Special feature article

Development of Space Creation Technologies

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Profile

1948	Born in Ojiya City, Niigata Prefecture
1972	Bachelor's Degree from the Department of Civil Engineering, Faculty of Engineering, The University of Tokyo
1974	Master's Degree in Civil Engineering from the Graduate School of Engineering, The University of Tokyo
1979	Ph. D from The University of Texas at Austin
1979	Lecturer, Department of Civil Engineering, Nagaoka University of Technology
1980	Associate Professor, Department of Civil Engineering, Nagaoka University of Technology
1998	Professor, Department of Civil Engineering, Nagaoka University of Technology
2003	Vice President, Nagaoka University of Technology
2004–2009	Board Member/Vice President, Nagaoka University of Technology
2009	Professor, Department of Civil and Environmental Engineering, Nagaoka University of Technology
2003–2007	Chairman, Japan Society of Civil Engineers Concrete Committee
2005–2007	Chairman, International Activities Committee, Japan Concrete Institute
2008–present	Chairman, Standard Specifications for Concrete Revision Subcommittee
2010–present	Director, Japan Society of Civil Engineers (Director, Research and Studies Division)
2010–present	Chairman, Technological Seminar Committee, Japan Concrete Institute
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1 Introduction

In Ojiya City of Niigata Prefecture where I grew up, we used to call people who came from outside the community "travelers". I would not say they were wandering travelers in period films, but many elderly people there at the time had lived their entire lives in the community, never venturing far, so going outside the community was a "journey" that took true resolve to accomplish.

Japan's first railway was laid in 1872 between Shimbashi and Shinagawa in Tokyo, as many people know from the famous song about a railway journey (1899). The railway network gradually expanded to other regions, with Niigata being connected to Tokyo's Ueno Station in 1898. That connection was by the Shin'etsu Line that passed through Takasaki, Nagano, Naoetsu and Miyauchi (Nagaoka City) before reaching Niigata. Ojiya, not even incorporated as a city then, was connected to the national network via a branch line from Miyauchi. It became a main line station more than 20 years later when the Joetsu Line opened in 1931.

The Shimizu Tunnel through the Echigo mountain range needed to be completed for the Joetsu Line to open, and a loop tunnel was constructed over a span of about 10 years. Tunnel boring technologies for deeper and straighter tunnels were developed later, allowing the Shinshimizu Tunnel to be completed in four years (in 1967) and the Oshimizu Tunnel in three years (in 1982). Thanks to those new tunneling and rolling stock technologies, the more than 11 hours required to travel between Niigata and Ueno in the Shinetsu Line era was shortened to around seven hours and later five hours. And with today's Joetsu Shinkansen (opened in 1982), travel time is under two hours. Going from Niigata to Tokyo today is no longer a "journey", with same-day trips made part of day-to-day business.

2 Stationhouses

The most familiar part of the railway to its users is the stationhouse in the user's town. I used Ojiya Station almost every day for three years when commuting to Nagaoka High School. The stationhouse at the time was the traditional form seen in movies about the era such as the 1999 film *Poppoya* (originally a novel by Jiro Asada). The stationmaster at the time was something of a celebrity in the community, and commuters were familiar with all of the station personnel. Unlike the soon to be decommissioned station in the film *Poppoya*, Ojiya Station saw many people commuting to Nagaoka City and was quite crowded at rush hour.

After graduating from high school, I spent my university years in Tokyo, and Ueno Station was extraordinary to me. Many people relocating to Tokyo from the countryside would pass through Ueno Station, and there were even hit songs in the 1960s expressing their feelings. Ueno Station was a terminal station that always seemed to be carrying a feel of somebody's hometown. While not as elegant as expressed by Takuboku Ishikawa, getting off a train at Ueno and hearing the various dialects of regions across Japan gave me a reassuring feeling.

To meet changing needs of the times, the Tohoku and Joetsu Shinkansen lines opened in 1982. With those lines running to Ueno in 1985, the station gradually changed in character. And it lost its role as terminal station when the Shinkansen lines were extended to Tokyo Station in 1991. Instead, demands emerged for the station to function as the town center for the Ueno area. Shops within the station were set up after privatization of Japan National Railways in 1987, and today the station that underwent many upgrades over the years is like a luxury shopping district. The white-base bright atmosphere is nothing like the station of old, giving a feel of the change of the times (Photo 1).

Photo 1 Shopping Center in Ueno Station

The same thing can be said for Kyoto Station that was completed in 1997. It is more like a shopping district with stairs than a station and has become a central shopping center for Kyoto (Photo 2).

The role of railways for regional cities also has greatly changed with the proliferation of automobiles, and so has the role of stations. Ojiya Station, serving a population of just under 40,000 and not having Shinkansen service, is becoming a local line station on the decline like the station in *Poppoya*. Nearby Nagaoka Station where the Shinkansen stops, on the other hand, is seeing the old city center being redeveloped centering on the station. And even the interior of the station is becoming a shopping center.

Photo 2 East Plaza of Kyoto Station

While this is not related to the topic of the article, many stations in Europe still maintain a terminal station feel. The photograph below was taken in Zurich Station. While the photo may seem to be of an airport and not express the station's terminal feel well, the electric display shows that trains arrive from and depart to locations throughout Europe (Photo 3).

Photo 3 Inside Zurich Station

3 Tunnels

The railway network that started out in 1872 as just 29 km between Shimbashi and Yokohama has grown to become a network from Hokkaido to Kyushu that encompasses more than 20,000 km (2,523 km for Shinkansen lines) under the Japan Railways companies. Looking at a topographical map of Japan, one sees that there are many mountainous areas with plains limited mainly to riverside areas between mountains and alluvial fans on coast areas. Thus, many tunnels were dug through mountains and bridges built over rivers to connect the plains.

