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STUDY ON THE SCREEN SEALING CHARACTERISTICS EXECUTED AT MILEANCA DAM (CASE STUDY)

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Abstract: *Using the solution of self-hardening mud to complete the Mileanca dam screen sealing has stopped the infiltration of water through the permeable layers. The screen seal has a width of 60 cm and a variable depth H = 7 to 11 m. It is embedded in the shale layer, to a depth of 1 m. The work was done by respecting the technology and the self-hardening mud recipe was established after laboratory assessment and land verification with the consent of the engineer and the beneficiary.*

Key words: *screen sealing, self-hardening mud, guiding beams, bentonite suspension, impermeable layer (clay marl).*

1. Introduction

The technical conditions for the execution of the sealing screen from self-hardening bentonite mud, using Kelly installation type, are based on the general requirements related to the execution of molded walls sealing screens.

The technical provisions were required for the smooth execution of the self-hardening bentonite mud sealing screen.

The main operations for the execution of the self-hardening mud sealing screen were:

▪ tracking the works according to the plotting plan coordinates;

▪ earthworks to create the work platform;

▪ execution of the facility trench by excavation with Kelly;

▪ filling the trench with self-hardening mud.

2. Features of the Sealing Screen

2.1. General Features

The main features of the screen are the following:

▪ maximum depth of panels (between the screen execution upper elevation and the restraint elevation);

▪screen width: 0.60 m;

▪ current length of a panel:

- 2.80 m primary panel
- 2.10 m secondary panel

The screen has a length of 370 meters with depth varying from 7 m to 11 m. Bentonite is the key component to achieve the self-hardening mud. The bentonite used to prepare the slurry of self-hardening mud fulfilled the conditions indicated in STAS 9305-81 [1].

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According to STAS 9305-81 [1], the active bentonite used in the preparation of self-hardening mud was accomplished by treating the bentonite with 2% ÷ 4% soda ash in accordance with STAS 2640-82 [2], as shown in Figure 1.

Fig. 1. *Aspects from the execution of the sealing screen at Mileanca dam – Excavation of a panel using specialized installation type Kelly*

2.2. Physical and Chemical Properties

Bentonite material obtained had the following physical and chemical properties:

▪ yield (m^3/t), which was determined according to STAS 9484/11-92 [3], representing the quantity of suspension (m^3) with the apparent viscosity (36 'Marsh') which can be prepared from one ton of bentonite. The minimum value was 12.50 m^3/t;

▪ free sand content, determined in accordance with STAS 9484/22-82 [4], the maximum allowable value being 5%;

▪ grinding fineness, determined in accordance with STAS 9484 / 16-74 [5], the maximum allowable residue 2% on the 0.16 sieve and 10% on the 0.063 sieve.

The quality check of active bentonite was made on lots of max. 10t in accordance with STAS 2411-75 [6]. When the received material check was not considered to comply with the conditions permissible in STAS 9305-81 [1], the material was refused.

Preparation of bentonite slurry was done in IBN mixers with vertical shaft type with a capacity of 3.5 m^3.

The order of placing components in the mixture will be water - activated bentonite, the mixing time is 5 minutes.

Considering the physical - chemical properties of the bentonite, it was indicated a dosage in suspension of approx. 80 kg/m^3. The dosage was finalized by laboratory tests in order to obtain a suspension of activated bentonite (hydrated 24 hours).

At the placing, the activated bentonite suspension (hydrated 24 hours) had the following characteristics:

▪ apparent viscosity determined by measuring the discharge time by Marsh funnel an amount of 1,000 cm^3 of suspension, the allowable time being 34 ÷ 37 sec;

▪ suspension density determined by weighing, the admissibility condition is 1.04 ÷ 1.06 kg/dm^3;

▪ suspension stability, representing the sediment volume in cm^3 to 100 cm^3 suspension allowed to stand for 24 hours, the minimum eligibility condition being 99 cm^3.

Preparation of bentonite suspensions to establish the physical and chemical properties was done in accordance with

STAS 9305-81 [1]. The water needed for preparation of bentonite suspension complied with STAS 790-84 [7].

2.3. The Properties Determined According to Laboratory Tests

The final recipe for the preparation of 1m^3 self-hardening mud for the sealing screen of the upstream toe of Mileanca dam was the following:

- 920 liters of water;
- 2.5 kg soda ash (required for bentonite dissolution in water);
- 100 kg bentonite;
- 200 kg cement type H II AS, according to NE012 - 1: 2007 [8].

