Invitation to the Geo-Tetsu Tour by Train Trips, Visiting of the Railway Route for Geohazard: A Case Study of the JR Dosan Line in Shikoku, Southwest Japan

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Abstract

Since 2009, Geo-Tetsu by train trips has been known as a tool of dissemination of earth sciences to the general public (Kato et al., 2009a). Japan is covered by a dense network of railway lines, even over its mountainous parts. There are steep slopes, sharp curves, landslides and various geohazards caused by fragile foundations along the railways. Many technological inventions were introduced to overcome these difficulties: the river improvement works, switchback operations, and re-routing lines. This research deals with the Geo-Tetsu route of the Dosan line operated JR Shikoku which coexists with geohazards for an important case study of such phenomena. We visit the various kinds of Geo-Points with geohazards, even along the disused line (old tracks, tunnels, bridges, rock sheds, rockfall protection, etc.). There we can touch the advancing technologies to maintain the safety operation of the railway, and feel the endeavors of engineers with loyal working facilities.

Keywords: Geo-Tetsu, Geo-Point, Dosan Line, disaster, disused line, railway facility

1. Introduction

Railway is the commonest transportation system in Japan. Its dense network covers even over mountainous parts which account for 70% of our country. The constructions of railways are directly related to geological setting and geographical features. That affects not only the route selection but also the facility specifications and safety operation.

Geo-Tetsu by train trips has been known as a tool of dissemination of earth sciences to the general public since 2009 (Kato et al., 2009a, 2009b; Fujita M., 2012; Fujita et al., 2013). The name Geo-Tetsu is licensed as the trademark No.5378786 by Fukada Geological Institute (Fujita M., 2012; Fujita et al., 2013; Geo-Tetsu website http://fgi.or.jp/geo-tetsu/). We will recommend many attractive Geo-Points where people can see representative geoscientific phenomena and railway heritages. It can offer the opportunities to get contact with geoscience in travelling by trains. Here we introduce the railway route which coexists with geohazards. .

2. Geo-Tetsu tour focused on geohazards

When you take a Geo-Tetsu route, Geo-Points with comprehensible commentary play an important role. On the train, the Geo-Points will give you some change, listening to motor sound, feeling the grades and the curves, and viewing railway facilities for disaster prevention through the window. You can also get off the train and walk around the disaster areas and along the disused line. There, you can think about the characteristic geohazard of local area through each geological background and the efforts of engineers. In this paper, we will trace the Geo-Tetsu route focused on geohazards understanding the geological setting and geographical features along the Dosan Line. Specifically, the Dosan Line was constructed disaster area in Japan, and many characteristic railway facilities exist there. Tracing them, we will show that the history of the Dosan line overcoming the disasters.

3. Region of the Dosan line

The Dosan Line is the main railway of Shikoku Island and connects to Okayama via the Great Seto Bridge. It is 198.7 km in total distance, crossing the island from Tadotsu facing the Seto-Inland Sea to Kubokawa on the Pacific coast. Shikoku Island is covered by the high mountains uplifted by tectonic motion of plates and the deep valleys are formed by erosion. Therefore the flat ground is limited, the