Construction started on the Tanna Tunnel (7.80 km) on the Tokaido Line in 1918 and was completed in 1934. Work was done by hand at the start, and later a digging method employing pneumatic presses powered by steam engines was developed. Work was plagued by being located in a fault zone that includes the Tanna and Hakonemachi faults and by a large amount of spring water. Two cave-ins were suffered during construction. Moreover, the 1930 North Izu Earthquake shifted the Tanna fault 2.4 m vertically and 2.7 m northward, forcing the tunnel to take an "S" shape.

The Shintanna Tunnel (7.96 km) for the Tokaido Shinkansen was completed in five years in 1964. Information from the digging of the Tanna tunnel was put to use in construction of the new tunnel. Thanks to that and advances in tunneling technologies over 25 years, the construction time could be shortened and the number of victims of accidents reduced.

Progress was made in development of technologies to dig larger and deeper tunnels to meet the demand for flatter track in line with increased railway speeds. The Shimizu Tunnel (9.7 km) through the rugged Echigo Mountain Range took ten years to complete after work started in 1922, but the Shinshimizu Tunnel (13.49 km) was completed in four years after work started in 1963. The Oshimizu Tunnel (22.22 km) on the Joetsu Shinkansen line, longest in the world at the time, was completed in just three years from a start in 1979. Advances in tunnel digging technologies were the key to enabling faster completion of longer tunnels.

The 53.85 km Seikan Tunnel (Photo 4) between Honshu and Hokkaido islands was the feat that brought Japanese tunnel digging technology to the attention of the world. It took 25 years from inception to start of construction in 1963, and another 22 years passed with numerous difficulties overcome before completion in 1985. Technologies such as a liquid glass injection construction method to prevent intrusion of water at the bottom of the ocean and highly accurate surveying technology using lasers impressed the world. That example of people overcoming such difficulties was even made into a movie in 1982. Tunneling technologies used on the Seikan Tunnel would later be utilized for the tunnel under the Strait of Dover between the UK and France.

Photo 4 Seikan Tunnel Construction[1)]

4 Bridges

Iron bridges were already in common use in the early 20th century as demonstrated by a song featuring them being introduced in third grade textbooks as early as 1912. Coincidentally, the Amarube Viaduct (Photo 5) designed by Railway Ministry engineer Seiichi Furukawa was completed in 1912.

Photo 5 Amarube Viaduct[2)]

The railway network that connects Japan's urban areas like a spider's web could only have been achieved with the advances in bridge technologies as well as in tunneling technologies. A number of technical developments were required to build long bridges over large rivers on the plains, and technical developments rivaling those were also needed for bridges spanning deep valleys in the mountains.

Unlike road bridges, the ratio of load (live load) taken up by the train with railway bridges is relatively large. Bending of the bridge from live load is also strictly limited to ensure stable travel of trains. Thus, it is difficult to build railway bridges with spans as large as those of road bridges. Many of those bridges are highly rigid concrete or prestressed concrete (PC) bridges, and technical progress in that area has advanced. Photo 6 shows the No. 3 Usui Bridge designed by British engineer Charles Assheton Whately Pownall and Seiichi Furukawa. The aforementioned Amarube Viaduct was an iron bridge, but it was replaced in 2010 by a PC (extradosed PC) concrete bridge (Photo 7) due to corrosion and degradation from the coastal salt air.

Photo 6 No. 3 Usui Bridge

Photo 7 New Amarube Viaduct[2)]

Railways came to run at even faster speeds after the opening of the Tokaido Shinkansen in 1964. The Sanyo, Tohoku/Joetsu and Kyushu Shinkansen lines have been completed, and construction of the Hokuriku Shinkansen is currently underway. New forms of bridges (Photo 8, 9) were studied and achieved in construction of those Shinkansen lines. In urban areas, however, construction needs to be done in limited spaces, so technical development is needed for construction methods as well as for design. An example of an urban bridge is shown in Photo 10. Those bridges have been recognized by the Japan Society of Civil Engineers (JSCE), winning the society's Tanaka Award (Excellence in Bridge Design and Construction).

Photo 8 Akayagawa River Viaduct[3)]

Photo 9 Sannai-Maruyama Over-road Bridge[4)]

Photo 10 Shintoshin Bridge[4)]

5 Conclusion

The JSCE published its first Standard Specifications for Concrete Structures in 1931, covering concrete structure design and construction technologies. Since then, it has published revised editions once every five years to summarize technical advancements. Engineers and researchers working on the revision come from industry, academia and government, and the contribution made by railway engineers and researchers is great. Technical development for prestressed concrete, research on fatigue strength of steel materials and technical development for Seismic Design and Seismic Stregnthening involve processes of execution and verification in actual work, so railway professionals provide extremely valuable information. In areas related to earthquake resistance in particular, damage to structures from the 2011 Tohoku earthquake being light proved the appropriateness of technical development since the 1995 Kobe earthquake.

Our technical development to protect against natural disasters is without end, however. Problems overlooked up to now are coming up as demonstrated by tsunami-resistant bridge structures becoming an issue that needs to be overcome in the future.

Reference:

1) Japan Railway Construction Public Corporation, Hakodate Construction Public Corporation, *Tsugaru Kaikyou Sen Koji Shi (Seikan Tunnel)* [in Japanese], First Half (1988)

2) *Kyoryo to Kiso* Vol. 45, No. 1 (January 2011)

3) Japan Railway Construction Public Corporation, *Joetsu Shinkansen Koji Shi (Omiya - Niigata kan)* [in Japanese] (March 1984)

4) Japan Society of Civil Engineers, *Proceedings of the 95th General Assembly* (September 2009)