particles (UPC's), estimated at 2 to 3%. Under the dark areas the paste is only slightly carbonated, *apparently leached of CH* (assuming it formed there), contains a relative abundance of UPC's (5 to 8%), and a dark brown cloudy coloration of the paste. The pigmenting material, scarce in the white-paste areas, appears to be within the *CSH* (outer product), occurring in discrete round to irregular submicron particles(?) with a very low index of refraction (possibly in the vicinity of 1.46), and isotropic, but larger particles are necessary to better define its characteristics. It may be iron ore (iron oxide-hydroxide). Concentrations of pigment-rich paste occur in Core C-2 paste but not as abundantly as in C-1.

Zone 2-- In the next 0.5 mm a variable zone of partial leaching occurs in which the CH and perhaps some of the calcium silicate hydrate (CSH) has been removed as described above, locally up to the top surface.

Zone 3--Microscopical description of the interior paste is virtually identical to that described for D-1, except the base of the plaster layer does not show discolored paste.

Bottom Surface: Irregular surface of shotcrete, showing no evidence of fracture through the shotcrete (broken aggregates and paste) in both cores.

Large Voids, Joints, and Macrocracks: Abundant, small, irregular voids occur in the substrate shotcrete of both samples, indicating lack of consolidation. The bottom surface of each core may have separated from the remaining shotcrete along one of these zones of high porosity.

Pre-disposed to delaminate

Reinforcement: None observed.

over abundance of voids - high w:c ??

Aggregates (A)

Coarse (C)--Shotcrete in both cores contains a pea-size, partially crushed gravel containing a wide variety of largely igneous and metamorphic rocks, including granite, gneiss, finely microcrystalline volcanic rocks, basalt, gneiss, metaquartzite, and others.

Fine (F)--Shotcrete: Sand containing ordinary quartz, feldspar, and fragments of the rocks mentioned above. Plastered mortar aggregate is crushed sand-size marble, with minor amounts of quartz, feldspar, and other rocks and minerals.

Gradation and Top Size: In shotcrete, evenly graded to top size of approximately 2.5 to 3.0 mm. In the topping, average size is 0.5 mm (35 mesh).

Shape and Distribution: In shotcrete, rounded to angular, equidimensional to prominently elongated coarse aggregate; angular, equidimensional to prominently elongated particles of fine aggregate; uniform distribution. In the plastered mortar, the marble aggregate is angular, equidimensional to elongated; uniformly distributed.

Paste 25 to 30% in the shotcrete: 30 to 35% in the plaster.

Color: Shotcrete--medium to light gray. Plastered mortar—dark gray.

Hardness: In the bodies of the shotcrete and plaster, the pastes are hard in Cores D-1 and D-2, being somewhat difficult to penetrate with the dental pick. However, the white top of D-1 is unusually soft.

Luster: At depth in both shotcrete and plastered mortar the lusters are vitreous (luster of broken porcelain). White areas on the top of D-1 are dull.

Depth of Carbonation: Carbonation depths on the Core D-1 surface averages 1.5 mm locally deeper, and on Core D-2 a depth of 0.5 mm, locally deeper under white areas.

Air Content: 4 to 6% in both shotcrete and 0.5 to 1.0% in the plaster. Not air entrained. The substrate shotcrete is quite absorptive to the lapping oil.

Paste-Aggregate Bond: Tight in both plaster and substrate shotcrete, indicated by numerous cross-fractured aggregates.

Calcium Hydroxide (CH)*: See above.

Unhydrated Portland Cement Clinker Particles (UPC'S)*: See above. Residual alite and belite crystals of both cores exhibit pronounced rims of inner-product CSH. Shotcrete shows a high degree of hydration.

Pozzolans*: None observed in the shotcrete or the plaster.

Secondary Deposits: Intergrown ettringite and coarsely crystalline CH commonly fill shotcrete and plaster voids as a porous assemblage of clusters of needle- and blade-shaped crystals.

Microcracking: Microcracks are extremely abundant in the paste of the plaster; cracks are approximately 2 to 3 microns wide and open. The cracks are mainly abuting aggregates, but a few pass through nearly the entire plaster, terminating within 0.2 mm of the base, one of which in Core D-2 passes around almost all aggregates, widens upward to 10 microns, and is filled with secondary coarsely cystalline CH and, near the top, secondary coarsely crystalline calcite. The walls of the latter crack do not appear sharp but are ragged, suggesting plastic or near-plastic deformation.

