FACTORS AFFECTING GROUT PERFORMANCE IN SWIMMING POOLS

Mike Wheat

Technical Director
Norcros Adhesives, UK

INTRODUCTION

In all communities the public swimming pool is an important asset both as a social and leisure facility and as a revenue generator. When a municipal pool is forced to close for unplanned reasons protests from the public are voiced in the local newspapers, on local radio stations and in the Council meeting rooms. Closure of the swimming pool is a very emotive topic and it can give rise to all sorts of rumours, including speculation that the reasons are associated with health risks to the community.

In many instances pool closure may be associated with poor workmanship, incorrect material specification or, more frequently, with ineffective pool management, especially of the pool water chemistry. During the last few years there have been several examples in the UK of large municipal pools which have had to be closed due to serious grout erosion or grout attack problems.

The paper sets out to examine some of the key design and operational factors which can influence grout performance in pools, calling on the experiences of many countries in Europe.

TYPES OF POOLS

The typical swimming pool complex will consist of a number of different areas utilising tiled surfaces, falling into the following broad categories:

(a) Water retaining structures/immersed surfaces.

(b) Wet trafficked areas.

(c) Dry trafficked areas.

Pools can vary from simple water retaining tanks to complex combinations of different water area types and experiences.

There are essentially four broad categories of pools when considering the design criteria. These are;

- Competition swimming pools - traditional rectangular swimming pool tank, usually 25 metre or 50 metre in length.
- Leisure Pools - variety of pool shapes in a free form style.
- Hydrotherapy pools - used to provide orthopaedic exercise and physiotherapy in hospitals and sports clinics.
- Health club, hotel and private facilities - facilities with specific category of user.

The pool water chemistry and operating temperatures of the different types of pools will vary and hence grout specification and performance can be affected. Similarly, any feature or equipment incorporated into the pool should be considered at the design stage when choosing the grout. Features such as;

- Moveable floors
- Booms
- Starter blocks
- Water features (wave machines, rapid water rides)
- Heated benches
- Bubbleseats
- Aqua sports (canoeing, sub-aqua during equipment)

REQUIREMENT FOR SUCCESSFUL POOL OPERATION

The choice of construction methods and the specification of materials associated with the build up of tiled finishes to swimming pools and ancillary areas is wide and varied, however, the goals to be achieved for a successful facility are;

1. Safety in use
2. Durability of performance of finishes
3. Technical performance of a specialist facility
4. Aesthetic performance

It can be argued that the tile grout can either play a part or can influence all four of these factors. To achieve the required standard of appearance it is essential to ensure that the quality of the workmanship and associated materials match those required standards.

There are four principal contributors to the quality of the tiling finish, namely;

- The quality of installing the tiles
- The quality of the grouting operation
- The quality of the grout
- The tile surface

Nothing detracts more from the appearance of the tiling finish than poor setting out, bad alignment, tile lipping etc. Quality installation begins with ensuring that the surface preparation and condition of the background are as recommended. The use of the correct tools, especially notched trowels, when applying the adhesive will influence the surface trueness of the tiling and the selection of the most appropriate adhesive to suit the combination of substrate, tile and service conditions is important. Equally, the adoption of the correct fixing method, especially on floors, will often play a part in the final appearance of the grouted joints. Voids in the bedding beneath tiles lead to the grout slumping in the joints, which, in turn, creates a reservoir for dirt accumulation, a situation made worse by a badly tooled, uneven grout surface. Further aspects of attaining a good standard of workmanship include setting out, cutting, alignment of joints and trueness of the finished plane of tiling.

We have all seen how shoddy grouting and poor quality joint finishes can spoil the appearance of even the most attractive of tiles. It is recalled that many years ago, Derek Johnson, the then Chairman of H&R Johnson Tiles, was always complaining that poor grouts and grouting ruined his beautifully crafted tiles - and he was usually right.

The final visual effect is the key in assessing the quality of grouting and to this end, the uniformity of the tile joints and the properties and composition of the grout are vital to success. The benefits of one component systems in ensuring consistent quality can assist and application, cleaning off and smoothing are critical.

GROUT QUALITY AND PERFORMANCE

Naturally, the quality and overall appearance of the grout itself and its ability to retain the original "as-finished" appearance through cleaning and maintenance regimes is a critical factor.

The presence of salts giving rise to efflorescence, the effect of water quality (hardness/softness), fast tracking and so on are all influences on appearance and durability. The inherent performance of the grout is what we are really focusing on in the paper. For the first time ever in Europe we shall soon have European Standards (EN) for ceramic tile grouts. The Standard will specify minimum performance requirements for flexural strength, compressive strength, shrinkage, abrasion resistance and surface water absorption.

