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Äspö Hard Rock Laboratory

Backfill production for Prototype Repository

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Summary

The tunnel and the upper meter of the deposition holes in the Prototype Repository are backfilled with a mixture of bentonite and crushed rock. This report concerns the production of the backfill material.

2311 tons of 0-20 mm crushed rock was produced from the TBM-muck once excavated from the ÄHRL. The crushing took place close to the Äspö HRL tunnel adit on July 2 and 3 2001.

The backfill was produced by mixing crushed rock with 30 % bentonite (dry weight) and adding water to about 12.5 % water ratio. A total of 1544 tons of crushed rock, 703 tons of bentonite and 110 m^3 water were mixed yielding a total of 2357 tons of 30/70 backfill material. The mixing took place between 01-08-08 and 01-09-15. The material was then stored in tents close to the entrance of the ÄHRL until the backfilling of the Prototype Repository tunnel started.

Sammanfattning

Tunneln och den övre metern av deponeringshålen i Prototypförvaret återfylls med en blandning av bentonitlera och krossat berg. Denna rapport behandlar produktionen av detta återfyllnadsmaterial.

2311 ton TBM-muck från som producerats under drivandet av tunneln i Äspö HRL krossades till fraktionen 0-20 mm. Krossningen gjordes i närheten av nedfarten till Äspö HRL den andra och tredje juli 2001.

Återfyllnadsmaterialet producerades genom att krossat berg blandades med 30 % benonit (torr vikt). Vatten tillsattes så att vattenkvoten justerades till ca 12,5 %. Totalt 1544 ton krossat berg, 703 ton bentonit och 110 ton vatten blandades. Detta genererade 2357 ton återfyllnings material (30/70). Blandningen skedde mellan 2001-08-08 och 2001-09-15. Återfyllnings materialet lagradas sedan i tält nära nedfarten till ÄHRL tills återfyllningen av Prototypförvaret startar.

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1 Introduction

The Prototype Repository is a full-scale simulation of a part of a repository with 6 deposition containing canisters and bentonite buffer and with a backfilled deposition tunnel. The buffer, backfill and rock will be instrumented for measuring mainly thermal, hydraulic and mechanical processes. This report describes the manufacturing of the backfill material.

The choice of production method and backfill composition for the Prototype Repository was based on experience from the Backfill and Plug Test /1-1/, laboratory tests and field tests made for the Prototype Repository /1-2/.

2 Crushing

2.1 General

In this chapter the crushing of the TBM muck to a grain size of 0-20 mm is described. 2311 tons of TBM-muck was crushed with a crushing plant close to the Äspö HRL tunnel adit between July 2 and 3 2001.

In the pre-tests reported in /1-2/ TBM-muck was crushed to a grain size of 0-5 mm. This process turned out to be more complicated than expected. The TBM-muck contains a lot of fines (11 – 18 percent < 0.075 mm) and this in combination with a high water ratio made the material very hard to handle.

The following conclusions were drawn from the pre-tests/1-2/:

"The high water ratio of the material makes it very difficult to crush to 0-5 mm with traditional cone or jaw crushers. These crushing techniques are based on the fines being removed before the crushing. The high amount of fines in combination with the high water ratio immediately makes a 5 mm sieve clog. If the fines are not removed they form aggregates that cannot be crushed. This causes high strain on the bearing axes of the crusher and might cause the crusher to break down. Sorting out fine material is also necessary in a continuous crushing procedure where cone or jaw crushers are used. The alternatives are to decrease the water ratio of the material or to use a different crushing technique."

It was decided that it would be too expensive to crush the material to 0-5 mm in the scale for the Prototype Repository. Instead the same maximum grain size distribution as used in the previous Backfill and Plug Test, 0-20 mm, was chosen.

2.2 Description of equipment and technique

A flowchart for the crushing is shown in Figure 2-1. The crushing was made in the following steps:

The TBM-muck was fed into a Powerscreen sorting works with a double sieve to sort out the 0-20 mm material with high water ratio.

The rest of the material (20-100 mm) was fed into a loop in a crushing station model "Mulle" with a cone crusher AC 4000. After crushing the material was sieved and the material less than 20 mm was fed onto the feeder coming from the sorting works and stored in a pile.