Estimated Effective Water-Cement Ratio: Shotcrete: 0.38 to 0.43(?). Plaster: 0.40 to 0.45.

Miscellaneous: The thin sections are oriented perpendicular to core tops and extend downward as far as 22 mm and up to 32 mm laterally.

*Percent by volume of paste.

P.O. Box 7842
Chandler, AZ
85246-7842

Dr. Don Campbell
Campbell Petrographic Services, Inc.
4001 Berg Rd.
Dodgeville, WI 53533-8508

Re: Chain of Custody
Delegeane plaster samples D-1 and D-2

Dear Dr. Campbell,

Could you please perform petrographic analysis on two samples of black pool plaster. The two samples were removed from the Delegeane residence in Tracy, CA on NOV 22, 1999.

The samples are identified as D-1 and D-2.

Upon completion of your analysis could you please sign this letter and return it with your report.

Sincerely,

Greg Garrett
President
Applied Material Technologies

Donald H. Campbell
Dr. Don Campbell

03 Jan 2000
Date

MIX-IN COLORS FOR CONCRETE

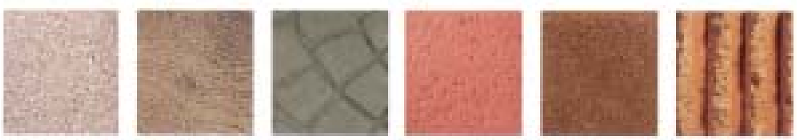
Uses: Davis Colors are used in cast-in-place, slab-on-grade, precast, tilt-up and ornamental concrete; shotcrete, mortar, concrete masonry units, pavers, retaining wall units and rooftile. They can also be used to color cast stone, plaster, stucco and other cement-based construction materials. Designed for mix-in use only; they should not be sprinkled or dusted onto the concrete surface.

Ingredients: Pure, concentrated pigments made of high-quality metal oxides recycled from iron or refined from the earth and specially processed for mixing into concrete. Davis Colors comply with ASTM C979 *Pigments for Integrally Colored Concrete*. They are lightfast, alkali-resistant, weather-resistant, durable and long-lasting like concrete. Davis Colors are available in a wide spectrum of standard colors and can be custom formulated to match design requirements. ✱ Unlike other Davis Colors, Supra-Instant® black #8084 is a specially treated carbon black. Carbon black is the highest in tint strength and the most economical, but can fade if concrete is not sealed against water penetration. Sealing and periodic re-sealing can minimize this effect.

Packaging: Concrete suppliers use our Mix-Ready® disintegrating bags or Chameleon™ bulk handling system. Mix-Ready® bags are tossed into the mix without opening or pouring. They disintegrate under mixing action, releasing pigments to disperse uniformly leaving no bags to litter the environment. The Chameleon™ is a computer-controlled automatic bulk-color dosing system.

Installation: Integrally colored concrete is installed the same way as high quality uncolored concrete. Choose a color on the inside of this color card and specify it by name, color number and dose rate. Create a custom color by varying the amount of color added to the mix. Confirm desired color with a fully-cured job-site test panel. Typical dose rates range from 1/2 to 7 lbs. per 94 lbs. of cement content and should never exceed 10% of cement content. Cement content includes portland cement, fly ash, silica fume, lime and other cementitious materials but does not include aggregate or sand. Davis Colors have been used successfully in a wide variety of mix designs and are compatible with commercially available admixtures. The only known incompatibility is with calcium chloride set accelerator which causes blotching and discoloration. ✱ Supra-Instant® black #8084 reduces or negates the effect of air-entraining admixtures.

Finishes: Paving and floors can be finished with pattern-stamped, broomed, troweled, exposed aggregate, salt-finished, sand-blasted, or many other visually appealing textures. Cast-in-place, precast and tilt-up structures can be textured with sand-blasting, bushhammering, grinding, polishing, special forms or form liners. The combinations and possibilities are endless. Here are just a few:



Exposed Aggregate	*Light Broom (wavy)*	*Stamped/ Patterned*	*Salt Finish*	*Sand Blasted*	*Form Liner*

Curing & Sealing: W-1000 Clear™ is a non-clouding, spray-on cure and sealer that meets or exceeds ASTM C309 standards and is specially formulated for colored concrete and exposed aggregate finishes. Other curing methods, such as water curing or plastic sheets cause discoloration. Color Seal™ is an optional, thin-film sealer that's tinted to match the shades on this Color Selector. When applied over colored concrete or the W-1000 Clear™, it provides a more uniform appearance.

