Application of bentonite in waterproofing of underground structures

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Abstract

Bentonite is a very important industrial material. Its dominant component is montmorillonite which makes at least 70% of its composition. Among various types of bentonite, the most commonly used is the sodium. It's characteristics, such as high swelling ability, the properties of thixotropy (in a mixture with water it transfer into the gel), and high water absorption capacity (it can absorb 12 to 15 times the mass of water from the dry substance itself) give it a great advantage in geotechnical works as waterproofing material. This paper presents an application of bentonite carpets as an isolation agent in the reconstruction of the wine basement and the construction of the Roxanich Heritage Wine Hotel in Motovun. Bentonite carpet consist of bentonite membrane with montmorillonite content of at least 80%, in between two layers of geotextile, all bonded by thick stitching. Waterproofing system completes with tapes Waterstops RX 101, bentonite granules, bentonite Bentoseal paste and polymeric waterproofing. This system was used throughout the basement extending to five underground floors. It was proved to be an effective waterproofing solution, appropriately engineered for its operation in difficult ground conditions.

1 Introduction

The durability and functionality of underground facilities depends largely on their protection from water. For this reason, in recent years, the clay geosynthetic barriers have been used increasingly as a protective sealing system. Water almost always causes severe degradation of the concrete structure and causes many problems for the users of the building. Therefore, the waterproofing system should completely prevent groundwater penetration into the object. The artificially produced hydraulic barrier discussed in this paper consists of a layer of bentonite clay that is mainly fixed between two layers of geotextile. In most cases, the geotextile is the load-bearing component, while the bentonite clay is the sealing impermeable barrier. The main mechanism that ensures low hydraulic conductivity of the bentonite clay is swelling. This paper presents the procedure for the application of the bentonite membrane and some laboratory tests performed for quality control of this material.

2 Material characteristics and application of bentonite membranes

Sodium bentonite is a special, non-toxic type of clay volcanic origin created several million years ago. The unique characteristic of this natural material is the capacity to increase volume after contact with water. In such a state, sodium bentonite can increase its volume 15-16 times from its volume in a dry state. Additionally, in such a state, it becomes a completely impermeable gel.

2.1 How bentonite membranes function

In contact with water, the bentonite is hydrated and produces a leakproof gel. In such a state it expands up to 16 times from the initial volume. The key point is the compression of bentonite granules between the concrete structure and earth, allowing complete sealing and protection of water, steam and gas. When this membrane is spread on the concrete, or concrete is poured on the membrane, the geotextile fibers are mechanically bonded to the concrete, so there are no water residues between the bentonite membrane and the structure. Bentonite membrane creates a continuous mechanical bond with concrete as illustrated in Figure1.

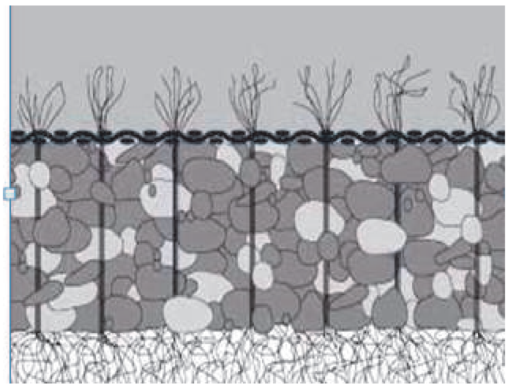

Fig. 1. Composition of bentonite membrane. The bentonite membrane consists of two solid polypropylene geotextiles on the outside and 4.88 kg of Volclay bentonite in granules per m^2. In contact with water or moist soil, Volclay bentonite is hydrated to produce a leakproof gel while the geotextile fibers mechanically bind to concrete.

This material is used as a protection and waterproofing of underground concrete structures from permanent or occasional water. Installation is quick and easy: it can be laid on fresh concrete, without primer and glue, and it can be easily cut around the corners. Due to its inherent flexibility and robustness, it can be placed on irregular surfaces, and the membrane joints simply overlap. The result is always consistent self-contained waterproofing.

