DAMAGE WHEN TILING SWIMMING POOLS AND ITS AVOIDANCE

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ABSTRACT

In this age of wellness and body culture, elegant bathing temples and sauna facilities are springing up everywhere. Ceramic coverings and glass mosaic in different colours and glazes give these facilities their timeless elegance. In order to preserve these qualities for as long as possible, all the skills of the tile-layer are required, both in terms of waterproofing and laying work.

Before the tile-laying work can be carried out, the waterproofing of the pool shell must first be carried out properly. While the wall and floor surfaces can be waterproofed without any problem, the waterproofing of floor drains, installation apertures and connection joints requires expert know-how. This document presents suggested solutions for the reliable waterproofing of these problem areas, placing particular emphasis on the laying of the pool head shaped components and fitting of the capillary break.

After a successful two week leakage test, the tiles and mosaic finally can be laid. The water quality must however be analysed as early as the planning phase. The decision must also be made as to whether cement waterproofing, laying and grouting products can be used, or whether epoxy resin-based materials must be used. The lime index method according to Felixberger (LI_F) enables a quick and reliable estimate of the lime-carbonic acid equilibrium of the pool water. The determination of LI_F requires only the pH value, the calcium hardness and the acid capacity of the water. For $LI_F > 0$ cement products can be used in the underwater area. In case of $LI_F < 0$ with increasingly more negative LI_F, the grouting, laying and waterproofing work must be carried out using epoxy resins.

Glass mosaic stands out for prestige and design. Several aspects however need to be taken into account during laying. In permanently wet areas, mesh mounted mosaic must not be used, since otherwise cavities or micro-organisms can develop. The adhesive of the front side paper gluing must be washed off before grouting and completely removed from the pool. In the case of translucent mosaic, care must be taken to ensure cavity-free bedding of the stones, since otherwise brown stains will develop on the rear side of the mosaic after filling the pool.

Even if the laying work is carried out extremely accurately, it cannot be emphasised often enough that the water treatment is decisive for the durability of the swimming pool. pH value and free chlorine level of the pool water, flushing of the filter system, regular mechanical cleaning of the pool etc. must be continually maintained in order to ensure long-term bathing pleasure.

1. INTRODUCTION

A summer holiday or a wellness course without an attractive swimming pool or sauna is hard to imagine. What can be more pleasant than sitting in a whirlpool or swimming in a pool, enjoying the view of the sea or the mountains? Swimming pools, jacuzzis, therapy baths, saunas etc. provide not only physical well-being, but also mental relaxation and revitalisation.

Aesthetically appealing pools are lined with ceramic coverings or glass mosaic. Ceramic and glass mosaic are available in a wide range of designs, colours and glazes, giving full rein to the creativity of the architect. Such coverings are also hygienic, easy to clean and extremely durable.

All the skills of the tile-layer are required in order to ensure that the bathing enjoyment lasts for as long as possible. The laying of tiles and mosaic in underwater and permanently wet areas is one of the most demanding tasks of this trade, particularly since the tile-layer often has to work under considerable time pressure as the last item of work to the pool. On the following pages, typical problems in the area of swimming pools will be addressed, and possible solutions presented.

1.1. PROFESSIONAL WATERPROOFING – A BASIC REQUIREMENT

Before work can be started on the ceramic lining, the pool must first be properly waterproofed. For this purpose, the pool shell must be examined for its suitability. It must have been left to harden for at least three months, so that the shrinkage process of the concrete is well advanced, in order to avoid excessive stresses in the subsequent tile lining. The concrete surface must be free of dust and completely firm (bond strength > 0.5 N/mm²). Cracks with a width of greater than 0.1 mm must be sealed with injection resin prior to the waterproofing work.

Pool surrounds and swimming pools are areas subject to high stresses from water according to DIN 18195-5 Point 7.3. Nowadays the waterproofing of such works usually is carried out using liquid waterproofing materials in combination with ceramic tiles or panels (in short: liquid applied waterproofing). These waterproofing materials are specified by the Deutsches Institut für Bautechnik (DIBt) in Berlin in construction product list A Part 2 under number 1.10. According to the specification, these waterproofing materials must be thoroughly tested. The requirements which must be fulfilled are specified in detail in the testing principles for the issue of a general appraisal certificate (abP). The tests according to these testing principles constitute a generalised suitability test for the liquid applied waterproofing materials. If the waterproofing material fulfils the criteria of the testing principles, the general appraisal certificate is issued by a material testing authority certified by the DIBt, and the liquid applied waterproofing material may and must carry the "Ü-Zeichen" (German conformity mark). Only waterproofing products carrying the German conformity mark may be used in areas highly stressed by water (pool, pool surround).

