Addressing Hard Rock Grounds using a Combination of an Ultra-large Free-section Excavator and Controlled Blasting

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Project outline

The Nago East Road aims to improve access between central and southern hubs such as Naha Airport and Naha Port, alleviate traffic congestion and improve traffic safety within Nago City, and support regional revitalization in the northern region. The Nago East Road No. 4 Tunnel is located nearest to the Naha City of the Nago East Road, with the length of 1,021 m that will reach the Sukuta region. Although the original plan was to use machinery excavation, at the start of construction, the ground turned out be harder than expected, so a blasting method was considered instead. However, since there were private houses dotted around the start tunnel portal and right above the tunnel route, the impacts of noise and vibration were of concern, leading to decision to excavate using a large machine using along with controlled blasting.

1. Problems that occurred while excavating hard rock grounds

During excavation using a free-section excavator (SLB-350S model), sandstone appeared in the phyllite at the face approximately 80m from the tunnel portal. This was an alternating layered structure with sandstone sandwiched between phyllites, and the strengths of the sandstone and phyllite were 101 MN/m2 and 37 MN/m2 respectively. Due to a large proportion of strong sandstone, the cycle time required for excavation increased, causing wear and tear on the bits in the excavator head and damage to the excavator itself, limiting tunnel excavation progress to about 2.4 m/day (Photo 1).

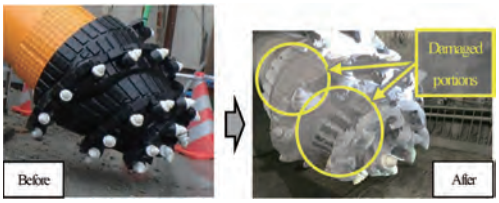


Photo 1 Damage to excavator head

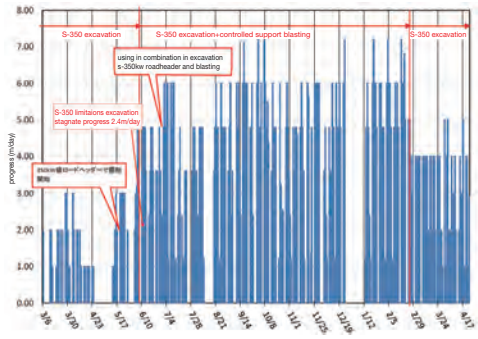
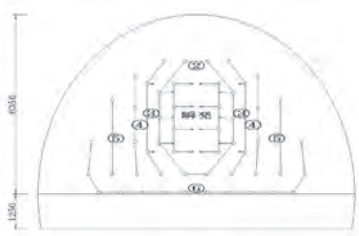


Fig. 1 Over-time change as excavation progresses

2. Machinery excavation along with controlled blasting

It turned out that excavation using a large machine caused delays in the construction process. The tunnel route was to pass through right beneath a village (minimum distance of approximately 40m from the tunnel center) and cattle sheds (minimum distance of approximately 40m from the tunnel center, with an earth cover of approximately 70m). Considering the geological and circumferential environmental conditions, it was decided to use controlled blasting in addition to machinery excavation in order to adhere to the construction schedule (Figure 2).



	cross section area	1 blasting progress length	fracture volume	boring number	number of holes drilled per ㎡	explosive usage	amount of explosive per ㎡
unit	㎡	m	㎥	hole	hole/㎡	kg	kg/㎥
top heading	63.3	1.2	76.0	56	0.9	44.8	0.59

Fig. 2 Controlled blasting plan for CII-b

3. Construction result

After chaging a construction method, the center of the face was cut by controlled blasting and the remains were removed by the excavator, reducing the excavation cycle time from 3 hr/m to 1.5 hr/m. Furthermore, the wear and tear on the excavator bits was reduced from 2.52 bits/m to 1.33 bits/m. As a result, a tunnel excavation progress of more than 4 m per day was achived (see Figure 1). In addition, both noise and vibration were below the standard values (noise: 85 dB, vibration: 0.1 kine), presenting no impact on neighboring residents and cattle sheds (Figure 3). The excavation using controlled blasting was completed approximately 130m before the end portal of the tunnel.

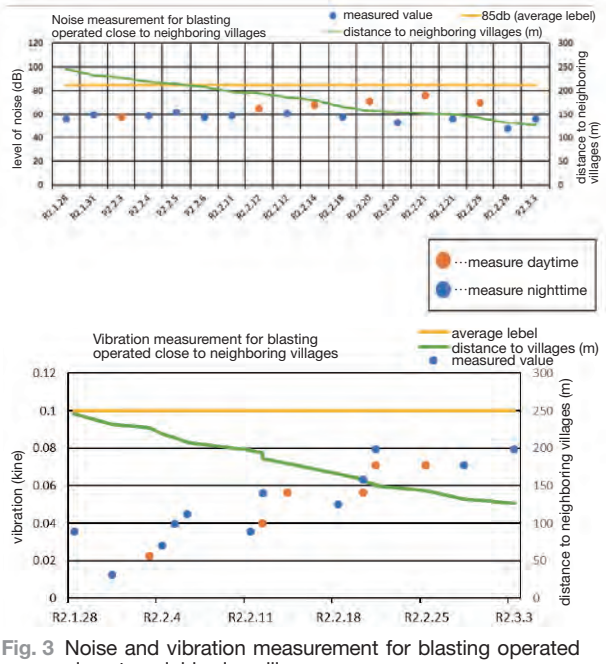


Fig. 3 Noise and vibration measurement for blasting operated close to neighboring villages