THE ROLE OF STRADDLE TYPE MONORAIL SYSTEM

HITACHI

Contents

Preface

The Haneda Line of Tokyo Monorail, operating on 13.1 km double track and being typical of Straddle Type Monorail System, has carried about 400 million passengers without a bodily trouble for a period of more than 20 years since its inauguration in 1964, the year of Tokyo Olympiad. And now it holds an indispensable position as a safe, rapid and reliable means of mass transit linking Haneda Airport to downtown Tokyo.

On the other hand, the Kokura Line of Kita-Kyushu Monorail, another Straddle Type Monorail System in Kita-Kyushu City, has completed the whole construction and running test and put in service in January, 1985.

Further in Japan, construction of the Straddle Type Monorail System is agreed upon for three sites in Osaka Prefecture, Okinawa Prefecture and Tokyo Metropolis, the Osaka Monorail is now under construction, while the other two projects are at planning stage.

Thus, the Straddle Type Monorail System is increasingly introduced for resolving the impasse of urban traffic congestion as an auxiliary means of transportation in big cities to ease metropolitan area of traffic problem as well as a trunk line of transportation in medium sized cities. This type of monorail system is, therefore, anticipated to serve successfully as an effective means of transit for inhabitants in cities.

Hereinafter, the features, construction and specifications of the Straddle Type Monorail System are introduced taking the case of the Kokura Line of Kyushu Monorail.

1. Position of Monorail System in Urban Transportation

(1) The monorail system has been developed to materialize a means of rapid and mass transit with low construction cost by making use of the aerial space on street not utilized up to date.

(2) A survey on the locations of the monorail systems previously constructed and presently under construction or final planning indicates that their routes are broadly classifiable into three categories.

① Route to form broad and versatile network connected with loop line or high speed railroad in the metropolitan area or large city;

Tokyo Monorail, Kita-Kyushu Monorail, Osaka Monorail, Tama Monorail of Tokyo Metropolis

② Route to serve as trunk line of transportion in medium sized city;

Okinawa Monorail

③ Route constructed inside or to connect with the site of large sized exposition and exhibition;

Osaka Expo Land Monorail

(3) The following is a rough estimation of the range of carrying capacity of the monorail system.

TABLE 1 PASSENGER CARRYING CAPACITY OF MONORAIL TRAIN

Carrying Capacity (Passengers) / Definition	Standard Size (Okinawa Monorail)		Large Size (Kita-Kyushu Monorail)	
	Head Car	Intermediate Car	Head Car	Intermediate Car
Capacity, Nominal [Passenger Room Area (m^2) / 0.35 (m^2/Person)]	82	92	90	100
Capacity, Operation Plan [Seating Capacity + Area for Standing Passengers (m^2) / 0.14 (m^2/person)]	138	152	168	191
Capacity, Fully Loaded [Seating Capacity + Area for Standing Passengers (m^2) / 0.1 (m^2/person)]	204	225	260	279

Large Size Train

Headway (min)	No. of Trains (per hour)	Carrying Capacity (passengers per hour)		
		2 Car Train	4 Car Train	6 Car Train
2	30	10,080 15,600	21,540 32,340	33,000 49,080
3	20	6,720 10,400	14,360 21,560	22,000 32,720
4	15	5,040 7,800	10,770 16,170	16,500 24,540
5	12	4,032 6,240	8,619 12,936	13,200 19,632

Note:
Upper Value: for Operation Plan
Lower Value: for Fully Loaded

Standard Size Train

Headway (min)	No. of Trains (per hour)	Carrying Capacity (passengers per hour)		
		2 Car Train	4 Car Train	6 Car Train
2	30	8,280 12,240	17,400 25,740	26,520 39,240
3	20	5,520 8,160	11,600 17,160	17,680 26,160
4	15	4,140 6,120	8,700 12,870	13,260 19,620
5	12	3,312 4,896	6,960 10,296	10,608 15,696

Note:
Upper Value: for Operation Plan
Lower Value: for Fully Loaded

If the length of platform is limited to be under 100m because of constructing station above the street, then the number of cars in a train would come to six.