2.2 Installation of bentonite membranes on the Roxanich Heritage Wine Hotel in Motovun

The Roxanich Heritage Wine Hotel in Motovun stretches to over 3,000 square feet. For the waterproofing sistem, on four different floors, a bentonite membrane is applied. The struction is performed on a complex, predominantly clay relief with the presence of groundwater. Considering that the entire municipality of Motovun is a water area with three sources of drinking water and six captured springs. The application of the bentonite membrane began by excavating the upper part of the site. Since it is a clay soil where excavation is carried out, the concrete is performed, on certain floors, as part of the groundwater control.
After compacting the substrate a bentonite membrane is placed on a surface with a minimum overlap of 10 cm. During the membrane installation fixing clips were applied. Before the application of bentonite membrane on vertical walls, as illustrated in Figure 2, surfaces were aligned. Larger cracks are filled with Bentoseal paste. The Bentonite membrane is laid on a lighter side of the concrete which is isolated.

Fig. 2. Application of bentonite membrane on vertical surfaces of the Roxanich Heritage Wine Hotel in Motovun. Installing the bentonite membrane on vertical concrete walls that are previously leveled off from the hollows and the sharpness. Bentonite membranes are placed on walls with a lighter side of the geotextile, with 10 cm cross-over. For fastening geotextiles, were used clamps (industrial clamps) every 30 cm.

After laying the membrane, the reinforcement and the one-sided wall formwork were laid and the wall concrete was performed, as shown in Figure 3.

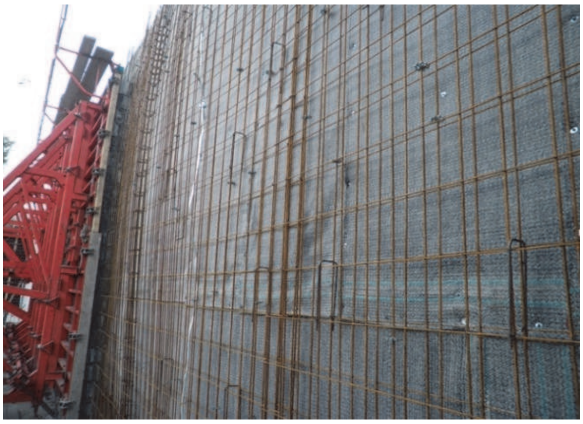

Fig 3. Installation of reinforcements on the bentonite membrane at vertical surfaces. After the simple laying of the reinforcement on the bentonite membrane, the one-sided wall formwork is laid and the new wall is concreted.

Fig. 4. Application of bentonite membrane below the base plate

3 Bentonite testing for quality control purposes

Test methods were performed in the geotechnical laboratory of Institute IGH d.d for the purpose of controlling the quality of bentonite membranes.

3.1 Consistency limits

Consistency limits were tested accordance with standard ISO / TS 17892-1. Parameters obtained with this type of test, its plasticity limits and liquid limits, are

used for classification. In the test a cup of the liquid limit device, of stainless steel, with a soil sample was raised and dropped by rotating an axis as shown Figure 5. The liquid limit is the value of the water content for which a standard V-shaped groove cut in the soil, will just close at the standard length of 13mm after 25 drops. If the groove closes after less than 25 drops, the soil is too wet, and some water must be allowed to evaporate. By waiting for some time, and perhaps mixing the clay some more, the water content would decrease, and the test can be repeated, until the groove is closed after precisely 25 drops. Then the water content must immediately be determined, before any more water evaporates. For plastic limit determination it is used about 15 g of moist sample. The sample was rolled on a glass plate with the hand to threads of 3mm diameter.
The procedure was carried out until threads of 3mm diameter shown signs of crumbling.

Fig. 5. Testing the liquid limit of bentonite granules. Specimen is placed in a cup of Cassagrande's apparatus resting on the base. It is necessary avoid entrapping air. A standard knife is used to divide the soil into two equal parts. The cup freely falls from a height of 1 cm by counting the number of bumps. The test is carried out until the two parts of the specimen are tied to the bottom of the 13mm length. The number of falls is noted needed to close the grove in the required lenght of. The test is carried out for four specimens. After the coupling is achieved, the sample is placed in a glass container and the moisture content is measured.

