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How to construct problem-free swimming pools

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Today, most swimming pools are tiled. If they are constructed correctly, these swimming pools will last for many years if periodic maintenance is completed. Thorough planning and precise construction is required. Choice of material is also important. Some pool owners have experienced that tiles tend to detach, especially at the bottom of the pool, and they wonder why this happens. This article sums up the causes and measures for problem- free solutions.

Figure 1: Pools will last for many years given that they are constructed correctly

Focus on concreting and concrete quality

Most tiled pools are casted in *waterproof concrete* where the concrete itself meets the requirements for tightness. The bottom of the pool can be founded directly on the foundation, but most are planned with room under the bottom of the pool. This ensures that you have access to the entire structure from the underside, and the area can be used as e.g. a storage room, adjustment tanks, sand filter etc.

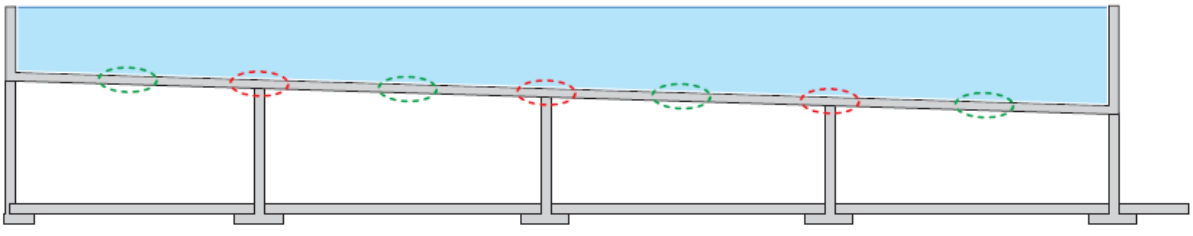
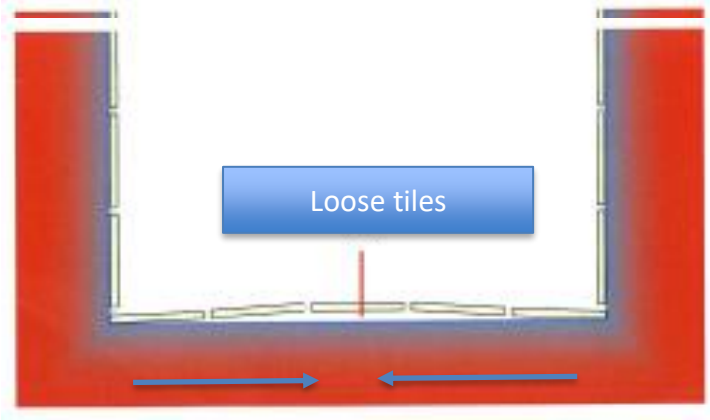


Figure 2: The concrete structure must be planned so that there is less shear strength between the tile and concrete than what the adhesive and membrane layer can endure.

In a typical pool construction, the bottom has the support of crosswise walls with regular intervals of e.g. 5-8 m. (Figure 2). The bottom of the pool is most vulnerable to both loss and movement strains depending on dimensions and rigidity. When the concrete bottom is exposed to water pressure, this will generate compressive stress in the adhesive layer in the area in the middle of the constructions (green fields) and similar stress above the construction (red fields).

The drying out phase in the concrete makes the entire construction shrink. Mostly on the exterior side where it dries the quickest, see figure 3. As the bottom of the pool is the largest surface, here large strains might build up so that the adhesive is unable to keep the tile in place, and they may fall off as shown on figure 4. Rapid temperature changes, e.g. when filling up or emptying the pool, may also cause movement. Such movement must be considered both in the planning and running phase. If you have a deep pool, i.e. large water pressure, it should be reinforced more than what the minimum requirement indicates. That limits the crack width above the crossfield walls, and the tension of the pressure side of the fields where the deformation caused by water weight is. It is important to dimension such bottom plates that are placed on cross walls according to the requirements for reducing crack width rather than capacity. If the crack width or the deflections are too great, the adhesive contact might fail, or the tile might break right above the crack.



