



NATIONAL PLASTERERS COUNCIL

TECHNICAL MANUAL

Guidelines, Methods & Procedures, and Technical Information

Based on U.S. Pool Plastering Common Trade
Practices for Utilization throughout the Swimming Pool Industry



TENTH EDITION

NATIONAL PLASTERERS COUNCIL

TECHNICAL MANUAL

TENTH EDITION

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- This document is referenced, referred to, and/or recognized by the following institutions and publications: Association of Pool and Spa Professionals; American Shotcrete Association; Portland Cement Association – Portland Cement Plaster/Stucco Manual EB0 49; American Concrete Institute – Guide to Portland Cement-Based Plaster 524R-16; American National Standards Institute; and International Code Council – American National Standard for the Plastering of Swimming Pools and Spas ANSI/APSP/ICC/NPC-12.

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FOREWARD

The NPC's Technical Manual contains guidelines, recommendations, and useful information based on common trade practices utilized throughout the U.S. pool plastering trade. Such practices have demonstrated a proven history of success. Alternative cementitious materials and finishes, which have entered the market in recent years, are presented on a limited basis. Proprietary materials and finishes are not within the scope of the document.

This document is intended as a guide to be used by swimming pool plasterers, pool builders, pool service companies, pool owners, architects, engineers, health departments, homeowner's associations, insurance agencies, and local, county, city, state, federal, or other governing regulatory bodies.

The intent of this document is to:

- Unify the swimming pool plastering trade in the utilization of proper materials, application, and common trade practice for swimming pool cementitious interior finish coatings.
- Promote realistic expectations of swimming pool cementitious surface coatings.
- Educate the swimming pool industry on the serviceability and expected longevity of cementitious interior finish coatings, based on maintaining proper service and water chemistry parameters.
- Teach methods of identification and remediation of swimming pool cementitious interior finish defects, failures, or deterioration.

The NPC promotes the belief that swimming pool plasterers should strive to deliver a quality product and service to the consumer. Many swimming pool plastering companies go well beyond the minimum guidelines and recommendations as set forth herein, as part of their business practices, and the NPC encourages them to do so.

It should be recognized and understood that:

Significant variations in materials and methodologies may be necessary in certain regions of the United States. Factors such as; unavailability of certain raw materials (sand, aggregate, cement, water), weather conditions, or placement conditions may compel the applicator to alter the guidelines herein.

The guidelines herein can be used as minimum levels of performance, workmanship, and materials.

Variations in the materials and/or workmanship requirements from those set forth herein may be established by contract between a plaster contractor and another party, or by statutory or contractual requirements established by federal, state, or local agencies, which have priority over this document. However, careful consideration should be given to the rationale for any variance or stipulation that conflicts with the current-accepted common trade practice of swimming pool plastering. Such variances should be negotiated and resolved as part of the contractual agreement.

PREFACE

Cementitious interior finish coatings for swimming pools consist of a mixture of hydraulic cement (typically white cement), sand (typically limestone, dolomite, quartz, or other silicate-based sand), or larger aggregate (typically small pebbles, crushed aggregate, quartz, or glass beads), special additives (modifiers for workability, durability, or set control), with or without pigments and other decorative enhancements, and water. Upon mixing cement with water, the cement particles react to form an interlocking network of chemical compounds, which ultimately becomes a rigid stone-like material. The final hardened material creates a very durable finish coating.

Uniqueness of the Swimming Pool Plastering Trade

The term “common trade practice” herein refers to common methods, processes, and materials utilized throughout the United States Swimming Pool Plastering Trade that are proven over the years to produce good results.

Plastering trade practices, methodologies, applications, materials, and mix designs, differ from that of concrete trade practices, methodologies, applications, materials, and mix designs. Therefore, trade-specific references, practices, methodologies, literature, or test results that pertain to other cement and concrete trades, or that do not pertain specifically to the swimming pool plastering trade, should never be compared, cross-referenced, or cross-utilized with each other, without first verifying that explicit compatibility and relevancy exists between the trades in a specific regard.

Hand-Crafted Finish

Variations across the finished surface are expected with hand-crafted products. Minor fluctuations in thickness, levelness, texture, and coloration are inherent (unavoidable) characteristics of the process. Benefits to the hard-trowel plaster finish include increased density and smoothness of the surface, which in turn increases durability. Benefits of the exposed-aggregate or polished finishes include aesthetic appeal, concealing minor imperfections, and further increasing durability. (See Section 3.0)

Watertightness

Cementitious surface coatings are actually semi-permeable membranes, and as such, some amount of moisture slowly permeates through the material. Swimming pool interior finishes are not typically designed or considered to be ‘waterproof’, but they are designed and considered to be ‘watertight’. While moisture or water vapor passes through the coating, free water (as a liquid) should not. (See Section 3.2)

Supplemental (Retemper) Water

Supplemental (retemper) water is often added during mixing to offset mix water loss due to evaporation, substrate absorption, and/or jobsite conditions. Supplemental (retemper) water ensures the plasterer’s ability to pump, place, spread, and properly finish the cementitious coating material, and facilitates proper hydration of the material. (See Section 6.1)

RECOMMENDED DELEGATION OF RESPONSIBILITY

Swimming Pool Plastering Contractor

It should be the responsibility of this party to perform in a manner that meets or exceeds the existing minimum standards for workmanship and materials that apply for a given project. Furthermore, this party should comply with any additional standard of compliance or stipulation that this party has agreed to in the contract. If this party is performing any function of the "Swimming Pool Service Contractor", such as start-up or ongoing pool maintenance, then this party should be responsible for those applicable portions as well. This party should provide plaster care start-up instructions unless the Swimming Pool Builder/General Contractor or Swimming Pool Service Contractor has this responsibility.

Swimming Pool Builder/General Contractor

It should be the responsibility of this party to ensure that the Owner/Operator/Agent or entity responsible for maintaining water chemistry and ongoing service of the pool finish can operate the equipment and understands the chemical and service needs of the pool. In the event this party elects to place this burden onto another entity, it should be that elected entity that is responsible to ensure that the Owner/Operator/Agent or entity responsible can operate the equipment and understands the chemical and service needs of the pool. If this party is performing the function of the "Swimming Pool Service Company" then that section should also be applicable.

Swimming Pool Consultant

It should be the responsibility of this party to ensure that the Owner/Operator/Agent or entity responsible for maintaining water chemistry and ongoing service of the pool finish has been given instructions for the care and maintenance of the interior finish coating and knows how to service, operate, and/or maintain the swimming pool. In the event this entity elects to place this burden onto a third party, then the third party should fulfill the responsibility of the Consultant. If the Swimming Pool Consultant or the elected party is performing the function of the "Swimming Pool Service Company", then that section should also be applicable.

Swimming Pool Service Company

It should be the responsibility of this party to ensure that the swimming pool is properly operated and serviced, and acceptable water chemistry ranges are maintained. In the event this party is contracted for, or only offers, a limited portion of the ongoing service necessary to ensure that the water chemistry remains within acceptable ranges, then this party should inform the Owner/Operator/Agent of such limitations. This party should also inform the Owner/Operator/Agent of any ongoing service or maintenance that remains to be performed, which is not included by contract or is beyond the service and maintenance offered. Preferably, this should be done in writing to avoid future conflict. Furthermore, this party should ensure that the Owner/Operator/Agent is informed of any necessary additional or ongoing water treatments, service, or other maintenance that should be done, which are not being performed by this party.

Swimming Pool Owner/Agent/Operator

It should be the responsibility of this party to ensure that the swimming pool is properly operated and serviced, and the proper water chemistry is maintained within acceptable ranges. If this party contracts a third party to service the swimming pool, then the Owner/Operator/Agent should perform the due diligence necessary to ensure that the contracted entity is performing the proper maintenance and water testing with the frequency of visitations necessary to maintain the water within acceptable ranges.

Architect/Engineer

It should be the responsibility of this party to stipulate, write, or otherwise require the Swimming Pool Plastering Contractor to use methods, measures, procedures, or materials that are common to the swimming pool plastering trade and are historically demonstrated to produce adequate results. Changes to, or deviation away from, methods, measures, procedures, or materials that are common and accepted trade practice can result in a defective coating material, or an inferior quality coating finish. (See PREFACE)

Manufacturer/Supplier

It should be the responsibility of this party to ensure that their products and materials meet or exceed existing minimum standards.¹ This party should strive to maintain quality and consistency of the materials. This party may elect to comply with certain additional requirements or stipulations imposed by certain city, state, or government agencies in order to be considered for certain work. If this party agrees to supply a product that meets the new criteria, then this material should maintain quality and consistency in terms of the required physical and chemical stipulations, throughout that work.^{4 5 6} This party should maintain current and accurate information on their products and materials, including: Safety Data Sheets, Chemical and Physical Data Product Sheets, Recommended Usage Instructions, and general product information.

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1.0 EVALUATING WORKMANSHIP AND MATERIALS (APPLICABLE STANDARDS AND SPECIFICATIONS)

The specified details of the workmanship and materials of the plaster application should be in accordance with project drawings and specifications, and with the Federal, State, and Local Standards and Specifications that apply. The workmanship and materials of the pool builder, preparation crews, and plastering contractor should meet or exceed the applicable minimum Standards and Specifications.

The ANSI/APSP (PHTA)/ICC/NPC-12 American National Standard for the Plastering of Swimming Pools, the ACI-524R Guide to Portland Cement Plastering, and the NPC Technical Manual, in conjunction with prevailing Codes, Standards, and Specifications, are the preferred sources for cementitious interior finishes for swimming pools. These publications are useful aids for project specifiers, architects, and engineers, to assist in contractual or specification writing. These publications are also useful for inspectors, laboratory technicians, and others who desire guidance in common trade practice, inspections, and failures analysis. The NPC Technical Manual (10th Edition) is especially useful in understanding the unique differences between swimming pool plastering and traditional interior plastering or exterior plastering (stucco).

1.1 Inspections

Work inspected after the plastering application may include the evaluation of workmanship and materials or determining the cause of any failure. Evaluating the shotcrete or substrate surface preparation may be done prior to plastering as a means of preventing issues before they occur.

In addition to the source documents referenced in Section 1.0, the following publications can be referred to when testing or analyzing swimming pool plaster surface coatings for the purpose of quality inspection or failures analysis:

- Proper Finishing and Curing of a Plaster - ASTM C 926 - Appendix.
- Thickness of Coats, Both Individual and Combined - ASTM C 926 - Tables 1, 3, and 4.
- Proper Bond Between Base Coats and Successive Coats - ASTM C 856, ASTM C 1324, ASTM C 932, ASTM C 926 –Section 5.
- Uniformity in the Surface Texture and Color of the Cementitious Surface Finish - ASTM C 926 - Appendix.

1.2 Mediation

When involved parties are in disagreement over the acceptability of the finish, or the cause and remedy of a specific issue relating to the finish, it is recommended that the involved parties agree upon mediation for resolution. The mediator should be an unbiased independent third party and an expert of the swimming pool plastering trade. Mediation can be implemented as a courtesy inspection (non-binding) whereby the involved parties, in principle, agree to abide by the conclusions of the mediator. Or, mediation can be implemented as a contractual inspection (binding) whereby the involved parties agree, in writing, to adhere to the conclusions and decisions of the mediator. Typically, the losing party pays for the costs of the mediator’s time and expenses.

The selected mediator should have a minimum of 5 years of experience in the pool industry, and sufficient knowledge of the swimming pool plastering trade and placement environment to reach accurate conclusions based on observation, inspection, and testing.

Mediation should only be undertaken by the following parties:

- An expert of the swimming pool plastering trade or an expert of the swimming pool

- construction trade,
- A knowledgeable representative of the Registrar of Contractors,
- A knowledgeable representative of a Local, State, or Federal agency,
- A knowledgeable consultant or representative of a construction materials failure analysis laboratory.

(See Section 2.0 Viewing Conditions and Section 9.2 Inspections)

2.0 VIEWING CONDITIONS

The proper viewing condition for an inspection should be limited to pools and spas with clean water and clean surface, free of algae, dirt, and debris. This allows for a proper inspection of the interior finish and would be representative of the anticipated 'look' of the finish during its service life. The pool should be full of water. Ideally, the water should be in a balanced condition.

