Technological Report on Hakkoda Tunnel: Excavating Through the Mines Preventive Measures for Acidic Mine Water from Muck

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26.455 kilometers long Hakkoda Tunnel on the Touhoku Shinkansen line is a long-length mountain tunnel that surpasses Iwate Ichinohe Tunnel, which has been the world's longest mountain tunnel until today. The surrounding area of this tunnel is interspersed with abandoned mines, which affect the rocks around the tunnel route. Rocks containing sulfurized minerals such as the iron pyrite are dispersed in the area. For this reason, the pollution of surrounding environment by acidic mine water from oxidization of sulfurized minerals during mucking came into question. As a solution to this problem, a two-step measure was taken in order to prevent oxidization of muck:

① To separate muck that could possibly produce acidic mine water from ordinary muck.

② To apply industrial waste management technologies to seal off mineralized muck from underground water, rainwater and oxygen.

Figure-1 : The location of Hakkoda Tunnel

Overview of the Tunnel

Hakkoda Tunnel is in excavation between the TenmabayashimuraIchinowatari section to Aomori-shi Komagome section of the new Hachinohe – ShinAomori zone of Touhoku Shinkansen line. Hakkoda Tunnel cuts practically east to west through the mountainous region on the northern foot of Mt. Hakkoda (figure-1). For the excavation, the tunnel was divided into six sections each approximately 4 to 4.6 km in length. In May 1999, the excavation work in the Nashinoki section, which is closest to ShinAomori started and since then, excavation in each section is underway.

Basic Principles of Mucking

Hakkoda Tunnel is surrounded by interspersed mineralized rocks except for the areas surrounding its two portals. Kamikita mine, which produces black ores, is in the area and numerous small-scale mines are dotted nearby producing copper, lead and zinc. In mine areas, the effect of acidic poisonous water flowing out from mines abandoned or in use, to the surrounding environment has always been an issue[1]. Similarly, in excavating tunnels in mine areas, acidification of spring water and leachate from muck can be expected and its treatment is a critical task.

In such situations in the past:

① The entire muck was used to build embankment structures, covering the surfaces with impervious sheets or concrete[2].

② The entire muck was transported and entrusted to companies with processing plants[3].

However, for Hakkoda tunnel, new technology had to be developed as there was no space left for embankment and the processing plant with limited capacity could not deal with the large amount of muck.

Prior to the excavation of Hakkoda tunnel, preliminary survey in order to grasp the distribution of mineralized rocks and the geological characteristics of the area was undertaken and the processing method of the mineralized rocks were examined As a result, we came up with two basic principles:

① To separate between muck which could possible produce acidic mine water (hereafter called "control-type muck") and those without such problem (hereafter called "ordinary muck.").

② To apply industrial waste management technologies to seal off mineralized muck from underground water, rainwater and oxygen[4, 5].

I would like to report on the separation and disposal technologies.

Separation

Basic Conditions

Based on the actual tunnel excavation work, we have determined the following three points as the basic condition of testing of muck:

① Muck produced in a day's excavation was separated as a unit as it was impossible to make finer distinction by each heading.

② It is necessary to obtain test results within 24 hours, as when it takes more than a day, it would require muck bins that could contain the accumulated muck.

③ It is necessary to test the soil ahead by horizontal drilling because the nature of the soil could undergo sudden changes in a day's excavation.

Separation Criteria

In order to assess whether the muck is a control-type or an ordinary type, outcome of long-term exposure (more than 10 years) of muck of which the sulfur content is already known at the planning stage of excavation will be taken into consideration. Moreover, layered rocks that appear on the headings of the tunnel will be collected by short-range boring and will be tested for the changing ph level of leachate over time using simplified leaching test. Based on these two results, the muck will be categorized as control-type in following circumstances:

① When a vein or an ore is visible on the headings by naked eyes.

② When the ph level of leachate is under 6, ten minutes (currently one hour) after the simplified leaching test (The extracted mine samples are dried and are ground to less than 10mm. Then, 100g of ground mine sample are placed in a container with 500ml of distilled water. After shaking in an apparatus, it is left at rest. The ph level is measured after 10 minutes, 1 hour, 24 hours, 7 days, 28 days and 56 days.)