Blue zone: water saturated concrete with little total shrinkage.
Red zone: The construction has dried out and the shrinkage has expired. The entire concrete structure become smaller.

Figure 3: A concrete construction will continue to shrink for several years after the casting (Illustration: Sopro)

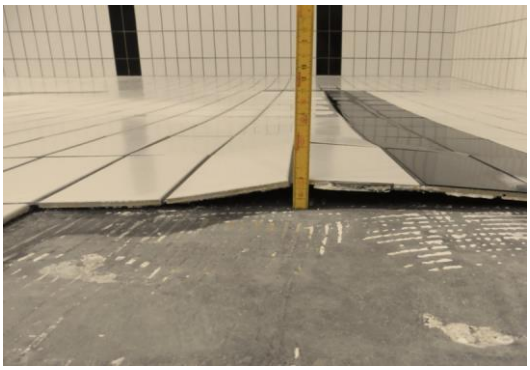


Figure 4: Movements from the foundation make the tiles become loose and create a ridge in the surface.

Measures

Ways of reducing the risk of tiles detaching from the bottom of the pool are:

- Extra reinforcements should be added in the stretch zone so that the stretching and deformations of the bottom plate are reduced, preferably the concrete should be so thick that chance of cracks in the tension zone or deformation in the stress zone is small.
- Be sure to have control over the shrinkage forces. You should choose concrete with B 45 (M40) quality, with a water-cement ratio of ≤ 0.4. The expected crack widths must be ≤ 0.2 mm.
- An alternative to strict requirements for crack width is to add an elasticity layer, e.g. a cement-based elastic fluid membrane. The membrane must be combined with a partition of the elastic joints in the tile layer. See the next subsection.

Using flexible liquid applied membrane to distribute strain?

There are both advantages and disadvantages by using a membrane as an elasticity improving layer in pools. The membrane types that are typically used today are flexible, , cement-based, liquid applied membranes that must be applied with a minimum thickness of 2 mm. There are advantages and disadvantages that must be considered.

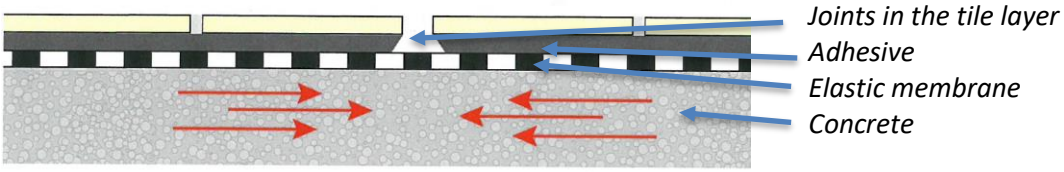
Table 1 shows the advantages and disadvantages of using membrane:

Advantages of using membrane	Disadvantages of using membrane
Tighten cracks and reduces risk for possible leakages in the concrete construction	Reduces the adhesion between the tiles and the foundation by a half.
Contributes to adjusting strains and movements between the concrete and tile layers.	Requires partition with elastic joint sealants in the tile layer. These joint sealants have a short lifespan in chlorine water.
Increases the lifespan of old concrete constructions exposed to corrosion attacks.	An extra layer of material increases the expense of both material cost and time used in construction phase.
Provides extra security against leakages e.g. by nozzles, light fixtures and other built in components	

If shrinkage in concrete, deformation due to loads, the amount of reinforcement etc. have been taken into consideration when planning and casting the waterproof concrete construction the need for membrane as a flexible layer will be reduced. The adhesion between the membrane and the foundation is, for most products, about 50 % of the adhesion tile adhesive can obtain. So, by using a membrane, the tile layer will get reduced contact with the foundation, but rise the ability to distribute the strain. Use of flexible membrane must be combined with a squared pattern with movement joints both in the pool bottom and on the walls. See figure 5. The distance between the joints should not be greater

than 5-7 m. Elastic sealant has a short lifespan in pools, and the life expectancy is 3-5 years. Rejointing in the operating phase takes time and will be expensive and complicated.

