Subsequent sealing of buildings made of textile reinforced concrete

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ABSTRACT: Many regions in Germany show a rising groundwater level. Hence the load case of buildings concerned changes from non-pressing to pressing water. Residential buildings not designed for the load case of pressing water have to be refitted. Conventional sealing methods are often associated with high complexity and high costs as well as the loss of living space. Furthermore in many cases they do not consider the additional static load of pressing water at all. This paper presents a newly developed subsequently applied sealing against pressing water. It is made of textile reinforced concrete. Using this composite material it is possible to produce a sealing system with a wall thickness of about 30 to 35 mm. During the production of an exhibit wall it became apparent that the spraying technique is an adequate and practicable method to produce a subsequent sealing of textile reinforced concrete.

1 INTRODUCTION

Many regions in Germany show a rising groundwater level caused by different reasons. On the one hand it may happen as a result of the climate changes in general. On the other hand the shut-down of open-cast pits in some regions and the involved cut-off of the appendant water drainage can also be a reason for the changing groundwater level. The rising level of groundwater has a direct effect on residential buildings not designed for this load case. The load case of buildings concerned changes from non-pressing water to pressing water. The buildings consist of base plates and masonry walls which are not completely waterproof. This leads to the problem that water penetrates the walls of the conventionally built basements. The buildings concerned have to be refitted with a subsequent sealing.

Presently there are several subsequent sealing methods to redevelop basements. It is possible to apply the sealing onto the walls from outside as well as from inside of the residential building. However, in most cases the subsequent sealings only seal the buildings against penetrating water. The changed load case and hence the additional static load are mostly not considered at all. Furthermore, conventional sealing methods often involve high complexity and high costs. In addition, sealing systems applied onto the inner walls are mostly associated with the loss of living space.

To minimize the mentioned problems this paper presents the use of textile reinforced concrete as a subsequently applied waterproof structure. With this composite material it is possible to produce thin-walled concrete building members with a dense structure and high compressive as well as tensile strength.

2 CONVENTIONAL SEALING METHODS

In case of a rising groundwater level the load case of residential buildings changes from non-pressing water to pressing water. To redevelop the affected basements it is possible to apply a sealing system from inside or from outside. It must be observed that the applied system not only fulfills the requirements placed in the sealings but also takes into account the additional forces arising by the hydrostatic pressure.

Sealing methods that are applied to the outer walls are generally associated with high complexity from the technical point of view and high costs. For these reasons these methods are not explained here. A subsequent sealing from inside entails better working conditions. In this chapter two conventional sealing methods from inside are presented.

The first sealing system consists of waterproof concrete which is installed on the inside of the basement walls and on the base plate (Fig. 1).

The second method uses e.g. a bituminous sheeting or coating to subsequently seal the basement. Here, the base plate and the masonry walls are covered with this dense layer. A layer of normal concrete is applied additionally to protect the sheeting against mechanical damage (Fig. 2).

The subsequent layers of concrete have to be steel-reinforced. As a consequence the wall thickness...
increases to avoid corrosion. This leads to an apparent loss of living space. In both cases horizontal water barriers in the masonry walls have to be arranged to avoid ascending water by capillary suction.

Applying the first sealing method (waterproof concrete) it is possible to reduce the loss of living space because this sealing system has to be applied only onto the inside of the outer walls. However, to avoid ascending water in the inner masonry walls, another horizontal water barrier has to be inserted at the bottom of all inner walls (Fig. 3). The disadvantage of this version is the high complexity and sensitivity in execution (Hinzen et al. 2006).

3 TEXTILE REINFORCED CONCRETE

Textile reinforced concrete consists of fine grained concrete and technical fabrics as reinforcement. The fabrics are mainly made of alkali-resistant (AR-) glass or carbon. Compared to steel-reinforced concrete the concrete cover can be reduced to a minimum as there is no corrosion risk with (AR)-glass or carbon fabrics.

Thus building members made of textile reinforced concrete are thin-walled. So if this composite material is used as a subsequent sealing from inside it will reduce the loss of living space.

