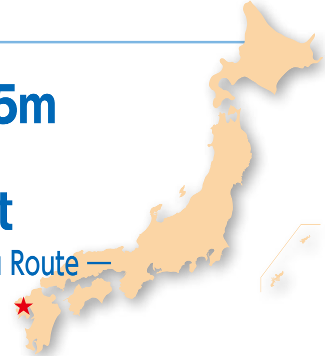

Constructing a Tunnel by NATM with Minimum 5m Covering Under a Dense Residential Area, while Considering the Surrounding Environment

— The Shin-Nagasaki Tunnel (West) Construction Site, Kyushu Shinkansen West Kyushu Route —

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Introduction

Kyushu Shinkansen (West Kyushu Route) is a high speed railway route that connects Fukuoka and Nagasaki Prefectures in the Kyushu island of Japan. Currently, construction of the about 67km part between Takeo Onsen (in Saga prefecture) and Nagasaki is going underway, to be finished in fiscal year 2022. The Shin-Nagasaki Tunnel (West) is a 7,460m long double-track cross section mountain tunnel. The Shin-Nagasaki Tunnel's (West) Construction site is the 3,575m part including the end point side of the tunnel. At this construction site, excavation was done in area A, right under a densely built residential area with minimal covering of 5m, and directly under area B, with minimal covering of 7.5m (Fig. 1 & Fig. 3). Challenges during excavation were the effects of the construction to the houses and other buildings, as well as steep slopes in the area of small overburden, and need of consideration to the residents living there. This report details about the measures taken to prevent land subsidence, percussion, and noise, and construction conditions of a tunnel directly under a densely built residential area with small overburden.

Fig. 1 Surface Condition of Area A

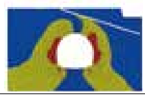
	Items of Analysis	Cross section ① (Area A)	Cross section ② (Area B)
Preconditions	Overburden	5.0m	9m
	Condition of Natural Ground	Andesite with multiple cracks	Andesite with multiple cracks
FEA Results	Land Subsidence	3.1m	4.6m
	Crown Subsidence	3.7m	6.0m
	Stress Severity 0.3 0.0		
Observation	Areas where overburden is 10m or less has possibility of crown collapse that effects near to the land surface.		

Fig. 2 FEA Results

1. Countermeasures to Prevent Land Subsidence During Excavation with Small Overburden

A Finite Element Analysis (FEA) was conducted due to concerns that the natural ground of surrounding the tunnel might loosen and create a subsidence during excavation, which would then affect the houses and steep slopes above the tunnel. The analysis showed that the ground loosened around the area near the ground surface where overburden was less than 10m, raising concerns of the stability of the crown and tunnel face (Fig. 2). After calculating the load of loosen bedrock, steel forepiling (ϕ114.3mm, t=4.2mm, L=12.5m@450mm, silica-resin) was used in the area of overburden less than the diameter of the tunnel (Fig. 3). The support pattern where steel forepiling was used is shown in Fig. 4. The area of steel forepiling was determined by considering the effects of collapse at 45 degrees in the direction of the tracks, and set up an allowance section of total 20m (10m+10m) at the starting and end points of the area where overburden was under 1D. Twenty-four-hour measurements were done during excavation, including land subsidence measurement by the total station, an extensometer, and placement of a land monitoring personnel in addition to convergence measurements.

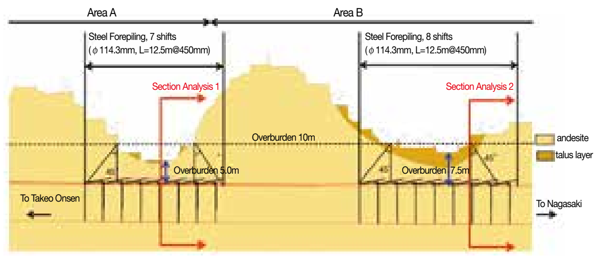


Fig. 3 Scope of Steel Forepiling

2. Reducing Percussion and Noise

The ground of the area with small overburden mainly consisted of andesite and tuff breccia. As the uniaxial compressive strength of the natural ground was around 22.4 ~ 76.8N/mm^2, categorized as soft rock to hard rock, making blasting system the usual choice. However, due to concerns of affected the houses built on the ground surface, and complaints from residents, a 350kw-grade boom type cutting machine (Photo 1), capable of cutting through hard rock was used to reduce percussion and noise during construction. Also, with due regards to the life-style conditions of the residents of the area, twenty-four-hour work was deemed difficult, and the construction was done only during the day.

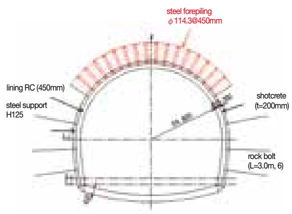


Fig. 4 Support Pattern where Steel Forepiling was Used

Photo 1 350kw-grade boom type cutting machine

3. Construction Results

Amount of land subsidence, noise/percussion rates were limited within control levels in both areas A and B (Tab. 1). In addition, there were no significant complaints from surrounding residents, and no damages were noticed from the houses that stood on the surface. Excavation work safely finished in October 2018, and installation and other works are being done to meet the launch in 2022.

Tab. 1 Measurements

	Amount of Land Subsidence		Surface Noise		Surface Percussion	
	Control Value	Measured Value	Control Value	Measured Value	Control Value	Measured Value
Area A	-50mm	-2mm	85dB	66.3dB*1	77dB	58.2dB*1
Area B	-50mm	-2mm	85dB	77.6dB*2	77dB	72.9dB*2

*1 Measured at surface of section where overburden was 5m
*2 Measured at surface of section where overburden was 7.5m