The transverse deformation test, illustrated here, which measures the deformability of a cast film of product, is applicable to cementitious grouts as much as it is to adhesives and there is a strong likelihood that we shall see a classification system being introduced for grout flexibility.

Others properties which are clearly important, especially in showers and swimming pools are water resistance and water absorption. Fungal and bacteria resistance are also key issues and the ability of the grout to perform in a wide range of joint widths is another factor. Other performance parameters include colour, surface finish and the ability to resist staining.

We can see from the following tables an illustration of the performance requirements to be demanded in the European Norm grout standard.

Specification for Cementitious Grouts	
1a Fundamental Characteristics	
Characteristic	Requirement
• Abrasion resistance	≤ 2000 mm^3
• Flexural strength under standard conditions	≥ 3.5 N/mm^2
• Flexural strength after freeze-thaw cycles	≥ 3.5 N/mm^2
• Compressive strength under standard conditions	≥ 15 N/mm^2
• Compressive strength after freeze-thaw cycles	≥ 15 N/mm^2
• Shrinkage	≤ 2 mm/m
• Water absorption after 30 minutes	≤ 5g
• Water absorption after 240 minutes	≤ 10g

Table 1.

Specification for Cementitious Grouts	
1b Additional Characteristics	
Characteristic	Requirement
• High abrasion resistance	≤ 1000 mm^3
• Reduced water absorption after 30 minutes	≤ 2g
• Reduced water absorption after 240 minutes	≤ 5g

Table 2.

Specification for Reaction Resin Grouts		
Fundamental Characteristics		
Characteristic	Requirement	Test Method
• Abrasion resistance	≤ 250 mm^3	EN 12808-2
• Flexural strength under standard conditions	≥ 30 N/mm^2	EN 12808-3
• Compressive strength under standard conditions	≥ 45 N/mm^2	EN 12808-3
• Shrinkage	≤ 1.5 mm/m	EN 12808-4
• Water absorption after 240 minutes	≤ 0.1g	EN 12808-5

Table 3.

Classification and Designation		
Symbol		Description
Type	Class	
CG	1	Normal cementitious grout
CG	2	Improved cementitious grout with additional characteristics (high abrasion resistance and reduced water absorption),
RG	1	Reaction resin grout

Table 4

There are fundamental or mandatory requirements for abrasion resistance, flexural and compressive strength, shrinkage and water absorption but, as with adhesives, there is also a higher performance category for abrasion resistance and water absorption which reflects the enhanced properties conferred by polymer modification. There is just one set of fundamental performance requirements for reaction resin grouts, accepting that these materials are inherently high performance products.

These sets of requirements give us a much simpler classification system than the one for adhesives, with two classes for cementitious grouts and one for reaction resin grouts.

Of course, the ability of the tile surface to retain its appearance, especially over time, through cleaning and maintenance is also an important factor. When it comes to grout specification in swimming pools less thought is generally given to the type of grout which is most suitable for the type of water and the service conditions to which the pool will be subjected. In many cases a basic cementitious grout of the CG1 classification in the European Norm will be specified.

Historically of course, most people would use neat white cement as the grouting composition but the shrinkage and rigidness of this make it unsuitable in today's environment. In recent years we have seen the development of a range of proprietary grouts using special cements and redispersible polymer powder technology, as well as a wide range of epoxide resin based systems, particularly those possessing water wipeability (ease of cleaning off during application).

FACTORS AFFECTING THE SELECTION OF GROUT IN SWIMMING POOLS

Where tiles are installed in swimming pools it is important that the grout will resist the effects of the pool water and other chemicals that come into contact with the tiling. If proper consideration is not given to this requirement the long-term durability of the installation will be put at risk. Even when the grout meets these criteria it is still necessary for the pool water to be maintained in a non-aggressive condition. Selection of the grout used in swimming pools is influenced by the following factors;

- Type of tile being used
- Quality of mains water supply
- Pool water treatment
- Balance index of the pool water
- Chemicals used for cleaning and maintenance
- Design of pool, features and location of tiling

TYPE OF TILE

Tiles for use in swimming pools should have a low absorption of 3% or less, classified as type A1 (EN121-extruded) or B1 (EN176 - dust pressed). Tiles for shallow beach areas, steps and ramps must conform to an appropriate classification for co-efficient of friction, "eg Classification C" when tested according to DIN51 097-1992 Ramp Test. This rating will only be maintained with the use of a suitable cleaning regime.

Mosaics used in pools are usually fully-vitrified ceramics or glass.

When selecting a grout for use with these tiles the lower the water absorption the stronger the case for using a polymer modified product since this will have enhanced adhesion to the tile edges.