Preparation of the self-hardening mud was done in the same vertical shaft IBN type mixer, the entry order of the components being: bentonite suspension, and cement. The mixture stir was done for at least 15 minutes, thus ensuring the mixture homogeneity.

The cement met the conditions of SR EN 197-1/2011 [9], checking the setting time, the volume constant and the mechanical resistance.

The transport of bentonite suspension from the preparation place to the placing site was achieved by pumping using rigid pipes.

2.4. Features of Self-Hardening Mud Depending on the Cast Panels Results

Compared to the recommended recipe and given the results obtained on the molded screen panels, the self-hardening mud characteristics were:

▪ maximum density 1.2 kg/dm^3;

▪ apparent viscosity determined with Marsh funnel 39 sec;

▪ suspension stability by determining the percentage of water separated from the free surface for 100 cm^3 of suspension 2.1%.

Some final physical characteristics of the self-hardening mud screen will be:

▪ minimum permeability coefficient of 2x10^{-6} cm / s;

▪ monoaxial compressive strength at least 300 kPa

The definitive recipe of the self-hardening mud was endorsed by the designer and the beneficiary and was established in tests both at the site laboratory and on the specialized and certified units, on the supplied materials.

2.5. Sampling Approach

Taking a sample of bentonite to be checked was performed at each new batch of supply and during progress in the preparation and placing.

For new lots of bentonite supplied, the lab supervisor took 2 samples of which one was used to its controls, and the other was sent to a specialized unit after being placed either inside or outside the bag two labels with the following particulars: drive execution, lab supervisor, bentonite indication, sampling date. Each sample contained at least 3 kg of bentonite.

For the tests made on the used bentonite, slurry preparation was done according to STAS 9484 / 22-82 [4].

2.6. Final Quality Control of Self-Hardening Mud

The quality tests of self-hardening mud screen were performed on samples taken from:

▪ trench immediately after the excavation operation of the secondary panel was finished (phase III of scraping the bottom), the sampling level being at a depth of at least 4m from the upper panel, the samples were kept wet in laboratory (in exicator) and tries were made at 28 days;

▪ nozzles, taken from boreholes executed at least 28 days from the date of the panel termination, in locations determined by the engineer and the beneficiary;

▪ minimum three (3) samples for each molded panel were taken to determine the quality of panel and at 10 panels was runned a drill for quality control work.

Attempts were made to determine the following characteristics:

▪ permeability coefficient (K) of the screen was made depending on the type of the embedded screen in a barrier layer, as well on as the flow of water infiltration.

Determination of permeability was based on laboratory tests on samples with Ø 7 cm and 2 cm height in parameters according to STAS 1913 / 6-76 [10].

The permeability coefficient permissible for the sealing screen did not have a value greater than 2×10^{-6} cm/s.

▪ monoaxial compressive strength, was made at 28 days, on prisms samples with dimensions 4x4x8 cm, with the coefficient of slenderness 2.

The screen takes through own deformations any equal or unequal subsidence of the surrounding land. The check was made at press according to STAS 8942/6-75 [11], the minimum permissible resistance to monoaxial compression was 3 daN/cm^2.

For each panel, from the bottom of the screen (in the region of the fixing in the clay marl) was yield a probe which was labeled (date, panel no., the depth of the recessed panel), and was preserved throughout during execution.

2.7. The Quality Check of Screen Execution After the Mud Hardening

The checking of the screen after the execution was done in order to control the work quality and the degree of waterproofing. The final verification was needed to reveal any deficiencies on works execution, but no execution deficiencies were found.

The screen checking was made by executing in the body sealing screen Ø 80÷100 mm diameter control drilling and extracting cores from different depths, which was examined in the laboratory. On these cores were determined samples for permeability and compression resistance. The panels checked were specified by the engineer and the beneficiary, the checks program being required to complete before the end. For guidance, a drilling was set at a 100 m distance from the screen.

Supervising the checks and recording the results was done by the quality control department of the site, in the presence of the project supervisor and the assistant geologist. How to check and all data obtained from checks was recorded in the finding minutes attached to the controlled panel files. In all these cards was mentioned the verification method adopted for each panel and the results obtained.