In general the construction product list allows polymer dispersions, polymer-cement combinations and reaction resins as waterproofing materials applied in liquid form. The construction product list places firm requirements on the minimum dry layer thickness, which must be maintained at all points of the waterproofing following complete hardening:

- Polymer dispersion 0.5 mm
- Polymer/cement combination 2.0 mm
- Reaction resins 1.0 mm

Guidelines for the proper application of liquid applied waterproofing materials have been issued by the "Fachverband Deutscher Fliesenleger" ("Association of German Tile-layers") in the notice "Hinweise für die Ausführung von Verbundabdichtungen mit Bekleidungen und Belägen aus Fliesen and Platten für den Innen- and Außenbereich" ("Instructions for the application of liquid applied waterproofing materials with ceramic tile and panel linings for interior and exterior areas"), issue 2005.

While the wall and floor surfaces can be waterproofed relatively easily, the waterproofing of floor drains, installation apertures and floor-wall connection joints requires expert know-how.

These waterproofing measures must be carried out with extreme care and consideration, since leaks and damage due to moisture is almost always due to one of these three points.

1.1.1. Floor drains and installation apertures

In order to economize or simply because of a lack of knowledge, floor drains which cannot be properly incorporated into the waterproofing system are frequently used. Either no additional waterproofing gasket can be mechanically attached to the floor drain, or the flange of the drain offers insufficient surface area or insufficient hold for the liquid applied waterproofing. Flanges of polyethylene (PE) or polypropylene (PP) are resistant to adhesion and do not allow a good connection to the liquid applied waterproofing. This almost inevitably results in later leaks.

In order to avoid damage, loose-fixed flanges (compression flanges) must be installed in the floor area. The fixed flange of the floor drain is installed flush with the floor plate, and then coated with the first layer of liquid applied waterproofing product. The floor gasket is placed in the fresh waterproofing, and the loose flange then bolted into place. This is followed by a second coat of the liquid applied waterproofing over the surface and the floor gasket, thereby integrating the floor drain so that it is waterproof. The same procedure applies for apertures in the pool shell for supply cables for spotlights, inlet nozzles etc. If no compression flanges are used, a wall gasket can also be fitted to the fix-flange with epoxy resin and liquid applied waterproofing. A requirement in this case is that the flange must be at least 5 cm wide.

If the floor drains and apertures are installed subsequently, voids for them are either cut-out during the construction phase or will have to be chiselled out later. In order to avoid water penetrating behind components installed at a later time, the chiselled-out area must be provided with an epoxy capillary break around the component with a width of at least 5 cm and a depth of at least 2 cm. After fitting of the mounting part, a Plexiglas disc is placed over the area to be sealed. The annular space around the mounting part is then sealed with epoxy resin with the aid of a tube and funnel. On the next day, the capillary break is primed with epoxy resin and scattered with sand, in order to enable a firm connection to the liquid applied waterproofing.

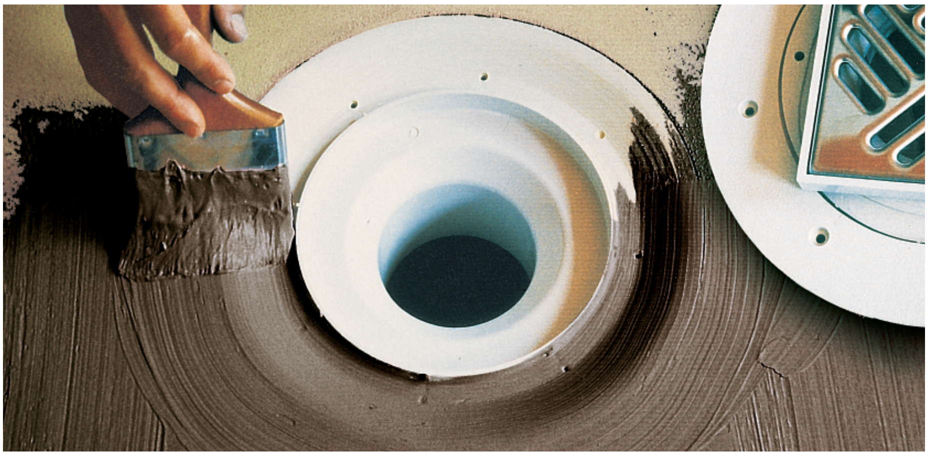

Figure 1. Coating of the fixed flange with subsequent fitting of the waterproofing gasket into the fresh liquid applied waterproofing