③ When the sulfur content of the rock amounts to more than 2wt% based on the result of chemical composition analysis.

Moreover, based on our construction experiences we have added the following criterion:

④ Igneous rocks with magnetic level under $50X10^{-6}$ emu/cm^3 according to the measurement using commercially available apparatus for magnetic level measurement.

Figure 2 demonstrates the flow of the test. Outside of

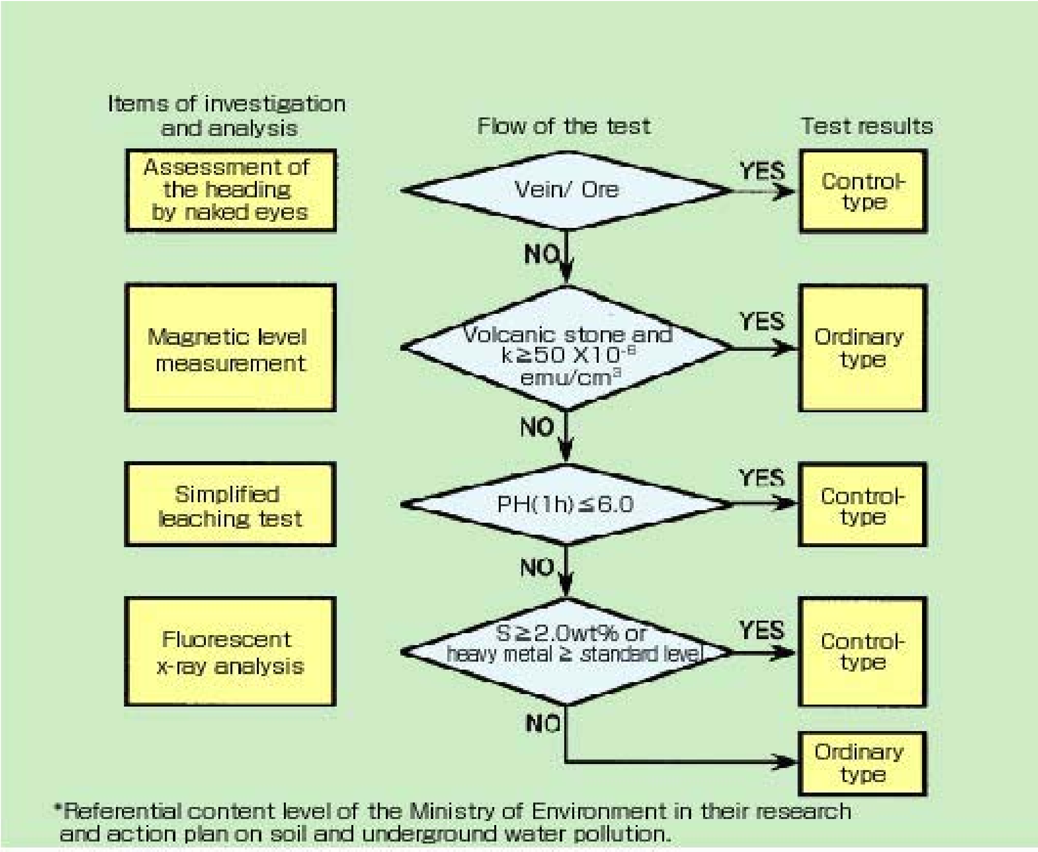

Figure-2: Flow of the control-type muck testing (excluding mudstones)

mineralized rocks, occurrence of acidic leachate from mudstones was reported. A separate criterion exists for the mudstones.

These test results can be obtained in 24 hours. Therefore, muck bins, placed at portals are divided into 2 sections so that a day's worth of muck can be stored in them. After the testing of rocks, the muck is transported to the disposal area.

Disposal

In disposing of control-type muck, since a long-term treatment would be necessary once the acidic leachate is generated, it is important to take adequate measures at the excavation stage. That is to apply the treatment method, which would not generate acidic leachate. Various methods could be assumed in order to prevent the generation of acidic leachate from control-type muck, but we have considered the following two methods:

① "Treatment by neutralization" which is to neutralize the acidic leachate with limestone.