(4) Consequently, appropriate carrying capacity of the monorail system is figured out to be approx. 5,000 to 40,000 passengers per hour per direction, which is well applicable to mass transit next to subway. [Fig. 1]

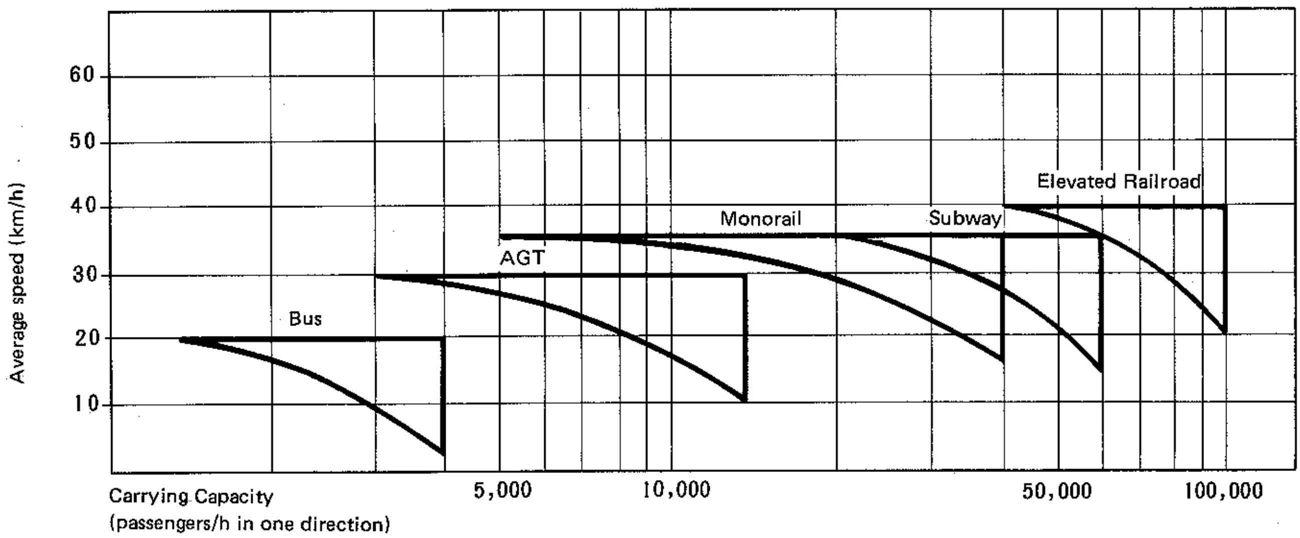


Fig. 1–Passenger carrying capacity of various means of transportation

(5) In many cities of the world, various experiments are being performed to resolve traffic problems. In case of constructing traffic facilities above roads, monorail system is considered to be the most appropriate means on account of its advantages described in the following chapter.

2. Features of Monorail System

Principal features of the Straddle Type Monorail System are as follows.

(1) Plentiful experience and record or construction
(2) Lower construction cost
(3) Simplified maintenance
(4) No environmental pollution
(5) Safer and better ride
(6) Can be built on narrow street
(7) Easy construction work at site

Explanation of each of the above features is given hereunder.

2-1 Plentiful Experience and Record of Construction

The Straddle Type Monorail System ever constructed up to date is seven (7) lines in Japan and five (5) lines outside Japan, and their total kilometrage reaches about 100 km in terms of single track.

The history of development and construction of the monorail is described below.

(1) History of the Straddle Type Monorail System

A prototype of the Straddle Type Monorail System was a scale model succeeded the first demonstration in 1952, when Mr. Gren, a Swedish engineer, recorded a maximum speed of 130 km/h on a 1.5 km long experiment track of reduced size (scale 1 to 2.5) constructed at Fuehlingen near Cologne, West Germany. Based on the results of this experiment, a life size test track of about 1.8 km in length was built at the same location in 1957, and tests on the practical model was performed. This practical model was called ALWEG Monorail System after the name of the inventer, Mr. Axel L. Wenner Gren, and it has laid the foundation for the Straddle Type Monorail System of today.

In 1960, Hitachi, Ltd. has introduced the technology of the ALWEG Monorail System in its judgement that the system would be the most prospective means of urban transportation.