A photo of the crushing equipment is showed in Figure 2-2.

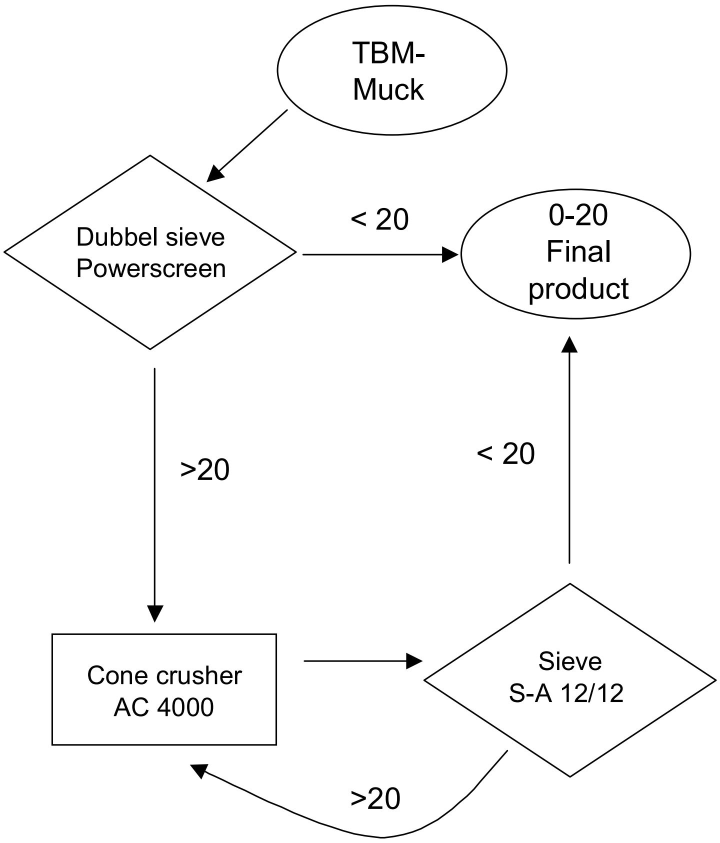

Figure 2-1. *Flow chart for the crushing*

Figure 2-2. *Photo of the crushing equipment.*

2.3 Grain size distribution

The aim was to achieve a Fuller grain size distribution curve as shown in Figure 2-3. The grain size distribution of the material from an initial test crushing 2001-07-02, also presented in Figure 2-3, deviated too much from the Fuller curve and the gap in the cone crusher was decreased to yield more material in the range 0,1 – 4 mm. This resulted in a grain size distribution more similar to the Fuller curve, see Figure 2-4.