The proper time of day for a visual inspection of a finish is during the day when the sun is not directly overhead, or on a cloudy day. This is considered the optimal time for observation, allowing for a true and representative observation of the interior finish. Inspections or observations should not be made at night. Observations aided by swimming pool lights or other sources of light that shine across the surface, instead of upon the surface, amplify imperfections and are not considered a true representation of the appearance of the surface. Certain oblique angles of light grossly exaggerate inherent fluctuations and/or the waviness across the surface finish.

Inspections or observations made when sunlight is directly overhead, or on windy days, or in poor lighting conditions are not considered a true representation of the appearance of the surface. Such conditions that hinder the ability of the observer, tend to minimize aesthetic features and imperfections. (See Section 1.2 Arbitration and Section 9.2 Inspections)

The trade considers an area to be an 'obvious deviation' when; upon viewing a 20' x 20' section of the coating surface, the inspector (viewer) can find the area of concern within 15 seconds of approaching the swimming pool, without having prior knowledge of the exact location. Proper viewing conditions must be present as described in this chapter.

3.0 AESTHETICS AND TOLERANCES

3.1 General

Currently, no standards, methodologies, or test methods have been established that measure, grade, or determine absolute tolerances for acceptability of levelness, smoothness, texture, or coloration of interior finishes. All cementitious interior finishes will have some degree of normal fluctuation in each of the above characteristics due to the nature of the hand-crafted plastering application, the inherent variation of raw materials, and the ongoing effects of the hydration and curing processes. Simply put, the tolerance levels for interior finishes are subjective. There are no absolute test methods or standards that will accurately quantify or qualify tolerability.

Swimming pool interior finish coatings must be leveled, smoothed, and finished by "free hand".^{3,18} In other words, the cementitious surface coating is not cast-in-place, molded, screeded, or guided by template, as with most cementitious applications. Therefore, all swimming pool interior finishes will have some inherent fluctuation in smoothness, levelness, texture, and coloration across the finished surface.² (See Section 3.0)

3.2 Watertightness

The surface of the cementitious coating should be placed and finished in such a way as to maximize its ability to hold water. There should be no open cracks (See Section 9.3), holes, or unsealed transition areas that allow water to pass freely through the interior finish. The plaster application should be finished in such a manner that provides a tight seal around plumbing fixtures, lighting fixtures, tile, rocks, or other transition materials.¹⁰

Though all cementitious surface coatings develop some shrinkage cracking or check cracking, these cracks typically reseal themselves within a few days after plastering as the cement continues to hydrate underwater.^{8, 14, 15} Cracks that do not seal underwater can be filled in accordance with Section 9.3.3.1^{27, 28}

Cementitious interior finish coatings are semi-permeable membranes. Therefore, moisture and water vapor permeate through the finish and into the substrate. Cementitious interior finish coatings are generally not designed to be "waterproof"; however, they should be "watertight", meaning water (in a liquid form) should not pass through the coating. Nevertheless, the interior finish does reduce the rate in which moisture penetrates through the structure.

3.3 Smoothness

The cementitious coating surface should be sufficiently smooth to the touch. The NPC defines "smooth" as a texture that is no rougher than very fine sandpaper (220 grit or finer) or similar to the smoothness of an eggshell. The intent of smoothness is to create a swimming pool surface that is easily maintainable and user friendly to bathers. However, it is not recommended that steps, benches, or walkout areas be overly smooth. Overly-smooth finishes in these areas should be avoided.

3.4 Texture

A basic tolerance for texture has not yet been established by the trade. The term 'texture' is predominantly used to describe the surface of exposed aggregate finishes. Texture describes the three-dimensional (3D) aspect of the raised aggregate at the surface, as opposed to the flat non-textured surface of the hard-trowel finish. There is no direct relationship between "texture" and "smoothness". A textured finish can be smooth or rough, and a flat non-textured finish can be smooth or rough.

3.5 Levelness

The finish of the swimming pool coating should be consistent across the surface. Though it is an expected feature or inherent characteristic of all

hand-troweled finishes to have some imperfection and waviness, a reasonable levelness should be attained. No section of a swimming pool's surface should have excessive waviness in comparison to another section. Transitions between walls, coves, floors, benches, steps, tiles, or around plumbing fixtures and lighting fixtures, should be smooth and uninterrupted.

The surface coating should not be used to level the swimming pool substrate beyond the maximum thickness tolerance allowances described in Section 3.6. Where the elevation of the tile line, piping, light fixtures, or other adjoining materials will not be level with the anticipated finish surface, the coating material should be applied, beveled, and finished in a way that provides a gradual slope and an even transition to the adjoining material.

3.6 Thickness

The cementitious surface coating should have a minimum thickness of $\frac{3}{8}$ " and a maximum thickness of $\frac{3}{4}$ ".^{1, 2, 3, 4, 5, 6} Though some fluctuation in thickness may exist in the interior finish, the majority of the interior finish thickness should remain within these tolerance levels.

The cementitious surface coating is not designed to have structural value; therefore, it should not be used for structural application where the integrity of the swimming pool structure is dependant.² Concrete, shotcrete, or gunite material that is designed to give the desired structural rating, is used for this purpose.

Brown coats or level-coating materials can be used in non-structural applications to level the swimming pool substrate, or to fill small to moderate-sized holes in a swimming pool shell provided the reinforcement network and the surrounding concrete, shotcrete, or gunite have not been compromised. Brown coats can be used to correct severe unevenness, or to repair a variance or unevenness in the substrate surface that is greater than the finish coating's maximum thickness tolerance.² The interior finish coating is an acceptable method for leveling minor fluctuations of the substrate, provided those fluctuations are

within the maximum thickness tolerance or meet one of the exceptions in Section 3.6.1.

3.6.1 Thickness Exceptions

Small areas of highs and lows, spanning no more than several feet in diameter per occurrence are allowed an additional tolerance level of 1/8" outside of the normal thickness tolerance levels of Section 3.6. (a minimum thickness of 1/4" and a maximum thickness of 7/8"). This added tolerance is necessary to allow the plasterer the ability to maintain a proper levelness tolerance over minor imperfections of the substrate and to transition to other abutting materials. However, it should be expected of the preparation crew and/or the plasterer to attempt to minimize these substrate highs and lows, if possible, by chipping, chiseling, grinding, filling in, patching, or otherwise preparing the substrate. High and low differentials in the substrate that encompass larger areas should not be corrected by the cementitious interior finish coating, as it would cause a large portion of the coating to exceed the minimum or maximum allowable thickness tolerances. These areas should be corrected prior to the application of the interior finish. This is typically done by adding an additional layer of shotcrete, gunite, brown coat, or leveling coat to the affected area of the substrate.^{1, 2, 18}

Another acceptable exception to the maximum thickness tolerance of the interior finish, is the use of the material to fill small holes, pits, or dig-outs (indentations around plumbing fixtures or lighting fixtures) in the substrate. Though the thickness of the cementitious surface in these areas will be greater than the acceptable maximum tolerance in these isolated spots, the cementitious material becomes an intricate part of the substrate structure in these areas by keying or locking into the substrate. Subsequent interior finish coats are then troweled to final set, which compresses, seals, and plugs surface cracks and seams around the fixtures.

When the interior finish material is used to fill small holes, pits, or dig-outs on vertical surfaces, it is necessary to place the material in separate stages and allow the material within the holes or dig outs to set or stiffen prior to placing the final finish coats.

Thicker areas, or areas having a large thickness variation, can sag and or separate from adjoining materials (such as plumbing and lighting fixtures) and have varying rates of shrinkage. Allowing the material used to fill holes or dig-outs to set or harden prior to applying the subsequent coats, ensures that the two materials set at different rates, and will allow the finish coating material in these areas to hydrate at a similar rate as the remainder of the interior finish.

3.7 Maintainability and Service Life

The interior finish should be applied and finished in a way that provides a consistent and even surface. Rough or pitted areas encourage the adherence of algae.

Proper workmanship and materials should produce a finish that is durable enough to achieve a minimum lifetime expectancy of (5) five years in a swimming pool environment, assuming the ongoing maintenance of balanced water, cleaning, and filtration remains in place, as set forth in accordance with the Guidelines and Standards of the Pool and Hot Tub Association.

4.0 MATERIALS GUIDELINES

As per ACI 524R – Guide to Portland-Cement Plastering: “The equipment used to mix plaster, the methods of curing, preparing substrates, mix design components, application, finishing techniques, and method of controlling cracking are only applicable to plaster and are not appropriate for concrete. Likewise, literature specific to concrete trade practice should not be assumed exchangeable or applicable to plastering common trade practice”. Therefore, it is important to recognize that trade-specific references, practices, methodologies, literature, or test results that pertain to other cement and concrete trades, or that do not pertain specifically to the swimming pool plastering trade, should never be compared, cross-referenced, or cross-utilized. It is important to verify that an explicit compatibility and relevancy exists between the trades in a specific regard. (See FORWARD for more specific detail and clarification)

Plaster materials should comply with building codes and project specifications. Packaged materials should be labeled properly, indicating the manufacturer, brand name, required health and safety information, and recommendations for use. Packaged materials that can be compromised by moisture should be protected. Each ingredient of a plaster mix design should be compatible with all other ingredients of the plaster mix design. Materials should be selected that are suitable for a given environment. Consider using high-performance durability materials under harsh environments. (See Section 8.0)

4.1 Batching and Mixing

Batching and mixing should ensure that each component of the mix design is thoroughly dispersed and integrally blended. The method(s) used should provide uniform proportions from batch to batch. The individual components being mixed should be in full-bag increments or measured to ensure that the amount of each component remains consistent from batch to batch.

The suggested sequencing of the mix design ingredients are as follows:

- Introduce approximately $\frac{2}{3}$ of the required water into the mixer,
- followed by certain admixtures or pigments when recommended by manufacturer),
- followed by $\frac{1}{3}$ of the required sand/aggregate,
- followed by the total amount of cementitious materials,
- followed by the addition of certain admixtures (when recommended by manufacturer),
- followed by the balance of sand/aggregate,
- followed by the addition of certain admixtures and pigments (when recommended by manufacturer),
- followed by the remaining $\frac{1}{3}$ of the required water, or enough water to reach a consistency that allows plasterers to properly pump, place, trowel, and achieve

the desired finish prior to the final set of the material.

4.2 Mix Design Ratios

The minimum acceptable ratio of cementitious material to sand/aggregate material, whether pre-blended by the manufacturer/producer or mixed at the jobsite, should consist of no less than one part of cementitious materials for every two parts of sand/aggregate by weight (1:2 cement/sand ratio).^{1, 2, 3, 4, 5, 6} Though the optimum ratio may vary regionally, a 4:6 cement/sand ratio or 4:7 cement/sand ratio are more commonly used.

4.2.1 Field Water-to-Cement Ratio

Field mix design water, or field water-to-cement ratio (w/c), is governed by three primary factors:

- The initial laboratory-controlled water-to-cement ratio ('ideal' lab conditions),
- The prevailing weather conditions (water evaporation),
- The prevailing substrate conditions (water absorption).

Jobsite field conditions determine the supplemental water needed; therefore, the field water-to-cement ratio (w/c) is established on the jobsite. Supplemental water is a deliberate increase of mix water, above the 'ideal' lab mix design, to offset the anticipated water loss, and to facilitate pumping, placing, and finishing operations. Supplemental water ensures that adequate moisture remains in the material, allowing hydration to continue unabated to final set.^{1,2}

While the above conditions are typically anticipated by an experienced plasterer or foreman having sufficient experience to determine how much supplemental water is necessary, unexpected field conditions or unforeseeable events can occur, requiring an additional dosage of supplemental (retemper) water, or secondary supplement of water. (See Section 6.1)

In basic terms, cementitious materials must not be allowed to "dry hard" or self-desiccate (harden from

lack of water). Instead, cementitious materials must be allowed to “set hard” or hydrate (harden from chemical reaction between the cement and water). (See Section 6.1) NPC Technical Bulletin #6 – *Hot Weather Considerations* is a useful publication for understanding the various anticipated and unforeseen jobsite conditions that determine the necessary water-to-cement ratio of the mix design.