Figure 5: If you apply an elastic waterproofing membrane combined with elastic joint sealants, it may prevent loose tiles. (illustration: Sopro)



Experiences:

- Elastic membrane combined with joint sealants contribute to preventing tiles from detaching or cracking where there are stress- or deformation movements from the concrete construction.
- In older pools with possible leakages, or where the quality of the concrete is unknown, membrane is necessary

Select a suitable type of adhesive

The function of the tile adhesive is to ensure that tiles attain the necessary adhesion with the foundation so that they do not detach. Most manufacturers of tile adhesive can deliver different products for different purposes and with different qualities. When planning and tendering, price and quality are often discussed. Sometimes standard adhesives are selected without checking how much strain the adhesive will be exposed to. When constructing pools, knowledge of adhesive qualities are necessary. Therefore, the adhesive suppliers in the Norwegian Building Ceramics Association have collaborated in a field study of the different properties of adhesives in aggressive, Norwegian pool water. The purpose of the project was not to rank the products, but to ensure that each supplier has the best possible knowhow for recommending *their* product for use in pools.

Field experiments

14 different types of adhesives were selected, and tiles were glued to concrete slabs. As there is great variation in water quality in Norway, tests were placed in two different pools with different water quality. The reduction of adhesion over time was measured after one and two years.

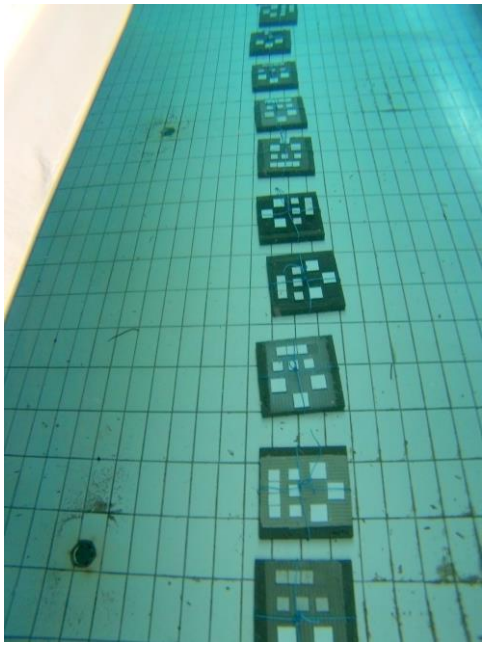
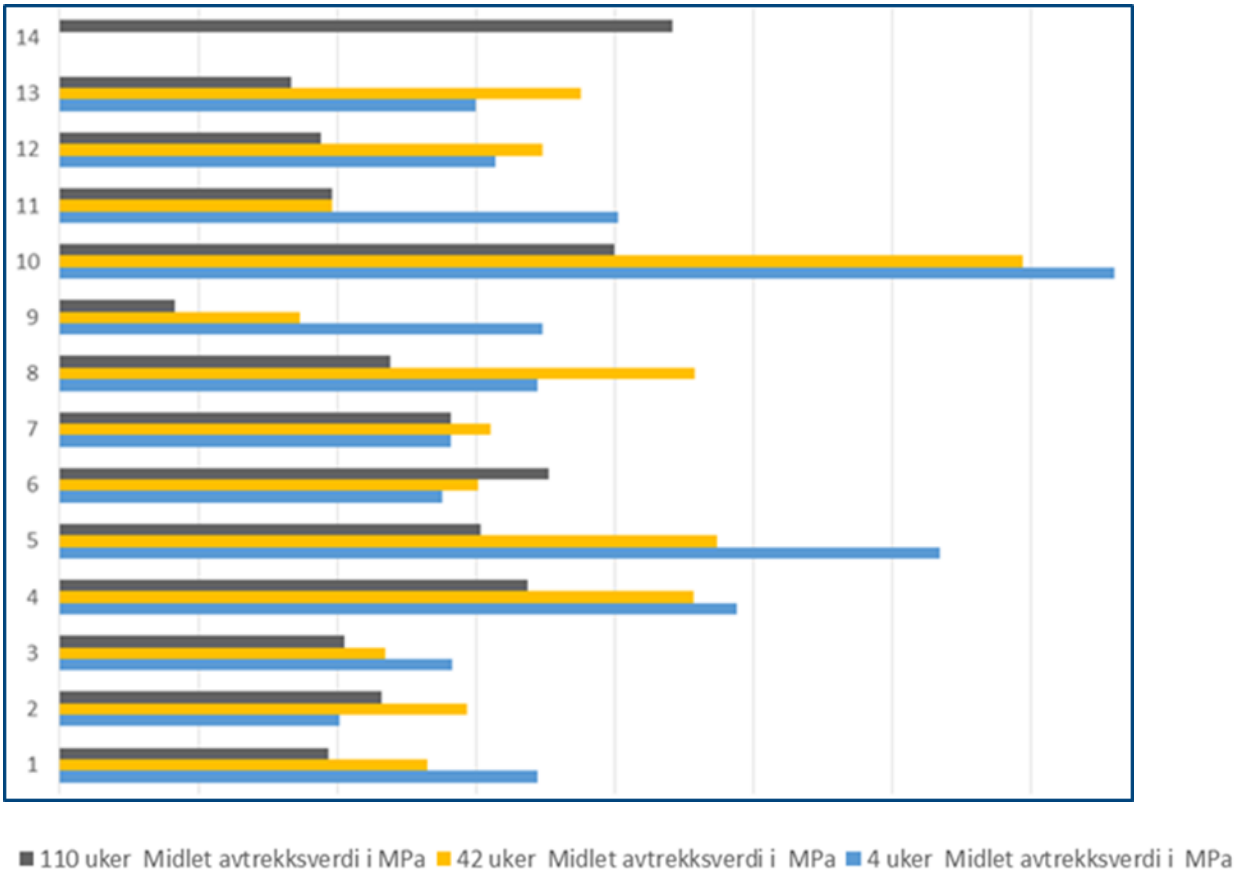