Quality Tips: For best results; materials, curing, weather conditions and workmanship should be uniform throughout a project. Quality starts with the concrete mix; use a low water-content, high-performance mix design. When planning a project, budget for craftsmanship.

Consumer Advice: Contractors are independently owned and operated without affiliation to Davis Colors. Choose a licensed and qualified contractor who provides written information and example projects you can see before you buy. Check the yellow pages, ask your local ready mix or building material dealer or visit www.concreteconnection.com to find contractors who specialize in colored concrete.

Specify Davis: Choose a color from this color selector and specify it by name, color number and dose rate. Add color call-out to plan documents or specifications. For complete architectural and guide spec information, visit our web site, refer to our architectural binder, call, fax or write. Our guide specifications can be found in SweetSource®, Spec-Data®, ARCAT/Spec-Disk® or at www.daviscolors.com/tech.

For samples or additional information contact:

Mixing Guide:

Use the same pigment-to-cement ratio, type and brand of cement and aggregates throughout project. Changes in cement and aggregate color affect final color.

Keep slump less than 5" (12.5 cm) and water content consistent. High water content causes concrete to appear pale or "faded". If higher slump is required, use a water reducing admixture instead of added water.

Calcium Chloride set-accelerator causes discoloration. Do not use with color.

Specify air content of 5% to 7% for improved workability and long term durability in freeze/thaw climates.

Schedule loads for consistent mix times. Deliver and discharge in less than 1-1/2 hours. Clean mixer thoroughly between color change-overs.

Confirm color number and weight in Mix-Ready® bag (or combination of bags) is the same required by mix design.

Wet mixer with 1/2 to 2/3 total batch water. Toss in Mix-Ready® bags and mix at charging speed for at least one minute. Add cement, aggregate and remaining batch water. Continue mixing at charging speed for at least 5 minutes (7 minutes for pea-gravel mixes).

Notice: In mixes with small aggregate or batches with short mixing duration, Mix-Ready® bags may not completely disintegrate. In sand-blasted or exposed aggregate finishes, use small bag sizes (15 lbs. maximum) or open bag and pour color normally.

The Chameleon™ is a computer-controlled color dosing system for Ready Mix operators exclusively from Davis. It improves color accuracy and availability. Chameleon™ dose rates differ from the rates on front of this card. For more information, go to www.daviscolors.com/chameleon.

Contractor's Guide:

Prepare a well-drained subgrade. Add a 2 to 3 inch (50 to 75 mm) layer of sand, gravel or crushed stone. Uniformly compact the subgrade and moisten evenly, leaving no puddles, standing water, ice, frost, or muddy areas.

If vapor barrier is used, overlap sheets and tape over holes in barrier. Place a 3" (75mm) layer of granular self-draining compactible fill over the barrier to minimize shrinkage cracking.

Position forms for uniform slab thickness. Follow American Concrete Institute standards for reinforcement and joint placement to control cracking.

Allow ample time and manpower for placement and finish work. Finish evenly and with care.

Begin troweling after bleed water evaporates. Late or hard troweling and edging causes "burns" or dark spots.

Water added at job-site to mixer or pumps will cause color to pale. Keep additions to a minimum and consistent among loads. Don't wet finishing tools or brooms or sprinkle water on the surface.

Do not sprinkle pigment or cement onto the surface.

Rotary, dry-broom, pattern stamped or rough finishes usually cure more even-colored than smooth-troweled finishes.

Uneven curing=uneven drying=uneven color. Cure colored concrete with Davis W-1000 Clear™ cure and seal. (Info at: www.daviscolors.com/literature/pdf/W-1000.pdf)

Do not use plastic sheets, water curing or curing products which discolor. Wood and other objects left on curing concrete cause discoloration.

Efflorescence is a white powdery substance that appears on concrete surfaces. A result of water evaporation, it is more noticeable on colored surfaces making them look faded or lighter in color when not cleaned off. Proper curing and protection against water penetration reduces tendency for efflorescence to occur. Remove with detergent or mild-acid cleaners formulated to remove efflorescence. Follow cleaner instructions and test in a small area to make sure cleaner will not etch or discolor the surface. Wear rubber gloves and eye protection.

