INSTALLATION OF CERAMIC TILE IN SWIMMING POOLS

American Institute of Architects
Continuing Education Seminar

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DESIGN CONSIDERATIONS

I. Primary types of swimming pool structures

A. Cast-in-place reinforced concrete

1. Definition - concrete placed or pumped on-site over steel reinforcing; vertical walls contained by formwork on both
2. Applications - typically large commercial pools, elevated pools, or on-grade pools in areas with poor subsoil conditions.
3. Design considerations for ceramic tile
a. forming & movement joints(general)- vertically formed walls and floors must be cast monolithically in order to avoid cracking and the need for movement joints (internal form must be suspended on external form);form carriers anchored above concrete recommended to avoid form ties. Reactive or dissipating (oxidizing) form release agents are recommended to avoid contamination with water repellent residue. Cast-in-place concrete more likely to crack from drying shrinkage and other factors if left to dry > 3 months after placement; damp cure for 7-14 days ; requires careful design consideration of movement joints; joints in shell must continue to ceramic tile surface to prevent random cracks from developing and transmitting to ceramic tile surface; increased steel reinforcing will increase resistance to shrinkage cracks (isolation membranes not recommended unless full coverage of pool shell with waterproof anti-fracture or crack suppression membrane
b. recommended to increase concrete coverage over steel reinforcing by 1/4 in (6 mm) to compensate for any bulk surface removal required to prepare surface (see below).

B. Gunite or shotcrete reinforced concrete

1. Definition -mortar or concrete projected through a hose and pneumatically projected at high velocity onto a reinforced surface, usually formed on one side by soil excavation.
2. Applications - below grade, small residential or light commercial pools with good subsoil conditions; may also be used over formwork.
3. Design considerations for ceramic tile
a. eliminates movement joints in pool shell - typically gunite pools do not require movement joints in the shell because the tendency for cracking from thermal movement is reduced. However, movement joints in tile surface required to accommodate thermal and moisture movement of tile of pool emptied for maintenance
Gunite walls thinner- absence of formwork means less heat from hydration resulting in less thermal induced plastic shrinkage stress.

Gunite is typically reinforced with high tensile steel fabric which provides a greater resistance to normal reinforcing size and frequency typical of cast-in-place reinforced concrete .

Quality gunite typically has a very low water to cement ratio cement, thus less susceptible to drying shrinkage cracking.

Compressive strength of quality gunite 8,000 psi (55 Mpa) with equivalent increase in tensile strength over typical cast-in-place reinforced concrete 3,000 psi(20 Mpa).

b. configuration problem for ceramic tile - structural design of gunite pools typically requires a radiused cove at floor-wall intersection, making larger ceramic tiles difficult to install

II. Movement / Expansion Joints

A. General - movement joints are necessary in cast-in-place concrete pool shells and typically not required in most small gunite concrete pool shells (see above); the structure of the pool requires careful design and construction sequencing in order to minimize the number of movement joints required.

lack of movement joints are one of the leading causes of failure in ceramic tiled pools, especially when pools are allowed to dry for long periods (> 3 months) after initial placement of concrete,when tile is installed within one month of concrete pour , or when pool is emptied for maintenance and allowed to dry out. Movement joints are often omitted because of difficulties with waterproofing /sealant installation and pool maintenance.

1. construction / cold joint - walls / floors typically are cast monolithically but large pools require multiple pours ; concrete will crack at these weak intersections and require movement joint with integral waterstops

2. control joint - prevents random cracking by controlling drying shrinkage in straight line; typical eliminated by use of additional reinforcing to control shrinkage and keeping concrete from drying out before filling.

3. expansion joint - accommodates thermal and moisture movement in large pools. *Example* - 50 m (164 ft) length pool expands 10 mm (.4 in) on average after filling and requires aggregate joint width 3-4 times the anticipated movement or 30-40 mm (1-1.5 in) wide.

4. sealing movement joints - whether a pool needs to be completely waterproof (prevents any leaks), or watertight (monolithic structure which contains water with minimal absorption and leakage), movement joints must be designed to prevent rapid loss of water.

a. primary protection - sealants provide primary closure of joints and can not provide 100 % effectiveness as a barrier to water leakage. Sealants must be suitable for water submersion and be installed with proper backer rods and tooling by specialists.

b. secondary protection - waterstops are flexible plastic or butyl rubber devices which are integrally cast in, or placed below movement joints in pools to provide a flexible yet monolithic, watertight connection across movement joints. Waterstops are critical secondary protection even when waterproof membranes are specified.