POOL WATER CHEMISTRY

It is clear that more and more countries have become increasingly aware of the potential attack of cementitious grouts by pool water and pool water chemicals. Pool water management is such a complex and vital part of the pool's safety and durability that, in the UK, a body known as the Pool Water Treatment Advisory Group (PWTAG) has published a comprehensive book of some 23 Chapters and over 140 pages solely on the subject of controlling and managing the pool water chemistry. Topics covered include:

- Water standards
- Pollution and hygiene
- Disinfection
- Water circulation
- Filtration
- pH value
- Water balance
- Infections - healthy swimming
- Microbiological monitoring
- Pool water chemicals
- Plant maintenance
- Cleaning

The majority of the above factors can have an influence, direct or indirect, on the grout performance in a swimming pool. Two of the most important elements are the nature and quality of the mains water supply and the use of pool water chemicals.

Specifically, the calcium/hardness level in the incoming water and the control and dosing of sulphate-containing chemicals into the pool water.

MAINS WATER SUPPLY

The composition and properties of the mains water supply will generally be governed by the geological nature of the water source. Water is taken from deep boreholes, shallow wells, springs, lowland lakes, reservoirs, rivers and upland streams. The nature of the rock or soil in contact with the water will determine the mineral content in it. With granite, water dissolves very little in terms of hardness, alkalinity or mineral salts and so soft water is produced. Many parts of the UK and Scandinavia have this type of water. Limestone or chalk formations and lowland rivers tend to provide the calcium salts found in hard water.

In some countries, and certainly in England, mains water supply can vary from day to day depending on the distribution network. It is quite normal in some areas to supply hard water some of the time, soft water at other times and even, on occasions, a balance of the two.

For the purpose of swimming pool water treatment hardness is usually termed total hardness (sum of calcium and magnesium contents), expressed as calcium carbonate. Different countries have different limits to classify a range from very hard to very soft water. The two examples shown illustrate the differences in the UK and Germany.

Characteristic		Hardness (mg/l $CaCo_3$)
Very soft	UK	<70
	Germany	<72
Soft	UK	-
	Germany	>72, <144
Slightly Hard	UK	>70 <140
	Germany	>144 <216
Moderately Hard	UK	>210 <280
	Germany	>216 <343
Hard	UK	>280 <420
	Germany	>343 <540
Very Hard	UK	>420
	Germany	>540

Table 5.

The basic principles are that ;

1. The higher the calcium content, the greater the potential for scale deposition.
2. The lower the calcium content, the greater the potential for corrosion and grout erosion.

It can be seen that the UK and Germany are in agreement that below 70mg/l. $CaCo_3$ (28mg/l Ca^{2+}) water is classed as very soft and hence becomes aggressive. Thus in soft water areas it is advisable to increase the calcium hardness content by using calcium compounds, such as calcium hypochlorite, as the disinfecting agent. However, it would be considered prudent to use an epoxide resin grout in such circumstances.

WATER BALANCE

Whilst grout loss in pools and on pool surrounds is well known where aggressive (very soft) water is present it is clear that more grout problems occur through the mis-use of dosing and cleaning chemicals.

Where alkaline disinfectants are used pH value correction is normally carried out by the addition of an acidic material, eg a solution of sodium bisulphate (dry acid). Too much sulphate or the use of the wrong dosing procedure (lowering bucket of sodium bisulphate directly into pool water) can cause severe corrosion problems. Initially, the grout will be affected but ultimately the adhesive, screed, concrete and even the glaze on the tile itself can be affected. The maximum permitted concentration of soluble sulphates in swimming pool water is generally accepted as 300mg/l (expressed as SO_3, equivalent to 360mg/l SO_4). This is a maximum level and the level in the pool water should be kept as low as possible since the rate and effects of sulphate attack will be dependant on concentration.

It is interesting to compare the experiences of countries throughout Europe with regard to the effect of hardness levels and the use of chemicals on the performance of ceramic tile grouts.

The experiences through Europe show good correlation with the geological regions from North to South. We can see that there is a clear trend towards an increasing use of epoxide resin-based grouts, especially in public pools. It is estimated that the use of