2.8. Control Boreholes Running in to the Sealing Screen Body

The position of control boreholes for screen tightness could be determined by the beneficiary who, in advance, has analyzed the laboratory results of the impermeability degree.

The boreholes will be executed only on the geologist presence. The control boreholes will have diameters of 80 to 100 mm. The optimal diameter can be determined experimentally, having primarily regarded to ensure verticality. Permeability samples will be carried downward.

During drilling execution screen probes will be sampled and inventoried after depth and stretch and filed in special evidence boxes. It will be ensured that the drilling site in panel field to be as close to the screen spindle. It will be checked permanently the horizontality and verticality of the rig. Digging will be made with diamond cutters, rotary system only and, in no case, by percussion drill. The depth of the boreholes will be equal to that of the panel plus 1.0 m in the bedrock. In some boreholes, indicated by the engineer, measurements of deflection will be made.

There was no need during the execution, for additional drilling control because they were not identified areas where the quality criteria were not satisfied.

3. Tests, Probes, Determination and Results of the Sealing Screen

3.1. Permeability Probe

The permeability samples were completed in top down system, in sections 3 ÷ 5 m deep, with simple mechanical packer, with open circuit and by raising it from the surface.

The permeability samples were carried out at least 90 days after the execution of the screen area. Before starting, permeability tests accurately recorded the water levels in the accumulation area.

The service pressure at the level of the test section was calculated and did not exceed 2.0 ÷ 2.5 atm. Samples were made in increments of 0.5 psi./½ hour. The maximum pressure of (2.0 ÷ 2.5 atm.) was maintained constant for 4 hours.

For permeability tests implementation these steps were followed:

▪ water was put in the mud settling stump to a level which is determined by a rod or a level tube. The mud settling stump had a capacity of more than 1 m^3, being adapted to the small water losses, which are estimated. For precision measurements was used calibrated float rod solidarity with mud settling stump or a measuring rod with float and micrometer;

▪ water was pumped under the first pressure stage and, when the measured gauge pressure was constant, the water level in the mud settling stump was measured at intervals of 5 minutes;

▪ water pumping under a pressure stage lasted until the injected flow remained constant at least three consecutive readings. When this condition was satisfied it was proceeded to the next pressure stage, the process being similar.

The results of permeability tests were registered to a control card, presenting inclusively the specific absorption capacity calculations with the formula:

$$q_s = Q/L \times T \times p \text{ (l/m} \times \text{min.} \times 0.1 \text{ at.)} \quad (1)$$

where:

-q_s - specific absorption capacity;
- Q - water flow lost under the regimen (liters);
- L - section length (meters);
- T - testing time (minutes);
- p - presiunea (pressure 0.1 at.)

The average admissible water loss may be q_s = 0.01 l/m × min. × 0.1 at. (Lugeon Criterion).

Samples permeability w ere run on all sections as a whole, without interruption to the hours. Following measurements are not allowed deviation from the vertical axis deviation greater than 10 cm.

3.2. Injections

The injections were made only in the boreholes and sections that have exceeded the maximum absorption capacities, respectively q_s = 0.01 l / m x min. x 0.1 at. (1.u.L)).

To achieve injections on intermediate sections of the drilling will be used a double mechanical packer using surface reinforcement. The injections will be made in the upward system.

The duration of injection, quantity of cement on ml and the water/cement factor, according to the specific permeability in the section are shown in the following table:

Duration of injection and dosages depending on the specific permeability Table 1

Specific absorption capacity q_s [l/m x min. x 0.1 at.]	**Factor A/C**	**Injection time [min.]**	**Maximum quantity of cement in suspension [kg/ml]**	**Observations on suspensions change**
0.01	10/1	30	20	No change in absorption below 10 l/min per section. Continue to the brim.
0.01 ÷ 0.03	5/1	30	20	
0.03 ÷ 0.05	3/1	30 ÷ 35	50	No change in the absorption of up to 25 l/min per section. Continue to the brim.
0.05 ÷ 0.15	2/1	45	100	No change in absorption of 30 ÷ 50 l/min per section. Continue to absorption of 10 l/min per section.
0.15 ÷ 0.40	1/1	45	150	No change in absorption of 50 ÷ 75 l/m, per section. Continue to absorption of 10 l/min per section.
> 0.40	1/2	60	200 ÷ 250*	No change in absorption of 75 ÷ 100 l/min per section. Continue to absorption of 10 l/min per4 section. It is limited to a total of 500 kg/m.