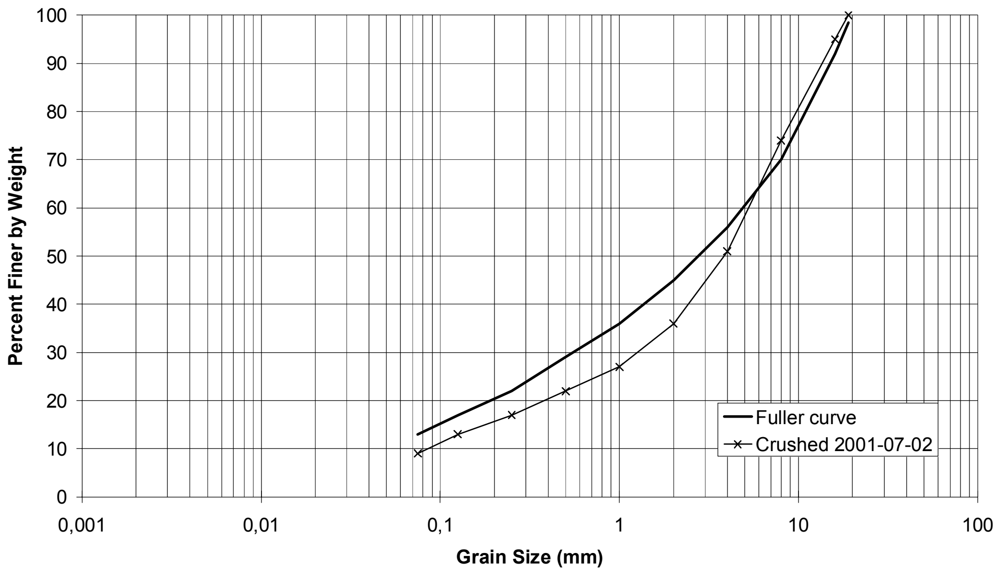

Figure 2-3. *The grain size distribution of the test crushing.*

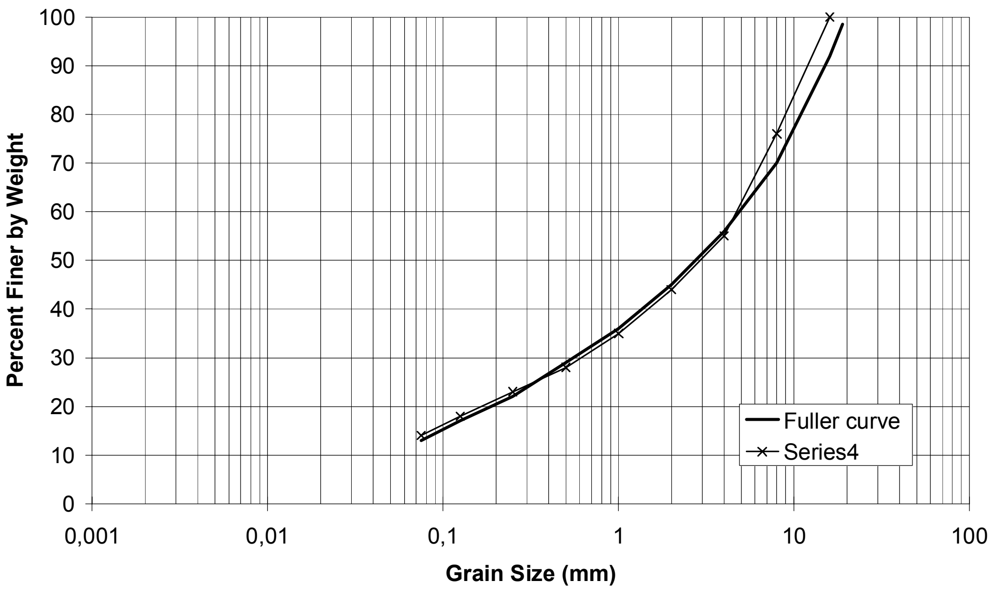

Figure 2-4. *The grain size distribution after adjusting the crusher*

After completed crushing 6 samples were taken at random. The grain size distributions are shown in figure 2-5.

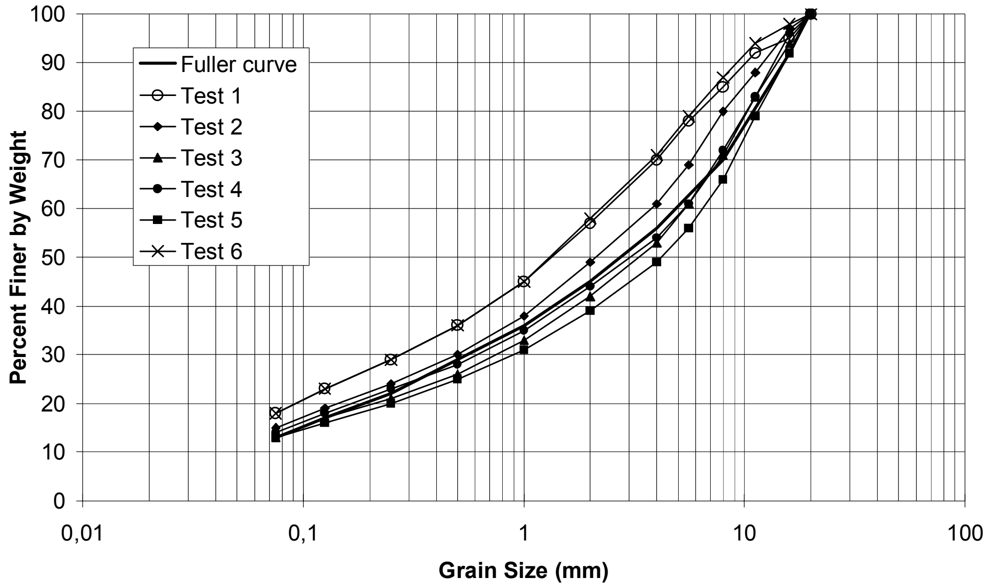

Figure 2-5. *Grain size distribution of the samples taken at random after the crushing*

Four more samples were taken at locations in the pile were it looked as if the material had separated. The results are shown in Figure 2-6.