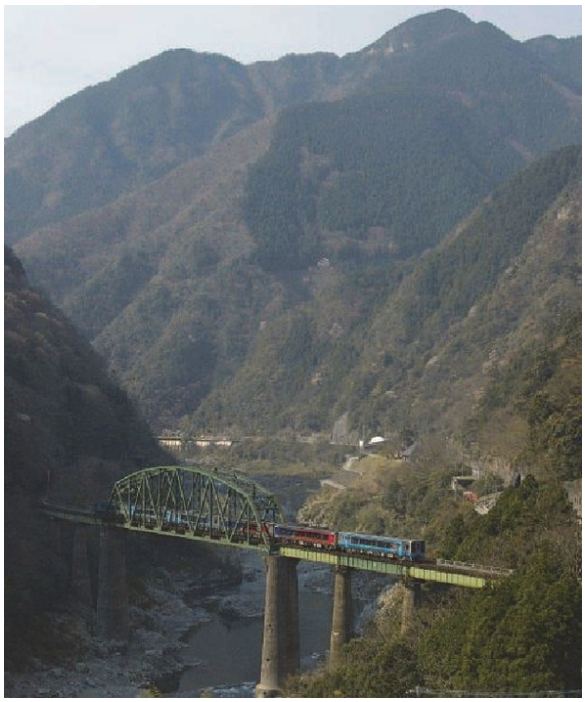

Photo. 1 JR Dosan Line crossing the Shikoku Mountains, Southwest Japan

railway lines constructed on the riverside steep slope (Photo.1). The train runs through the whole geological structure of the Shikoku area from North to South (Fig.1). The characteristic of geohazards are difference of each geological setting. Various methods were taken for safety operation of the railway by engineers when the Dosan line was opened.

4. The Dosan Line overcoming the disasters

4.1 Cross the mountain pass by switchback

The Sanuki Mountain district which consisted of Cretaceous Izumi Group is located at the border of Kagawa and Tokushima Prefecture. The Sanuki Mountain district is rifting by active faults of Median Tectonic Line (MTL), and the deep valleys is forming by erosion of branches of Yoshino River at the south foot of the mountain. There are also landslide zones affected by active faults of the MTL, surprisingly, some villages are scattered at the upper part of steep slope in the landslide (Photo.2). This section between Sanuki-saida Station and Hashikura Station is one of the difficult constructions in the Dosan line.

When the train goes over the Sanuki Mountains, it must run up continuous grade 25 ‰. In order to make the train stop and depart safely in the middle of the incline for going over the mountain pass, the switchback was constructed at Tubojiri Station opened in 1929 as signal station. The station and switchback facilities were constructed on the artificial land which filled up a river channel (Fig.2, Photo.2), because that was located in the rugged valley, and little flat ground was around there. The flow of the river was changed at three places, and they were transferred by headrace tunnels. At a glance, the location of the station looks dangerous, but the erosion does not advance in old river channel, and the filling abutted the valley wall is stable enough to collapse. Therefore the area is relatively safe from disaster.

