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Engineering and Construction for Railway Projects in Southeast Asia

Mitsuo Ichinose, Shigeyuki Komatsu, Hiroshi Ozeki

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Kawasaki Steel has executed several railway construction projects, both in Japan and overseas, based on the construction experiences of its own integrated steel mills which included railway systems for bulk materials transportation. This report describes Kawasaki Steel's development of railway construction and engineering and railway systems for tracks, electric facilities, signals and telecommunication, by referring to executed projects for Indonesian National Railways.

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Engineering and Construction for Railway Projects in Southeast Asia*



Mitsuo Ichinose
Staff Manager, Building Engineering Dept., Construction Div., Engineering & Construction Div. Gr.

Shigeyuki Komatsu
Staff Manager, Plant Control Technology Dept., Steel Plant Div., Engineering & Construction Div. Gr.

Hiroshi Ozeki
Staff Deputy Manager, Civil Engineering Dept., Construction Div., Engineering & Construction Div. Gr.

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1 Introduction

In Southeast Asian countries, the chronic traffic congestion in urban districts caused by rapid motorization has produced not only social and economic problems, but also energy and environmental problems such as waste of fuel and emissions of exhaust gas. The transport of passengers and goods by railway is advantageous from various aspects of transportation efficiency including energy, mass transportation and environment. In every Southeast Asian country, the effective utilization of railways is being reviewed and various projects for the modernization and expansion of existing are being carried out.

Through the construction of its own integrated steelworks, Kawasaki Steel has formulated techniques for each stage of the planning, design, construction and maintenance of railway facilities. A railway system is an integrated system composed of many specialized components such as civil engineering, building construction, tracks, traction power lines, substations, signal equipment, cars, machinery and train operation control. Kawasaki Steel, which has much experience with the construction of plants including steel mills both in Japan and abroad, possesses great capability to undertake integrated project composed of civil and building works, electrical and instrumentation equipment, machinery, utilities, etc. On the basis of this know-how for constructing railway systems and plants, since 1987 the company has received orders for and carried out railway projects of package ordering type in Indonesia and the Philippines in which civil engineering, building construction, tracks, traction power lines, power lines, substations, signal equipment, and telecommunications equipment are integrated[1].

This report presents Kawasaki Steel's history and development of railway know-how, outlines the equipment composition of a railway system by citing the example of a package ordering-type railway project carried out in Indonesia, and describes the engineering and construction of railway facilities in which the peculiarities of railway systems are considered.

2 Kawasaki Steel's Railway Know-How

In 1951, Kawasaki Steel began construction of its two integrated iron and steel works, i. e., Chiba Works (site area: 8 720 000 m^2) and Mizushima Works (site area: 11 280 000 m^2). At steelworks it is necessary to transport massive amounts of materials on the expansive premises. Especially in the pig iron transport from the blast furnace to the steelmaking shop and in the slab transport from the steelmaking shop to the rolling mill, there is no method that replaces railways, so the contribution of railways to material distribution within a steelworks is great. The total length of the railways constructed at the two sites is 220 km (**Photo 1**).

Through the construction and operation of its steelworks, Kawasaki Steel has thus accumulated know-how

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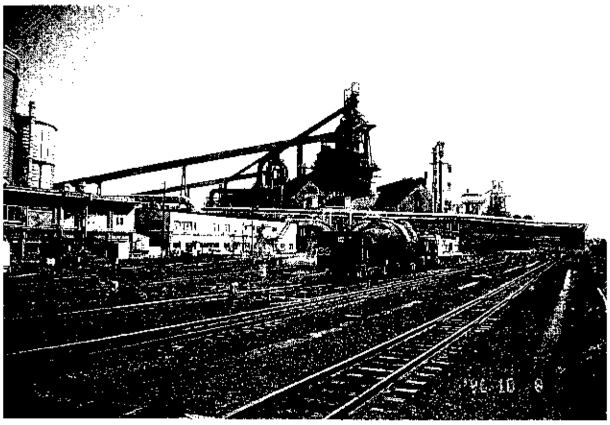

Photo 1 Railway in Mizushima Works

Photo 2 Oigawa Abt system railway

for arranging station lines based on plant layout and transportation plans, as well as for the design, construction and maintenance of civil works, tracks, signals and safety equipment.