COUNTRY	MANUFACTURER/ TEST HOUSE	EXPERIENCE	CURRENT RECOMMENDATIONS	OTHER COMMENTS
Austria	A (Test House)	Attack of cementitious grouts well known but usually due to "wrong" water treatment and excessive use of water chemicals. Some leaching due to soft water.	Reaction resin grouts used in most public pools. Some public pools use epoxies around water line and cementitious below. Cementitious used in private pools.	Do not support artificial hardening of water as staining, scaling, encrusting etc can occur. Safest solution is use of reaction resins.
Finland	B	Numerous examples of soft water eroding cementitious grouts. Similar experiences with soft "Fjord water" in Norway.	Optiroc (formerly Partek) ban cementitious grouts in swimming pools – only epoxies recommended.	Hard water areas in Finland suffered no problems with grout erosion of cementitious materials.
France	C	Problem well known in Europe but only partially due to low hardness. Most problems caused by other chemicals. Bacteria and fungus development also experienced due to porosity and pH.	Specify epoxy, cement epoxy or polymer-modified cementitious grouts for public pools.	Pure water corrosive to cement.
Germany	D	Grout attack mainly from aggressive chemicals and wave movement, not soft water.	Generally recommend epoxy grouts for improved wear and water resistance.	Many problems ± 20cm of water line.
	E	Water 20-40 mg/lit calcium classed as aggressive to concrete and cementitious materials. Ca++ over 70, risk is small but can have problems at "pool head" and channels.	Epoxy grout generally recommended but if Ca++ over 70 cementitious used except at "pool head" and channel.	Levels of 50mg/lit far too high. Cost of maintaining this level would be greater than using epoxy in first place.
	F	Below 50-60mg/lit. Ca++ problems known to occur with cementitious grouts.	Stipulate >60mg/lit Ca++ hardness, water must have limestone – CO_2 equilibrium, pH 7.2-7.6.	White and grey cementitious products suitable in defined conditions.
	G	Grout loss problems rare. Where it has occurred acidic chemicals usually the cause. Low Ca++ out of grout over a period of time.	Cementitious grouts suitable unless water very aggressive.	Oppose high levels of Ca++, will create deposition (scaling) on tiles, joints, fittings etc.
Holland	H	**Not a common problem in Holland. No special requirements for water in swimming pools.**	**Recommended epoxy as first choice but if too expensive polymer-modified cementitious.**	**350mg/lit Ca++ far too hard. 72mg/lit is regarded as quite hard.**
Italy	I	**No problems experienced with cementitious grouts in hundreds of pools.**	**Standard cementitious grouts.**	**Any problems more likely to be associated with aggressive cleaning disinfecting chemicals.**
Sweden	J	**Very few problems over 30 years with cementitious grouts. One pool, Ca^{2+} 10mg/l suffered grout erosion.**	**Sometimes recommend epoxy at water line; cementitious elsewhere.**	**Subject of calcium concentrations rarely considered.**
Switzerland	K	**Occasional problems in soft water areas of Switzerland.**	**Cementitious grouts used but epoxy grouts generally recommended.**	**German DIN Standards used as reference for Ca^{++} levels.**
UK	L	**Few problems directly related to soft water. Far more where sodium bisulphate added directly into pool.**	**Cementitious or polymer-modified cementitious. Epoxies being used more frequently.**	**350mg/lit Ca^{++} is considered far too high. 200 mg/l $CaCo_3$ (80 mg/l Ca^{++}) acceptable.**
	M	**Examples of soft water erosion in UK.**	**Increase Ca^{++} hardness of water. Epoxy occasionally recommended.**	**Figure 200mg/litre Ca^{++} suggested.**

Table 6.

epoxide instead of cementitious grout will generally add around 10-15% to the overall tiling and grouting costs for a 25m pool. This extra cost could be less than the chemical cost of artificially increasing hardness. In addition, if it adds to the long-term durability and reduces repair and maintenance costs then it could prove to be a very cost-effective measure.

Other chemicals which can have a detrimental effect on grout performance are strongly acidic cleaning chemicals, often used on the pool surrounds. These materials should be used in a dilute form but occasionally, especially to remove stubborn stains, they are applied in a concentrated form; this gives rise to attack of cementitious grouts.

Other factors which can contribute to grout erosion are those associated with mechanical forces such as the effects of wave machines, rapid water rides and run out areas beneath flumes. In these areas epoxide resin grouts are normally recommended.

Grouts can be the subject of the growth of algae on their surface especially in outdoor pools or indoor pools exposed to sunlight, particularly where the pool hydraulics are poor. The introduction of canoes, for example, can give rise to algae and even phosphates used in mains water treatment can cause algal growth. It is important to act immediately when these are signs of algal growth. With no-one in the pool brush and vacuum off algae, increase disinfectant levels and filter off the detached algae. If unsuccessful it will be necessary to use a proprietary algicide. Algal growth should not happen if the pool is designed and operated correctly.

CONCLUSIONS

It is apparent that if the pool water management is carried out properly and efficiently then polymer-modified cementitious grouts should perform perfectly satisfactorily in conventional swimming pools. However, it is recognised in many countries, and through their relevant trade associations, that those responsible for operating the plant still have much to learn about the chemistry of pool water, especially the control of sulphate ion concentration. In the meantime more people are specifying and using epoxide resin grouts as an insurance against poor water management.