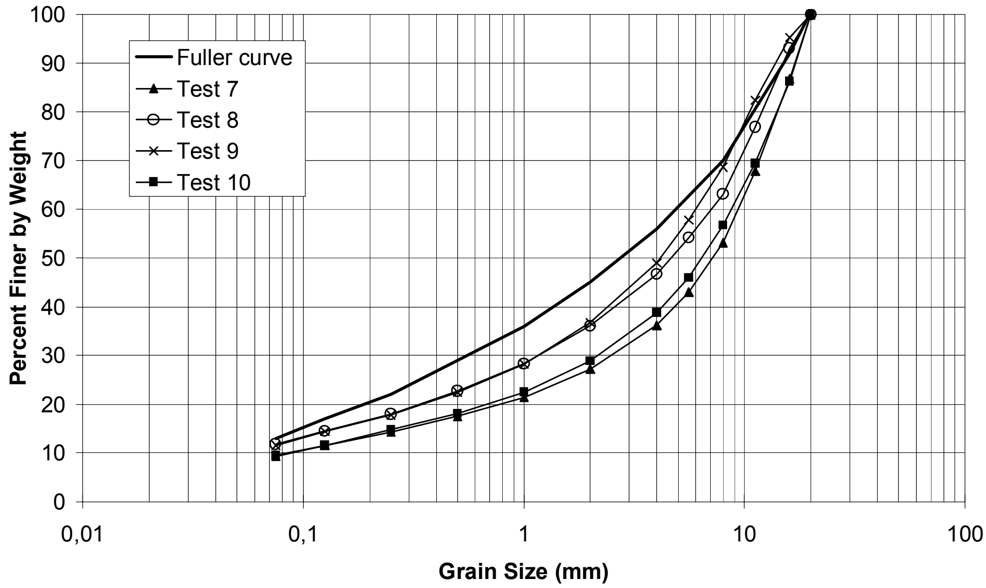

Figure 2-6. *Grain size distribution of samples taken from a part of the pile that seemed to have separated.*

3 Mixing

3.1 General

A total of 2412 tons of 30/70-backfill material were mixed close to the ÄHRL adit from 01-08-08 to 01-09-15. In addition 40 tons of 20/80 bentonite /sand mixture for manufacturing blocks were mixed.

3.2 Description of equipment, technique and components

The mixing station consists of a paddle mixer, four pockets for the ballast (crushed TBM-muck), one water tank and a silo for the bentonite. The ballast is transported to the mixer with conveyer belts and the bentonite with a screw. A picture of the station is shown in Figure 3-1.

Figure 3-1. *The mixing station*

The mixing station (Tecwill Cobra C80) is originally a concrete mixing station that has been adapted and used for mixing crushed rock and bentonite for covering refuse dumps. The station could be operated during moderate raining but has to be stopped during heavy rain. The mixing procedure is computer controlled from a control room located in the station. Each mix results in a receipt.

The pockets are equipped with lids that protect from rain. During the mixing of backfill the pockets were loaded with a front-end loader with material taken from different places in the pile. For each mix ballast material was taken from all four pockets, this increased the homogeneity of the mixed backfill. The bentonite silo was loaded from a truck and was transported to the silo by the use of air pressure.

The mixing water was collected from the water pumped from the ÄHRL and one sample of the water was taken each day of the mixing. The water samples are stored at the ÄHRL. The water was transported to the mixing station in tanks and pumped to the internal tank of the mixing station. The water was added to the mixer by sprinkling during mixing.