4.3 Cementitious Materials

The cementitious materials should conform to the applicable ASTM Standards or Specifications. Commonly used cementitious materials include:

Portland Cement

- ASTM C 150

Blended Cement or Pozzolan-Modified Cement

- ASTM C 595
- ASTM C 595 (Limestone)³⁵
- ASTM C 1157

Pozzolans and Mineral Admixtures

- ASTM C 618

Silica Fume

- ASTM C 1240

4.4 Sand/Aggregate

The sand/aggregate materials should conform to the applicable ASTM Standards or Specifications. Commonly used sand/aggregate materials include:

Plaster Finish Sand

- ASTM C 897

Exposed Finish Aggregate

- ASTM C 33

If necessary, sand should be washed, to remove any alkali, sulfate, chlorine, or other residues, to below concentrations that are considered harmful or deleterious to the cementitious interior finish. The sand should not have more than trace amounts of iron. The gradation of the sand should be optimized to promote workability during the plastering application and to minimize shrinkage cracking.

Typically, the sand for hard-troweled smooth finishes consists of a mixture of eight to ten different mesh sizes, ranging from about a coarse #12 mesh to about a fine #200 mesh, with the predominant

percentage of the sand tending to be in the median. Plaster mix designs that contain a varied gradation from fine to coarse sizes, tend to create a denser matrix, which in turn, reduces the amount of cement paste between sand particles.

Exposed-aggregate finishes typically consist of small aggregate having fewer gradations or mesh sizes than hard-troweled smooth finishes. If necessary, aggregate should be washed to remove any alkali, sulfate, chlorine, or other residues, to below concentrations that are considered harmful or deleterious to the cementitious surface coating. Aggregate should not cause rusting or staining.

Certain metal compounds within the aggregate may be present if they can be demonstrated by testing or historical performance to consist of a species or mineralogical form that is stable in a swimming pool environment.

4.5 Water

Potable water is generally acceptable for usage as mix water for plastering. Alternatively, ASTM C 1602 non-potable water can be allowed under certain criteria.

4.6 Admixtures

Admixtures should be compatible with the other components of the mix design. Admixtures should be dosed and mixed as recommended by the manufacturer or supplier and should not exceed their recommended dosage level or mix design concentration. Admixtures should be allowed to mix for the amount of time necessary to produce a homogeneous mixture.

4.6.1 Calcium Chloride

Calcium chloride (CaCl₂) should not exceed 2% of the weight of the cementitious materials for any cementitious surface coating mix design. Calcium chloride, whether in the liquid, flake, or granular form, should be fully dissolved and dispersed within the mix water prior to the addition of the cementitious materials.² Calcium chloride addition is recommended as follows:

- Introduce approximately 2/3 of the required

- water into the mixer,
- addition of calcium chloride,
- followed by certain admixtures or pigments (when recommended by manufacturer),
- followed by $\frac{1}{3}$ of the required sand/aggregate,
- followed by the total amount of cementitious materials,
- followed by the addition of certain admixtures (when recommended by manufacturer),
- followed by the balance of sand/aggregate,
- followed by the addition of certain admixtures and pigments (when recommended by manufacturer),
- followed by the remaining $\frac{1}{3}$ of the required water, or enough water to reach a consistency for plasterers to properly pump, place, trowel, and achieve the desired finish prior to the final set of the material.

The 2% limit for calcium chloride is generally accepted in the swimming pool plastering trade. The 2% limit was adopted from the concrete trade^{19, 20} and the stucco trade¹⁸ as calcium chloride can accelerate the deterioration of metal reinforcements such as rebar embedded in concrete or metal lath embedded in stucco. Although swimming pool interior finishes have no metal reinforcement embedded within, the 2% limitation on calcium chloride is currently being recommended by the NPC. A joint publication of the Portland Cement Association and the National Plasterers Council – Technical Bulletin #5 – *White Cement & Swimming Pool Plastering* explains the acceptability of calcium chloride with white cement.

While not recommended by the NPC, dosages slightly above the 2% may not be problematic to the longevity of cementitious pool finishes.^{18, 21, 22}

Literature shows that calcium chloride in amounts between 1% and 2% can provide the beneficial properties of: increased strength, increased density, and increased solid surface area within the

cementitious matrix at early ages.²¹ Calcium chloride between 1% and 2% is shown to lower porosity and increase the watertightness of the cementitious microstructure at early ages.^{18,22} These properties can be beneficial for the longevity of an interior finish, especially when exposed to aggressive water at an early age.

Calcium chloride can alter the coloration of the interior finish. Calcium chloride can cause white surface coatings to exhibit a darker hue, and pigmented finishes to exhibit increased blotchiness or mottling.²

4.6.2 Polymeric Admixtures

Polymeric admixtures are often included in a mix design to enhance various properties. Chemical additives and chemical admixtures for interior finishes are categorized by their technology and by their ability to influence various characteristics of cementitious materials. The more common chemical additives and chemical admixtures fall under the following classifications:

- Water reducing
- Accelerating set
- Retarding set
- Viscosity and rheology modifying
- Compensating/corrective
- Corrosion inhibiting
- Deterioration limiting
- Permeability reducing

and are used to enhance:

- Water repellency
- Bonding
- Plasticity
- Workability
- Anti-segregation
- Pump-ability
- Durability

Today, most mix designs include some chemical additive or admixture to create or enhance the desired characteristics needed to pump and place the material, and to achieve the desired finish. Many mix designs use multiple chemical additives or

admixtures. Their successful usage requires compatibility with all other components of the mix design, and the limiting of adverse effects to other necessary characteristics such as set time, workability, and strength. Manufacturer's instructions and recommendations should be followed.

The producer/manufacturer of these products should be consulted with regard to proper usage, such as: compatibility with other components of the mix design; proper installation and application; compatibility to a water submersion placement environment; and compatibility to swimming pool chemicals in concentrations within acceptable and proper range anticipated during service life.

Certain polymeric admixtures can be used as a co-binder or as a secondary binder system to the cementitious binder. Such products are typically marketed as polymer-modified plaster. Many proprietary prepackaged products fall into this category. Polymeric admixtures or polymer-modified plaster products should be used in accordance with manufacturer recommendations.

4.6.3 Pozzolanic Admixtures

Supplementary cementitious materials (SCMs) are pozzolans conforming to ASTM C 618. SCMs can be used as plasticizers to enhance:

- Workability
- Rheology
- Pumping
- Placing
- Finishing
- Durability

Certain SCMs can aid in the control of plaster's set. SCMs can also improve the durability characteristics of plaster by adding resistance to alkali silica reaction, acid attack, carbonation, and leaching of cement compounds. SCMs should be used in accordance with manufacturer recommendations.

4.6.4 Pigments

Organic pigments, inorganic pigments, or a combination of organic and inorganic pigments are

often used in the swimming pool plastering trade to produce the vivid colors and hues desired by the Architect, Builder, Specifier, and/or Owner. The pigment(s) should be compatible with other components of the mix design. ASTM C 797 recognizes inorganic and organic pigments for use in integrally-colored cementitious materials.¹ It is recommended that the manufacturer or distributor be consulted to ensure compatibility with other components of the mix design. Pigments should be used in accordance with the manufacturer recommendations.

Proprietary pigment packages must be compatible with other components of the mix design and have a satisfactory history of at least two (2) years in a swimming pool environment or under equivalent test conditions (where the water chemistry was maintained according to ANSI/APSP Standards acceptable ranges).^{3,4}

Pigments used in the swimming pool plastering trade should be compatible with hydraulic cement-based materials. The pigment should thoroughly disperse in the mixer when properly dosed and given an adequate mixing time.² The usage of certain additives, such as calcium chloride, may alter the coloration of the pigment. Consistency of mixing procedures is critical to ensure uniform batch to batch color.

Pigments should not significantly alter the initial or final setting time, the water-to-cement ratio, or reduce the 28-day compressive strength of the material by more than 90% of the equivalent non-pigmented interior finish mix design.¹

Organic and inorganic pigments are held or "locked" into the matrix of the cementitious material at final set. However, organic pigments have a much smaller particle size than inorganic pigments, and are therefore more susceptible to loss in the event of deterioration of the surface of the interior finish. As deterioration of the upper surface proceeds, cementitious binder compounds are lost, resulting in an increase in porosity at the surface. Initially, the smaller pigment particles are removed from the surface. Eventually, all pigment particles can be

removed from the surface, resulting in the complete loss of coloration.

NPC Technical Bulletin #4 - *The Most Common Reasons for Loss of Color* is a useful publication for the understanding of common coloration issues post placement.

5.0 SURFACE PREPARATIONS FOR POOL SUBSTRATES

Currently, the ASTM C 926 Standard Specification for Plastering places the responsibility to provide an acceptable interior finish onto the plastering contractor, and requires the specifier to stipulate, or the builder to provide, a substrate surface that the interior finish can physically bond to, or specify the means or method to ensure an adequate bond can be achieved. This rationale potentially removes the plastering contractor from the decision-making process with regard to substrate achieving proper bond. The ACI 524 Guide has adopted similar language. The ANSI/APSP/ICC/NPC-12 American National Standard for Plastering and the National Plasterers Council adopt a similar position, but recommend that the specifier and/or builder consult with the plastering contractor to assist in determining the best method to ensure bond, based on the physical condition of the substrate.

When the plastering contractor contracts directly with the owner, the responsibility for achieving an adequate physical bond is placed on the plastering contractor unless otherwise stipulated by contract.

5.1 Surface Conditions for New Pool Substrates

The substrate should be placed and finished in a manner that leaves the surface rough, coarse, or porous enough to ensure that the interior finish can achieve a good mechanical bond to the substrate.

The substrate surface must be clean and free of debris, loose substrate, or any other material that might interfere with the ability of the interior finish to bond to the substrate.

The placement of the interior finish should be applied in a manner that achieves a good mechanical

bond with the substrate. Typically, this is achieved through applying heavy trowel pressure, with the trowel on edge, to the first coat, or scratch coat.^{1, 2, 18}

However, even a good mechanical bond between the substrate and interior finish can be compromised if the interior finish does not remain submerged in water during its service life, or if there is significant movement to the swimming pool structure. Excluding such situations, which are not in the control of the plastering contractor, the plastering contractor should meet the minimum bond requirements, where applicable of either:

- The Federal, State, or local minimum bond requirement, or
- The minimum bond requirement or warranty period agreed to by contract.

5.2 Surface Conditions for Renovation Pool Substrates

The requirements for the surface condition of the substrate for renovations are similar to new pool substrates and should be in accordance with Section 5.0 and Section 5.1. Additionally, the existing substrate structure should be inspected and determined to be structurally and materially sound.

The plastering contractor should report unsound materials or uncovered structural problems, to the builder or owner prior to resurfacing the swimming pool. When such issues are found, it is recommended that all Parties agree in writing upon a remedy, such as, how to repair the substrate or whether to repair the substrate. This may help to resolve future conflict in the event of bond failure or other problems relating to the condition of the substrate or structure. Alternatively, some builders and plastering contractors include contractual contingency clauses that detail the responsibility and/or procedural duties when substrate or structural issues are uncovered.

In addition to the substrate requirements of Section 5.0 and Section 5.1, the following procedures are considered acceptable practices for preparing a renovation substrate when done in a manner that

provides a surface to which the interior finish can achieve a good mechanical bond: ²⁵

- Acid wash the substrate and neutralize, then apply a polymeric bonding agent,
- Strip off, or chip off, the old cementitious surface coating,
- Re-gunite or re-shotcrete the substrate,
- Sandblast or hydro-blast the surface to a sound and rough surface,
- Sandblast or hydro-blast the surface, then apply a polymeric bonding agent,
- Sandblast or hydro-blast, then apply a brown coat,
- Sandblast or hydro-blast, then apply a cementitious pre-coating material incorporating a polymeric bonding agent.

5.2.1 Surface-Applied Bond Coats

Surface-applied bond coats should be used for:

- Smooth or dense substrates, when prepared in accordance with Sections 5.0 – 5.2,
- Soft or damaged substrates, when loose or friable materials have been removed, and prepared in accordance with Sections 5.0 – 5.2.

Surface-applied bond coats can have a secondary beneficial effect of reducing moisture loss from a freshly-placed plaster in certain conditions, such as:

- Hot, dry, or windy conditions that cause wetting or misting of the substrate to be less effective,
- Highly absorptive substrates that can wick mix water from fresh plaster.

