Renovation Challenge of Underground Quarries for Oya Tuff

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ABSTRACT

The Oya region in Utsunomiya City, Tochigi Prefecture, Japan has been queried for the Oya tuff or the Oya stone which is one of the most popular building stone materials in Japan. The number of underground quarries has reached over 200 there. And many of those are below residential zone. Only a few quarries are still active in this region. This paper introduces the progress of underground space quarrying dimension stone of Oya tuff. Since some old underground quarries had collapsed, the area is regarded as unstable and dangerous for ordinary life and has become difficult to renovate those underground quarries remained there because it is hard to agree with doing among the local administration and inhabitants. This paper also mentions the background of the problems and the trial to breakthrough them.

1. INTRODUCTION

The Oya tuff or the Oya stone that is one of the most popular building stone materials in Japan has been quarried from the Oya region (Figure 1). It is soft to produce an interior decoration wall, a fence and so on. Currently some stone dealers are quarrying Oya tuff at only about 10 underground quarries. There have been over 200 remained underground spaces in this region. Several underground remained quarries had been collapsed since this Oya region has been quarried for the Oya tuff. Two huge collapses of them occurred in 1989. The unsafe rumour of the Oya region had gotten whole over Japan. These accidents also have affected to the commercial activities and have stopped planning the renovation of the remained underground quarries. Consequently the number of tourists has reduced. The inhabitants and people concerned in the Oya region are eager to neglect the ugly rumour. The Oya District Improvement and Promotion Foundation that the Tochigi prefecture government had found with the Utsunomiya municipal office in 1990 has established 125 small seismographs around the old remained underground quarries in Oya regions and has been monitoring the advance of major indication collapses to secure the safety of inhabitants since 1989 (Murayama et.al. 2004). On the other hands, the inhabitants and the stone dealers of the Oya regions have Fig. 1. The location of Oya, Utsunomiya City in Japan (After University of Texas Library, 2007).
Fig. 2. An underground quarry excavating Oya tuff.

Fig. 3. An old public hall built with Oya tuff in Utsunomiya City, Japan (the Oya Reclamation Committee 2004).

Table 1. Averaged material properties of sampled Oya tuff in the initial state (Seiki and Aydan, 2003).

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry density</td>
<td>1.57</td>
</tr>
<tr>
<td>Significant porosity (%)</td>
<td>7.9</td>
</tr>
<tr>
<td>Water content ratio (%)</td>
<td>5.4</td>
</tr>
<tr>
<td>Inferred uniaxial strength (MPa) *</td>
<td>6.9</td>
</tr>
</tbody>
</table>

*Inferred Uniaxial strength is evaluated by the needle penetrator

also tried to break through those worse reputations. This paper introduces the utilizing trial and the present state of Oya tuff underground quarries. In addition, it also explains the issues of these renovations to be attractive region for sightseeing.

2. CHARACTERISTICS OF OYA TUFF

2.1 Geological aspects

Oya tuff classified into rhyolitic welded tuff geologically is quarried at a hilly region where locates at about 200m in elevation nearby Oya town, Utsunomiya City, Tochigi Prefecture, Japan. Oya tuff that belongs to the Ashio belt is in the Tertiary formation above the base rocks, which consists in chert, sandstone of the Palaeozoic era and the Mesozoic era. And it is covered with the diluvium of the Quaternary period, the conglomerate stratum and Kanto loam stratum. Oya tuff piled up at a marine environment about 20 Ma ago and has a porous structure and bluish-green pumice in splashed patterns together with chunks of the clay mineral (AGCI, 1999). Its clay mineral mainly consists in montmorillonite and zeolite.

2.2 Engineering characteristics and usage of Oya tuff

Oya tuff which is mainly bright greenish colour soft rock can be easily scalped and excavated and has damping characteristics against dynamic loads resulting from earthquakes, fire resistant, soundproof and damp proof. It is, however, easily weathered and degraded (Seiki and Aydan, 2003). Oya tuff, which mainly decorates the sidewalls at an internal and external building (Figure 2) and is used for the materials for retaining wall around the houses, is a famous about the building stone in Japan. Oya tuff is mainly categorized into fine grain or Saime and coarse grain or Arame. The product quality of fine grain Oya tuff is generally better than that of the coarse one. Some material parameters are shown in Table 1.
3. PROGRESS OF QUARRYING UNDERGROUND

3.1 Brief history of quarrying Oya tuff

From 1860s to 1910s open pit quarries had been commercially popular to excavate the proper dimension stone of Oya tuff (Tateno, 2005). From 1910s to 1920s, Oya tuff is mainly quarried from underground due to the quality of stone materials. Eventually, a large number of quarries have been excavated there (Figure 3). The mesons combined two kinds of quarry method to cave those quarries remaining chain pillars below the ground surface. One is called the Hiraba-bori or shaft quarrying method which vertically excavates the quarries getting the dimension stones along the shaft-like spaces from the certain depth (Figure 4). The other is called to the Kakine-bori or drift quarrying method which horizontally excavates to quarry the dimension stones at the sublevel (Figure 5). As the Kakine-bori is a method to avoid excavating the unnecessarily shallow formations and only get the better quality building stone material. Since 1976, Oya tuff quarries have kept to the Quarry Law which restricts the room dimension querying stones and the interval distance among remained pillars. These scales are concerned with safety levels evaluating the limit of the space dimension in connect with supporting pillars. The cross section and the interval of pillars remained directly affects to the quarry profitability. This regulation lays down that a side of the cross section of pillars remaining in the quarries should be longer than 7.3 m (= 4 ken, 1 length in ken is equivalent with approximately 1.8182 m) for the fine one and 9.1m (= 5 ken) for course one, respectively. Moreover, the interval among the pillars should be less than 10.9 m (6 ken) in course and fine ones (Tokyo Commerce and Industry Department, 1983).