Even now, the switchback operating does when

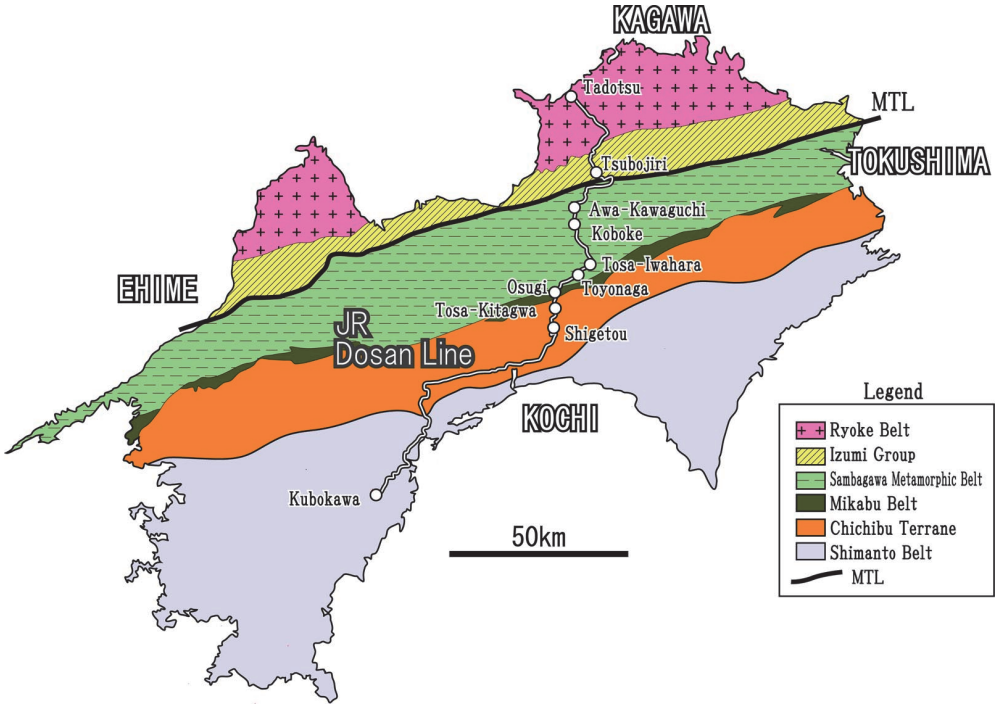

Fig.1 Geological map of Shikoku Island and the route of the JR Dosan line
(Geological map based on Editorial Committee of Shikoku, Regional Geology of Japan, ed., 1991)

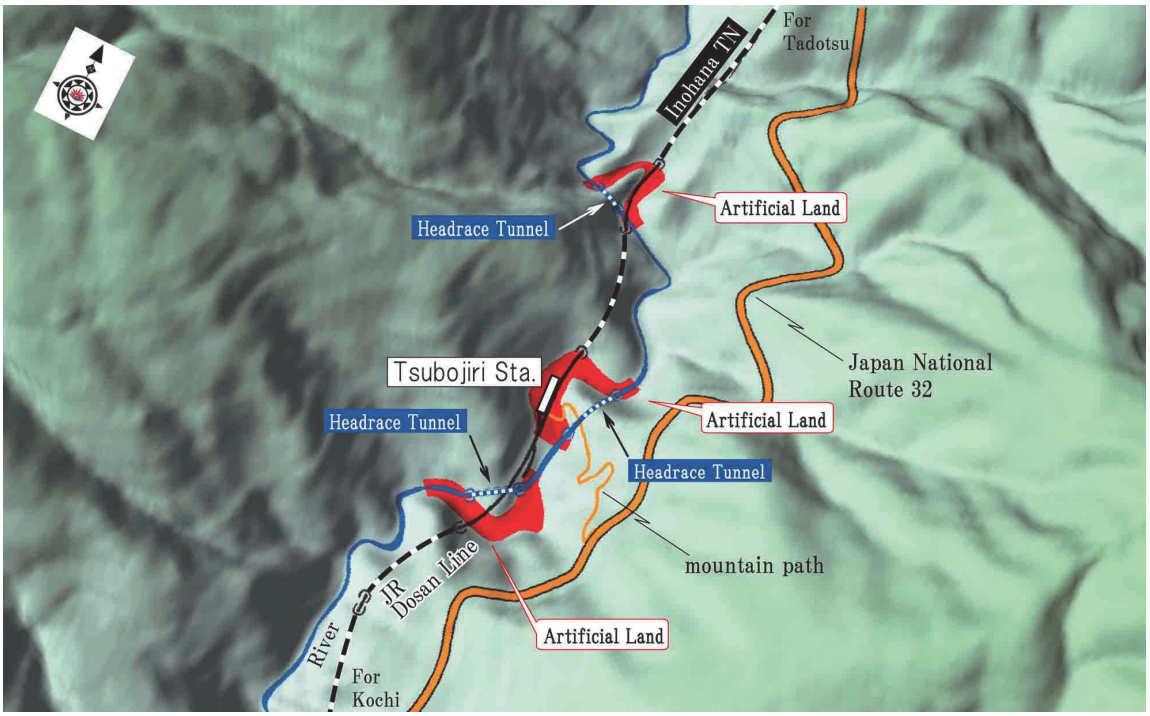

Fig.2 Map around the Tsubojiri station of the Dosan Line
(Kato, 2013; Base map Kashmir 3D, http//www.3d.com/)

Photo.2 Overlooking view of the Tsubojiri station and the landslide on the mountain (Kato, 2013)

the local train runs through the Tubojiri Station. The passengers are surprised that the train and track change the direction and the reverse scenery. When you get off at the Tubojiri Station, you can feel the endeavors of the engineers with loyal working railway facilities.