Surface-applied bond coats can be sprayed onto the substrate or applied by brush or roller. They may be applied as a water-based or single-component formulation in undiluted form, or in a cementitious slurry form. Surface-applied bond coats should adhere to ASTM C 932. Surface-applied non-dispersible latex bond coats should conform to ASTM C 1059 (Type II). Surface-applied bond coats should be resistant to re-emulsification during service life in a water-immersion condition. Surface-applied bond coats should be used in accordance

with manufacturer recommendations. ASTM Standards where applicable should be followed.¹

5.2.2 Integrally-Mixed Bonding Agents

Integrally-mixed bonding agents are generally added as a separate ingredient of the mix design at the mixing stage. Integrally-mixed bonding agents improve the ability of the interior finish to adhere to the substrate, and may also provide additional flexural and tensile strength. Unless otherwise specified, integrally-mixed bonding agents can be used in conjunction with surface-applied bonding agents.

Integrally-mixed bonding agents should conform to ASTM C 1059 (Type II). Integrally-mixed bonding agents should be resistant to re-emulsification during service life in a water-immersion condition. Integrally-mixed bonding agents should be used in accordance with the manufacturer recommendations and ASTM Standards where applicable should be followed.¹

6.0 COMMON TRADE PRACTICES – MIXING AND FINISHING TECHNIQUES

6.1 Proper Usage of Mix Water (Temper Water) and Supplemental Mix Water (Retemper Water)

Initial field mix water includes an increase in the mix water, beyond the "laboratory" mix design water, to ensure plasticity, pump-ability, workability, and offset the anticipated water loss during application due to prevailing field conditions. This includes the **expected** water loss experienced with most mild to moderate field conditions due to evaporation, absorption, temperature, and low winds.^{1,2}

Example 1: To achieve an equivalent mix design of 0.45 water-to-cement ratio (w/c) used in a laboratory-controlled environment, an actual field mix design might require a 0.50 water-to-cement ratio (w/c) in order to offset the anticipated water loss associated with prevailing mild to moderate field conditions.

Supplemental water, or a secondary supplement of water (retemper water) is an increase in water beyond the initial field mix water, which may be

necessary to overcome extreme or **unforeseen** field conditions after the application has begun. This includes unexpected high water loss during application associated with abnormally high evaporation, high substrate absorption, high temperature, high winds, and/or low humidity.^{1,2}

Example 2: (using the same lab mix design from Example #1) A 0.45 water-to-cement ratio (w/c), which required a 0.50 field mix design water-to-cement ratio (w/c) for anticipated mild to moderate conditions, may require supplement of water to a 0.55 water-to-cement ratio (w/c) in order to offset the unanticipated water loss associated with unforeseen or extreme field conditions during application.

Supplemental water (retemper water) provides additional moisture to ensure that an equivalent amount of water, to that of the lab design water-to-cement ratio (w/c), is still present as the material nears final set. Supplemental water ensures that the hydration of the cementitious materials continues through to final set and facilitates the placing and finishing operations. Because supplemental water directly offsets the water loss during the plastering application, the *actual* field water-to-cement ratio (or the 'effective' w/c ratio) is equal to the *ideal* lab water-to-cement ratio (or the 'empirical' w/c ratio) as the material nears final set. Therefore, supplemental water, when properly dosed according to the prevailing field placement conditions should not decrease strength properties or the overall quality of the interior finish.

The NPC does not condone plastering in adverse conditions or environments. However, instances do arise whereby it may not be possible or practical to avoid such an environment. Unexpected conditions may arise after work has begun. In such instances, additional supplemental water may be required. Over-tempering must be avoided.^{2,18} Over-tempering can weaken a cementitious material.³

6.2 Proper Usage of Lubricating Water

The use of lubricating water is considered an acceptable practice and commonly used within the swimming pool plastering trade to create a hard and smooth finish. If used improperly, lubricating water

can be damaging to the upper surface of the interior finish. Therefore, lubricating water should not be allowed to dilute the cementitious material at the surface.

The intended purpose of lubricating water is to maintain moisture at the upper surface of the interior finish, to prevent the surface from prematurely hardening by drying out. Lubricating water also acts as a trowel lubrication aid, which enhances the ability of plasterers to compress, seal, and finish the surface.

Lubricating water should be applied sparingly to the surface of the interior finish, or the trowel, and only one trowel pass should be made until the remaining water is evaporated, absorbed, or removed. Troweling can resume immediately after water is no longer "standing" (visible) on the surface.²

However, when incorporating the float or leveling process, or when necessary to rework or re-mix the upper portion of the finish coat, it is common practice to apply water sparingly and work the water into the surface with a rubber sponge float to a depth of approximately 1/8". This gives the plasterer the ability to re-level the finish coat or to even out the moisture content across the surface of the interior finish. In this instance, lubricating water can also be considered supplemental (retemper) water as the sponge or float process becomes a method of redistributing moisture between the upper-surface and the inner-matrix of the material thereby replenishing and/or redistributing mix water.

6.3 Cold Weather

It is important that the cementitious binder continue to hydrate and strengthen. The placement of an interior finish in cold weather is considered an acceptable practice, as long as, the daily average mean temperature (the daily average of the highest high and the lowest low, from midnight to midnight) is above 40°F (4°C) and the substrate is not frozen. Optionally, special precautions can be taken to protect the material from freezing. Once the interior finish has reached final set, the temperature of the interior finish should not be allowed to freeze before

the pool is filled. Cementitious materials will resume hydrating and continue to gain strength when the temperature of the coating rises above 40°F (4°C). Cementitious materials continue to hydrate underwater and achieve a significant portion of their ultimate strength underwater, during the first few months after installation.

7.0 GENERAL PERFORMANCE GUIDELINES FOR EXPOSED-AGGREGATE FINISHES

7.1 EXPOSED FINISH TYPES

7.1.1 Exposed-Aggregate Finish

A textured finish achieved by the removal of cementitious paste material at the surface of the product, thereby exposing the aggregate component of the mix. The exposed-aggregate finish process should incorporate a method of repeated water washing and troweling during placement that removes the cement and other fine materials from the surface. The process should expose and consolidate the aggregate at the surface. The process should facilitate the compaction of the aggregate at the surface and ensure that the aggregate is sufficiently embedded into the cementitious binder material.

7.1.2 Exposed-Quartz Finish

A blend of quartz sand, often in a variety of colors, mixed together with a cementitious blend of materials and other additives, which is placed similarly to a hard-trowel plaster finish. Once the product has been placed, the surface is typically exposed. However, some finishes are intentionally left unexposed or under-exposed, depending on the desired texture or aesthetic effect, or may be further exposed at a later time.

7.1.3 Polished Finish

A plaster, pebble, or quartz finish that is polished to provide increased smoothness. Typically, this is achieved using diamond abrasives.

7.2 General Characteristics

It is normal for exposed-aggregate finishes to have a variation in the surface aggregate density, or a variation in the concentration of aggregate across

the finished surface. Some variation is expected with most exposed-aggregate finishes. This variance can be intensified when the color of the cementitious binder, which holds the aggregate in place, is in dramatic contrast to the color of the aggregate. Therefore, complementing colors should be considered, when choosing an aggregate color and a background color, to minimize color contrast.

7.2.1 Watertightness

Exposed-aggregate finishes must meet the applicable General Performance Guidelines specified in Section 3.0.

7.2.2 Over-Exposed Finishes

Over-exposed finishes can be identified by the visual absence of the cementitious binder material that holds the aggregate. Over-exposed areas can be rougher to the touch and can result in a premature loss of the aggregate across the surface.

7.2.3 Under-Exposed Finishes

Under-exposed finishes can be identified by the visual absence or lower concentration of the aggregate. Under-exposed areas have the appearance of blotchy or "bald" areas that are markedly lacking aggregate, as compared to the remainder of the finish.

7.2.4 Determining Exposure Tolerances

Some fluctuation of over-exposure and/or under-exposure is present on all exposed-aggregate finishes; however, the overall finish should be consistent in variation across the surface. An area should be considered acceptable if the intended surface finish has minor fluctuations across the finish. However, it should be considered unacceptable, for example, to have a noticeable under-exposed area or 'bald spot' with little or no aggregate, or no similarity of texture as the overall finish surface.

The trade considers an area to be an 'obvious deviation' when; upon viewing a 20' x 20' section of the coating surface, the inspector (viewer) can find the area of concern within 15 seconds of approaching the swimming pool, without having prior knowledge of the exact location. Proper

viewing conditions must be present as described in Section 2.0.

8.0 HIGH-PERFORMANCE DURABILITY FINISHES

High-performance durability finishes are often designed to lessen or slow the rate of deterioration caused by aggressive water. Such finishes can generally withstand slight 'negative' saturation index (LSI) conditions. High-performance durability finish products should be able to demonstrate a history of satisfactory performance, increased durability, and enhanced service life in such water conditions.

Though high-performance durability finishes can lessen and often withstand the effects of certain aggressive water conditions, they are still susceptible to issues relating to 'positive' LSI water conditions, such as calcium precipitation, mineral scaling, or metal staining, as are all materials submersed in water. Therefore, certain manufacturers may recommend a shift from NPC's recommended LSI 'Ideal' Range, toward slightly 'negative' LSI water, such as the ANSI/PHTA 'Acceptable' Range. In this way, the spirit of the NPC's recommendation to maintain a balanced water condition is upheld because the slightly more aggressive range reduces the likelihood of mineral scale formation.

9.0 GUIDE TO TROUBLE-SHOOTING AND REPAIR

9.1 Introduction

Interior finishes for swimming pools can be designed to provide added resistance to ultraviolet light, weather, moisture, aggressive chemicals, or a combination of these. Interior finishes should provide aesthetic appeal and have a surface that can be maintained, as well as provide a barrier to slow the ingress of water and aggressive chemicals into the structure and the reinforcement within the structure. However, interior finishes are not considered a structural element of construction. Interior finishes are not intended to resist structural movement, such as: settlement of the structure; soil expansion; freeze/thaw expansion and contraction;

or structural load stress differential created by filling or draining water from the structure. Structural movement can result in cracking or delaminating of the interior finish and/or debonding of the interior finish from the substrate.

9.2 Inspections

Structural defect failures generally involve one or more of the following:

- improper water cure of the substrate,
- Structural movement forces.

Interior finish defect failures resulting from improper application generally involve one or more of the following:

- Inferior materials,
- Improper mixture proportioning,
- Improper surface preparation,
- Improper placement or finishing techniques,
- Delayed or improper initial water fill.

Ongoing service and maintenance related failures generally involve one of more of the following:

- Filling the pool with soft water,
- Pool water having a significant metal content,
- Improper chemical balance of the water,
- Improper service of the swimming pool,
- Draining the pool for an extended period,
- Freeze/thaw damage due to draining some or all of the water for winterization.

Trouble-shooting interior finishes for swimming pools should be done by professionals that understand the common trade practices of swimming pool plastering and its uniqueness to that of other plastering trades or concrete trades.

Often, investigations utilize the combination of an expert in the swimming pool plastering field and a construction-related failures analysis laboratory. Construction-related failures analysis laboratories, experts, consultants, or other qualified personnel

should consider the uniqueness of the trade and the uniqueness of the placement environment (i.e., submersion in water and contact with various pool water chemicals) when conducting an investigation. Failure to understand and account for the unique materials, placement, application, and finishing techniques, as well as the unique placement environment, can lead to erroneous testing and conclusions. (See FORWARD for more specific detail and clarification)

An onsite inspection should be performed initially to identify or confirm the potential concern, defect, or failure. The initial onsite inspection typically provides verification of an issue or concern through a visual examination of the finish, and often includes the physical sanding and/or chemical treating or testing of a small area of the finish. (See Sections 1.2 Mediation and 2.0 Viewing Conditions)

During the initial inspection, a cause and/or remedy can sometimes be established; the responsible party(s) identified, and often a resolution to the issue(s) can be arranged. If a cause and/or remedy cannot be established, further investigative work may be necessary.

More in depth investigations require additional information gathering to resolve such issues. It is recommended, that a timeline of events be developed, to include any information that may be instrumental in understanding and resolving the issue, such as:

- Date of installation,
- Date of initial complaint,
- Substrate preparation,
- Mix design components (run, lot, pallet number, if known),
- Mix design proportions,
- Mixing procedures,
- Placement procedures,
- Finishing techniques,
- Qualification of personnel,
- Installation issues,
- Weather records,
- Fill and start-up procedures,

- Ongoing service and maintenance of the swimming pool,
- All available water chemistry records of tap water and pool water (from filling to present),
- Any other information that may be helpful in understanding the cause of the defect, failure, or service maintenance issue,
- Listing of the responsible parties for each of the above-listed events.