Within a research project concerning the development of small sewage plants made of textile reinforced concrete (Hegger et al. 2003) it was found out that the functional efficiency of this construction is based on the fact that the composite material is resistant to chemical attack as well as water-impermeable. Furthermore the wall thicknesses of the small sewage plants could be minimized. The density of the textile reinforced concrete and the minor wall thicknesses led to the idea to develop a subsequent sealing of textile reinforced concrete.

Concrete features a high compressive strength. The composite material of fine grained concrete and fabrics gains additional tensile strength and a ductile behavior (Brameshuber 2003).

Within this research project two kinds of short fibers (AR-glass and PVA) were investigated to verify their effectiveness concerning the increase of the strength and the improvement of the crack distribution. Figure 4 shows the crack distribution of two slabs after being tested in a 4-point-bending test. The one in Figure 4 a is reinforced with 4 layers of fabrics (AR-glass, 40.7 mm²/m) and 1.5 Vol.-% AR-glass fibers, in Figure 4b with 4 layers of fabrics (AR-glass, 40.7 mm²/m) and 1.5 Vol.-% PVA fibers. The slabs were wetted to visualize the cracks.

It becomes apparent that a reinforcement consisting of a combination of fabrics and AR-glass fibers leads to an obvious improvement of the crack distribution.

For the use of textile reinforced concrete as a subsequent sealing the addition of AR-glass fibers becomes important. It improves the crack distribution and decreases the crack widths and crack spacings. Concerning the water-impermeability of the textile reinforced concrete these issues are very important to improve the properties of the composite material.
4.1 Principle of the subsequent sealing

Figure 5 shows a principle of a subsequent sealing made of textile reinforced concrete. In a first step the base plate and the masonry walls of the residential building are prepared with a system of special anchors. Afterwards fine grained concrete and fabrics are applied in layers with a defined position of the fabrics inside the concrete. The goal is to yield a wall thickness of 20 mm as depicted in the detail of Figure 5. At the moment a wall thickness of 30–35 mm is practicable.

4.2 Production technology

The requirements on the production technology are complex. To redevelop residential buildings it must be possible to apply the textile reinforced concrete to the walls as well as to the base plate. This means to insert the textile reinforced concrete in a horizontal as well as in a vertical alignment. The fine grained concrete must be adhesive to the walls during the production process. Hence the fine grained concrete has to be water-impermeable, resistant to chemical attacks of the groundwater, fulfill the requirements on the load bearing capacity as well as on the practicability and finally it has to be adjusted to the chosen production technology.

As a result of the requirements on the fine grained concrete and the construction of the subsequent sealing the spraying technique is the best production technique to apply the textile reinforced concrete to the base plate and masonry walls of residential buildings.

The spraying technique is very similar to laminating. It means to insert fine grained concrete and fabrics in layers. The fine grained concrete is sprayed to the walls and base plate with a pressure of 2 to 3 bar (Fig. 6). This process is based on a low pressure system as it is used to spray plaster to the inside or outside walls of a building. To ensure a good penetration and bond behavior, the fabrics are rolled into the applied fine grained concrete with a steel roll.

Using the spraying method it is possible to produce building members with a defined position of the fabrics inside the concrete. Furthermore it is also possible to produce building members in a horizontal as well as in a vertical alignment with a high amount of reinforcement. Concerning the production of a subsequent sealing made of textile reinforced concrete...
the spraying technique is a practicable method to redevelop residential buildings (Mott & Brameshuber 2007).

To fulfill the requirements on the fine grained concrete a new mix was developed (Table 1).

The mix contains short ARglass fibers to increase the flexural strength and to improve the crack distribution as mentioned in chapter 3. Further on, methyl cellulose is added to the mix to improve the thixotropy and tack. Both, fibers and methyl cellulose, strongly influence the thixotropy of the spraying mix. Reasons are the water-absorbing behavior of the fibers and the water-retraining property of the methyl cellulose. All this reduces the workability but up to a certain amount it increases the ability to be pumpable, sprayable and especially to adhere to vertical surfaces.