The mixing sequence is listed below:

1. The dry components were mixed for 2 minutes
2. Water was added
3. Mixing for two more minutes

In the beginning of the mixing period a too long mixing time after addition of water was used. This led to formation of aggregates. When the mixing time was decreased this problem seized.

After each completed mixing sequence a shutter in the bottom of the mixer was opened and the mixed material collected in the bucket of a front-end loader The loader then transported the material to the tents for storage. One sample was taken from every mix and placed in double plastic bags.

The water ratio was determined for five samples every day and the amount of added water adjusted when needed.

A receipt for the mixing is shown in Table 3-1.

Table 3-1. Receipt for one mixing round

Weight crushed TBM muck (kg)	656
Weight bentonite (kg)	297
Weight of water (kg)	46

The bentonite originates form Milos in Greece (Silver and Baryte Ores Mining Co) and was ground and dried to a powder with 90-95 % smaller than 0.074 mm. in a facility in Luleå. A number of basic laboratory test have been made and were reported in /1-2/.

3.3 Homogeneity

3.3.1 Accuracy of mixing station

The mixing station delivered receipts stating how much material had been applied in each mix. The values from the receipts were used for calculating the bentonite content of each mix assuming that the water ratio of the TBM-muck was 6 % and the water ratio of the bentonite was 11 %. The results show that the bentonite content of almost all of the mixing rounds was between 28 and 32 % (dry weight).

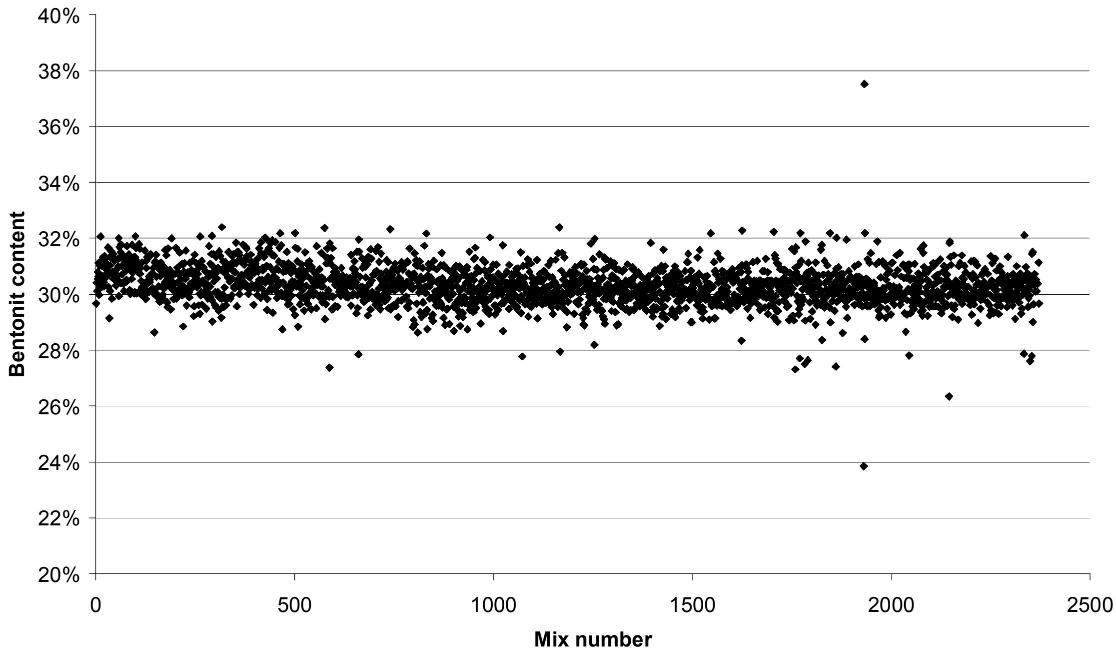

Figure 3-2. *The bentonite content of each mix*

3.3.2 Grain size distribution

Some separation could be observed visually. The mixed material fell about 1.5 m from the mixer to the bucket of the front-end loader and this caused some separation. Some coarse grains rolled down the slope of the material and were gathered at the edges of the bucket. The material in the top of the pile in the bucket was finer than the average material. Great care was taken when placing the material in the tents for storage to avoid further separation.