3.2 Collapse of old underground quarries and its influences

Several huge collapses above old remained underground quarries happened in 1989 and 1992. And large and deep halls and grand subsidence had appeared at those regions (Figure 6 & 7). There were however, no victims even though several houses, storages, infrastructures, and agricultural land disappeared into the subsidised halls. After those accidents, small seismographs have been monitoring the advance indication collapsing underground quarry (Figure 6).

3.3 Monitoring and diagnosing underground quarries

Being aware of collapsing the underground quarries, the administration of Tochigi Prefecture, Japan ordered researchers and geologists to judge the grade of structural stability. And it revealed the safety management map in 2001 as the results (the Tochigi Prefecture government, 2001). The map show almost underground quarries categorized into 4 safety grades, A, B, C and D. Underground quarries had been divided into around 350 sectors and about 100 sectors were classified.
into group D which is the most dangerous grade even though it indicates that underground quarries are generally stable except huge earthquakes. Individual underground quarry needs to assess the integrate stability if the owner consider to renovate and utilize them continuously on the map.

4. CHALLENGE FOR RENOVATION OF OYA REGION

4.1 Trial to request the Special Reconstruction District of the Oya region

The inhabitants, the persons concerned and the Utsunomiya Municipal Office are trying to breakthrough the deadlock. At first, the region needs to declare a consequence improvement of safety. At least it needs to fill up some of old underground quarries which are regarded as unstable and danger structurally. Indeed there are many possibilities filling up to the underground quarry. One of the most feasible way are to fill them with the molten slag which is remained substances of general rubbishes burning in over 1200 degrees centigrade and is granulated in a process to reduce molten heat in air or water, because the subsidy of the slag from the administration can be expected to compensate the constriction fee filling up there. Although the researchers have never certificated the long-term safety of molten slag clearly it is promising material to do it. And now, the inhabitants at the Oya region and the Utsunomiya Municipal Office try to agree with submitting the Special Reconstruction District of
4.2 Concept filling remained unstable underground quarries

Recently, the Utsunomiya Municipal Office and the inhabitants still have been discussing safety and environmental impact fill up those unstable old underground quarries by the molten slag as fixing and buffering materials. As almost administrations providing the molten slag pays subsidies to demanders The persons concerned proposed to use those subsidies compensating the expend-iture. Figure 8 shows a conceptual view filling an underground quarry. At first, it is expected that the professional committee involving some of the inhabitants, the civil engineers and the geologist assesses those underground quarries to criticise the safety concerning a feasibility balance between benefit and cost, individually. Secondly, starting to fill underground quarries the activities will have continued several decades. After the periods the fields will have been monitoring to certificate a structural stability and check the no leakage of heavy metal constituents from the molten slag.

4.3 Utilization of remained underground quarries in the Oya region

Many trials to plan and construct the underground facilities, storage for fruits and vegetable, cosmic lay research laboratory, rice cookie factory, museum had existed before several huge collapses of old remained undergrounds occurred in 1989 and 1992. Most of them had stopped construct facilities or utilizing. Some of them, however, still exit in the Oya region. Figure 9 shows the Oya stone museum, which privately offers exploring experience in underground space to the visitors. The museum, which
has utilized a part of large remained underground quarry, helps the Oya region and Oya tuff famous whole over Japan. Figures 10 and 11 show two examples which store Japanese liquor and hams. As commercial values stored in underground quarries gradually increase because Oya tuff contents a few amount of zeolite which helps to absorb ethanol and to extend the storage period, it is believed that the underground quarries gets the quality of matured foods better than generally stored ones. It is necessary to certificate the safety of the Oya region to wipe away bad impression and to raise the number of the facilities. The citizens of Utsunomiya city has expected to declare a safety proclamation of the Oya region and reconstruct to be attractive commercial region and sightseeing spot.

5. SUMMARY

This paper introduced the progress and the trial renovating the underground quarries in the Oya region, Utsunomiya City, Tochigi Prefecture, Japan. It points out the issue to renovate a number of underground quarries as followings. Produced Oya tuff, one of the most famous building stones in Japan and is geologically classified into welded rhyolitic tuff, stone dealers has excavated over 200 underground quarries extracting better quality of building stone material below the residential region there. Some of them have still been quarrying. Almost of them, however, have been abandoned to preserve them. The number of visitors has reduced and some plans and constructions for the renovation of underground quarries are abolished in underground quarries since some old underground quarries had to collapse and subside in 1989. Securing those underground quarries needs to remove the blot of the Oya region. Despite the responsibility of renovation is ambiguous among the administrations and the quarry manufactures they, however, have been preceding the permission to the Special Restructure District for the Oya region. It devaluates necessary interests to the local administration from Japan government to fill up useless and unstable underground quarries with the molten slag. Underground quarries for Oya tuff are expected to breakthrough the issues to renovate this region even though it is also necessary to propose the acceptable criterion which classifies stability attitude of remained underground quarries there.

6. ACKNOWLEDGEMENTS

We acknowledge the staffs of the Oya District Improvement and Promotion Foundation, the members of the Oya Reclamation Committee and the staffs of the Oya Region Maintenance Agency to give us the value information and comments to write this paper. And we also specially thank to the inhabitants and the persons concerned to the Oya regions, Utsunomiya City, Tochigi Prefecture, Japan.

REFERENCE