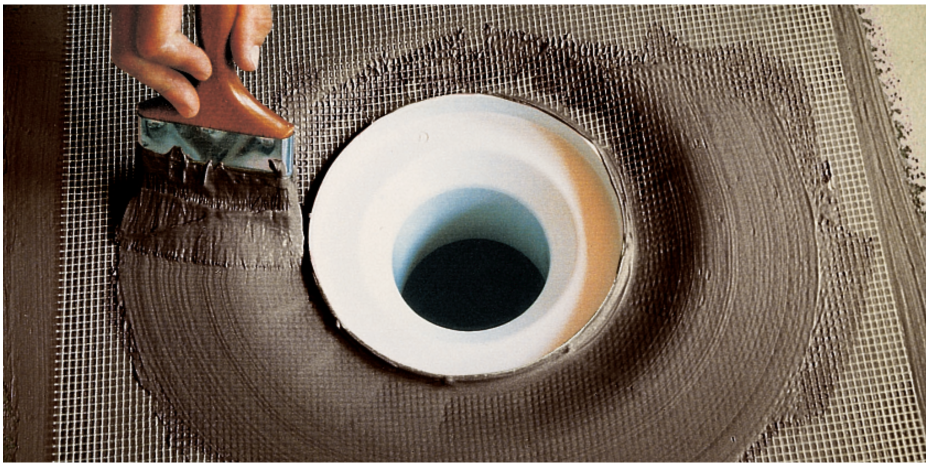

Figure 2. Second Coating

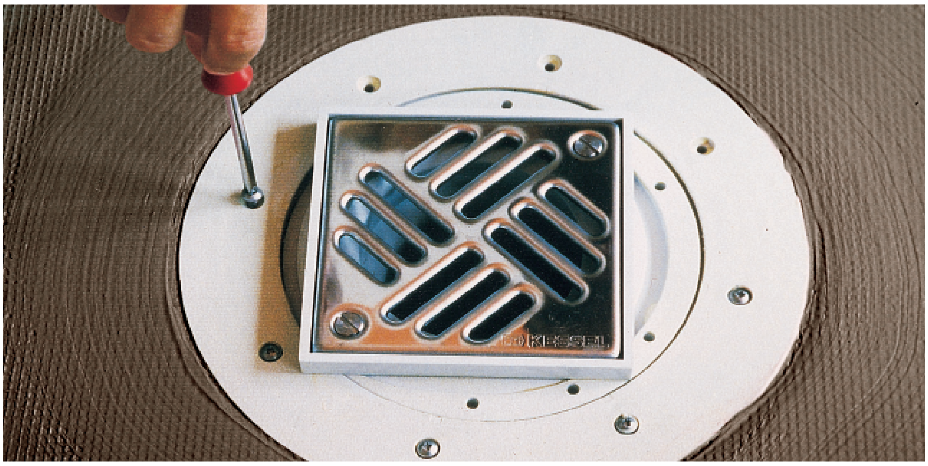

Figure 3. Bolting of the fixed flange after coating of the waterproofing gasket with liquid applied waterproofing material

1.1.2. Floor-wall connection joints

Due to the high relative movement of the wall and floor in relation to each other, the wall-to-wall and floor-to-wall transition areas must be waterproofed with elastic waterproofing tape. Liquid applied waterproofing cannot compensate for these relatively large movements in the long term. Waterproofing tapes are approx. 10 – 12 cm wide elastomer tapes with quilted side sections for a better integration into the surface liquid applied waterproofing. While less-expensive waterproofing tapes have a continuous mesh lining and are therefore less flexible, higher-quality tapes have an elastic central section. The following procedure has proven itself for proper bedding of the waterproofing tape into the liquid applied waterproofing: the corner area is provided with the first coat of waterproofing. The waterproofing tapes are then fitted in the wall-to-wall and floor-to-wall transition areas, if possible in the form of loops. The quilted side sections of the waterproofing tapes, but not the elastic centre section, are then coated with liquid applied waterproofing.

Figure 4. Application of waterproofing tape to the fresh liquid applied waterproofing

Figure 5. Subsequent coating of the waterproofing tape with a second coat of liquid applied waterproofing

1.2. POOL HEAD – IT'S ALL DOWN TO THE DETAILS

The transitional area from the pool wall to the pool surround with integrated pool head – comprising the overflow channel with installed components and channel cover – is particularly susceptible to damage. Detailed planning and precision during construction are essential in order to avoid leaks at this critical area.

Most pool head constructions today are carried out with a raised water level. This means that the water level is at the same height as the ceramic covering of the pool surround. These are not only more aesthetically pleasing, but also ensure a continual overflow of water into the overflow channel. This also prevents hygienically problematic deposits on the pool walls above the water level.

The pool edge components are fitted in a cut-out area of the pool shell provided in thick-bed mortar. Tight and compact cement mortar with a low free lime content should be chosen for laying, since otherwise lime deposits may occur in the area of the overflow channel inlets, accompanied by blooming on the pool walls.