4.2 Replacement railway line due to disaster

Replacement the railway line of the Dosan line has been promoted for disaster prevention (refer to Fig.1 and Table1). We can find the disaster topography and the disused line from the train window, when the train goes in continuous short curves, makes the groan of engine sound and increases the speed through replacement section in a long tunnel.

In October, 1945, a landslide occurred by the heavy rain of typhoon in Kunimasa area between Awakawaguchi Station and Nishiu (now Koboke) Station, and the extension 270m of railway line was buried. It took two months for recovery after the disaster. In order to avoid the secondary damage of landslides, the 2,178m Yamashirodani tunnel was constructed in 1950. It was said that the large quantity of spring water welled out during the Yamashirodani tunnel digging was effective for making the landslide stable unexpectedly. This is the oldest replacement section of the Dosan line.

In September, 1948, the slope collapse occurred two times along the Dosan line between Iwahara Station and Toyonaga Station, and the locomotive derailed. For protecting from the accident, it was constructed a rock shed extended 33m there, however in February, 1962, the shed fell down together with the railway track to Yoshino River. It is considered that the accident was caused by distributions of the crystalline schist in this region. It was exfoliated and collapsed after creep deformation for a long time (Yamada et al. 1971). In this case, the train which was suspended slope was checked by the survey prior to

Table.1 Re-routing sections of the Dosan Line

period	section			newly founded structures	remains of structure	relating natural disaster
Nov.1950	Awa-Kawaguchi	~	Koboke	Yamashirodani TN (2178m)	many piers and ditchs	landslide by typhoon, Oct. 5, 1945
Aug.1956	Oboke	~	Tosa-Iwahara	Shushi TN (860m)	tunnel	landslide with subsidence and moving of roadbed and deformation of retaining wall
Nov.1968	Oboke	~	Tosa-Iwahara	Oboke TN (4179m)	tunnel, piers	landslide with deformation of retaining wall, rock-fall damages
Aug.1963	Tosa-Iwahara	~	Toyonaga	Oshiro TN (675m)	topography of collapse	landslide with derailment, Sep.,1948, and landslide with a shed and railway track, Feb.,1962
Jun.1954	Otaguchi	~	Tosa-Ananai	Wada TN (1198m), Trasfer of the Tosa-Ananai Sta.	Nishiyashiki TN, Akimori TN, Ananai Bridge	consecutive deformation around Nishiyashiki TN by slow moving landslide
Feb.1973	Osugi	~	Tosa-Kitagawa	Osugi TN (2583m)	Yoboushi Bridge (pathable)	landslide, May 1966
Mar.1986	Osugi	~	Tosa-Kitagawa	Otoyo TN (2067m), Transfer of the Tosa-Kitagawa Sta. on the bridge	many tunnels and bridges	rock-fall damages etc.

Note: Data based on Tamura T., ed., (1968), Yamada, G., et al., (1971), Kubomura K.,(1973), Imao K. (2007), Yokoyama, S., et al., (2012) , and Kato, H., (2014)