Since the 1980s the company has used its railway know-how obtained through the construction of steelworks at home and abroad. The types of work carried out to date, along with the year of completion and site of work, are enumerated below:

(1) Construction of a personal rapid transit system at New Saint Andrews Golf Links (1985, Tochigi Pref.)
(2) Construction of the Oigawa Abt system railway (1988, Shizuoka Pref., **Photo 2**)
(3) Construction of a personal rapid transit system at Golden Lakes Golf Links (1990, Tochigi Pref.)
(4) Depot and workshop construction project of Indonesian National Railways (1991, Indonesia, **Photo 3**)
(5) Maintenance depot construction project of Philippine National Railways (1990, the Philippines)
(6) Central Line track elevation project of Indonesian National Railways (1993, Indonesia, **Photo 4**)
(7) Central Line signaling project of Indonesian National Railways (1994, Indonesia)
(8) Bekasi Line signaling project of Indonesian National Railways (1994, Indonesia)
(9) Bogor Line signaling project of Indonesian National Railways (1994, Indonesia)

Projects (6) to (9) were integrated project that involved almost all types of railway facilities, i.e., civil and building works, tracks, traction power lines, substations, communications equipment and signal equipment.

Photo 3 Construction of depot in Jakarta, Indonesia

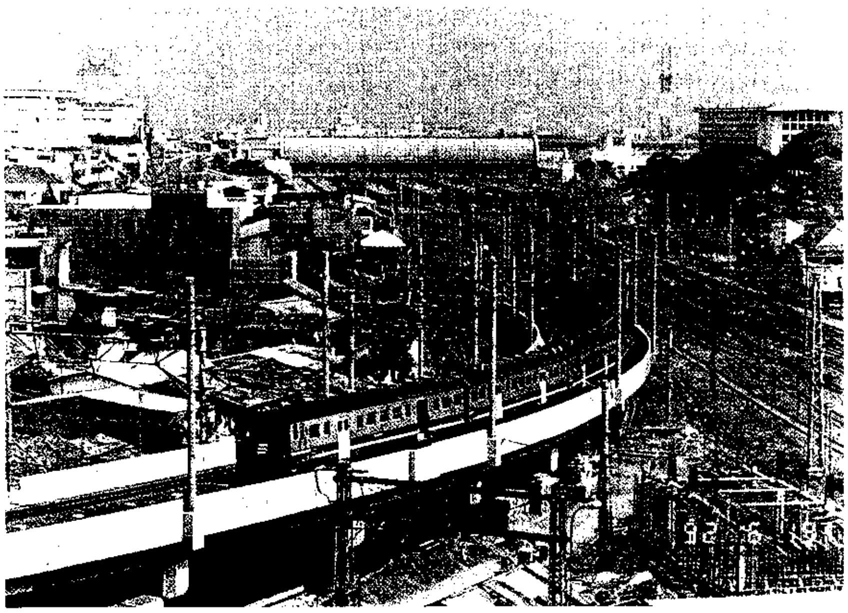

Photo 4 Elevated railways in Jakarta, Indonesia

he specifics of project (6) to (9) are shown in **Fig. 1** ıd **Table 1**.

Characteristics of Railways and Railway Facilities

A railway is generally defined as "a facility that has a ›finite site as a means of land transportation and trans- ›rts passengers and goods by operating cars using echanical and electric power on tracks composed of ils, sleepers, ballast, etc."[2] The characteristic of a rail- ay is that cars and engines equipped with steel wheels ıvel on "dedicated" steel rails. The steel rails are not ıly for the travel of cars, but are also something used r traction power lines and signal equipment.

Furthermore, a railway is generally a public means of ınsportation and, therefore, high reliability is required. t the same time, the facilities or system must be ›signed so that even if a problem occurs, it has little if ıy effect on train operation, because, as is characteris- ; of railway facilities, a problem in one part of the sys- m has an effect on the whole system. Trains travel only ı a railway (tracks) and, as shown in **Fig. 2**, railway cilities such as substations, traction power lines, signal ıuipment and telecommunications equipment are stalled in parallel with tracks. These are independent cilities dedicated to the railway.