Repair techniques should be considered and selected from a practical and an aesthetic viewpoint. Some of the methods of repair covered in this manual may not meet acceptable appearance standards. The primary focus of an interior finish repair, as described herein, is to re-establish the integrity of the surface coating to meet general performance guidelines as recommend in Section 3.2 Watertightness. A secondary focus is to achieve an acceptable aesthetic appearance.

9.3 Cracks

9.3.1 General

The method of repairing cracks is generally determined by the type of cracks. Cracks can be classified into one of these three types:

- Closed shrinkage cracks that develop during application or within the first twenty-four hours after final set,
- Open shrinkage cracks that develop during application or within the first twenty-four hours after final set,
- Structural movement cracks, tensile stress cracks, and all other cracks, that develop throughout the life of the coating, subsequent to the first twenty-four (24) hours after application.

9.3.2 Closed Shrinkage Cracks

Closed shrinkage cracks (check cracks), or normal shrinkage cracks, form from the normal volume loss that occurs within a newly applied interior finish, due in most part, to moisture loss that the cementitious portion of the interior finish coating

experiences as it sets and dries. Normal shrinkage cracks are typically reversible, meaning they seal themselves. These cracks tend to fill, or seal shut underwater within twenty-four hours of total immersion in water. As the cement hydration continues, some of the newly formed compounds (primarily calcium hydroxide) fill the crack space. For many other cementitious products this may not be the case, however, for cementitious materials that are kept in total water submersion environment, normal shrinkage-related cracks generally reseal. A crack that remains open after immersion would be classified as an open shrinkage crack. (See Section 9.3.3)

Upon draining of a swimming pool, closed cracks may become visible when the dry cementitious surface is initially wetted. Though the crack is sealed or closed, the density of the material within the crack is lower than the overall density of the remainder of the surface coating, therefore, water will absorb into the closed crack areas at a faster rate than the remainder of the coating. This allows the once invisible cracks to become visible, for a time, until either the plaster coating becomes fully saturated, or fully dries.

Closed cracks (check crack) are more noticeable on smooth surface finishes. Closed cracks can also become noticeably visible if, prior to their sealing, dirt or dust becomes trapped within the cracks. The cracks re-seal underwater, however, the location of the cracks remains visible, due to the dirt trapped within. Closed cracks do not affect the performance of the interior finish and are considered a normal characteristic of cementitious smooth finishes.

9.3.2.1 Remedy

For cracks that do not reseal, refer to Section 9.3.3.1 for remedy. For cracks that have trapped dirt within a sealed check crack, two options are available as a remedy:

- Closed shrinkage-related cracks can be opened with a knife, an abrasive grinding blade or similar tool, allowing the cementitious mixture to penetrate, or key into, the crack,
- Closed shrinkage-related cracks can be left

alone. These cracks generally only penetrate the upper surface of the interior finish and do not penetrate through the coating. Check cracks do not affect the intended functional purpose of the interior finish.

The decision to repair a shrinkage-related crack that is closed, yet remains visible, is generally for aesthetic concern only. Determining what is considered “acceptable” in this case can be problematic. Mediation can sometimes be the best option. (See Section 1.2) Shrinkage-related cracks that are closed, yet remain visible due to a color variation from that of the remainder of the plaster coating, can sometimes be visually improved by draining the pool and allowing the surface to dry and/or be torched to remove possible trapped moisture and to even the overall coloration across the interior finish surface.

9.3.3 Open Shrinkage Cracks

Open shrinkage-related cracks are formed when excessive moisture loss creates stress cracking within the surface coating during set or drying that do not reseal. Open shrinkage cracks can be cracks that penetrate only the upper 1/8” of the surface of the interior finish, or they can be cracks that penetrate through one of the coats of the interior finish. The following are known causes of open shrinkage cracking:

- The water loss from the interior finish during the plaster application due to the evaporation of moisture from the upper surface (insufficient mix water or supplemental water). The water loss from the interior finish during application due to extreme weather conditions, such as; high wind, high temperature, and/or low humidity,
- The loss of moisture from the surface of the interior finish due to the high absorption of the substrate, such as; a substrate that is placed using a non-homogeneous mixture; an insufficiently wetted substrate to start the absorption process just prior to interior finish application; an overly-dry substrate

that has not been soaked down to lower its' absorptive capacity; or improperly cured substrate,

- The use of excessive supplemental (temper) mix water, beyond that amount needed to maintain a proper time of set and/or the early ongoing hydration (over-tempering),
- The use of excessive lubricating water, beyond that amount needed to ensure proper placing, tooling, and/or finishing of the interior finish surface,
- Working the surface while the interior finish is too wet or working the interior finish too much (over working),
- Not sufficiently working the interior finish at the appropriate time when the tensile strength of the surface coating exceeds the stress associated with initial water loss. In other words, the entire thickness of the coat is too weak to withstand the water loss, creating plastic shrinkage (under-working),
- A cement-rich mixture, beyond the normal standard of the trade as conforming to the NPC Technical Manual and/or ASTM C 926,
- The neglected or delayed filling of the swimming pool with water immediately following the completion of the plastering application,
- Some combination of the above.

9.3.3.1 Remedy

Smaller open shrinkage-related cracks should be cleaned and filled with a cement paste, with or without a polymer additive, or with cement and a fine sand, with or without a polymer additive or other patching material. The repair material should be forced into the crack and the excess material should then be rubbed off with a glove or a fabric using a motion across and not along the crack. Larger open shrinkage-related cracks should be repaired in a similar manner, except the crack patching material should have a sand or a filler material with a slightly courser grit included. Interior finishes that have open shrinkage cracks that are too numerous, or in situations where

numerous crack-patch repairs would not be considered acceptable, resurfacing may be the only alternative. Determining what is considered “acceptable” can be problematic. Mediation can sometimes be the best option. (See Section 1.2)

9.3.4 Structural Movement Cracks or Tensile Stress Cracks

Structural movement cracks or tensile stress cracks are significant cracks that extend through the entire thickness of the interior finish. Unlike shrinkage-related cracks that are limited to a maximum crack width as defined by the volume change that a cementitious material undergoes during its set, structural movement cracks can continue growing in length and width until movement stops in the underlying structure. Structural movement cracks typically follow the stress pattern that the crack relieved. Structural movement cracks are generally found at areas of stress, and typically not in numerous numbers, as compared to shrinkage-related cracks.

Structural movement cracks can be working cracks or non-working cracks. Working cracks are the result of an ongoing structural movement that continually opens, closes, slides, lifts, or lowers the cementitious surface at, or along, areas of stress in the pool structure. Non-working cracks are inactive and do not exhibit further structural movement. Working and non-working structural movement cracks can be repaired, however, for certain working cracks, the cementitious surface should be removed and the structural problem causing the movement corrected. If the cracks are non-working and the stress issues creating the original structural movement have stopped, then the interior finish can be repaired in a similar fashion to that of open shrinkage cracks. (See Section 9.3.3.1)

Possible contributors to the cause of structural movement cracks or tensile stress cracks can be:

- Structural movement of the swimming pool structure due to soil expansion or settlement,
- Improper structural design of the swimming pool, allowing movement or

cracking of the substrate and thereby cracking the interior finish coating.³⁶

9.3.4.1 Remedy

Smaller structural movement cracks or tensile stress cracks should be cleaned and filled with cement paste, with or without a polymer additive, or cement having a fine sand, with or without a polymer additive, or other appropriate patching material. Larger structural movement cracks or tensile stress cracks should be cleaned and filled with cement having slightly coarser sand, with or without a polymer additive, or other appropriate sanded patching material. The repair material should be forced into the crack, and the excess material should then be rubbed off with a glove or a fabric using a motion across, and not along the crack.

The remedy and repairs for structural movement cracks, as described herein, are either for cosmetic repair, or for a temporary patch repair, to the surface coating only. These cosmetic repairs do not take the place of any structural repair that is necessary or required to restore the swimming pool structure. Swimming pool structural repair is not in the scope of this document.

9.4 Inferior Workmanship and Materials

9.4.1 General

The materials of a hydraulic cement cementitious surface coating should conform to specifications, standards and guidelines referred to in ASTM C 926 and ACI 524, except where excluded by standard trade practices. The term "trade practice" herein, includes the raw materials which make up the cementitious interior finish, the mix design, the mixing and placement procedures, the application and finishing techniques, the curing regimen, and the subsequent method of service and maintenance of the interior finish. (See Section 1)

The handling, mixing, and placing of the interior finish should conform to ASTM C 926 and ACI 524. Though finishing techniques can vary, they should be done in a manner that creates a durable interior finish. Proper curing of the swimming pool substrate prior to plastering and proper curing of

the surface coating by immersion underwater should conform to ACI 308 and ASTM C 926 and ACI 524. This manual may be used as a guide to further understand the proper mix design, proper application and finishing technique, and proper curing regimen for swimming pool interior finishes. When these Standards and Specifications for plastering (including materials, mixture proportioning, mixing, application, and curing methods) are not followed, or when placement conditions are not considered and dealt with, the integrity and the durability of the interior finish may be adversely affected.

Possible contributors to a weakened interior finish can be:

- Excessive sand in the mix design without a sufficient cement binder,
- Excessive mixing water, resulting in a weaker interior finish and excessive laitance,
- The addition of hydrated lime or lime putty to the mix design can cause the interior finish to deteriorate prematurely and increases laitance. Hydrated lime or lime putty should not be used as a mix ingredient to any interior finish. The constant water-contact environment can cause the hydrated lime or lime putty to be unstable, and can dissolve the hydrated lime or lime putty from the interior finish in a water submersed environment,
- The excessive use, or improper use, of certain additives and admixtures,
- The placement of an interior finish during the time that daily average mean temperature (the daily average of the highest high and the lowest low from midnight to midnight) is below 40°F (4°C), or the placement of the surface coating on a frozen substrate, or where special precautions have not been taken, can cause a bond failure and/or cause the slowing or stopping of set and hydration of the cementitious materials within the coating,
- Improper gradation of the sand (too much fine material can cause the interior finish to

crack and increases water demand, too much coarse material can inhibit bonding to the substrate and can lower the workability),

- Impurities in the sand, water, or other ingredients that are not in compliance with ASTM C926, ACI 524, or other applicable specification, can result in an inferior surface coating,
- Insufficient surface coating thickness as specified in ASTM C926 can cause cracking,
- Improper preparation of the surface of the substrate causing cracking due to bond failure.

9.4.2 Remedy

Inferior interior finishes, or "weak" interior finish, can sometimes gain sufficient strength through ongoing curing underwater to stop or reduce efflorescence, dusting, or chalking of the surface. However, if the interior finish is not immersed underwater within twenty-eight (28) days after placement (dependent upon which region of the United States, and which season of the year the interior finish is placed), subsequent curing or immersion will have little or no beneficial effect.

When an inferior or "weakened" interior finish can be cured, treated, or otherwise improved, allowing the overall integrity of the interior finish to recover to a level that approximates the anticipated life expectancy of a non-affected interior finish, the finish coating is considered acceptable.

An inferior finish that remains inferior after allowing twenty-eight (28) days to fully hydrate underwater should be removed and replaced.

9.5 Debonding and Delaminations

9.5.1 General

Debonding can be classified into two categories:

- *Adhesive* bond failure, or the failure of the interior finish to bond to the substrate surface (shotcrete, bond coat, etc),
- *Cohesive* bond failure, or the failure of the

interior finish to hold together, or to split apart.

Bond failures generally occur during the placement of the interior finish although many debonded areas are not noticed until after the coating is underwater.