In Japan, the monorail system was first built for Inuyama Amusement Park near Nagoya in 1962, then were constructed successively for Yomiuri Land in 1963, Haneda Line of Tokyo Monorail in 1964 and Osaka Expo Land in 1970 and Kokura Line of Kita-Kyushu Monorail in 1985. [Photo. 1, Photo. 2 & Photo. 3]

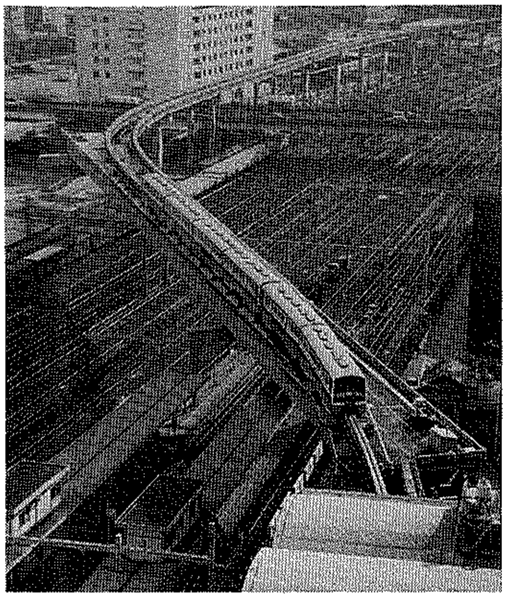


Photo. 1–Haneda Line of Tokyo Monorail (Tokyo, 1964, 13.1 km Long Double Track)

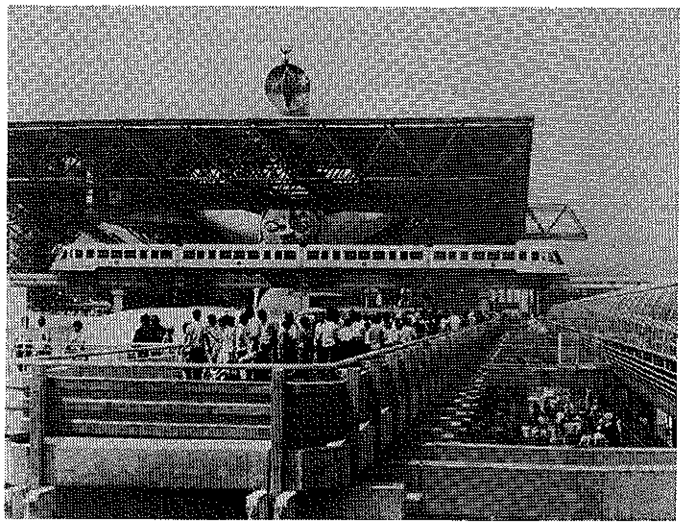


Photo. 2–Osaka Expo Land Monorail (Osaka, 1970, 4.3 km Long Single Track)

Utilizing these valuable experiences, the Kita-Kyushu Monorail was operated as a full-scale means of urban transportation.