Principal components of railway facilities are the ıck facility for the traveling of trains, the electric trac- ›n facility composed of substations for the electric ›eration of trains and trolley lines, and the train opera- ›n control facility composed of signal equipment for eventing collisions of trains and telecommunications uipment to conduct monitoring and provide verbal and data communications.

4 Track Facility

Tracks on which trains travel are composed of ballast, sleepers, rails and accessories. Gravel, crushed stone, etc., are used as ballast, which widely distributes the load from trains and transmits it to the subbase. Ballast also prevents the movement of sleepers caused by the lateral movement of trains and the expansion and contraction of rails by temperature. In addition, ballast absorbs the vibration energy due to trains, facilitates the drainage of rain water, and prevents the growth of weeds. Sleepers keep the track gauge of right and left rails, distribute the load of trains received by rails to the ballast, directly support the weight of trains, guide trains with a smooth traveling surface so that they do not derail, and form the return path for traction power currents and the track circuit for signal currents. A turnout device for changing track direction is also an important component.

5 Electric Traction Facility

Substations for converting the electric power of general power system into a form suitable for electric traction and traction power line for supplying the electric power from substations to cars are necessary for operating cars. These are collectively called the electric traction facility. The circuit for the power supply from a substation to cars through a feeder wire is called the feeding system. There are two types of feeding systems: DC and AC. Here, a DC electric traction facility like the type used in the aforementioned Indonesian project is described. The features of a DC electric traction facility are the use of DC series motors capable of producing a large tractive force when a train starts and the freedom from inductive disturbance to the communications lines and signal lines installed close to the railway track. In railway, currents of 1 500 V, DC are generally used.

The features of the electric traction facility are as follows:

(1) The steel rails on which cars travel are a component that composes an electric circuit.
(2) The fluctuation and movement of loads that depend on the operation condition of cars are large and the facility can cope with overloads.
(3) The equipment composition provides redundancy so as not to interrupt train operation. Functions include a monitoring and backup function that makes it easy to take action even if an accident occurs.

5.1 Substations

A DC substation receives a three-phase AC high-voltage current from an electric company, lowers the voltage to an appropriate level by a transformer, converts AC into DC by a rectifier, and supplies the power thus transformed to traction power line.

The capacity and location of a substation are determined in consideration of the transmission system of the electric company, operation and maintenance, and future predictions in addition to the load capacity and voltage drop limit determined from car conditions, train formation, train schedule, and such track conditions as grade. In general, substations are installed at intervals of 5 to 10 km.

Southeast Asian countries usually have hot and humid weather and the frequency of lightning is high. Thus the weather conditions are severe for electrical equipment. Furthermore, it is necessary to take effective measures to prevent the entry of small animals, etc. The environmental conditions for the present design are as follows:

Maximum temperature: 40°C
Minimum temperature: 20°C
Average temperature: 28°C
Maximum humidity: 95%

The equipment of a substation is composed of (1) power receiving equipment, (2) main transformer, (3) rectifier, (4) DC feeding equipment, (5) negative cubicle, (6) auxiliary transformer cubicle, (7) control power cubicle, and (8) remote supervisory control equipment.

From the nature of the substation used for electric traction that loads are trains, load fluctuations arising from the starting, stopping, acceleration and deceleration of cars are large and there is a possibility that large overcurrents may flow instantaneously when there is trouble in cars and traction power lines. Therefore, the substation is required to withstand overload operation and S-type specification (overload 150%: 120 min, 200%: 5 min, 300%: 1 min) is adopted as the overload capacity of the main transformer and rectifier.

The DC output from the rectifier is fed from feeding cubicles through traction power lines to cars. The feeding cubicle houses a DC high-speed circuit breaker (HSCB) and a fault selection relay (50F). Given the peculiarities of environmental conditions of traction power lines, automatic reclosing circuit control is conducted in case of a trip due to accidents such as contact between trees and traction power lines. Furthermore, a