An interior finish that has achieved a proper mechanical bond will generally maintain that bond throughout the service life of the coating. A physical bond, or a mechanical bond, is created when the plasterer forces the wet material into the open, porous, scratched, etched, or otherwise roughened substrate or undercoat, thereby keying into, or interlocking the two surfaces. The failure of an interior finish to properly bond with the solid substrate or a cementitious surface undercoat (e.g. waterproof coating or bond coat) is generally due to one of more of the following:

- Surface carbonation of the undercoat or solid substrate increases the surface density, or decreases the porosity of that surface, which can reduce or prevent the ability of a interior finish to achieve proper bond,
- Surface efflorescence or surface laitance on the substrate or undercoat can reduce or prevent the ability of an interior finish to achieve proper bond,
- An overly smooth or overly dense substrate surface or undercoat surface can inhibit an interior finish from keying into, or bonding with, the substrate or undercoat,
- An overly dry substrate or undercoat, or a substrate or undercoat having a high rate of absorption. A rapid moisture loss at the interface between the interior finish and the substrate can cause the interior finish to stiffen quickly. Rapid drying at this interface, as opposed to a slow stiffening or setting can cause debonding, as the plasterer has little or no time to force the wet coating material into the pores of the substrate before rapid drying occurs,
- A solid substrate or undercoat that is overly wetted, or overly water saturated, prior to

receiving the interior finish. Water or moisture that is visible on or within a substrate that occupies the open pore spaces, restricts the ability of the coating to key into the substrate, and reduces the absorption capability of the substrate. This can prevent or reduce the proper bond of the interior finish to the substrate,

- An interior finish that is applied too thinly over the substrate can dry before it sets. Thin coats can have excessive tensile cracking caused by the stress of shrinkage far exceeding the low tensile strength of the thin coat. The result is a weakened interior finish that may not maintain bond,
- An interior finish that is applied overly thick. (See Section 3.6) Overly thick coats can exhibit abnormally large shrinkage cracks and a 'pulling away' from the substrate, resulting in possible debonding,
- A non-cleaned or contaminated substrate surface can reduce or prevent bond. Examples of contaminants would be dirt, oil, acid, form-release agents, or loose debris,
- A scratch-coat, brown-coat, or other surface undercoat that is not properly scratched, scored, notched, or otherwise properly prepared to receive the interior finish,
- Delamination within the upper nominal $\frac{1}{8}$ " (3.2mm) of the interior finish can be caused by over troweling the finish surface, or by troweling the finish surface after the interior finish is fully hardened,
- Failure to immerse the interior finish underwater in a timely manner after placement,
- Failure to maintain the interior finish immersed underwater throughout the service life,
- Failure to maintain constant moisture to the interior finish in the event the swimming pool is drained.

9.5.2 Buckles, Blisters and Spalls

Buckles are bulges of the interior finish due to a separation from the substrate, or from the

undercoat (debonding), or from a delamination within the interior finish that have not yet lifted off or broken away. Buckles are generally caused by a failure of one coat to bond to another coat within the interior finish, or the failure of the interior finish to bond to the substrate. (See Section 9.5.1)

Blisters are small round bumps on the surface of an interior finish. Blisters are separations occurring within the upper surface of the interior finish that have not yet lifted off or broken away. Generally, blisters are caused by trapped air.

Spalls are delaminations or separations occurring within the upper surface of the interior finish that have lifted off or broken away. Spalls can be caused by abrasion or hard blows to the interior finish surface, aggressive water chemistry, freeze/thaw cycles, or from the interior finish not being submerged in water and being dry for too long.

Blisters and spalls are generally delaminations of the thin upper-finish layer of the interior finish. Blistering and spalling can be caused from the following:

- Failure to immerse the interior finish underwater after placement,
- Failure to maintain immersion of the interior finish underwater throughout the surface life,
- Failure to maintain constant moisture within the interior finish in the event that a swimming pool is drained,
- Repetitive impact or abrasion to the surface of the interior finish during service life,
- Overly-aggressive swimming pool water chemistry. Over time, aggressive water will attack and deteriorate cementitious products. The upper-finish layer of the surface coating (approximately $\frac{1}{8}$ " [3.2 mm] in depth) is especially affected. Calcium hydroxide, the weakest hydration product of the cementitious interior finish that can be leached from this layer causing this upper layer to weaken and/or detach from the remainder of the topcoat.^{2, 7, 9, 11, 16,}

^{17, 22, 23, 24,}

- Freezing temperatures that occur after final set but prior to submersion.

Buckles are caused by the same issues as delamination or debonding. (See Section 9.5.1)

9.5.3 Remedy

Isolated debonded areas should be removed. The substrate surface, over which the patch is to be applied, should be clean and made free of all loose materials or contaminants. A bonding agent should be used prior to, or in conjunction with, the application of the repair coatings. The new coats should be applied in a similar manner, and in the same number of coats, as the existing interior finish. It is considered common practice to remove completely, the portion in need of repair down to the substrate, thereby ensuring that the new coating is properly keyed into the substrate and the remaining coating. The repair coating should be properly cured. Some repairs can take up to ninety (90) days to fully hydrate before they become less noticeable. The entire coating can be removed and replaced, re-coated or multi-coated, stained, painted, or otherwise treated if the repairs are too numerous or overly noticeable to the point of being unacceptable.

Small blisters and spalls, lifted areas, broken or chipped areas, and minor blemishes can sometimes be repaired underwater. Buckles, blisters, and spalls that have not yet lifted off or broken away can be left alone without fear of damage to the structural integrity of the swimming pool; however, any visible cracks should be filled underwater to prevent water from freely entering into the void space and leaching cementitious compounds or other components from the interior finish.

9.6 Discoloration

9.6.1 General

Discoloration of the surface of an interior finish can be classified into three sub- categories:

- Normal discoloration
- Abnormal discoloration
- Staining discoloration.

Normal coloration variation, also referred to as 'normal mottling' generally has a uniform shading,

blotchy, or cloudy appearance across the surface of the interior finish. Abnormal coloration variation, also referred to as 'abnormal discoloration' refers to a condition where the surface is not uniform in coloration or shading across the surface of the interior finish.

Normal mottling typically results from differences in moisture content and/or the rate of hydration present within most newly placed cementitious materials. Normal mottling shade variations are not considered a failure or defect, but a normal characteristic of most cementitious products, not needing remedy.

Abnormal discoloration, including sporadic shaded areas, excessive blotchiness, and smaller discolored spots, can be due to one or more of the following:

- Contaminated sand can cause small discolorations, especially if the sand contains iron, which can rust,
- Color pigment that is not mixed thoroughly can show as concentrated spots or lines of exaggerated color in the surface coating finish, or as obvious contrast in color differences from one area to another if exact ratios were not kept from batch to batch during mixing,
- Wide variation in the water content from batch to batch of the finish coat can cause color variation, especially to colored interior finishes, and is noticeable at the juncture where one batch ends, and another begins. A complete difference in the shade of color from one batch to another may also be noticed,
- Excessive dry spots, or excessive moist spots (weepers), or uneven areas of moisture in the substrate can cause isolated spots of discoloration of a similar size to that of the area affected. Weepers are areas within or below the substrate that release a constant moisture flow, generally in small, localized spots of several inches to several feet in diameter onto the surface of the substrate. Substrates having moisture variations can cause discoloring across the

entire surface coating. The resulting appearance can be that of an exaggerated form of normal mottling, or as severe blotchiness, or as large, isolated areas that are either lighter in color or darker in color to that of the remainder of the coating. Moisture variation in the substrate can affect the rate at which a coating dries and sets, which in turn affects the coloration of an interior finish,

- Substrates can have contaminants or minerals that can adversely affect the coloration of an interior finish,
- Rain or other water sources can cause the discoloration of a newly placed interior finish that has reached final set but has not yet been immersed underwater. Intermittent water that splashes or wets a portion of the finish during this time can cause discoloration to that area. Water that is introduced to an interior finish during this time should be immediately removed, or the entire surface should be wetted over in uniform fashion (without leaving ponded areas) to limit discoloration. In the same manner, an interior finish that receives an unexpected rain, spray, or splash of water, can be misted in its entirety, if possible, to lessen any potential discoloration. Pigmented finishes are especially prone to discoloration. Water contact should be avoided after final set or applied in a uniform manner across the surface (without leaving ponded areas) when unavoidable.
- Calcium chloride can cause an interior finish to exhibit a darker hue, and can increase mottling,²
- Trowel burn, over-troweling, or troweling past final set, can cause an exaggerated form of mottling, or severe blotchiness. These dark gray appearances come from the metal of the trowel being deposited onto the cementitious coating surface. This discoloration is often in an arc or in the pattern that follows the motion of the trowel used by the plasterer. Trowel burn is created by over-troweling the cementitious

surface finish, by troweling the finish near the final set without supplemental (retempering) moisture to lubricate the finish, or by troweling the finish past final set,

- Large differences in the thickness of the interior finish can cause discoloration. Typically, thicker areas of the interior finish will be darker in color, while thinner areas will be lighter in color. Areas of the interior finish that are thicker, tend to retain moisture longer, which causes the rate of hydration to be different from that of the remainder of the interior finish. For thinner areas, moisture is lost sooner, which causes the rate of hydration to be different from that of the remainder of the coating.
- Corrosion of rebar that is imbedded within the substrate can cause discoloration to the interior finish. Rusting iron can migrate to the surface of the interior finish and appear as a rust stain. Often, the steel or iron reinforcement that is rusting within the substrate is buried several inches within the substrate; however, rust can migrate through the substrate to the surface of the interior finish. Depending on the oxidation state of the iron migrating to the coating's surface, the rust stain can appear in varying coloration, from an orange-red, to a deep greenish-black or brownish-black, to black. The distinction between this type of discoloration and stain discoloration is that this discoloration comes from substrate beneath the interior finish, while stain discolorations are precipitated onto, or absorbed into the surface. The remedy for this type of discoloration must include not only the removal of the rust spot on the surface, but also the removal of the source metal that is rusting.

Staining discoloration may be due to one or more of the following:

- Staining discoloration can be precipitated onto, or absorbed into, the surface from liquid spills or splashes of water after final

set and before immersion in water,

- Certain materials whether metal, mineral, organic, or inorganic can stain the surface while the coating is in the early stages of curing and hydration, just after final set and prior to immersion in water,
- Certain materials whether metal, mineral, organic or inorganic can stain the surface if allowed to dissolve, disintegrate, oxidize, or otherwise react with the interior finish underwater,
- Oils or dirt from human hands or feet, or from pets or animals prior to fill,
- Precipitations of calcium or of iron or of some mineral (such as in certain fertilizers) or metals (such as in certain algaecides),
- Efflorescence can discolor the surface. Salts, usually white in color, are transported from within the cementitious portion of the interior finish, in the presence of moisture, and are precipitated or deposited on the surface. This can be especially noticeable on pigmented interior finishes,³⁷
- Water that drips from the decking, rain, dew, or water that is not wiped off or washed off while cleaning the tile or decking after plastering.

9.6.2 Remedy

Stains or discolorations can sometimes be repaired by lightly sanding or grinding the surface, by acid washing or bleaching the surface, by the use of certain stain removers or chemical treatments, or by removing and patching the affected area. It may be advantageous when working with large areas, to treat the entire surface. Acid washing, bleaching, torching and chemically washing the entire surface can sometimes lessen the degree of discoloration to an acceptable appearance. A small area of the surface coating should be tested prior to treating the entire surface to determine if the chemical treatment is effective in removing the stain or discoloration and is not damaging to the interior finish. Otherwise, the surface can be repaired by replastering.

Interior finish discoloration is typically within the surface of an interior finish, while stains are

typically on the surface. Discolorations are typically remedied by draining the pool and applying chemical treatments, torching, and/or exposure to air and sunlight. Stains are typically remedied by in-water chemical treatments and/or physical removal (sanding) of the stain from the surface. Alternatively, draining the pool and acid washing, bleaching, torching, or otherwise chemically treating the surface can sometimes remove staining. However, care should be taken as many chemicals can damage the surface of an interior finish. A combination of chemical treatments and physical processes can also remove stains caused by metal or mineral precipitants, build-ups, or surface roughness that increase the ability of stains and mineral scale to adhere to the surface. If all other options are exhausted, the surface can be replastered.

9.7 Long-Term Deterioration

9.7.1 General

The service life of an interior finish is determined largely by the environment in which the coating is placed.^{2, 11, 17, 22, 23, 34} The factors that influence or accelerate the deterioration of an interior finish are as follows.