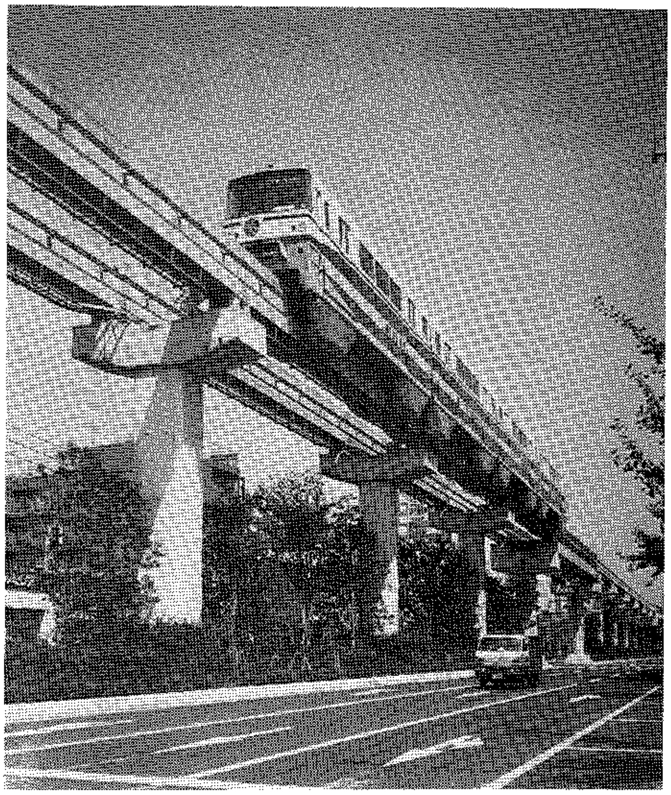


Photo. 3– Kokura Line of Kita-Kyushu Monorail (Kita-Kyushu, 1985, 8.4 km Long Double Track)

On the other hand, typical examples or the ALWEG Monorail System constructed in various cities of the world are the Disney Land (1959, U.S.A.), Turin (1961, Italy), Seattle (1962, U.S.A.), and the Disney World (1971, U.S.A., famous for its trains that pass through a building). [Photo. 4]

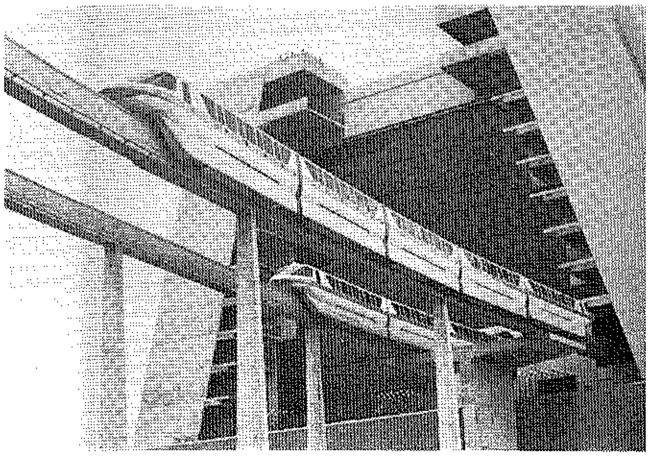


Photo. 4 Monorail System in the Disney World (Florida, U.S.A., 1971, 4.4 km Long Double Track, Extension in 1982, 5.6 km Long Single Track)

(2) Record of construction and progress of development

Thus far, the history of straddle type monorail was referred to and its record of construction up to date is given in the table below. [Table 2]

TABLE 2. RECORD OF CONSTRUCTION

In Japan

1961	Nara Dream Land, 0.9 km (Single Track)
1962	Inuyama Amusement Park, 1.4km (Single Track)
1963	Yomiuri Land, 1.3km (Single Track)
1964	Haneda Line, Tokyo Monorail, 13.1km (Double Track)
1966	Mukogaoka Amusement Park, 1.1km (Single Track)
1966	Himeji City, 1.6km (Single Track)
1966	Yokohama Dream Land, 5.4km (Single Track)
1970	Osaka Expo Land, 4.3 km (Single Track)
1985	Kokura Line, Kita-Kyushu Monorail, 8.4km (Double Track)
under construction	Osaka Monorail, 13.5 km (Double Track)
under planning	Okinawa Monorail, 11.1km (Double Track)
under planning	Haneda Line Extension, Tokyo Monorail, 6.5 km (Double Track)
under planning	Tama Monorail, Tokyo Metropolis, 16km (Double Track)

Outside Japan

1958	Hühlingen, West Germany, 1.8km (Single Track)
1959	Disney Land, Cal. U.S.A., 3.8km (Single Track)
1961	Turin, Italy, 1.2km (Single Track)
1962	Seattle, Wash., U.S.A., 1.6km (Double Track)
1971	Disney World, Flo., U.S.A., 4.4 km (Double Track)
1982	Disney World, Flo., U.S.A., 5.6 km (Single Track)

As shown in the table, Hitachi, Ltd. has accumulated the record of construction one after one and piled up various improvements one upon another, and finally brought the Straddle Type Monorail System to completion as a useful means of urban transportation.

Because the monorail car operates literally on one track beam, many new technologies, quite different from the case of the ordinary electric car, have to be developed. Railroad engineering is generally called an accumulation of empirical technologies, and each of them advanced to the next step of development making the past records a stepping-stone to the future.