DAVIS COLORS

Tel: 800-356-4848
Fax: 323-269-1053
www.daviscolors.com

PRODUCT

Davis Colors™ are color "Admixtures" made of metal or mineral oxides either recycled from iron or refined from the earth that are lightfast, limeproof and permanent. They transform concrete into the stuff dreams are made of.

The Davis Colors™ card shows a spectrum of concrete colors. Custom color shades are made by varying the amount of color added to the mix. Mix-Ready™ colors are designed for mix-in use only, **not** "dust-on" use.

Every batch of Davis Colors is tested to verify it exceeds industry requirements for consistency. Color of concrete may differ from color card or samples and is influenced by the base-color of cement, mix water content, finishing methods and curing conditions.

Please read the Davis Colors™ Card, How-To Brochure or contact Davis Colors for tips on using this product.

PACKAGE

Mix-Ready™ bags are made of special paper which rapidly get soggy and disintegrate under mixing action releasing color deep in the mixer to disperse uniformly. Color handling is clean and environmental waste minimized.

CONTENTS

Iron Oxide (C.A.S. 1309-37-1 or 1317-61-9 or 51274-00-1 or combination), Silicon Dioxide-Amorphous (C.A.S. 7631-86-9)

STORAGE

Keep dry in a cool place, away from sources of heat or open flame.

HAZARDS

Contact a Doctor if accidentally ingested. This product is non-hazardous and non-toxic. Protect against inhalation, wear eye protection and avoid contact with skin or clothing. Clean-up with soap and water. Refer to MSDS for complete handling information.

HANDLING

Keep unused product in closed container. Protect against spillage and accidental contact—product can stain and create quite a mess.

DISPOSAL

Recycle in process whenever possible. Verify current regulatory status with state waste agency or the EPA before disposing in authorized landfill. Product passes EPA 1990 TCLP criteria (40 CFR part 261-329/90). Non-RCRA waste.

DIRECTIONS

- Select a color by number and mix rate from the color card.
- Confirm the color number and weight in this bag (or combination of bags) is the same required by the mix.
- Use the lowest number of bags required for the batch. Mix limit for this bag = 1 per cubic yard (meter).
- Wet mixer drum with approximately 1/2 to 2/3 total batch water. Toss in Mix-Ready™ bags and mix at charging speed for at least one minute.
- Add cement and aggregate and remaining batch water. Continue mixing at charging speed for at least 5 minutes (7 minutes for pea gravel mixes).

MIXING TIPS

- Keep slump less than 5" (12.5 cm) and water content consistent among batches.
- Do not use with Calcium Chloride set-accelerator.
- Schedule loads for consistent mix times. Clean mixer thoroughly to prevent color carry-over.

JOBSITE TIPS

- Grade, compact and moisten subgrade thoroughly and evenly.
- Allow **extra** time for placement and finish work, finish evenly and with care.
- Do not over-trowel. Rotary, dry-broom or rough finishes usually cure more even-colored than smooth troweled finishes. Do not wet broom.
- Water added at job-site to mixer or pump will cause color to "pale"—keep additions to a bare minimum and consistent among loads.

CURING TIPS

- Cure colored concrete with Davis W-1000 Clear Cure & Seal or Color Seal II in a matching color.
- Do not use plastic sheets, water-curing or other curing products which can discolor. Wood contact can stain fresh concrete.

LIMITATION

Package and contents have not been tested for compatibility with every admixture or in all mix designs. Confirm compatibility with the concrete—mix and check a test pour before finalizing mix design. Field check mix characteristics throughout pour(s).

DAVIS COLORS

Made in U.S.A. by Davis Colors
Los Angeles, CA 90023 • (323) 269-7311
Beltsville, MD 20705 • (301) 210-3400