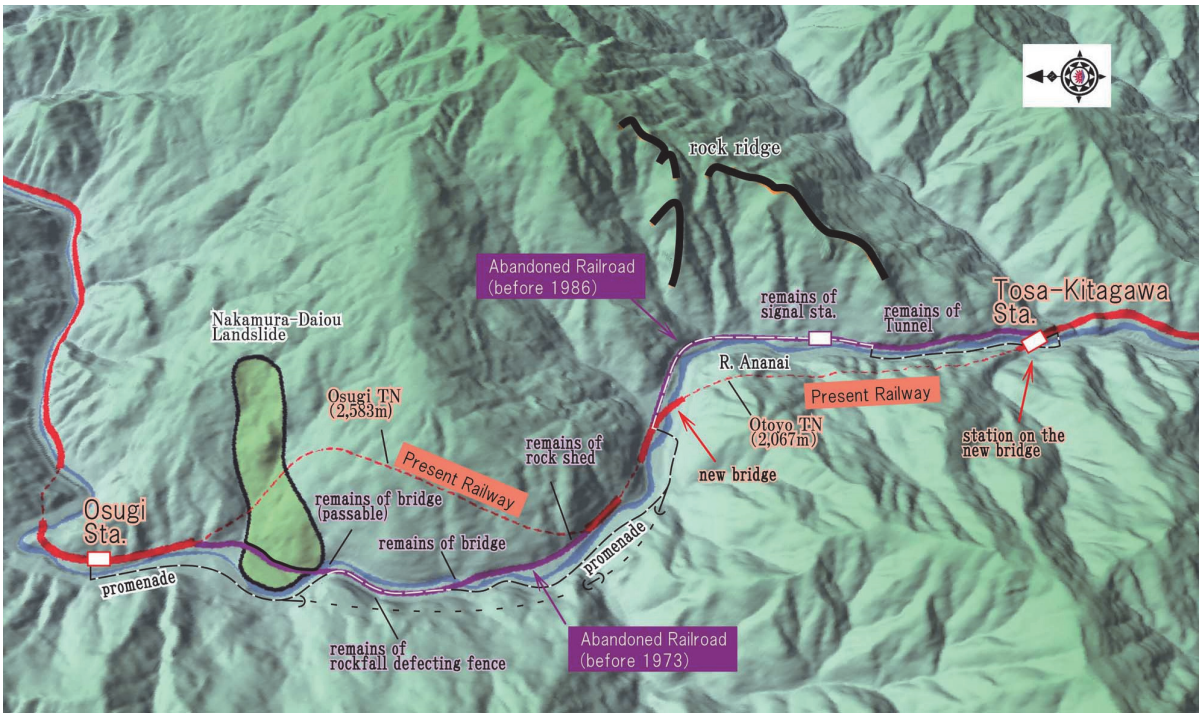

Fig.3 Walking path looking at abandoned tracks between Osugi Station and Tosa-Kitagawa Station (Yokoyama, S., et al., 2012; Kato, 2014; Base map Kashmir 3D http://www.kashmir.3d.com/)

the collapse. In the next year, this section changed the route to the 675m Oshiro tunnel. There we can see the huge landslide above disused line and watch a lot of falling rocks in the Yoshino River, from the Route 32 paralleled to the Dosan line.

4.3 Disused railway lines by disasters

Even today, we can recognize railway tunnels, railway bridges, communications cable facilities, rock-fall protection fences, and detectors for falling rock etc., along the disused railway lines as many railway inheritances due to disasters.

The longest disused section in the Dosan line exists between Osugi Station and Tosa-kitagawa Station (6.1km) along the Ananai River at the Kochi Prefecture (Fig.3; Photo.3-a; Yokoyama, S., et al., 2012). The train must run over the toe of landslide that consists of Mikabu greenstones in northern part of the section. On the other hand, it must run through the rock-fall area that consists of quartz schist in southern part of the section. There are many disasters occurred frequently, the railway route on river side was changed to two long tunnels and a railway bridge.

In northern part, the 2,583m Osugi tunnel was dug to avoid the landslide as alternative route in the