The process of technological development of the Straddle Type Monorail System for urban transportation can be divided into three steps.

The first step of the development has been closed on the completion of the Osaka Expo Land Monorail which was built based on the technical outcome of the Haneda Line of Tokyo Monorail.

Through the success of the above monorail, safety, reliability, rapidness, mass transit, preservation of fine urban sight, confortable ride and so forth, which are essential to the means of urban transportation, were well proven.

A distinctive feature of this development is the materialization of flat floor for monorail car to raise passenger carrying capacity. In case of the Haneda Line of Tokyo Monorail, driving tires protrude above the floor of passenger room, accordingly special attention was paid to seat arrangement to ensure maximum carrying capacity. Since the Osaka Expo Land Monorail, car floor was made flat and exactly the same as the ordinary electric car, and the carrying capacity of car per unit length was also made even.

The second step of technological development is marked by the completion of the Kita-Kyushu Monorail. A principal feature of this step is the development of low noise monorail car to meet the requirement of the times. In addition, furnishing air conditioning equipment, and application of ATO (Automatic Train Operation) and chopper control system was realized. And furthermore, total administration system was adopted to rationalize management and operation of the total monorail system.

The third step is the further development to be accomplished for application to Osaka Monorail and others in very near future. Hitachi, Ltd. was engaged in the study for Kita-Kyushu Monorail to develop related and peripheral equipment well matched with advanced electronic technology (aiming at smaller size, lighter weight, higher performance), to reduce total cost and to upgrade the quality of service to passengers.

2-2 Low Construction Cost

As the structure of the monorail system is very simple and small in size as well as standardized to utilize concrete construction, its construction requires smaller amount of cost.

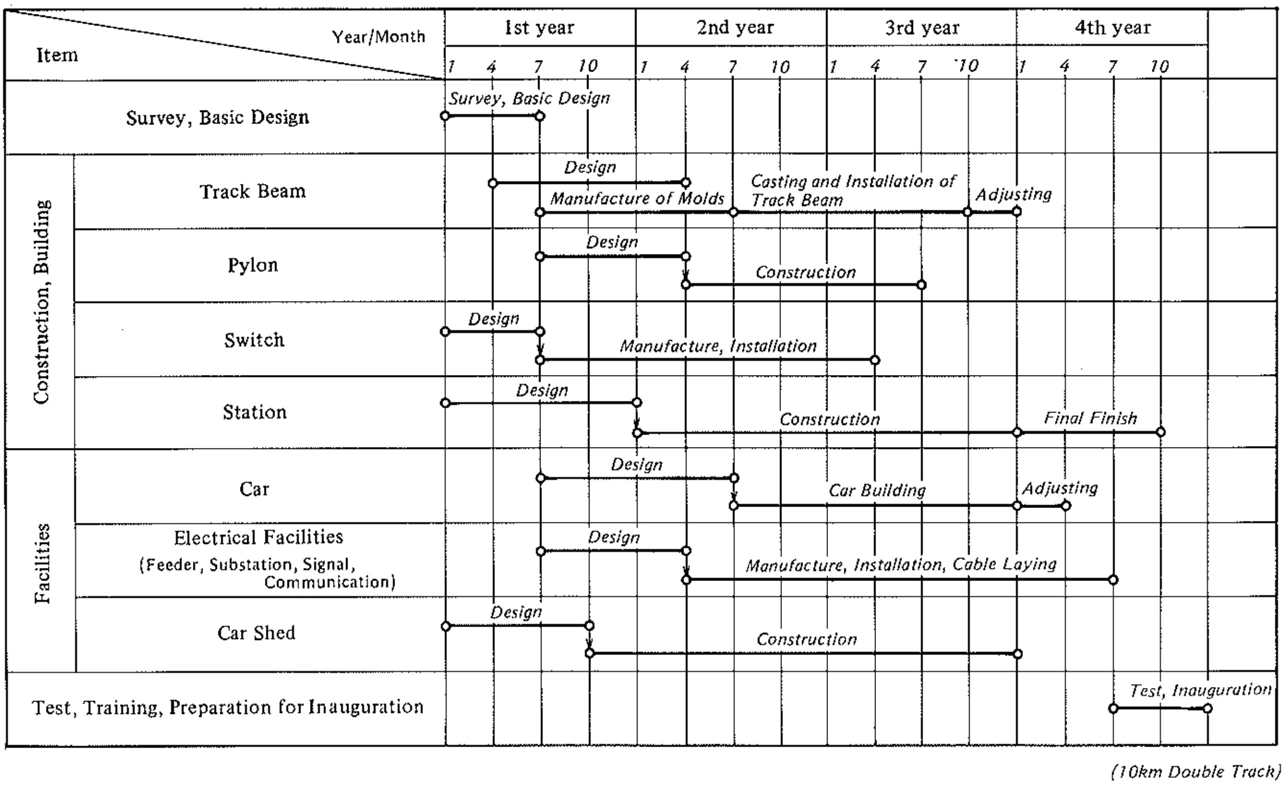
Further, the monorail system can be constructed in shorter period of time and so its construction has less influence on environment.