The laying of pool edge components demands a particular degree of accuracy and precision from the tile-layer, in order to ensure perfectly functioning pool hydraulics and pool water treatment. For the continual and even overflow of the pool water, the regulations require a maximum variation of the pool edge from the horizontal of 2 mm over the complete course of the overflow channel.

In particular for a raised water level, a capillary break of epoxy resin in the pool head area is essential. The capillary break must be located flush with the upper edge of the overflow channel or the pool edge, in order to prevent water penetrating into the pool surround as a result of hydrostatic pressure.

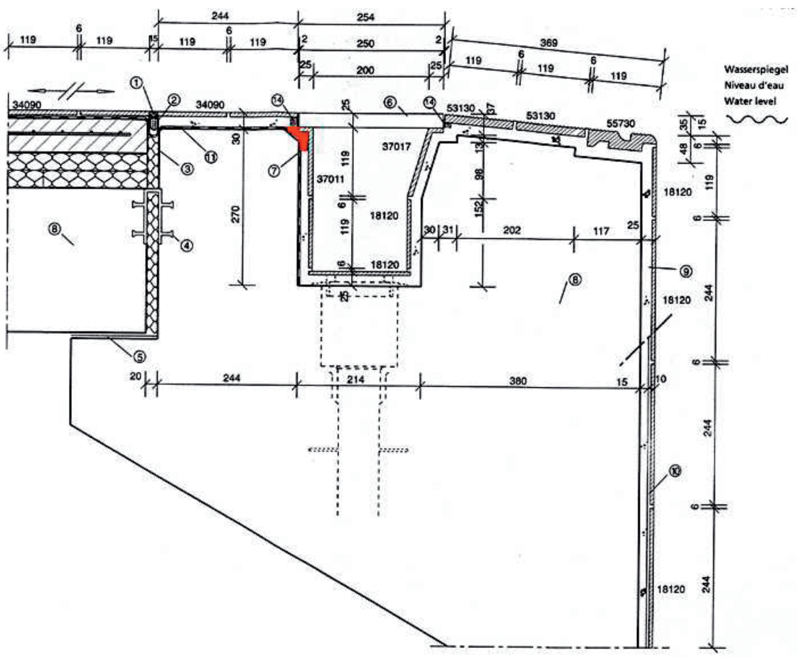

Figure 6. A capillary break of epoxy resin (marked in red) at the pool head prevents water penetrating from the pool …

Figure 7. … into the pool surround area, leaving it continually wet.

If the capillary break is absent, water penetrates into the underneath construction of the pool surround, leaving it continually wet (principle of communicating vessels). The "overflowing" water either drips into the underneath construction or dissolves lime and alcalisilicate out of the tile adhesive of the pool surround and transports this over time via the capillary pores of the joints to the pool surround surface. Over time, this produces unsightly lime and silicate deposits. The latter present serious problems, since they cannot be removed from the surface.

After the pool head has been waterproofed, and before the laying of the tiles/ mosaic, the pool must be tested for leaks by being filled for two weeks with chlorinated water (2 mg/l). The chlorination prevents bacteria settling in the waterproofing during this testing phase.

1.3. POOL WATER QUALITY – CRUCIAL FOR THE CHOICE OF TILING MORTAR AND JOINT GROUT

The question of the water quality must also be addressed during the planning phase. Depending on the content of magnesium, ammonia, sulphate and corrosive carbonic acid, cement-based waterproofing, laying and grouting products may be sufficient; otherwise epoxy resin-based materials will have to be used.

For lack of space, only the aspect of "corrosive water" is dealt with below. Various parameters determine whether water is corrosive or scale-forming. pH value, acid capacity ($KS_{4.3}$) and calcium hardness have the greatest influence on these characteristics.

There are many theoretical discourses based on the Langelier saturation index and also convenient software programmes which calculate accurate figures for the lime-carbonic acid equilibrium. The mathematical requirement is enormous, and requires a computer, which may not always be available on the spot. The influence of the major parameters of pH, $KS_{4.3}$ and calcium hardness are not transparent.

The method of the lime index according to Felixberger (LI_F) is presented below. With the aid of the measured values for pH, calcium hardness and acid capacity ($KS_{4.3}$), this figure can easily be calculated, the influence of the individual parameters clearly confirmed and the lime solution characteristics of water determined. The LI_F cockpit enables a rapid decision on the type of materials to be used (cement/epoxy).

Before we describe the determination of the lime index according to Felixberger (LI_F), we should first briefly explain the three major parameters of pH value, acid capacity ($KS_{4.3}$) and calcium hardness.