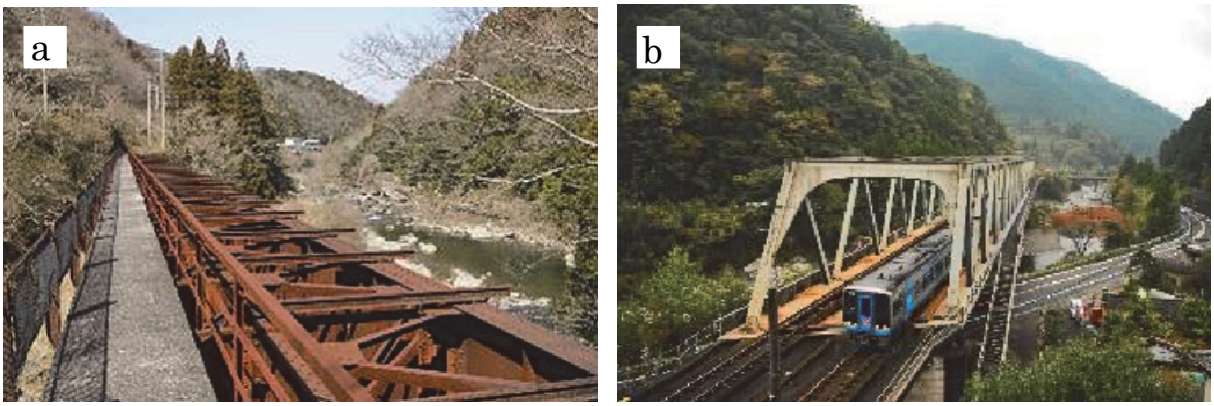

Photo.3 a：Remains of railway bridge located between Osugi Station and Tosa-Kitagawa Station
b：Tosa-Kitagawa Station built on a railway bridge

underground. We can read from a topographical map the aim of replacement of the railway (Fig.3). The new route is shorter and more straight line than ex-route, the train is able to pass at high speed consequently.

In southern part, Tosa-Kitagawa Station was transferred to a railway bridge from the ex-location along the Ananai River. The station having a platform on a railway bridge is rare in Japan (Photo.3-b). The construction of Tosa-Kitagawa Station on the railway bridge is advantageous for disaster prevention, because it does not suffer from influence of the slope failure directly. We can recognize that a lot of huge quartz schist rocks of the past collapse still remain in the Ananai River.

4.4 Recent railway disaster

For geohazards, it has been performed various measures along the railway route of the Dosan line, but in recent years railway disasters often occur.

In 1998, the Dosan line between Shigeto Station and Shingai Station was forced to the suspension of approximately three months, because the roadbeds flowed by the flood disaster occurred in Kochi Prefecture. More recently, in August 2014, the railway route at border of Tokushima and Kochi Prefecture was suspended for 12 days, because of the roadbeds collapsed by typhoon. In those two cases, although the passengers were inconvenient, the trains and human life did not damage.

In contrast to them, the large-scale slope failure took a heavy toll of human lives at Shigeto Station in Kochi Prefecture on July 5, 1972 (Photo.4). The heavy rain continued for two days, it triggered the collapse. At first, the slope collapsed within the small area several times, at the north side of Shigeto Station facing to Route 33. And then, a large slope failure occurred around 10:50. The train which just stopped at the station was involved in the debris flow and fell to the Ananai River. About 60 people that were the crews, the passengers, the inhabitants, and the fire fighters etc. died of the disaster. In the source area there is distributed the Chichibu terrane which was formed in high angled reverse-dip. It is suggested that

Photo.4：Shigeto Station six days after the disaster on July 11, 1972. The station facilities and the stopped train were washed away by slope collapse (Photograph by OYO Corporation)

the collapse was happened by unstable and long-term weathering. It is one of the examples that showed the strictness of nature in Shikoku mountain district as a slope disaster. Now surroundings of the Shigeto Station are restored, there we can understand the disaster to compare with the present and the past by a photograph.

5. Conclusions

The slope disasters along the Dosan line are caused by the fragile geology and the steep topography. It is the characteristic of the Dosan line that we can understand the earth movement and the mechanism of the disasters as a familiar railway history. In other words, the history of the railway disasters is the most familiar evidence as the movement of the earth. In harsh natural environment, the engineers continue keeping maintenance of the safety service of the railway, and the railway facilities remain as results of their effort. We hope the Geo-Tetsu tour becomes to know the diversity of the earth, and it becomes an opportunity to get a chance in the method of preventing disasters. The pleasure of the Geo-Tetsu is acquires knowledge along the railway by oneself. Everything we feel through the train trips as Geo-Tetsu bears something geoscientific.

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