9.7.1.1 Aggressive Chemical Attack

Interior finishes are susceptible to aggressive water chemistry or to any chemical that is capable of deteriorating cementitious materials or other components of the interior finish. Depending on the value of the Langelier Saturation Index (LSI), a coating can either be stained or etched. Often, staining and etching may be exhibited on the surface of an interior finish as the pool water fluctuates from one extreme to the other. Visible signs of salt crystallization, surface efflorescence, or cracks that are emitting efflorescence or mineral scale deposits are common signs of a positive LSI, or "scaling" condition. Visible signs of etching at the tile line, around fittings, and of check cracks, where the water is capable of leaching cement compounds from the surface, are common signs of an interior finish in contact with a water that has a negative LSI, or "aggressive" condition.

If care is not taken to ensure that the water of a swimming pool is kept in the 'Ideal Range' that is considered by ANSI/APSP Standards^{3,4} to be balanced, and which ensures that a sufficient amount of carbonate alkalinity buffer is constantly present, then the interior finish is considered susceptible to damage from that water and deterioration may result.

Water-soluble salts, acids, or ions such as sulfate, chloride, and bicarbonate can be transported into the matrix of an interior finish and react with the cementitious compounds. The resulting chemical reaction between the cementitious compounds and these salts, acids, or ions, in the presence of water, can cause deterioration to the interior finish. Acidic water aggressively attacks and dissolves the surface of cementitious materials. However, water that has low calcium hardness (soft water), or water that has low carbonate alkalinity can cause leaching of certain compounds from within the cement, especially calcium hydroxide from within the matrix of the interior finish.^{2, 7, 9, 11, 16, 17, 22, 23, 24, 34}

9.7.1.2 Unsound or Reactive Sand/Aggregate Particles

Certain unsound particles of reactive sand or aggregate can react with the cement, in the presence of moisture, to cause deterioration of the cementitious materials. However, it is not likely for a few unsound or reactive sand/aggregate particles (aggregate < 1/8" [< 3.2 mm]) of such small size to create a significant amount of expansion, which would be necessary to cause deterioration within the matrix of a cementitious surface coating.²

Unsound or reactive sand/aggregate particles at, or just below, the surface of the coating, can disintegrate, creating a nominal 1/8" to 1/2" (3.2 mm to 13 mm) diameter pop out or hole. Swimming pool surface coatings are constantly submerged in water of near neutral pH and typically having a low concentration of alkali.

Other impurities in the sand/aggregate that can cause small spots of staining or small spots of deterioration on the surface of the coating generally are found to contain one or more of the following

minerals, elements, or metals: certain clays, certain cherts, certain zeolites, certain shales, opaline materials, certain metals such as iron or copper, and certain minerals containing a high concentration of potassium and/or sodium.

9.7.1.3 Freezing and Thawing Deterioration

Freeze/thaw damage of a swimming pool surface coating is rare due to the fact that the coating remains underwater during its lifetime in most regions of the United States. However, in certain colder regions of the country, a portion or all of the water is drained for winterization. This practice is never recommended, as any portion of the interior finish that does not remain constantly underwater is susceptible to freezing and thawing deterioration, and to irreversible shrinkage. The resulting damage to the cementitious binder causes a weakening of the surface. Initial damage may be limited to efflorescence and laitance at the surface. Continued damage may result in the loss of aggregate, flaking, and peeling of the interior finish surface. The worst freezing and thawing damage is generally seen where the finish is half in and half out of the water, or where the finish undergoes intermittent wetting and drying cycles. Ultimately, freeze/thaw damage can result in a complete failure of the cementitious binder material.

Interior finishes typically have sufficient air-entrainment to resist minor freezing and thawing conditions. Interior finishes that are most susceptible to deterioration by freezing and thawing, are those that have: a dense (non-porous) matrix, a hard trowel finish surface, a sealant or a water-resistant coating applied to the surface; or are placed in an environment where the interior finish undergoes intermittent wet/dry or freeze/thaw cycles.

9.7.1.4 Carbonation

Carbonation proceeds from the surface of the interior finish and progresses inward over time. Carbonation typically only penetrates a portion of the thickness of the interior finish. Carbonation of all cementitious materials takes place predominantly from a reaction with the calcium hydroxide portion of the cement and carbon dioxide in air, or

bicarbonate ions in water.^{2, 7, 8, 9} For swimming pool interior finishes, the rate of reaction and the depth of carbonation varies as a function of the permeability of the material, the prevailing water conditions, and the coating's exposure to a source of carbon dioxide or carbonate ions. Typically, the carbonation of an interior finish is not deleterious. However, if certain conditions prevail, secondary reactions can occur, and deterioration can take place.^{11, 12, 16, 17, 23, 26, 29}

The initial reaction of calcium hydroxide in cement with carbon dioxide (in air) or bicarbonate ions (in water) to form calcium carbonate is beneficial. However, calcium carbonate in contact with water that has a low carbonate alkalinity initiates a secondary chemical reaction that converts the solid calcium carbonate into water-soluble ions of calcium and bicarbonate, which is a deleterious reaction.^{11, 22, 23, 26, 29} Under these conditions, carbonation is considered a deleterious threat to a cementitious surface.

The surface carbonation of a newly-placed interior finish prior to immersion in water (for example, from use of gas heaters or torches while finishing) can exaggerate the mottled discoloration, or blotchy appearance, of the hard trowel finish surface. Increased pollution of the major cities in the United States has contributed to the increased carbon dioxide in the air.

Carbonation of a newly plastered interior finish can also cause shrinkage cracks or hairline cracks to remain open. The calcium hydroxide compound of the cement that typically re-seals these cracks underwater is converted to a less soluble calcium carbonate and is no longer available as a water soluble "filler" of the cracks.^{26, 27}

9.7.1.5 Aggressive Water Deterioration

The term "aggressive water" is considered to be water that is chemically imbalanced and able to remove, dissolve, or otherwise react with materials within the interior finish. Water that has low hardness, low total dissolved solids, low pH, and/or low carbonate alkalinity will deteriorate the interior

finish.^{2, 11, 22, 23} Refer also to the ANSI/APSP Standards, Appendix A. (See Section 9.7.1.1)

9.7.1.6 Leaching Deterioration

Leaching of the soluble cementitious materials can take place whenever water or moisture is allowed to percolate through a cementitious material. Water that is not maintained in the ideal range, or as defined by ANSI/APSP Standards^{3,4} to be "balanced", will deteriorate the cementitious binder by dissolving or leaching the more susceptible cement compounds from within the interior finish.

Aggressive water leaching generally appears as localized etching in spots across the surface, or as etching at the tile line, around fittings, and etching of check cracks. This etching at the surface is the visible appearance of leaching that is occurring within the matrix. These transition areas are susceptible because they are calcium-rich regions and essentially serve as pathways to the inner matrix and more soluble cement compounds whenever aggressive water is present. Continued leaching can cause complete dissolution of the cementitious binder over time in those regions of the coating.^{11, 22, 23, 34}

9.7.2 Remedy

The remedies for repairing a deteriorated interior finish are similar to those described in Section 9.5.3. Lasting repairs should involve the removal of any unsound materials. Patching should match the levelness of the remaining unaffected portion of the cementitious surface and should blend reasonably with the texture and color. Alternatively, widespread deterioration may require replastering the entire interior finish.

10.0 TERMINOLOGY

Acid Washing

1. The cleansing of the plaster surface, through controlled dissolution of the material on a cementitious coating's surface to remove efflorescence, dirt, or other unwanted stains. 2. The process of etching a cementitious coating's surface in order to expose the aggregate or sand to create the exposed aggregate finish. 3. The use of a low-strength (diluted) acidic solution used for removing certain cementitious surface stains, dirt, precipitants, or marks, whereby the stain is removed while little, if any, of the cementitious surface has been compromised.

Admixture

A material other than water, aggregates, cementitious materials, and fiber reinforcement, used as an ingredient of a cementitious mixture to modify its freshly mixed, setting, or hardened properties and that is added to the batch before or during its mixing.

Aggregate

1. The inert granular portion of a mix design that is typically sized, graded, and/or apportioned to maximize a cementitious coating's physical and aesthetic characteristics. 2. The sand, rock, or stone portion of the mix design.

Balanced Water Chemistry

1. The NPC considers "balanced" water chemistry to be swimming pool water kept in such a manner so as to maintain the chemical condition of the water: a) within the approved ANSI/APSP Standards ideal levels^{3, 4} and; b) constantly carrying a sufficient buffer so as to minimize the water's tendency to erode, etch, or otherwise deteriorate the cementitious coating. 2. The process of ensuring that the water's pH, carbonate alkalinity, total alkalinity, hardness, total dissolved solids, and chlorine (sanitizer) content, is being monitored and maintained to be constantly within ideal range (or a "balanced" condition).

Bond (Adhesion)

The ability of a hardened cementitious coat to adhere to the substrate or to a previous cementitious coat by molecular forces, interlocking action, or both.

Bond (Chemical)

Bond between materials that is the result of cohesion and adhesion developed by chemical reaction.

Bond (Cohesion)

The ability of a hardened plaster to hold itself together.

Bond (Mechanical)

The ability of a plaster coat to key into, embed with, or otherwise lock together with an existing plaster undercoat or substrate.

Bond (Failure)

The failure of the cementitious coating to remain adhered to the underlying substrate.

Calcium Chloride

A crystalline solid with the chemical formula (CaCl₂) available in various technical grades, used as an accelerator of cement-based mixes.

Calcium Chloride Solution

An aqueous solution of calcium chloride (usually at a specified concentration so that a given amount can be gauged to provide a specific setting time) expressed as a percent calcium chloride by mass of portland cement.

Calcium Nodule

A slang term used in the swimming pool plastering trade referring to a calcium carbonate formation on the surface of a finish coat resulting from the percolation of water that is capable of leaching cement compounds from voids, bond failures, cracks, or a weak sub-boundary layer in the cementitious coating, which is then precipitated onto the surface.

Cement (Blended)

A hydraulic cement essentially consisting of Portland cement, slag cement, or both, uniformly mixed with each other or a pozzolan or mineral filler through intergrinding or blending.

Cement (Hydraulic)

A binding material that sets and hardens by chemical reaction with water and can do so underwater. For example, portland cement and slag cement are hydraulic cements.

Cement (Limestone)

A hydraulic cement essentially consisting of portland cement and finely interground limestone.³⁵

Cement (Masonry)

(NOT RECOMMENDED FOR SWIMMING POOL FINISHES) A hydraulic cement used for masonry and plastering construction, containing one or more of the following materials: portland cement, slag cement, portland-pozzolan cement, natural cement, slag cement, or hydraulic lime; and, in addition, usually containing one or more materials such as hydrated lime, limestone, chalk, calcareous shell, talc, slag, or clay as prepared for this purpose.

Cement (Plastic)

(NOT RECOMMENDED FOR SWIMMING POOL FINISHES) A cement manufactured expressly for the stucco plastering industry consisting of a blend of cement and lime that may include pozzolans, fillers, or additives to increase plasticity, workability, and crack resistance of the cement and the stucco plaster.

Cement (Portland)

A hydraulic cement produced by pulverizing clinker formed by heating a mixture, usually of limestone and clay, to 1400 °C to 1600 °C (2550 °F to 2900 °F). Calcium sulfate is usually ground with the clinker to control set.

Cement (Portland-Pozzolan)

A hydraulic cement consisting of an intimate and uniform blend of portland cement or portland blast-furnace slag cement and fine pozzolan produced by intergrinding portland-cement clinker and

pozzolan, by blending portland cement or portland blast furnace slag cement and finely divided pozzolan, or a combination of intergrinding and blending, in which the pozzolan constituent is within specified limits.

Check Cracking

1. The common random crack pattern of a plaster surface that generally self-heals through the ongoing hydration and curing process, also known by the slang terms of map cracking, hairline cracking, pattern cracking, or eggshell cracking. 2. Small cracks associated with the shrinkage from moisture loss and consolidation within a cementitious coating during set. 3. Small shallow cracks at closely spaced but irregular intervals on the surface of a plaster.

Compaction

See 'Consolidation'

Cohesiveness

The ability of a fresh plaster mixture to hold together during application and for the mixture to remain inter-mixed during the pumping, placing, and finishing processes.

Cohesion Failure

The failure of the hardened cementitious coating to hold together. (See 'Spalling')

Consolidation

1. The process of reducing the volume of entrapped air in a fresh cementitious mixture, usually accomplished in plastering operations by inputting mechanical energy³⁰ through the use of trowels. 2. The process of improving the density by inducing a closer arrangement of the solid particles in freshly mixed surface coating.