1.3.1. pH value

The pH value is a measure of the acidic or alkaline effect of water. The scale ranges from 0 to 14. Distilled water is neither acidic nor alkaline, and is therefore completely neutral. This has a pH value of 7. The further the pH value falls below 7, the more acidic is the water. Conversely, the water is more alkaline the more the pH value approaches 14. If the pH value falls below 7, the water is then capable of dissolving lime and also corroding metallic parts such as pipes, filter system etc. In the alkaline range, a pH value above 8 can result in lime deposits in the pool area. Ideally, the pH value of pool water should be between 7.2 and 7.4, since the anti-bacterial effect of chlorine is greatest within this pH range.

1.3.2. Acid capacity ($KS_{4.3}$)

The acid capacity is a measure of the buffer capacity of the water against acids and alkalis, and is therefore responsible for the pH value stability of the pool water. Under the addition of equal quantities of acids and alkalis, the pH value therefore changes less, the higher its acid capacity.

The determination of the acid capacity is carried out by adding hydrochloric acid until the pH value of the water sample reaches 4.3. It is then specified how many mmol of hydrochloric acid would be needed per litre of pool water in order to reduce the pH value to 4.3.

Too low an acid capacity makes achievement of a stable pH value more difficult. The guidelines for public swimming pools recommend establishing an acid capacity of 1.6 to 2.4 mmol/l. In order to increase the acid capacity by 0.2 mmol/l, 1.8 kg of sodium hydrogen carbonate ($NaHCO_3$) must be added per 100 m^3 of water.

1.3.3. Calcium hardness

The calcium hardness results from calcium compounds dissolved in the water. If the calcium content is too low, and the water therefore too soft, there is only little calcium available in order to buffer carbon dioxide. Such water can quickly become corrosive by absorbing carbon dioxide from the air. If on the other hand the calcium content is too high, this can result in the formation of scale and/or cloudy pool water.

Water treatment specialists recommend a calcium content of 80 to 120 mg per litre of pool water.

Since the three characteristics of ph value, acid capacity and calcium hardness mutually affect each other, the assessment of the lime-carbonic acid equilibrium of water requires further information.

1.3.4. Calculation of the lime index according to Felixberger (LI_F)

The calculation of the lime index according to Felixberger (LI_F) requires measurement values of the pool water including the pH value, the calcium content in milligrams per litre and the acid capacity ($KS_{4.3}$) in mmol per litre.

The lime index according to Felixberger (LI_F) is calculated from the sum of the pH value, calcium index (CI) and acid capacity index (AI) minus 10.5.

$LI_F = pH + CI + AI - 10.5$

The calcium index and acid capacity index required for the calculation can be taken from the following tables.

Calcium hardness [mg Ca/l]	24	32	40	48	60	80	120	160
Calcium index (Cl)	1.4	1.5	1.6	1.7	1.8	1.9	2.1	2.2

Table 1.

Acid capacity [mmol/l]	1.2	1.6	2.0	2.4	3.0	4.0	6.0	8.0
Acid capacity index (Al)	1.4	1.5	1.6	1.7	1.8	1.9	2.1	2.2

Table 2.

The figures for other levels of calcium hardness and acid capacity can be interpolated.

1.3.5. Conclusiveness of the lime index according to Felixberger (LI_F)

Strictly speaking, only water with $LI_F = +0.7$ is in lime equilibrium, meaning that it neither dissolves or deposits lime.

Experience shows that water with a LI_F of 0.0 to +0.7 does not corrode cement-based laying and grouting materials. Such materials can therefore be used for laying and grouting with a $LI_F > 0$.

With $LI_F < 0$, water dissolves lime, so that the grouting at least must be carried out using epoxy resin. Since the deeper layers of the adhesive and waterproofing are protected against the corrosive water by the grouting, it is sufficient if epoxy products are used for laying from $LI_F < -0.5$ and for waterproofing from $LI_F < -1.5$.

LI_F range	**LI < -1.5**	**-1.5 < LI_F< -0.5**	**-0.5 < LI_F < 0.0**	**LI > 0.0**
Waterproofing	Epoxy	Cement	Cement	Cement
Laying	Epoxy	Epoxy	Cement	Cement
Grouting	Epoxy	Epoxy	Epoxy	Cement

Table. Laying recommendations in permanently wet areas in relation to LI_F

The principal procedure for determining the LI_F value for the following example is explained by means of the lime index cockpit for pool water with a pH value of 7.5, a calcium content of 120 mg/l and an acid capacity of 2.0 mmol/l:

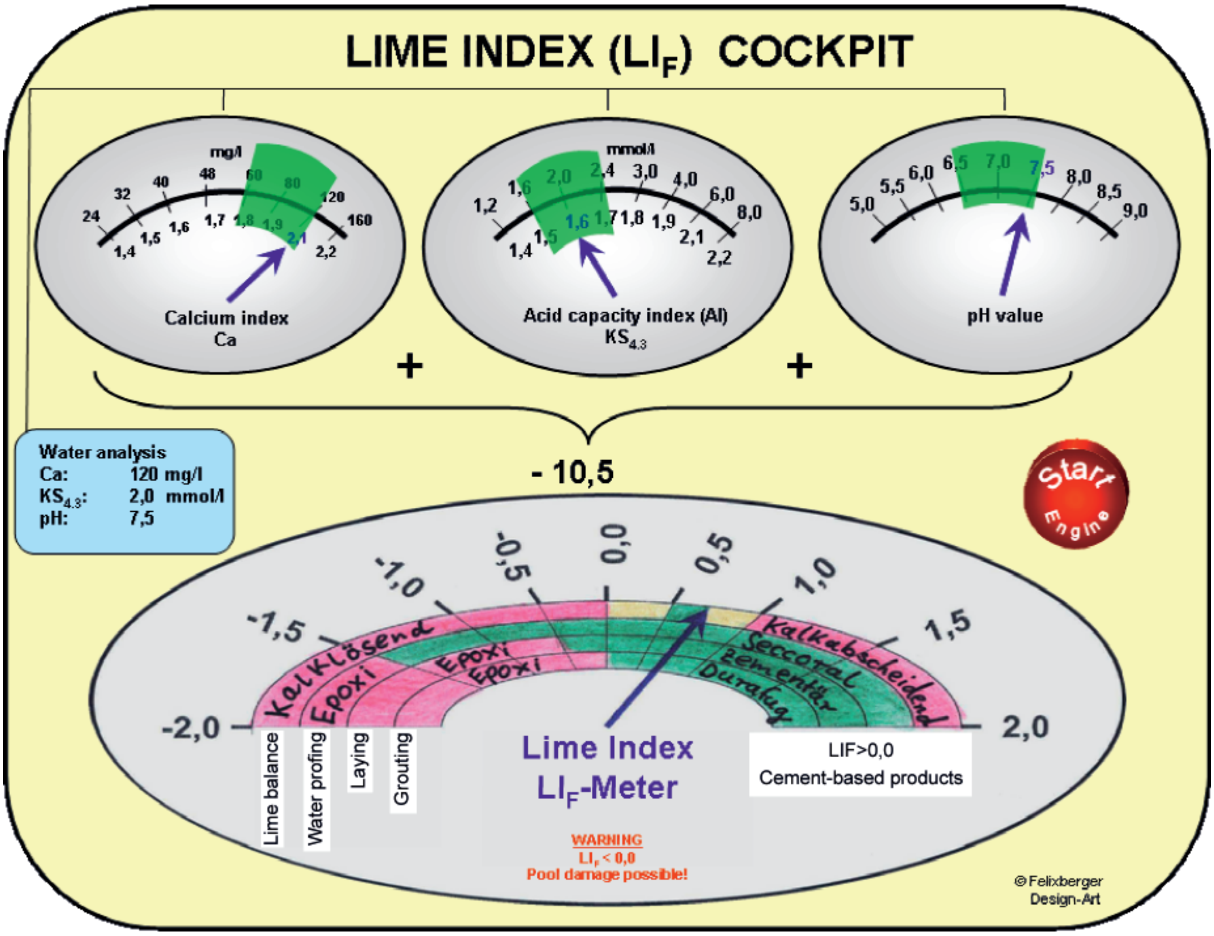

Figure 8. Lime Index Cockpit

1. Allocation of the calcium index to the available calcium content of 120 mg/l $\rightarrow$ CI = 2.1
2. Allocation of the acid capacity index to the available acid capacity of 2 mmol/l $\rightarrow$AI = 1.6
3. pH value is included in the calculation as $\rightarrow$pH = 7.5
4. Calculation of the lime index according to Felixberger: $LI_F = 2.1 + 1.6 + 7.5 - 10.5$ $\rightarrow$**$LI_F = 0.7$**
5. A comparison with the above table shows that cement-based products can be used for laying, grouting and waterproofing, since the $LI_F > 0$.

In summary, the lime index cockpit according to Felixberger enables a decision with regards to the usage possibilities of cement-based laying and grouting products in underwater areas in a matter of seconds. The method is not only quick, but can also be carried out easily and without a computer with the aid of the cockpit. The only measurement values needed are the calcium content in mg/l, the acid capacity in mmol/l and the pH value. These findings can be obtained within 30 minutes at low cost from a water analysis laboratory.