The mixing technique was tested in the early spring year 2000 /1-2/. The only difference between the test and the manufacturing was the ballast material. In the test 0-5 mm ballast was used while 0-20 mm was used for the Prototype Repository. The conclusion from the test was that the material was homogeneous. A ballast material with a grain size of 0-5 mm thus seems more favourable in terms of homogeneity.

A similar mixing procedure was made in the Backfill and Plug Test /1-1/. Backfill with a similar grain size distribution but another bentonite type (MX-80) was used. Two factors contributed to a better homogeneity in the Backfill and Plug Test:

1. During the mixing the fine material stuck to the coarser grains and prevented separation, this was not the case in for the Prototype Repository.
2. The fall from the mixer in the Backfill and Plug Test was only about half a meter to be compared with about 1.5 metres for the Prototype Repository.

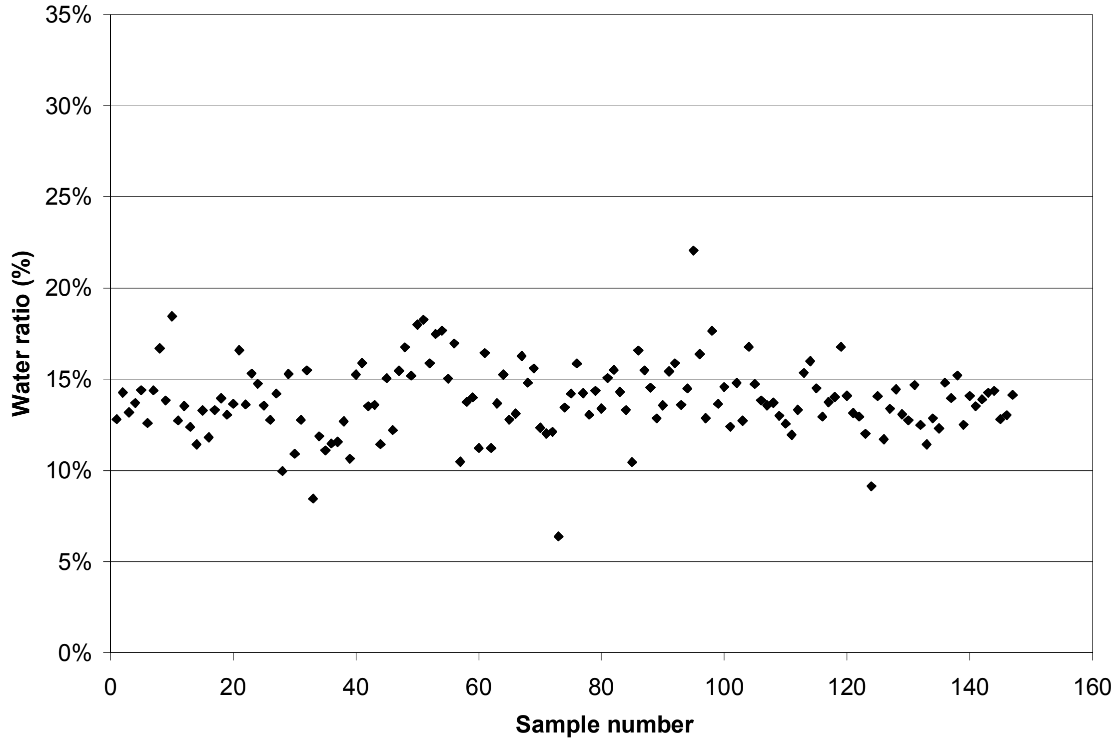

Figure 3-3. *The water ratio of the 30/70 measured during the mixing.*

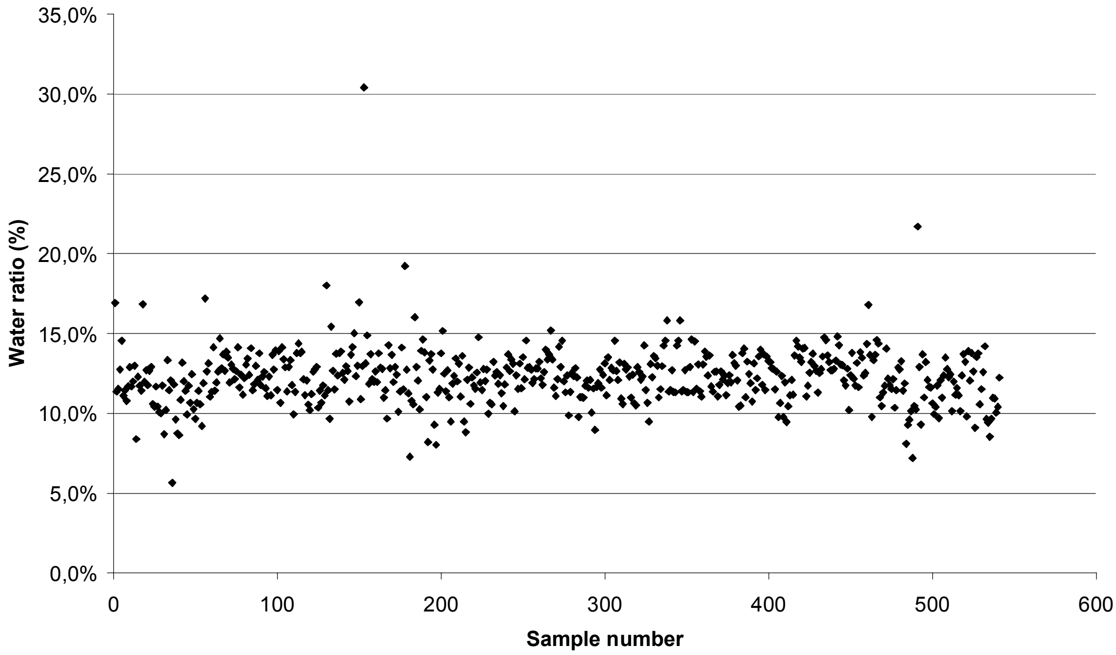

Figure 3-4. *The water ratio of the 30/70 measured during backfilling*

3.3.3 Water ratio

Water ratio was determined in five to ten samples every day of mixing (depending on the amount of material mixed). The results are shown in Figure 3-3. The water ratio varied more than expected. The main reason for this is that the water ratio of the crushed TBM-muck varied a lot. The water ratio of the measured samples was between 3.3 and 11.2 %. The water ratio of the 30/70 was also measured during the backfilling of section 1 of the Prototype Repository and the results are presented in Figure 3-4.

The average measured water ratio during mixing was 13.8 % while the average measured water ratio during backfilling was 12.2 %. The reason for the difference is probably that the samples taken during mixing were from the top of the pile in the bucket of the front-end loader where the material consisted of more fines than the average material.