Craze Cracking

A slang term used within the industry referring to small random cracks. (See 'Check Cracking')

Curing (Shell Structure)

The act or process by which the gunite, shotcrete, or concrete, continues hydration. Curing is typically done by wetting the shell frequently to ensure that

the structure of the swimming pool achieves good strength. Wetting the shell frequently also ensures that the absorption capacity of the shell is lowered to a point at which prevents the cementitious surface coating from losing abnormal amounts of mix water during the placement and finish applications.

Curing (Plaster)

The act or process by which the cementitious surface coating continues hydration. Curing is typically done by immersing the cementitious coating in water as soon as possible after final set. The hydration of the cementitious compounds will continue underwater.

Delamination

1. The separation within a material or composition.
2. The separation of the upper surface of the surface coating known also as spalling, a blistering, and/or flaking.
3. The separation between two coats of a cementitious material known also as debond or a bond failure.

Efflorescence

Soluble compounds, predominantly calcium hydroxide, which migrate in presence of moisture, from within a cementitious product to the surface followed by the precipitation and carbonation of the soluble compounds onto the surface.

Etching Deterioration

1. The physical or chemical removal of material from the surface of the plaster.
2. The visible pitting of the surface of the plaster due to chemical or physical processes.
3. Any chemical or physical action on a surface that is capable of removing or dissolving away elements or compounds of that surface. (See 'Pitting' and 'Spot Etching')

Float (Sponge Rubber)

A flat trowel -like tool with varying surface textures of sponge rubber that can be used by a finisher to open the surface, level the surface, retemper the surface, and roughen the surface, which depending on the usage intended will even the drying time across the surface, restore workability, or create roughness needed for bonding a subsequent coat.

Freeze/Thaw Cycle

Seasonal weather and temperature changes that can create expansion and shrinkage within a material, which in turn causes stress within the material and can lead to tensile cracking, debonding, spalling, and delamination.

Gunite

A proprietary term for a type of shotcrete. (See 'Shotcrete-[Dry-Mix]')

Hairline Cracking

A term used to designate any fine or small crack, whether a structural movement crack, or a shrinkage-related crack, that has widths so small as to be barely perceptible.

Hydration

In cementitious materials, the chemical reaction between hydraulic cement and water.

Key

To create a mechanical bond between a plaster coat and another surface by roughening, scratching, scoring, etching, or otherwise creating a surface that the plaster can interlock with.

Laitance

1. A layer of weak material derived from cementitious material and aggregate fines either carried by bleeding to the surface or to internal cavities of freshly placed mixture; or separated from the mixture and deposited on the surface or internal cavities during placement of the mixture underwater.
2. A weak plaster surface of a new plaster that can be easily scratched off using a coin or other dull object.

Lubricate

The acceptable act of applying moisture to the plaster surface, or to the trowel, to maintain moisture within the upper surface and to enable the plasterer the ability to compress, smooth, and hard-trowel finish the surface.

Lubricating Water

The water necessary to allow for the optimum performance of the trowel to smooth or otherwise

work the plaster to achieve the desired surface finish.

Marcite

A regional term that is used in place of the term plaster.

Mottling

1. The blotchy appearance across the surface of a cementitious finish, which can have varying shades of color, usually in a random pattern and are typically more pronounced in darker-colored finishes. 2. The normal variations in a cementitious material as a result of the ongoing hydration process, which typically lessen or disappear over time. 3. The abnormal discolorations associated with trowel burn, trapped moisture, or other situations, that typically do not resolve themselves.

Over-Temper

To add water to a cementitious material in excess, creating a surface coating that is weak or inferior, typically resulting in a weak surface exhibiting laitance.

Pitting

1. A term denoting a form of etching. 2. The development of small cavities in the surface of the cementitious coating. (See 'Etching Deterioration')

Plastic-Shrinkage Cracking

Cracking that occurs in the surface of a fresh plaster soon after it is placed and while it is still plastic.

Plaster

1. A material combination of cement, aggregate, and water, with or without other admixtures, that when mixed thoroughly, placed properly, and finished properly, creates an interior finish coating that adheres to the substrate of the swimming pool structure, that is maintainable and has a desired decorative aesthetic. 2. A mixture consisting essentially of a cementitious material or materials, fine aggregate, and water that forms a plastic mass. When applied to a surface, the mixture adheres to it and subsequently hardens. 3. The act of placing such material.

Plaster Dust

A slang term used in the swimming pool plastering trade referring to the calcium salts, namely calcium hydroxide, that are released from cementitious materials when submersed in water, and if not removed from the water in a timely manner, will react with carbon dioxide or carbonate ions within the water to form a calcium carbonate precipitate.

Pop Out

The breaking away of a small portion of the cementitious coating surface due to localized internal pressure that leaves a shallow, typically conical, depression.

Pop Off

See 'Pop out'.

Pozzolan

A siliceous or siliceous and aluminous material that in itself possesses little or no cementitious value but that will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds having cementitious properties.³⁰

Precipitate

1. The solid material, which is formed out of solution by chemical or physical reaction. 2. In a swimming pool, it is the minerals and/or metals that come out of solution and settle onto the coating's surface that can adhere, resulting in unsightly stains and roughness.³⁷ (See 'Scaling')

Rebound

1. Shotcrete materials, or wet shotcrete, that bounces away from the surface against which the shotcrete is being projected. 2. Any portion of material during shotcreting that is considered "dead" or no longer useable and should be removed from the shell.

Replaster

A re-coating of the interior finish in a pool.

Retemper

1. To add a supplemental dosage of water during mixing to offset adverse placement conditions, such as excessive substrate absorption or excessive evaporation, that would otherwise deplete a significant portion of the design mix water. 2. To add an amount of water necessary to ensure the plasterer's ability to properly pump, place, work, and finish the material by compensating for the water loss due to unforeseen placement conditions. 3. To add a supplemental dosage of water necessary to ensure the material sets hard before it dries out due to prevailing placement conditions. (See 'Supplemental Water', 'Temper' and 'Over-temper')

Sanding

The process of smoothing or polishing the surface of a cementitious coating with power sanders, sandpaper, grinders, or other abrasive, to create a smooth aggregate finish, or to repair rough areas, or to remove stains, or to remove precipitated minerals and/or metals, or to remove adhered plaster dust.

Scaling

1. A mineral compound that precipitates out of solution by chemical or physical reaction. 2. In a swimming pool, it is the minerals and/or metals that come out of solution and adhere to tile, interior finish, or other surfaces, resulting in unsightly stains and roughness.³⁷ (See 'Precipitate')

Set

1. The reaction mechanism that takes place in which the physical, chemical, or mechanical properties develop as a cementitious material changes from a fresh slurry phase to a hardened solid phase in the presence of adequate moisture. (See 'Hydration') 2. The condition reached by a cement, mortar, plaster, or concrete that has lost plasticity and becomes hard. 3. An arbitrary degree of stiffness usually measured in terms of resistance to penetration or deformation.

Shadowing

A slang term used in the swimming pool plastering trade used to denote the light mottling affect caused by the normal early- hydration state of a

cementitious coating that typically lessens or disappears over time.

Shell

1. The structure of the swimming pool that is formed by using wet shotcrete, dry shotcrete (also known as 'gunite'), or concrete, which is either poured, sprayed, or packed into a reinforcement network. 2. The substrate onto which the cementitious coating is applied.

Shotcrete

Concrete placed by a high-velocity pneumatic projection from a nozzle.

Shotcrete (Dry-Mix)

Shotcrete in which most of the mixing water is added at the nozzle. Also known as gunite.

Shotcrete (Wet-Mix)

Shotcrete in which the ingredients, including water, are mixed before introduction into the delivery hose.

Shrinkage-Related Cracking

The cracking of the cementitious coating due to: loss of water; consolidation of materials during set; chemical reactions during hydration; or some combination of these, which occurs during the application process or within twenty-four (24) hours of final set. (See 'Check Cracking')

Smooth

Smooth as defined by the NPC is considered to be a surface finish having a texture no rougher than very fine sandpaper (220 grit).

Spalling

The lifting off or peeling away of the upper surface finish of a cementitious coating.

Spot Etching

A slang term originating in the swimming pool plastering trade that denotes a type of etching deterioration of the surface of a cementitious coating by chemical attack. (See 'Etching Deterioration')

Structural Movement Cracking

The cracking of a cementitious coating due to the structural movement of the swimming pool structure or substrate.

Supplemental Water

1. To retemper during mixing to offset adverse placement conditions, such as excessive substrate absorption or excessive evaporation, that would otherwise deplete a significant portion of the design mix water. 2. To add an amount of water necessary to ensure the plasterer's ability to properly pump, place, work, and finish the material by compensating for the water loss due to unforeseen placement conditions. 3. To retemper during mixing as necessary to ensure the material sets hard before it dries out due to prevailing placement conditions. (See 'Temper', 'Retemper' and 'Over-temper')

Temper

To add water to a cementitious mixture as necessary to initially bring the mixture to the desired consistency to allow plasterers to pump, place, work, and properly finish the material. (See 'Retemper' and 'Over-temper')

Tensile Cracking

The cracking of a cementitious coating associated with bond failure, abnormal shrinkage, or delamination, whereby the cementitious coating is stressed beyond its ability to hold together or to remain bonded, due to pulling forces. The failure of the cementitious coating to hold together caused by the flexing or movement of the substrate or pool structure.

Trowel Burn

A gray mottled discoloration on the newly hardened cementitious surface coating, which generally appears in the shape of, or the 'shaded look' of, the final troweling motions of the technician applying the coating.

Troweling

The hand application, distribution, consolidation and finishing of the surface coating.

Wash-Out

The erosion of a freshly plastered surface coating caused by the fill water, uncontrolled weepers, rain, leaky piping, or some other water source, pouring or flowing over, or directly onto, the finish.

Watertight

The NPC denotes a cementitious surface as being "watertight" when it does not leak water; however, it is known that cementitious coatings are considered semi-permeable membranes and as such, a small amount of water vapor does permeate through the coating, allowing moisture to reach as far as several feet beyond the shell of the swimming pool.

Weepers

A slang term used in the swimming pool plastering trade that denotes any moisture or ground water that can migrate through the shell of a swimming pool from the back side.

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West Conshohocken, PA 19428
www.astm.org

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38800 Country Club Drive
Farmington Hills, MI 48331
www.concrete.org

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25 West 43rd Street
New York, NY 10036
www.ansi.org

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2111 Eisenhower Avenue
Alexandria, VA 22314
www.apsp.org

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Skokie, IL 60077
www.cement.org

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Whittier, CA 90601
www.icboes.org

AC10 Acceptance Criteria for Quality Control Manuals

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5360 Workman Mill Road
Whittier, CA 90601
www.iccsafe.org

Section 104.2.8 and Chapter 47

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The substantive updates and revisions in the 10th Edition are as follows:

1. Section 1.1 ‘*Inspections*’ heading was added to the existing language on inspections in Section 1.
2. The term ‘Arbitration’ was changed to ‘*Mediation*’ throughout the document.
3. Section 2.8 ‘Arbitration’ was moved and revised to Section 1.2 ‘*Mediation*’.
4. Issue dates were removed from ACI reference literature.
5. Revised the usage of multiple terms to describe the interior finish for swimming pools, such as: ‘plaster’, ‘finish coating’, ‘cementitious finish coating’, and ‘surface coating’ to ‘*interior finish*’ throughout the document.
6. Section 2.1.1 ‘Viewing Conditions’ was changed to Chapter 2 ‘*Viewing Conditions*’.
7. Revised title of Section 5.2.1 ‘Surface-Applied Bonding Agents’ to ‘*Surface-Applied Bond Coats*’.
8. Added reference to NPC Technical Bulletin #6 – ‘*Hot Weather Considerations*’ in Section 4.2.
9. Revision of Section 6.1 ‘*Proper Usage of Mix Water (Temper Water) and Supplemental Mix Water (Retemper Water)*’ and Section 6.2 on ‘*Proper Usage of Lubricating Water*’ for accuracy and clarity.
10. Minor revisions and updates to all Chapters.
11. Updated references and added new references to correlate with newly added material.
12. Added terms ‘*Cement (Limestone)*’ and ‘*Scaling*’ and definitions to the Terminology Section.



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