S−31 Environmental impacts of the reuse of excavated rocks: Study cases in Japan and Peru

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1. REUSE OF SOIL MATERIALS

Excavated soils and rocks are generated in large quantities worldwide every year from economically essential practices such as construction and mining. Reusing or recycling of these materials would reduce the use of new resources by utilizing otherwise wasted materials. This would save space in landfills, which would be particularly beneficial in countries with limited space, such as Japan, and decrease the environmental impact in countries where mining is economically important, such as Peru.

The Japanese government has encouraged industries and consumers to follow the "3R Concept", which consist of "reduce", "reuse", and "recycle", in order to contribute to sustainable development. Reusing materials will reduce the amount of by-products and wastes disposed of and reduce the amount of natural resources used. In 1991, the "Law for the Promotion of the Utilization of Recyclable Resources" was established. According to this law, the following items generated by the construction industry are considered to be recyclable by-products: (1) steel slag discharged from iron and steel manufacturing; (2) coal ash from electric power plants; and (3) waste cement-concrete, waste asphalt-concrete, waste wood, waste sludge, etc. In addition, in 2000 the "Basic Law for Establishing the Recycling-based Society" was issued. The purpose of this Law is to make possible the policies to transform Japan into a "Resource Recycling Society". Under this, individual laws were established to encourage different industries to use specific recyclable materials. In the case of construction industry this law was called "Law for the Recycling of Construction Materials". Moreover, in 2002, the "Soil Contamination Countermeasures Law", related to the influence on the reuse of surplus soils generated from construction works, has been established.

Different types of waste are generated every year from construction works, as shown in Table 1. Table 2 shows the amount of wastes disposed at landfills. The differences in mass between Tables 1 and 2 correspond to reduced and reused material. Beneficial reuse (recycling) of waste asphalt concrete and cement concrete is currently high (98 to 99%). However, only 45% of waste sludge is reused, while 30% of this material is disposed of. The use of new soil materials extracted from mountains or river beds is around 32 million m^3, which results in a negative impact on the environment (Katsumi et al. 2008; Katsumi et al. 2010).

To the best knowledge of the authors, no specific laws and/or regulations exist on reuse of excavated materials coming from construction and mining.

When recycled materials are used in geotechnical applications, such as embankments, the potential for pollution or natural contamination should be considered. Some by-product materials, such as industrial waste (coal ash, slag, and scrap tire) and municipal solid waste (MSW) incinerator ash may contain toxic chemicals (heavy metals, boron, fluorine, among others). In addition, some of have the potential to induce an adverse environmental effect even following treatment prior to the geotechnical application. Thus, the characterization of soil and waste becomes a very important source of information in order to judge whether or not a certain type of soil and/or waste would be environmentally compatible. For this purpose, leaching (or elution) and composition (human availability) tests are conducted and the results are used to determine whether the leaching level exceeds the environmental standards or not. If it does, necessary measures should be taken in order to prevent a negative environmental impact (Katsumi et al. 2008; Katsumi et al. 2010).

Table 1 Generation of waste from construction works (data from the Japan Ministry of Land, Infrastructure, and Transport) (unit: 10,000 ton)

Year	1995	2000	2002	2005
Asphalt concrete	3,570	3,010	2,970	2,610
Cement concrete	3,650	3,530	3,510	3,220
Wood wastes	630	480	460	470
Sludge	980	830	850	750
Mixed waste	950	480	340	290
Others	140	150	140	360
Total	9,910	8,480	8,270	7,700

Table 2 Landfill amount of waste from construction works (data from the Japan Ministry of Land, Infrastructure, and Transport) (unit: 10,000 ton)

Year	1995	2000	2002	2005
Asphalt concrete	680	50	40	40
Cement concrete	1,290	130	90	60
Wood wastes	390	80	50	40
Sludge	840	490	270	190
Mixed waste	850	440	220	210
Others	90	100	100	60
Total	4,150	1,280	700	600

2. NATURAL CONTAMINATION FROM EXCAVATED ROCKS

Natural contamination of soil and groundwater by metals and metalloids derived from waste rock and mine tailings has been the cause of serious health and environmental problems in many countries. Acid rock drainage (ARD), with subsequent heavy metal leaching—which are not degradable by simple mechanisms and will remain present for a long time— is usually observed in countries located in geologically active areas, such as Japan, or in countries where mining is crucial for economic development but waste management is limited due to economic reasons, such as Peru.

ARD is produced when sulfide minerals, such as FeS_2, Cu_2S, PbS, ZnS, $CuFeS_2$, or FeAsS are oxidized in the presence of oxygen and percolating water. Although this phenomenon occurs naturally, mining and excavation for infrastructure construction accelerate the generation of ARD by increasing the quantity of sulfides exposed. Exposing these rocks to the atmosphere will destabilize them and, therefore, oxidation will occur through a variety of mechanisms. Sulfide oxidation and host rock dissolution do not end until the mineral is fully weathered, which can take hundreds of thousands of years.