INSTALLATION PROCEDURES

I. Surface Preparation

A. Preparation and Cleaning - Concrete pool shells are rarely smooth , free of contamination and defects, and level enough for direct bonding of waterproof membranes or ceramic tiles. Improper preparation and cleaning are a primary cause of failure of waterproof membranes and leveling mortars (renders and screeds) in pools. Cast-in-place concrete walls present specific defects such as form release or curing agents, and surface defects such as honeycombing and laitance. Floors are subject to surface defects such as dusting,crazing,and laitance from improper finishing, as well as significant ground in construction contamination.

1. Typical Methods

a. High Pressure Water Blasting - 5,000-8,000 psi (34-54 Mpa) to remove severe contamination by removal of top 1/8-1/4 in (3-5 mm) and to expose aggregate for improved mechanical bond of standard Portland cement leveling mortars (screed and renders).

b. High Pressure Water Cleaning - 1,000 psi (6.8 Mpa) to clean surface dirt and contamination or weakened surface layer (laitance) without aggregate exposure; use in conjunction with detergents and degreasers to remove dirt or light coatings of oil or other contamination.

c. Shot blasting - effective for floors and walls (with hand held equipment); removes and collects debris in one step from top layer 1/16-1/4 in (1-6 mm) with fine to coarse steel pellets. Use to remove existing paint coatings or concrete surface defects such as laitance.

d. Grinding - variety of mechanical scarifying methods available, must insure final cleaning of residue with high pressure water or air

e. Grit Blasting - includes traditional sand blasting, which is effective but intrusive and hazardous; or new methods incorporating water soluble, mechanically refined sodium carbonate grit media

f. Acid cleaning - this method is not recommended if other methods are available because improper dilutions and improper application methods (failure to saturate surfaces with water) and improper neutralizing/rinsing of residue can deteriorate concrete surface and or cause post installation efflorescence from residual soluble chlorides. Residual chloride can also inhibit bond, accelerate set of cement based mortars and adhesives, or cause chloride ion deterioration of steel reinforcing.

g. Low pressure water/scrubbing - ordinary garden hose washing with bristle brush scrubbing is satisfactory if concrete has no surface defects or oily, organic contamination. Any cleaning agents must be completely rinsed/neutralized.

B. Wall Patching, Plastering or Rendering - necessary if concrete can not be designed and finished accurately to meet levelness (flatness) tolerance for direct application of ceramic tile using thin set method 1/8 inch in 10 ft (3 mm in 3 m) or if plumbness (vertical) deviation is within 1 inch (25 mm).

1. Latex Portland cement leveling mortar (render) - 1:3 pc: masonry sand with latex additive recommended for best adhesion and performance under thermal and moisture movement differential and exposure to effects of water treatment; should be mixed to a plastic consistency and applied no greater than to 1/2 in (12 mm) thick per application; carry underlying movement joints to surface.

2. Portland cement mortars - same requirements as above, except surface preparation must expose aggregate of concrete, or spatter dash coat must be applied to increase mechanical key for improved bond typically provided by latex additive.

C. Floor Leveling or Screeding - necessary if concrete can not be designed and finished accurately to meet levelness tolerance for direct application of ceramic tile using thin set method 1/8 inch in 10 ft (3 mm in 3 m).

1. Latex Portland cement mortar - same type of mortar as B.1 above,applied from 1-2 1/2 in (25-65 mm) mixed to a semi-dry consistency and placed over a latex/cement slurry bond coat, leveled between screeding boards and thoroughly compacted.

II. Waterproofing

A. Methods of waterproofing swimming pools

1. External or "sandwich" slab waterproof membranes - sheet or fluid applied membrane installed between two layers of concrete or between grade and concrete shell; this method is costly and typically used when external or negative hydrostatic water pressure is present to protect ceramic tiles from delamination when pool is emptied, or with membranes that do not allow direct adhesion of ceramic tile.