② "Control method" in which industrial waste management technologies are applied in order to shut out the muck from underground water, rainwater and oxygen.

For the first method, we considered using crushed limestone or calcium carbonate as neutralizers. However, based on the test results at the tunnel planning stage, we have determined that the first option would require a long period of time before neutralization becomes apparent. The latter option was too expensive and it could not be applied to this project either.

We have decided to apply the second method for this project as its effectiveness was certain and realistic method in terms of cost exists.

As for the specifications of control-type disposal facility, we have taken into account the examples of existing industrial waste disposal facilities and decided on structures on each section

(Figure-3). The base area is made impermeable by placing double liner sheet with long-term durability (made of low-density polyethylene). In order to protect the sheet, crushed stones and mortar are sprayed in between the ground and the sheet and 50 centimeters of gravels are placed on top of the sheet. When the construction is complete, it will be covered by an impervious sheet.

Although damage to the impervious sheets at the base is unlikely during or after the construction, in case when the damage occurs, it would be difficult to excavate and to repair the sheets. Therefore, it would be necessary to create a system that allows the immediate detection and repair of the damages to the impervious sheets.

Example of Nashinoki Section

The control-type disposal facilities are to be located in each section and their designs are under the process of optimization to fit the conditions of specific sites. Following is the example of the Nashinoki section.

Since the control-type disposal facility in Nashinoki section is located on a gentle slope, it takes the form of a mound in order to reduce the volume of muck (Figure-4). Moreover, since a wide area is available for the leachate storage pond, we have newly developed a bag-shaped storage, which does not require a canopy (Figure-5).

There are two main systems of detecting the breakage of impervious sheets, the physical system and the electrical system. The physical system can be subdivided into:

① Detection by sections of single impervious sheet
② Detection by suction, pressurization and gravity flow of double impervious sheets.

For Nashinoki section, we have applied the latter, suction/double impervious sheet method called "T&OH System" because its past records showed its long-term stability and because it facilitated the reparation of breakages.

Figure-4: Control-type disposal facility in Nashinoki section

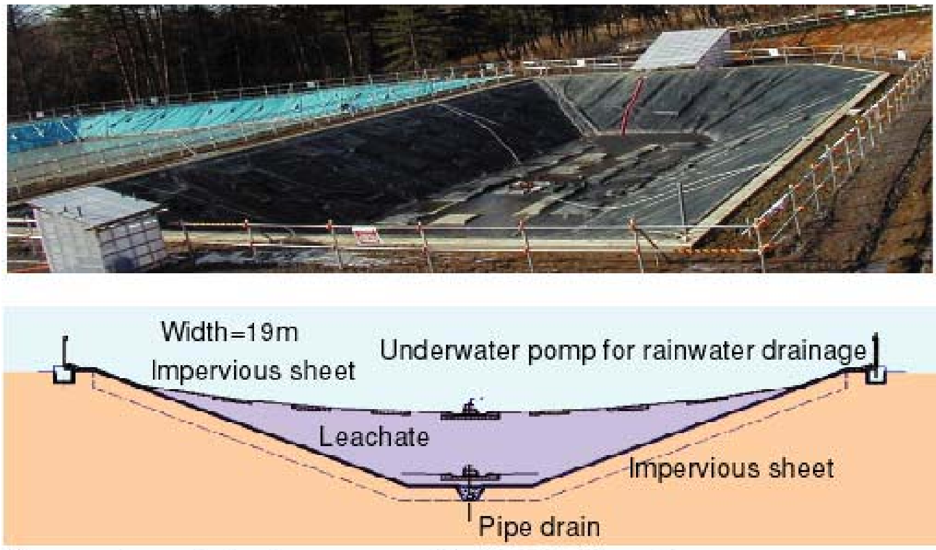

Figure-5: Leachate storage pond in Nashinoki section

Conclusion

We believe that the knowledge on separation and disposal of muck producing acid leachate that we have gained through this project could very well be applied to future projects. However, in setting the standard level of the testing criteria, the characteristics of the rocks in each region should be taken into consideration.