In recent years, many parties, including governments, have started to be aware of natural contamination when excavated soils are reused in geotechnical applications. In Japan, particularly, several types of metals such as As and Pb are present in higher concentrations compared to the average level in the world. This is because Japan is located in a geologically active area, which favors the accumulation of these elements. Moreover, in mountainous areas of Japan, there are several rock formations which may contain pyrite (FeS_2) and other minerals that may contain high amount of As and Pb. Thus, acid drainage with subsequent As and Pb leaching, becomes an important issue. To prevent this environmental problem spreading, constructing an adsorption layer is considered a relatively new and cost-effective measure and is the method studied by the authors of this article. This method places a layer of material (GCLs, bentonite, or zeolite, for example) that has adsorption capacity against heavy metal, as shown in Figure 1. This will help keep the groundwater clean and will guarantee health security, environmental security and, if the area was not to be used for human water consumption but for crop irrigation, food security as well.

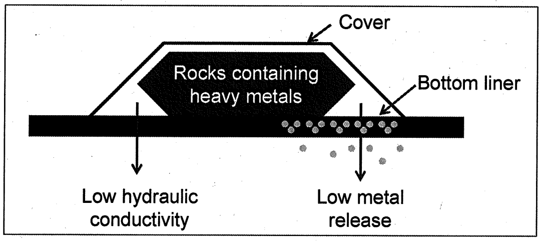

Figure 1 Example of a containment for rocks with natural contamination potential by using a buffer layer

In the authors' research, an evaluation of the barrier performance of bentonite in waste rock containments when exposed to extreme conditions of pH and metal concentration (ARD) was conducted. The experimental part consisted of sorption tests with natural rock leachates from different sites of Japan, as well as an artificial ARD. Also, 9-month hydraulic conductivity tests were performed in order to evaluate the field application of this material. Nine different natural rock leachates obtained from different parts of Japan were used. Four of them were liquid samples, collected from four ore deposits (Kaminosawa, Okunosawa, Honko and Tateishi) of the Kamikita mining complex (Aomori Prefecture) on July 2010. The other five rock drainage samples were obtained after the leaching test using rocks from excavated sites and natural ground located in Yamanashi, Hyogo, Miyagi (2 samples) and Tokyo. In addition, an artificial ARD was prepared in the laboratory based on the drainage composition of a Pb-Zn-(Cu) deposit located in Cerro de Pasco, Peru. Results showed that bentonite has good performance against ARD, although complementary research is ongoing in order to guarantee long-term performance in the field.

3. TECHNICAL VISIT AT OTOINEPPU TUNNEL, OSAJIMA TUNNEL, AND OTONAKA TUNNEL, HOKKAIDO, JAPAN

The Otoineppu bypass No. 40 (19 km), Figure 2, is part of a 250 km road project that will connect Asahikawa city (starting point) and Wakkanai city (ending point). The project aims not only to connect cities, but to reduce road traffic accidents.

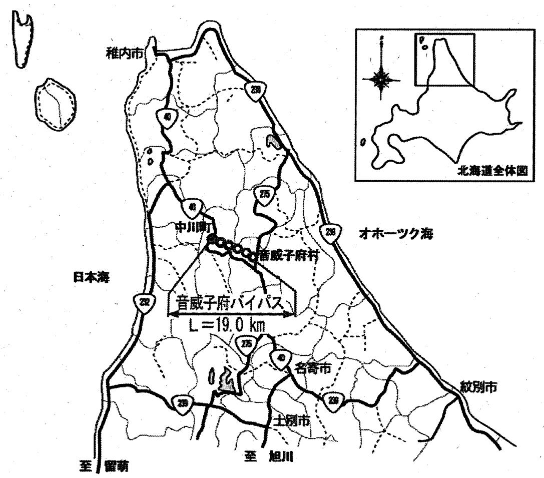

Figure 2 Map of the Otoineppu bypass No. 40 Project

The authors visited the Otoineppu tunnel, Osajima tunnel and Otonaka tunnel construction sites. Excavation soils and rocks from some parts contain arsenic in their mineralogical composition and therefore proper disposal of this material is taken into consideration. In most cases the concentration is not high, but an adsorption layer is placed in the bottom part of the embankments (Figure 3 and 4) in which the excavated material is placed. The adsorbent layer is usually 30 cm high and consists of a mixture of soil and an iron oxide material (30 – 100 kg/m3) depending on the arsenic composition. In some parts of the tunnel construction, a type of soil called “Jamon gan” (that has arsenic sorption capacity) will be probably found and therefore it can be mixed with the excavated material that contains arsenic in order to prevent its leaching.

Figure 3 Road construction using excavated rocks

Figure 4 Oxide material used for adsorbent layer (brown)

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