* after the consumption of the recommended amount of suspension, the injection is stopped and allow it to set at least for 72 hours, after which the injection is resumed with 5 : 1 suspension.

Refusal could be considered when for a meter of the section, the slurry flow injected at maximum design pressure does not exceed 0.3 ÷ 0.5 l/min. For the specific case of the screen consolidation in areas with cracks, are considered sufficient the recipes A/C = 5/1 and 3/1. The other cases were considered in exceptional circumstances. For the suspensions stabilization will be used bentonite in an amount of 2 kg per 100 kg of cement (2%).

It is recommended to start with unstable suspensions injections (simple water-cement mixtures) to continue with stable suspension and eventual ending with unstable suspensions until obtaining refusal.

The cement used for preparing the A/C mixture will be of the H II AS (NE012 - 1: 2007) [8]. The water was clear and meet the technical requirements of STAS 790/84 [7]. It did not contain solutes above 1.5%, of which sulphates and did not exceed 1%. It did not contain organic substances.

3.3. Laboratory Methodology

3.3.1. Conventional Viscosity

It is determined using Marsh funnel and represents the time in seconds in which 1000 cm^3 of suspension is flowing from funnel, according to STAS 9305-81 [1].

3.3.2. Cone Check

The hopper is filled with fresh water (1000 cm^3 water), and the hopper is depleted. If the emptying time is greater or less than 28 ± 0.5 sec. then it is dirty, deformed or has a threshold between the cylindrical tube and the tapered body. It is forbidden to use deformed funnels, with thresholds in the connecting section or dirty funnels.

3.3.3. Determination of Conventional Viscosity

Soak the funnel with water and close the hole. Fill with 1,000 cm^3 suspension through a 1.5 ÷ 2.0 mm sieve. The sieve may be attached to the upper half of the cone section. It is measured the time of filling the 1.000 cm^3cup.

3.3.4. Decanting

It is determined in 1.0 l cylindrical glass vessels with a diameter of 60 mm. The suspension is left in the cylinder for 2 hours. It is read the decanted water column height at the top and is related to the overall height, the ratio being the decantation.

3.3.5. Density

It is recommended to use the cylinders used to determine the decantation. Weigh the cylinder filled with suspension. The difference between the weight of the cylinder with suspension and the tare is the specific weight of the suspension. It is recognized to by determine the density using hydrometers after testing the errors obtained by comparison with data obtained from the weighing method.

3.3.6. Gelation

It is determined using a rod of Ø 3.5 mm, 50 mm long, weighing 3.5g. The tip of the rod is conical with h = 10 mm. The opposite end is threaded or grooved for a 10mm length. A ring PVC is put on a tile or glass and filled with suspension. From time to time the rod is introduced in the suspension on a vertical position. The gelation beginning is recorded when the rod does no longer enter till the support and remain in suspension with the knurled portion of 1 ÷ 2 mm above the suspension. Gelation end is recorded when the conical tip of the rod enters in the suspension only up to half height.

3.3.7. Relative Rigidity

It is determined with a striated bran steel plate. Immerse the plate suspended by a device with a thin cable on a winding reel. It is hold for 2 seconds in the suspension and easily manually extracted by rotating the drum. The weight of the plate with suspension is measured by hanging it on a precision balance pan. The difference between the weight obtained and the tare is R, suspension stiffness, which in practice is reported more convenient in the form:

$$Rr = R/p \qquad (2)$$

where:

- Rr - the thickness of the suspension layer adhered to each side of the plate;
- R - suspension stiffness;
- P - specific weight of the suspension.

All these determinations are made for

each batch of material supplied by the site and each recipe suspension. The number of measurements should be at least one month series.

Filling the drilling will be carried out with a suspension of high consistency (A/C = 1/1 ÷ 1/2). During the drilling filling air holes are not allowed into the drill or incurred due to technological processes.

4. Conclusions

Casting the sealing screen from self-hardening mud, with embedding in the layer of marl at the upstream toe of Mileanca dam led to stopping the seepage under the dam, leading to an increase in its stability and substantial improvement of the technical parameters of the reservoir, which holds approx. 14.7 mil. m^3 of water.

The adopted recipe following the laboratory and field studies in agreement with the engineer and the beneficiary led to the establishment of parameters and implementation conditions.

Subsequent determinations and checks showed that the sealing screen was well done.

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