Tabel 1: Test results of plasticity limits

Sample number	1	2	3	4
Water content (%)	32,55	33,93	36,4	32,08
Number of drops (*N*)	16-16	27-27	33-33	44-44
Liquid limit w_L (%)	482,86			
Plastic limit w_p (%)	38,58			
Plasticity index ***Ip***	444,29			

3.2 Strain testing of bentonite membrane

Strain testing was performed according to standard HRN EN ISO 10319: 2001. A dry laboratory specimen was tested in a Zwick / Roell Z100 testing machine with a constant stretching expansion as illustrated in Figure 6. The tensile strength is determined on the sample lengths of 100 mm and the minimum width 200 mm, where the sample width should be adapted to the characteristics of the material. The sample was tested under conditions of 23 degrees celsius and relative water content of 50%. Test speed 12mm / min. with 150 bar pressure steel jaw. During the test, the sample runs at a rate of 20 ± 5% / min, with constant deformation gain. The deformations were measured using extensometers, which monitor the displacement of the two reference points, at an initial spacing of 60 mm.

Fig. 6. Strain testing of the bentonite membrane in the laboratory testing machine. Testing results of the possible breakdown of the material and desired deformation at the appropriate tensile force.

The device is completely guided with computer program that determines the sample deformation size with accuracy of 0.02mm. as illustrated in Figure 7.

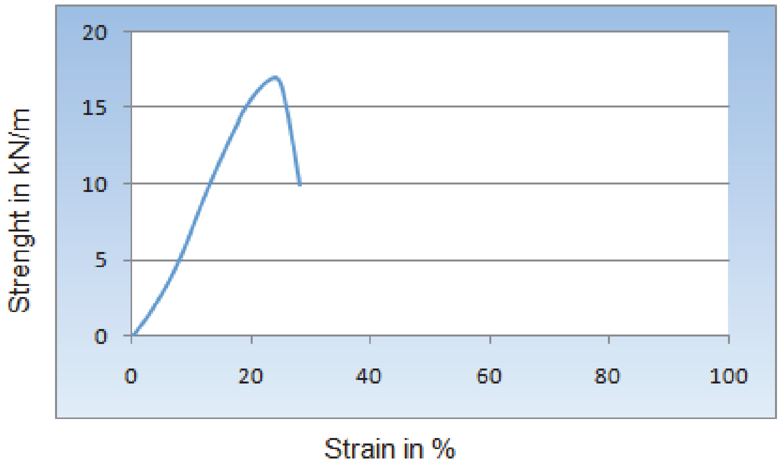

Fig. 7. Display the results obtained by tensile test of the sample. Increasing tensile stresses the material resistance is increasing to external impact. Achieving limit values causes breakage or cracking of the bentonite membrane.

The following table shows basic data on the selected bentonite membrane tested for tensile stresses (Table 2). Tensile strength a_f is expressed in kN / m, directly from the data obtained by testing, using equation

$$a_f = F_f \cdot c \qquad (1)$$

where F_f is the maximum force expressed in kN and c the ratio of the minimum number of tensile elements of the test sample (Ns) and the minimum number of tensile elements in 1 m of width of the bentonite membrane. Sequence strength was calculated based on the formula, according to HRN EN 10319

$$J_{sec} = (F_c \cdot 100)/\varepsilon \qquad (2)$$

where F_c is a determined force at deformation ε, expressed in percentage.

Tabel 2. Results

Longitudinal sample testing	J sec N/m m	F_f (kN)	a_f (kN/m)	ε_f (%)	Test time (min)	Deformation (mm)
1	230,4	3,35	16,7	23,4	1,8	14,02

Based on the obtained results and the comparison of the technical characteristics according to EN 13491:2004, a tensile test showed acceptable results.

4 Conclusion

The use of bentonite membranes for waterproofing and protection of underground structures exposed to water is in increase. The reason for this is quick and easy installation, minimal preparation and simple processing of critical details. Laboratory testing of certain properties of the bentonite membrane was carried out to prove the characteristics of the materials as required by the technical specification EN 13491: 2004. Based on the obtained results and literature, certain materials qualities are confirmed. Active component of bentonite granules, with 80% montmorillonite between the two layers of geotextile associated with thick stitching make the complete waterproofing system. For complete proof of accordance with technical specifications, it is suggested to test the swelling and water penetration index.

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