2. Direct bond waterproof membranes - sheet or fluid applied membrane designed for direct bond of ceramic tile using adhesive mortars. Protects underlying leveling mortars and concrete shell from saturation and prevents problems caused by moisture penetration such as moisture expansion, chemical attack (chloride ion deterioration of reinforcing steel), and efflorescence.

3. Crystallization additives or coatings – this type of waterproofing is either dosed as an additive to the ready-mix concrete, or applied as a coating after the concrete is set, but while still damp. These products work by combining with free calcium hydroxide produced by the cement hydration to form a crystalline growth which eventually fills the pores of concrete over time and renders the concrete waterproof under hydrostatic pressure. The problem with subsequent tile installation is that the resulting decreased porosity of the concrete makes tile adhesion with cementitious adhesives difficult. Manufacturers of these products limit or provide no guarantee of tile adhesion.

B. Water / Flood testing - Test for watertightness after application of any renders, screeds and waterproof membranes are complete; observe minimum manufacturer's cure times for membranes (> 14 days). Fill at slow rate of 2 ft (600 mm) per 24 hours and test for 7 days after filling. Maximum water loss not to exceed 3/8 in (10 mm) from absorption and slight seepage. If waterproof membranes are not used, allow saturated concrete and renders / screeds to dry out to some extent prior to installation of ceramic tile finish

1. Leak detection - The use of fugitive dyes such as food coloring or proprietary leak detection products in conjunction with scuba diving equipment are an effective method to trace any leakage detected during flood testing.

III. Selection and Installation of Ceramic Tile

A. Considerations for selection of ceramic tile

1. Pre-mounted ceramic mosaics - use of paper faced ceramic mosaics is recommended; use precaution when considering back mounted mosaics using PVC rubber dots or adhesive mounted mesh; the types and quality of mounting methods vary and resulting bond strengths may be very low after saturation and chemical attack of pool water.

2. Moisture expansion - use only impervious (< .5 %) or vitreous (< 3%) tiles to reduce effects of moisture expansion, or in the case of exterior pools in cold climates to eliminate freeze/thaw problems . Tiles over 3-7% absorption may permanently expand from moisture exposure and can delaminate from excessive differential movement

B. Installation recommendations

1. Dry-set thin set mortars - cost effective with adequate performance under ideal conditions; do not withstand chemical attack or significant differential movement from moisture expansion and drying shrinkage

2. Latex adhesive mortars (thick or thin bed) - use latex additives suitable for water submersion; avoid soluble polymers such as PVA or dry re-dispersible polymers such as EVA; latex improves adhesion, reduces chemical attack by coating Portland cement, and imparts flexibility to withstand moisture expansion and shrinkage

3. Epoxy adhesives - recommended to eliminate deterioration from chemical attack; many epoxies suitable for interior and exterior, and have flexibility and exceptional adhesive qualities to withstand differential movement from thermal and moisture expansion and drying shrinkage.

IV. Grouting of Ceramic Tile

A. Types of Grouts

1. Portland Cement - Portland cement grouts mixed with water are cost effective grout joint filler, but do not withstand attack from water treatment and become rough or need periodic replacement/repair.

2. Latex Portland Cement - latex additive coats Portland cement particles and pigments and reduces attack from water treatment chemicals; latex imparts flexibility to withstand moisture expansion when pool filled and shrinkage when emptied.

3. Epoxy - 100 % solid epoxy contains no Portland cement and is not subject to effects of water treatment resulting in a hygienic and permanent grout surface; epoxies may discolor when exposed to ultraviolet rays in exterior application, but no effect on performance.

4. Movement joints - in addition to any movement joints carried through from the underlying concrete shell to the ceramic tile surface, additional joints must be provided every 12-16 ft (4-5 m) in exterior pools to provide for thermal or moisture movement, especially upon emptying of pool for maintenance.

a. sealants for movement joints - Recommended type of sealant is a two-part bulk grade polyurethane or a one-part cartridge grade polyurethane suitable for constant water submersion.

MAINTENANCE

I. Opening, seasonal closing, and idling for maintenance repairs

A. Curing -Observe an average minimum cure time of 14 days for Latex Portland cement installations to prevent latex migration and 7 days for epoxies to reach maximum chemical resistance prior to filling pool. Curing times can be significantly increased or decreased due to temperature and humidity effects on curing.