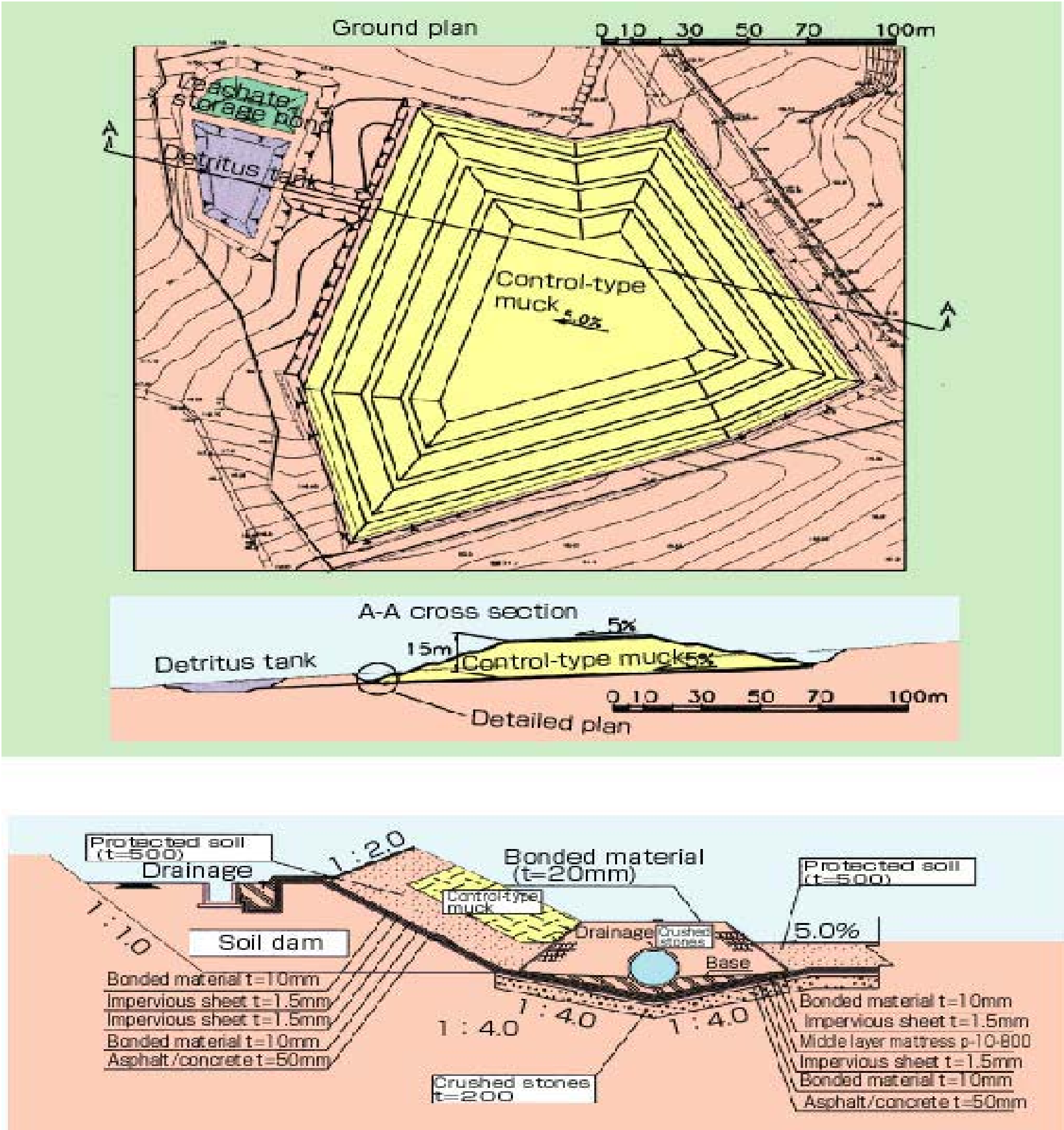

Figure-3: Control-type disposal facility

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