Since PC track beam is cast in plant, construction schedule would not be affected by the environmental conditions as in the case of general civil structure.

In addition, as the structure (like pylon and foundation) is small in size, the area of street to be occupied by the construction work is also limited.

Accordingly, the construction of a monorail system takes a shorter period of time as compared with the other systems. The most economical construction schedule to build a 10 km long monorail system is considered to be about 3 years at the present time in Japan. [Table 3]

TABLE 3 CONSTRUCTION SCHEDULE (For Reference)



(10km Double Track)

2-3 Simplified Maintenance

Maintenance work of the monorail system is almost the same as the conventional railroad, and equipment are arranged underfloor by body-mount method to ease inspection from the side.

As most of the track beam and the pylon are made of concrete, painting is not needed and so their maintenance cost is reduced. [Photo. 5]

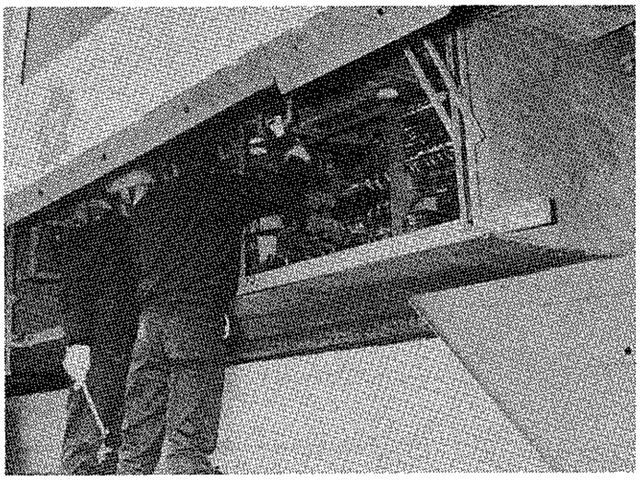


Photo. 5–Equipment installed underfloor

2-4 No Environmental Pollution

Among the elements of environment along a transit route, noise and urban scene are considered to be particularly affected by the construction of transit system. Monorail system makes less noise and do not spoil urban scene.

As for the noise, the Kita-Kyushu Monorail cleared the target value (70 dB (A) measured at 10 m sideward from the center of track beam and 1.2 m above the ground). As to the urban scene, structure of the monorail system does not spoil fine urban scene as it is much slender than that of slab construction. Comparison with the elevated railroads and AGT (Automatic Guide-way Transit System) is shown in Fig. 2 for reference. Furthermore, the monorail system has less influence on obstructing sun light and radio wave. In conclusion, the monorail system is the most superior as compared with other means of transportation in terms of adverse effect on environment. [Fig. 2]