The fresh concrete properties density and spread were determined according to the German Standard DIN 18555-2:1982-09 as well as after the spraying process. Table 2 shows the fresh fine grained concrete properties.

A noticeable point is that the production technique has got a high influence on the compacting of the concrete. The structure of the sprayed concrete obtains its density from the spraying process. The concrete is pumped and leaves of the nozzle accelerated by air pressure. Accordingly, the fine grained concrete gets strongly compacted by the air pressure in combination with hitting the surface. Hence the density is higher in comparison with the one compacted with usual compacting equipment.

The hardened concrete properties compressive and flexural strength as well as the dynamic Young’s modulus were determined at a testing age of 28 days. First the dynamic Young’s modulus was tested by using the resonance frequency method according to a German guideline (Bunke 1991). To take the production process into account the specimens were sprayed. Their dimensions were 30·30·160 mm³. The same prisms were used to determine the flexural strength in a three-point bending test with a span of 100 mm. The testing machine was displacement controlled. As there are no guidelines concerning the loading rate, a reasonable value of 0.2 mm/min was chosen. The compressive strength was determined according to the German Standard DIN 18555-3:1982-09 by using the above mentioned prisms again. The mechanical properties as well as the density are shown in Table 3.

Due to the higher content of cement paste and the addition of methyl cellulose the dynamic Young’s modulus of the spraying mix shows a comparatively low value of about 31,500 N/mm². The methyl cellulose apparently influences and decreases the value of the compressive strength, too. The reason for this behavior and the effectiveness of the methyl cellulose has not been clarified completely until now.
5 EXHIBIT WALL

To check the functional efficiency of the developed subsequent sealing an exhibit wall that can be subjected to hydrostatic pressure was produced. Therefore a masonry wall consisting of calcium-silicate units with a wall thickness of 115 mm was built and prepared with special anchors. Afterwards the subsequent sealing made of textile reinforced concrete was sprayed onto the masonry. The thickness of the textile reinforced concrete wall was 30 mm. The wall is framed with a steel construction with acrylic walls like an aquarium. This allows the wall construction to be subjected to hydrostatic pressure. Hence it is possible to test the tightness of the sealing method in a long-term test. The front and side view of the exhibit wall can be seen in Figure 7.

It could be determined that the spraying technique is an adequate and practicable method to produce a subsequent sealing made of textile reinforced concrete. Initial observations of the wall subjected to hydrostatic pressure reveal the application potential of this construction. Long-term tests have been conducted for more than one year so far.

6 CONCLUSION

A new method for a subsequent sealing made of textile reinforced concrete for basements in case of pressing groundwater is presented in this paper. Conventional methods to redevelop residential buildings are often associated with high complexity and high costs as well as the loss of living space. Using textile reinforced concrete the wall thickness of the subsequent sealing can be minimized. Furthermore the dense structure of the fine grained concrete leads to a water-impermeability and a high chemical resistance. The water-impermeability is also ensured by small crack widths and crack spacings as a result of the added short ARglass fibers.

The tightness of the construction was investigated in a long-term test by an exhibit wall. This set-up allows subjecting the wall construction to hydrostatic pressure. Thus the functional efficiency and the design of such a subsequent sealing could be demonstrated. It was shown that the spraying technique is an adequate and practicable method to produce a subsequent sealing of textile reinforced concrete. With this production technique it is possible to produce building members in a vertical as well as in a horizontal alignment. Also a defined position of the fabrics inside the concrete can be ensured.

Accordingly it is possible to produce a subsequent sealing made of textile reinforced concrete. The construction can fulfill two functions. It can seal the basements of residential buildings and bear the additional load due to pressing groundwater up to a water pressure of about 0.2 bar. This is equivalent to a water column of 2 meters. The required wall thickness of the textile reinforced concrete amounts to only 30 to 35 mm. Hence the subsequent sealing of textile reinforced concrete may offer a cost-effective method to redevelop residential buildings in case of pressing groundwater with a minimized loss of living space.

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