Hydrotint
LIQUID COLOR FOR CONCRETE, MORTAR & PLASTER
CO-MO-BLAK® / HYDROJET
D886
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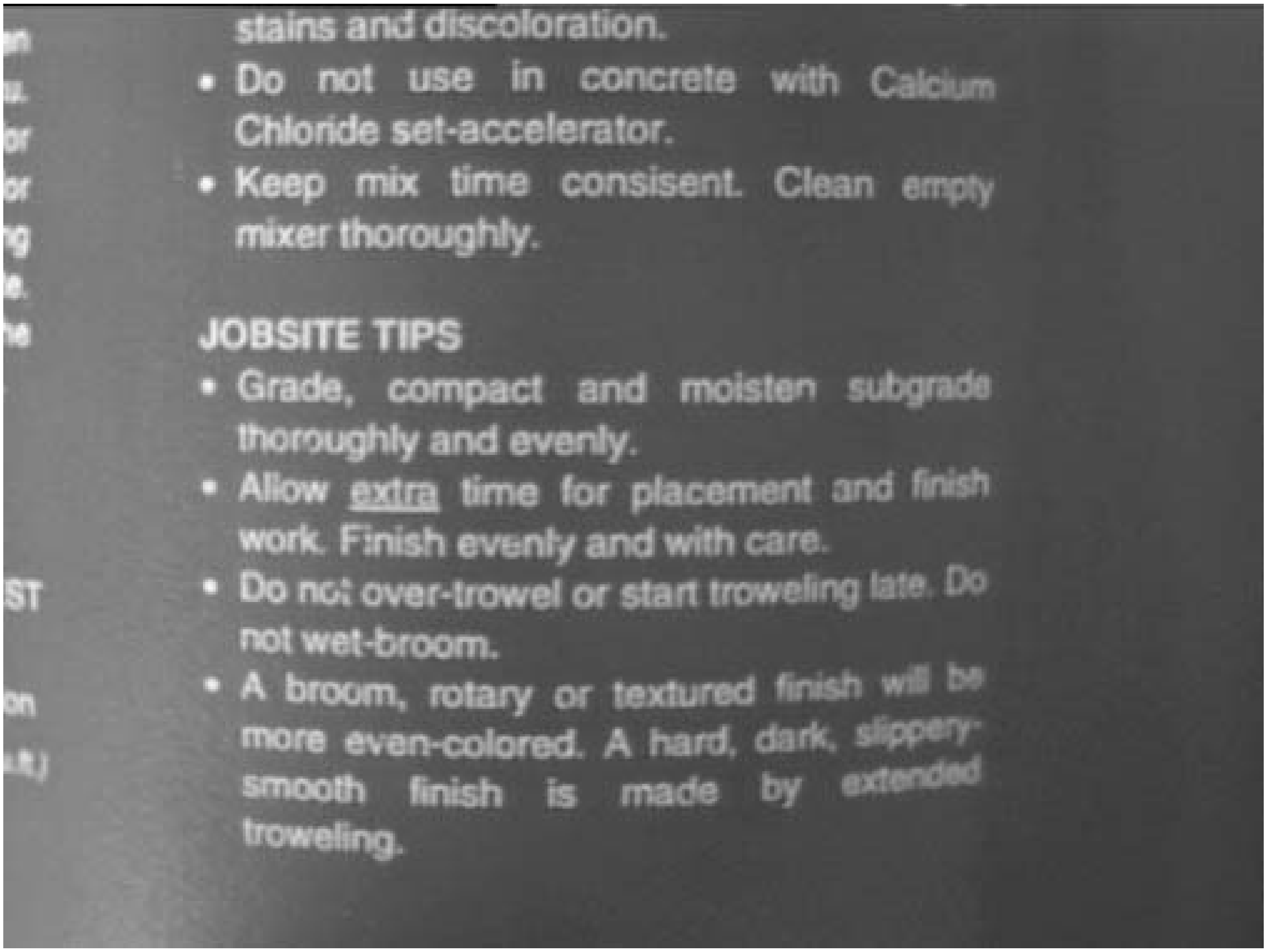
MADE BY DAVIS COLORS
LOS ANGELES, CA • BELTSVILLE, MD
SHAKE OR STIR BEFORE USE • PROTECT FROM FREEZING
REPLACES TAMMS HYDRO COLORS



stains and discoloration.

- Do not use in concrete with Calcium Chloride set-accelerator.
- Keep mix time consisent. Clean empty mixer thoroughly.

JOBSITE TIPS

- Grade, compact and moisten subgrade thoroughly and evenly.
- Allow <u>extra</u> time for placement and finish work. Finish evenly and with care.
- Do not over-trowel or start troweling late. Do not wet-broom.
- A broom, rotary or textured finish will be more even-colored. A hard, dark, slippery-smooth finish is made by extended troweling.