1.4. MOSAIC – BEAUTIFUL BUT PRONE TO DAMAGE

Architects and designers like mosaic. In the design of stylish swimming pools in particular, mosaic allows the use of a wide range of colours and freedom of design. Colour progressions, decorations, pictures and designs in all conceivable colours can be produced.

Due to its smooth rear side and possible transparency, this places the great demands both on the laying and grouting materials, and the skill of the tile-layer.

It should be noted that in permanently wet and underwater areas, only mosaic sheets with paper or film on the front side must be used. Mesh mounted Mosaic is unsuitable for three reasons:

- The rear side of the mosaic demonstrates poor adhesion, and the surface area is further reduced by the mesh mounting by up to 50%.
- The mesh mounting adhesive can provide a source of nutrition for micro-organisms, which can lead to contamination by micro-organisms.
- The mesh mounting adhesive is in many cases not water-resistant, meaning that the connection between the mesh mounting and the mosaic pieces can fail over time.

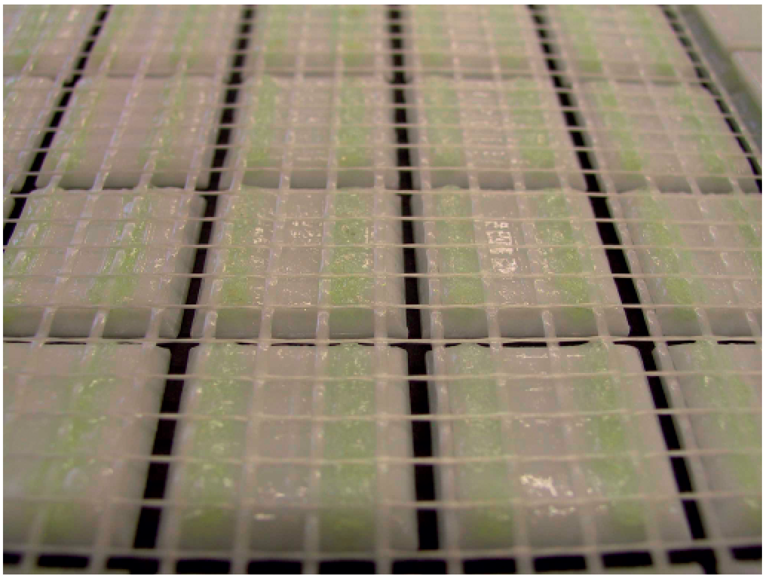

Figure 9.Mesh mounted Mosaic

Figure 10. Mesh mounted Mosaic must not be used in permanently wet and underwater areas, since this can rapidly lead to cavities and detachment of the mosaic pieces (hydrolysis of the adhesive!).

Figure 11. In the case of translucent mosaic in particular, laying and grouting must be carried out using epoxy resin in order to prevent cavities.

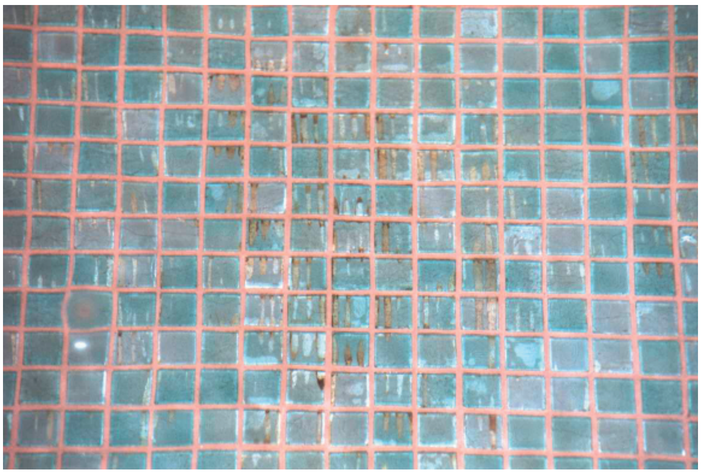

Figure 12. Otherwise this will result in the formation of brown stains or – even worse – micro-organisms.

In the case of foil-mounted mosaic sheets, the complete rear side of the mosaic is available as the adhesion surface.

The grain of the paper must be taken into account when laying the mosaic sheets. The best success is achieved if the grain is always laid in the same direction, and ideally vertically. The mosaic sheet is placed in the adhesive bed, and then tapped in with the flat side of a grout float. When positioning the next sheets, it is important that the spacing between the mosaic sheets corresponds to the spacing of the individual mosaic tiles. Cavity-free laying in underwater areas is essential, since any cavities behind the tiles or the individual mosaic pieces are isolated from the continual water treatment, and can become a breeding ground for micro-organisms. In the case of translucent glass mosaic, cavities can also lead to brown staining on the rear side of the mosaic.