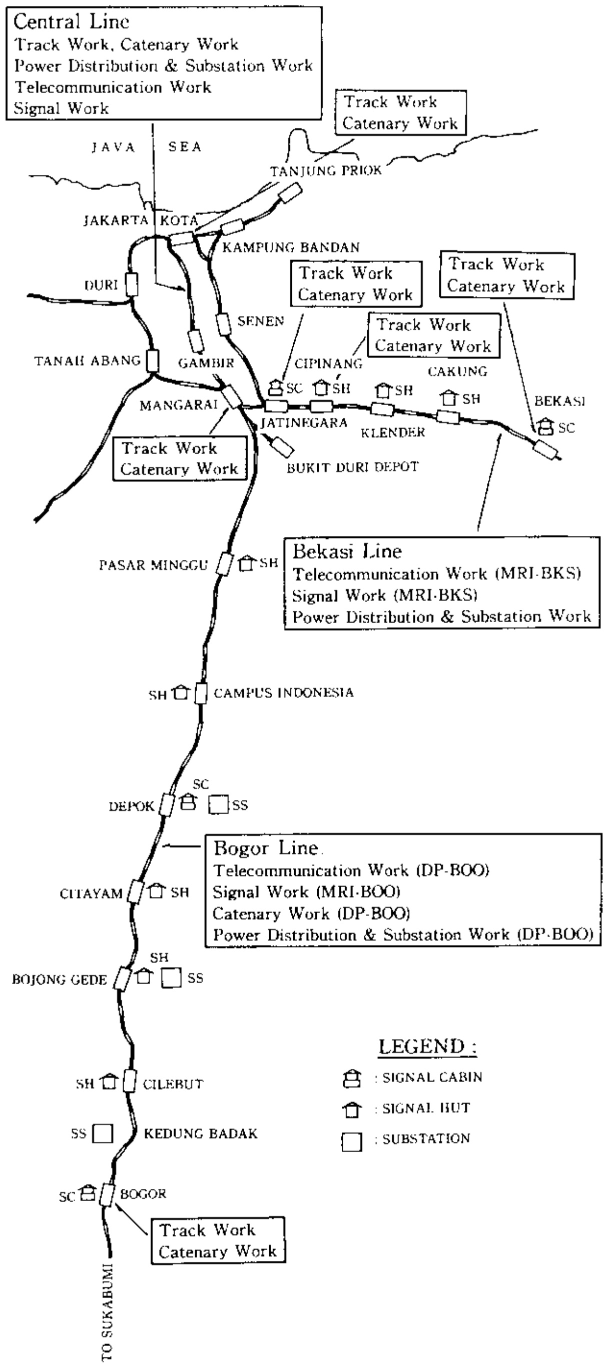

Fig. 1 Map for Indonesian Railways project

Table 1 Major work item and volume

Project \ Work	Track work		Electrical work			Signal and telecom.	
	Track panel (m)	Railway switch (unit)	Substation (OHC) (set)	Substation (signal) (set)	Trolley wire (m)	Interlocking system (set)	Telecom. cable (m)
Jabotabek Central Line track elevation	19 600	9	3	2	20 300	1	10 500
Jabotabek Central Line signalling project	5 890	67			380	2	910
Jabotabek Bogor Line signalling project	1 220	11	1	2		2	28 500
Jabotabek Bekasi Line signalling project	2 940	28				3	350
Total	29 650	115	4	4	20 680	8	40 260

dual feeding circuit is provided so that train operation is not hindered by the maintenance and inspection of circuit breakers, etc. Although the number of feeding cubicles is determined by the number of trolley lines, it is planned so that addition and expansion can be easily carried out when the number of trolley lines is increased in the future. The specifications of a circuit breaker are as follows:

Rated voltage: 1 500 V
Rated current: 2 000 A, DC
Short-circuit current: 50 000 A

The remote supervisory control equipment is for conducting the remote supervisory control of substations, and a central station and a local station form a pair. The central station is installed in the central supervisory center and the local station is installed in each substation. The central station and local station, which are connected by two pairs of communications cable, constantly supervise the opening and closing of main circuit breakers and the condition of equipment, while simultaneously, permitting the communication with substations by attached telephone sets without hindering the supervisory control function during inspection.