B. Filling - fill pool with water at rate of 2 ft (600 mm) per 24 hours to allow gradual exposure to water pressure, thermal and moisture differentials Initial alkalinity of pool water is very high from exposure to Portland cement based finishes, grouts, and mortars; careful and frequent balance is required (see *balance* below). Do not fill if potential thermal gradients exist (very cold source water, exterior pool exposed to several days of solar radiation

C. Draining - empty pool water at rate of 12 in (25 mm) per 24 hours to prevent hydrostatic pressure from delaminating tiles or leveling mortar (in pools with waterproof membrane). Pool must have hydrostatic relief valve to allow any ground water pressure to be released into the pool rather than on the pool shell. Slow draining rate allows pressure to be relieved at a rate commensurate with the volume capacity of the relief valve. Failure to properly relieve pressure can result in catastrophic structural damage to the pool shell, waterproof membrane and tile finish.

D. Closing (seasonal) - pool should be drained only below outlets and kept partially filled to minimize stress on the tile. Keeping pool filled prevents negative hydrostatic pressure(absorbed water within pool shell and from subsurface ground water) from affecting ceramic tile and waterproofing bond,and prevents significant movement that can occur from drying shrinkage and thermal differential.

II. Effects of Water Treatment in Ceramic Tiled Swimming Pools- Swimming pool

water chemistry is a very complex, but essential component to proper operation and maintenance of a ceramic tiled swimming pool.

A. Source water – source water typically has sulfate content of trace to 250 ppm. Concentrations over 250 ppm can be corrosive to cement materials.

B. Disinfection -Chlorine is the most popular and effective disinfection agent for swimming pool water. Bromine, chlorine gas, ozone and other non-chemical disinfection systems available

1. common misconception is that chlorine treatment is the cause of attack and deterioration of Portland cement materials used to install ceramic tile in swimming pools. This is basically not true; any concentration of chlorine high enough to aggressively attack Portland cement based materials would cause bathers to become seriously ill. Chlorine is only strong enough to eliminate bacteria and algae growth. Improper chlorine levels (1.0-2.0 ppm normal level) will make balance of water (see below) difficult.

2. Chlorine uses and depletes calcium during the disinfection process; calcium balance is essential to prevent calcium depletion and deterioration of cement mortars and grouts

C. Water balance- the balance of the water is primarily responsible for problems with maintenance of ceramic tiled swimming pools. Acidity, alkalinity and the amounts of mineral salts (water hardness) in swimming pool water must be kept in balance to prevent, among other things, contamination and deterioration of Portland cement based grouts, adhesive mortars, and leveling plasters.

1. pH value - The term pH is used to measure balance between acidity and alkalinity of water on a scale of 0-14, with 7 indicating a balanced or neutral state. Swimming pool water needs to maintained between a pH of 7.2 & 7.8. If pH is too high (alkaline), mineral deposits will form on tile and grout, especially at the waterline. Mineral deposits may also form beneath the surface of ceramic tiles and exert pressure resulting in decreased bond strength or delamination.

If pH is too low (acidic), etching and deterioration of Portland cement based materials will occur. If this condition persists, grout may become rough or completely deteriorated, leading to further deterioration of adhesive mortar and leveling mortars beneath the tile.

2. Mineral content (calcium hardness) - water hardness or the amount of calcium is defined as the quantity of dissolved minerals (calcium) in water. If the level of calcium is too low (below 200-250 ppm, pool water will use the free calcium present in cement grout, leading to deterioration and etching. Balancing minerals (calcium) will also reduce mineral deposits on ceramic tiles, grout, as well as prevents deposits and corrosion of pool plumbing.

3. Total Alkalinity - measures the amount of carbonates in the pool water, which are buffering agents that control pH. Low total alkalinity results in an acidic condition and unstable pH levels, resulting in corrosive effect on cement materials.

4. Metal content - Iron and copper are common metals occurring in source water. At low pH (acidic below 7.2) metals are in solution. At normal pH (7.2-7.8), metals are out of solution. Dissolved metals can be deposited as a stain on ceramic tile, grout, and pool fittings/ fixtures