Figure 6: 28 concrete slabs with 10 test pieces each were tested in two different water qualities for two years.

Table 2 shows the water quality in the testing pools and the length of the test period.

Test pools	Water aggressivity measured by LSI factor	Water attribute	Exposure period	Number of weeks
Test pool 1	- 1.34	Very aggressive	2015-2017	110
Test pool 2	- 0.39	Moderately aggressive	2016-2017	60

Figure 7 shows the development of the contact over time for the 14 different adhesive types in the experiment.



Explanation, value in MPa
[Black] 110 weeks
[Yellow] 42 weeks
[Blue] 4 weeks

Experiences

- Adhesives from the different suppliers show a significant difference exposed in aggressive pool water. The average adhesion reduction after 42 weeks was 8 %. After 110 weeks the reduction was 30 %.
- Even with a 30 % reduction, the average value is still over 1.0 MPa, which is the requirement for a C2- quality adhesive according to NS-EN 12004.

- The water has a negative LSI factor in both the pools, see table 2. The water quality contributes to the adhesives losing solidity over time. Here, there was significant variation between the products.

Pool water and choice of material

Most places in Norway, the water is soft (low calcium concentration) with low carbonate content (low alkalinity). This means that the water is aggressive, i.e. it can wear down and reduce the lifespan of cement-based materials. The water aggressivity exposed directly to cement may be calculated based on alkalinity, hardness, as well as pH value and temperatures. As an indicator of aggression, the so-called Langlier Saturation Index (LSI) is used.

Table 3: Characterisation of water based on the LSI index:

	Svært aggressivt	LSI < -1.00
	Moderat aggressivt	-1.00 < LSI < -0.15
	Lite aggressivt	-0.15 < LSI < 0
	I likevekt	LSI = 0
	Lite utfelling	0 < LSI < 0.15
	Moderat utfelling	0.15 < LSI < 1.00

A LSI=0 means that the water is in balance, while a negative LSI will lead to the lime, which is the main cause of cement, disintegrating. The more negative (minus) the LSI, the more aggressive the water.