After approx. 30 minutes, the paper is removed by dampening it with a sponge until it starts to peel off the mosaic. The paper is best removed diagonally from bottom to top, so that the individual mosaic tiles are not displaced. The position of the individual tiles can still be corrected after removal of the paper.

Foil-mounted mosaic sheets can be positioned more easily. The foil does not need to be dampened, and only needs to be removed after about four hours or longer, since faulty areas can be recognised when positioning the mosaic sheets. Excess adhesive is removed from the joint chambers before complete hardening of the tile adhesive using a cutter or stiff brush.

Before the grouting of the mosaic, the paper adhesive must be carefully washed off the mosaic surface with a 5 % soda solution, and the resulting washing water completely removed from the pool. Since the wall surfaces are covered with mosaic first, care must be taken during this cleaning work to ensure that no paper adhesive remains in the joint chambers or on the floor waterproofing, since otherwise severe contamination by micro-organisms may occur in the floor area.

In the case of 2-component materials such as epoxy resins, the correct mixing ratio must be maintained and mixed in a clean pot. In order to ensure the homogenous and thorough mixture of the laying and grouting product the pre-mixed mixture is transferred into another clean container and re-mixed thoroughly. Correctly mixed grouting mortar will fill the joint chambers. On completion of grouting work, the surface should be drawn off firmly using a grout float in order to remove as much excess material as possible. Cleaning of the surface begins before hardening of the grouting compound, for epoxy grouting approx. 20 minutes, and for cement grouting approx. 40 minutes after application of the grouting material. The surface is dampened with warm water using an epoxy sponge or pad and initially cleaned with circular movements, taking care not to press down. This process is repeated until the surface is completely clean. The sponge should be wrung out frequently. Finally, the surface is wiped down one last time using a clean sponge and clean water. In order to obtain the full gloss of the mosaic and for final cleaning, any remaining streaks are removed on the day after grouting with a soft, damp sponge (e.g. fine epoxy sponge). For easier cleaning approx. 5% spirit can be added to the washing water.

The swimming pool should only be filled when the grouting material has completely hardened. In the case of epoxy products and depending on the weather conditions, this may take up to several weeks. If the pool was filled too early, the hardening process of the resin could be irreversibly interrupted. The joint surface remains soft, enabling the development of micro-organisms which can also use it as a source of nutrition.

1.5. FULLY FUNCTIONAL WATER TREATMENT – AN ABSOLUTE MUST

Even if the tile-layer has carried out his work with extreme accuracy, the customer will not enjoy his swimming pool for long if the water treatment does not function efficiently and reliably from the very beginning.

The emphasis here is on "from the very beginning". Experience shows that in the case of private swimming pools in particular, even though modern water treatment systems are installed, months often go by until the user is familiar with the operation of the system, and it is calibrated correctly. In this way, the apparently so exact digital display values for free chlorine and pH value may for long periods not actually correspond to the real values of the pool water. Over this period, this can result in massive contamination of the pool. Once micro-organisms have settled in the pores of the grouting material, in the cavities of the adhesive bed or in the waterproofing, it is almost impossible to remove them.

The pool circulation should be allowed to run continuously wherever possible, and not switched off at night or during holiday periods. Micro-organisms do not sleep, nor go on holiday.

The required pump capacity for private swimming pools should be designed so that the complete pool volume can be circulated within two hours.

The heart of a properly functioning water treatment system is the filter system. The filter medium consists of quartz sand, anthracite or pumice with defined particle sizes. The filter bed consisting of one or more of these materials is usually flowed through from top to bottom, and when it becomes dirty it can be cleaned again by flushing in the reverse direction.

Filters collect organic contaminants such as hair. Micro-organisms in the filter can multiply rapidly, particularly if the pool circulation is switched off. The filter should be flushed carefully twice per week for at least five minutes. The initially cloudy flushing water should be clear towards the end of the flushing process. If the flushing water is clear from the very beginning, the filter should be checked to ensure it is operating properly.

It is essential that the user is trained in the maintenance of the water treatment system, and in the care of the joints and ceramic covering in the surround area, the overflow channel and the pool. He must be aware of how important a properly functioning water treatment system is for the durability of the appearance of the joints and ceramics. Attention is drawn in this respect to DIN 19643-1 "Aufbereitung von Schwimm- und Badebeckenwasser" ("Treatment of swimming pool water").

In summary, the importance of a properly functioning water treatment system cannot be repeated often enough. The pH value, circulation time, free chlorine content of the pool water, flushing of the filter system, regular mechanical cleaning of the pool etc. must be maintained and carried out on a regular basis, otherwise it is only a question of time until bio-films and micro-organisms occur.

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