5.2 Traction Power Line

Electric lines installed in parallel with a track in order to supply power to cars through power collectors, including works indicating the electric lines, are called traction

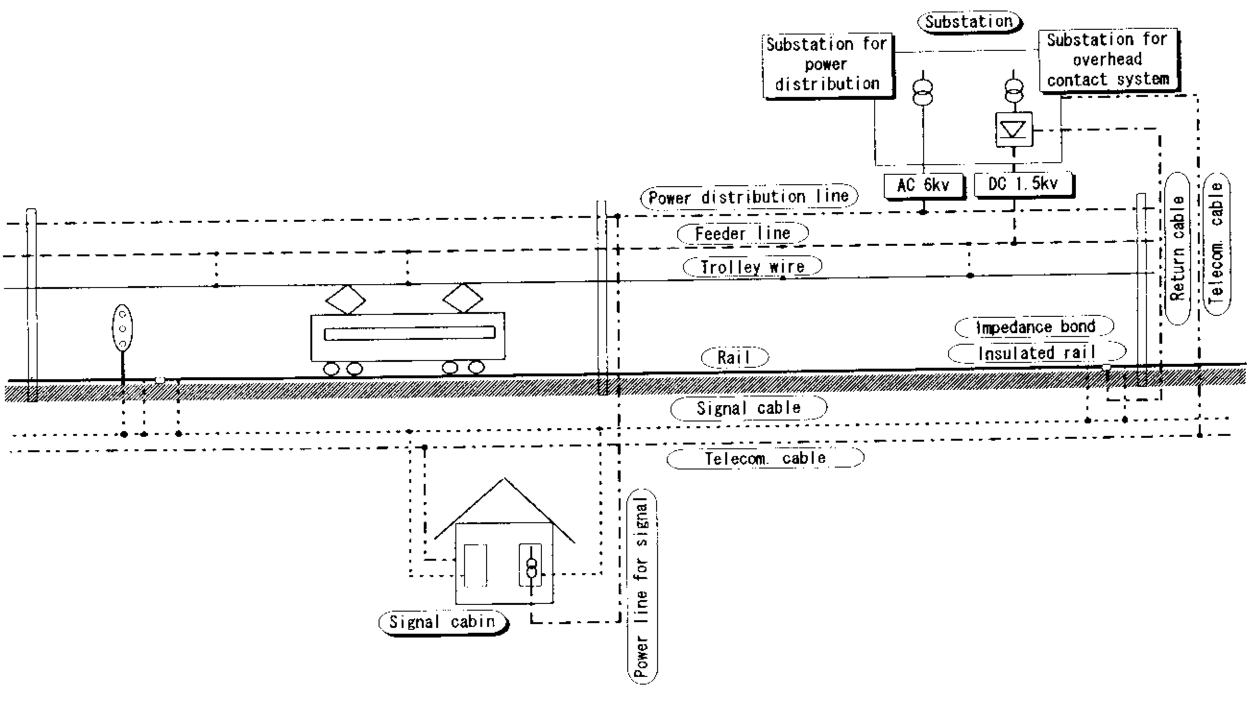

Fig. 2 Railway system

power lines.

A traction power line is composed of the following equipment:

(1) Trolley wire that comes into direct contact with the power collector of a car

(2) Catenary wire for suspending the trolley wire at a constant height above the track surface

(3) Feeder wire for supplying electricity from a substation

(4) Rails that provide the feeder for returning the power supplied to the car back to the substation

As is apparent from the composition of the DC feeder line shown in Fig. 2, feeder wires are installed in parallel with traction power lines because of the use of large currents and connect substations in parallel, thus reducing the voltage drop due to loads. The voltage drop limit is 900 V for 1 500 V, DC and the maximum voltage drop occurs when trains at the longest distance from a substation receive large currents when starting and while traveling on an upward grade. Therefore, it is necessary to take measures suited to this voltage drop. Furthermore, a feeding section in which switchgears such as circuit breakers are installed is arranged between substations to divide feeding during accidents and maintenance work.

A trolley wire is made of hard copper and has a circular section with grooves. Tension is applied to a trolley wire and there is a problem of contact with pantographs. Therefore, a trolley wire is not directly connected to another trolley wire; rather, they are electrically connected by an air joint in which continuous trolley wires are laid in such a manner that their terminal ends overlap each other.

6 Train Operation Control Facility

Because trains travel on dedicated rails and their braking distance till a complete stop is long, it is necessary to install safety equipment for preventing such accidents as collisions. The equipment for this purpose is signals and telecommunications are used for operation, including during emergencies.

6.1 Signal Equipment

The non-existence of another train in the section in front of a train is sufficient for preventing collisions. For this purpose, tracks are divided into specific sections into which only one train is allowed at a time and the entry of another train is not permitted. This train operation system is called the block system. The signal equipment in the block system is composed of a block instrument, track circuit, interlocking device, signal apparatus and point machine.