Contractors that plan and build pools often do not focus on setting requirements for water quality when building new or upgrading existing swimming pools. Suppliers of water management equipment and systems do not design for neutral LSI index in the water, unless the builder specifies this as a criterion. The Norwegian requirements for pool water have not focus on materials and durability, but rather on sufficient hygienic- and wellness level for the users. Therefore, due to not focus on effect of aggressive water in planning and operating phase, several owners and caretakers of pools experiences that joints are deteriorating, and, in the worst case, tiles become loose.

Figure 8: If the joint has deteriorated to such a level that the adhesive become visible, this indicates that the water is «eating away» the cement.

Experience shows that almost all pools where the tiles have loosened, have had a water quality with a LSI index indicating *very aggressive* or *moderately aggressive* water. We have thought that if the joint grout is intact they will protect the adhesive against aggressive water and that the risk of chemical attack of the adhesive is small.

Studies have shown that the robustness of the adhesive may also be weakened by reactive compounds, such as chlorine, sulphate, acids etc.

Experiences:

- The water quality has not been the focus when selecting adhesive and jointing materials. Most manufacturers of adhesives and joint sealants are not from Norway, and they most likely do not conduct thorough examination of the suitability of their products combined with typical, Norwegian pool water. Standard adhesives have been used rather than products matching local water. The price has most likely often been the determining factor for the choice of product. But, the material cost is a minor factor compared with the total cost.
- Many types of adhesives will probably work if strains and movements between the concrete and tiles do not occur. But if movements occur in combination with aggressive water, tiles may detach where there become strains. Then, the water become easy access and the deterioration of the cement happens quicker.

Solutions:

A premise for using cement-based adhesive and joint products is specification with neutral or moderately aggressive pool water. (LSI value according to table 1.) A way of achieving this is to add lime minerals through a marble tank. If this is not done, consider using epoxy joints, possibly also epoxy adhesive. Epoxy ensures better contact and is not affected by the pool water. But epoxy requires more work when mixing and applying the product, and it is more expensive and less environmentally friendly than other products. If epoxy joints are selected you will most likely avoid rejointing for 25-35 years, whereas when using cement-based joints they will have to be redone after 10-15 years.

Figure 9: A marble filter tank that adds minerals to the water continuously does not take up much space

Eight advice for durable tiled swimming pools

Advice concerning concrete

- Plan and build concrete constructions so that you have control with shrinkage, stress and deformations.

Advice concerning water

- Always define which pool water quality the water purification system should deliver. It should have a LSI factor in the neutral zone. If necessary, a marble filter tank or similar should be mounted.

Advice concerning materials

- A cement-based fluid applied membrane combined with a partition of the tile layer with elastic joint sealants can reduce the shear stress between the concrete and the tile layer.
- Do not install elastic joint sealants if it is not necessary with regards to possible movements. Elastic joint sealants have a short lifespan, and rejointing can be expensive and time-consuming.

- If the untreated water or the pool water is of a *very aggressive* quality, epoxy-based jointing or adhesive products are recommended. Epoxy is not affected by aggressive water and tolerates chlorine and sulphate strain.

Advice concerning construction

- When casting and constructing; ensure that the concrete surfaces are coarse, not completely smooth. Use "blastring" or sandblasting devices that removes cement skin and opens up hidden weaknesses in casted concrete surfaces and provides a coarse surface for adhesive or possible membrane.
- Use buttering-floating to ensure best possible adhesion and complete contact surface. The adhesive should have a thickness of 4-5 mm. Ensure that the adhesive coverage is sufficient throughout the process.

Advice concerning the running and operation phase

- When starting up new water management systems, the company responsible for the installation must conduct a follow-up on the water quality periodically by measuring and estimating the LSI index. Simple tools for measuring both hardness and level of alkalinity do exist and should be used regularly, in addition to the obligatory measurements of pH value, temperature, and chlorine. If the joints start deteriorating, e.g. there is a lot of sand at the bottom of the pool, this is a symptom of the water not in mineral balance and need regulation.