3.4 Storage

The material was stored in four tents. Gravel and bentonite mixture was used for keeping rainwater from entering between the tent canvas and the ground. The tents were covered with sheets of wood on the inside to allow more material to be stored per tent. The material was stacked as high as possible without driving on it with the loader and thereby compacting it. The material was covered with tarpaulin to prevent drying and also to protect from condensated water dripping from the tent ceiling.

4 Conclusions

The problems encountered in the pre-tests /1-2/ with the fine wet fraction of the material sticking and clogging the crushing equipment were avoided by increasing the maximum grain size diameter to 20 mm and by the choice of sieving / crushing equipment. However the homogeneity of the produced 0-20 was, due to inhomogeneity in the TBM-muck, not as good as expected. The TBM-muck used as ballast was produced during the testing and adjusting of a TBM (Tunnel Boring Machine) in the ÄHRL, which has led to a TBM-muck with a varying amount of fines. The experience from the previous crushing for the Field Test of Backfilling, the Backfill and Plug Test and the pre-tests for the Prototype Repository is that the amount of fines (< 0,075 mm) is only marginally affected by conventional crushing technique. If ballast material in the future is taken from the production phase it is most likely that the TBM-muck will be more homogeneous.

The mixing worked satisfactorily and a total of 2357 tons of 30/70 backfill material were produced in 25 days of mixing. The measured water ratio varied some due to the variation in water ratio in the crushed TBM-muck, this leads to the conclusion that both the original and the crushed ballast must be protected from rain, especially if the ballast contains much fines.

References

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