The block instrument and track circuit compose a pair. A facility for detecting that a train is within a specific section by making use of the rails in the above specific divided section (block section) as part of an electric circuit is called a track circuit. Sections of tracks for detecting a train are installed at intervals of several hundred meters to 2 km as a track circuit. The rail joints at the two ends of a track circuit are electrically insulated. A feeding transformer is connected to one end and a track relay is connected to the other end so that when a train enters the section, a short circuit occurs between the rails due to contact between the wheels and the track relay, thus detecting the entry of the train. When cars are operated, the rails are used as the return path for the feeder current for returning the power supplied to the cars back to the substation. Therefore, the signal current and feeder current are separated from each other at the insulated joints installed to form the track circuit so that the signal current flows through the track circuit only and the feeder current flows through the whole track circuit as one return conductor. An impedance bond is installed for this purpose.

The interlocking device is a control device for preventing the crossing and collision in the traveling routes of trains in places where tracks branch and intersect as in a station yard. This device is usually installed in the signal cabin in a station yard.

The signal apparatus is used to indicate such operational conditions as moving, stopping, speed and route for drivers and is usually represented by a signal.

The point machine is a device for switching the point of turnout of a track.

Power-supply equipment is necessary because the above signal equipment is electrically operated. In some of the above substations, a transformer for the power supply to the signal equipment is installed and power is supplied in the form of three-phase alternating current of 6 kV to each signal cabin. The power supply system to the signal cabin is so designed as to permit power supply from multiple substations. Therefore, even if a substation from which power is usually supplied malfunctions, power can be supplied from another substation.

In the signal cabin, voltage is lowered by a transformer and power is then supplied to each piece of signal equipment. Furthermore, a battery charger and battery are installed to form an automatic charging circuit. The capacity of the storage battery is large enough to supply power for 6 hours.

6.2 Telecommunications Equipment

Since the invention of the telegraph, telecommunications equipment has been used for communications between stations to ensure the safety of trains. Today, telecommunications equipment includes communication circuits and has many functions. Various kinds of voice communications equipment, such as emergency telephone sets along tracks and talking apparatus for train shunting in a station yard, are installed according to both the method of use and daily communication, such as the communication between adjacent stations, between the train dispatcher and the signal cabin, etc.

In addition to the above purposes, communication circuits are used to transmit the remote supervisory control signals of substations and to exchange data with the interlocking devices of signal equipment.

7 Engineering of Railway Facilities

When railway work is planned, a master plan is first formed on the basis of the expected demand for transportation. In this planning stage, a decision is made based on whether the improvement and expansion of existing facilities or the installation of new facilities is more feasible. This is done by considering the present capacity and condition of transportation, functions of the railway network to be eventually built, maintenance of functions during the construction period, etc. During the course of this process, the required performance and specifications of each of the above facilities and the arrangement of equipment are examined and determined. This master planning and design are usually carried out by the owner and engineering and construction companies like Kawasaki Steel join the project from the stage of detailed design of each facility including construction plans.

In this case, design and planning in which the natural and social conditions in the project region are taken into consideration, are important for the smooth execution of the project. In an actual project in Indonesia, (1) equipment specifications suited to high temperature and high humidity and (2) installation of lightning arrestors for preventing damage due to lightning beyond the ordinary specifications were adopted in consideration of the weather conditions of this tropical zone. In addition, the following protective measures were taken to prevent the entry of persons onto railway property: (3) adopting the direct burying method for cable laying without using troughs and (4) causing low-voltage currents to flow in exposed wiring such as overhead lines.

8 Conclusions

Railways are an excellent transportation system in terms of transportation efficiency, energy consumption and environmental soundness, although their share of land transportation has been decreasing due to the development of automobiles and airplanes. Nevertheless, the characteristics of railways such as mass transportation, punctuality and safety are indispensable for maintaining urban functions. In addition to ordinary railways, subways, light rails and new traffic systems are being planned, especially in developing countries.

The authors want to contribute to regional development through the construction of railways on the basis of the experience and know-how obtained from recent projects undertaken in Japan and Southeast Asia, as well as on the basis of the railway know-how acquired through the construction of steelworks.

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