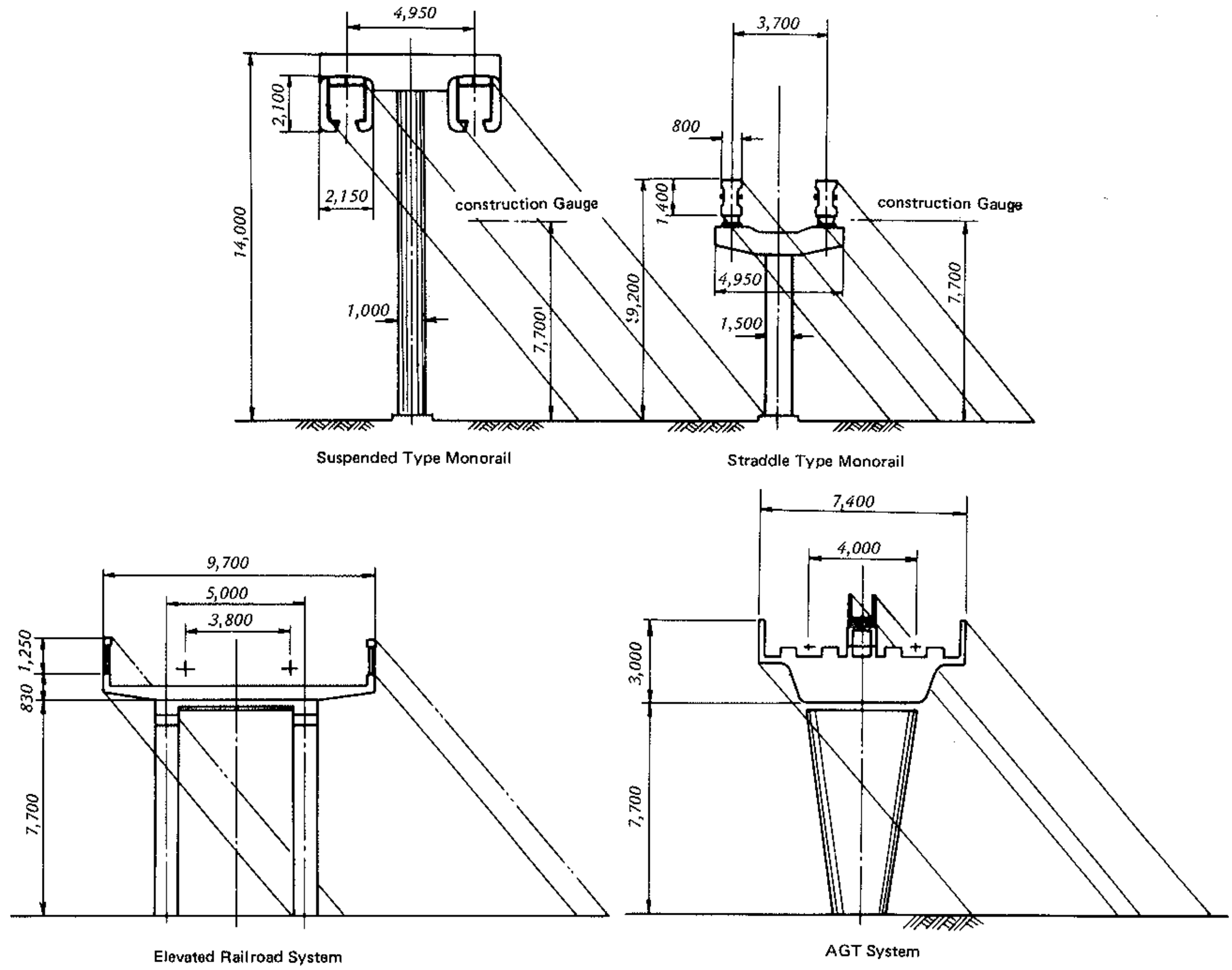


Fig. 2–Comparison of various track systems

2-5 Safer and Better Ride

As the Straddle Type Monorail System intersects other means of transportation by two level crossing, collision will never occur, and as the car itself travels with bogie truck deeply straddling on track beam, neither will derailment. The bogie truck has such construction as stout against winds and resistant to lateral vibration.

As the wheels are rubber-tired and, in addition, pneumatic springs are furnished to bogie truck, confortable ride is assured. Since the track beam is of precast construction and all of the straight beam, curved beam, beam with transient curve or cant can be cast at will in the same special mold, highly accurate beams are readily available to enhance riding quality. Further, because the floor of passenger room is flush, seat arrangement similar to that of the ordinary railroad can be applied to spacious passenger room of 2.9 m in width. [Fig. 3, Fig. 4, Photo. 6, Photo. 7]

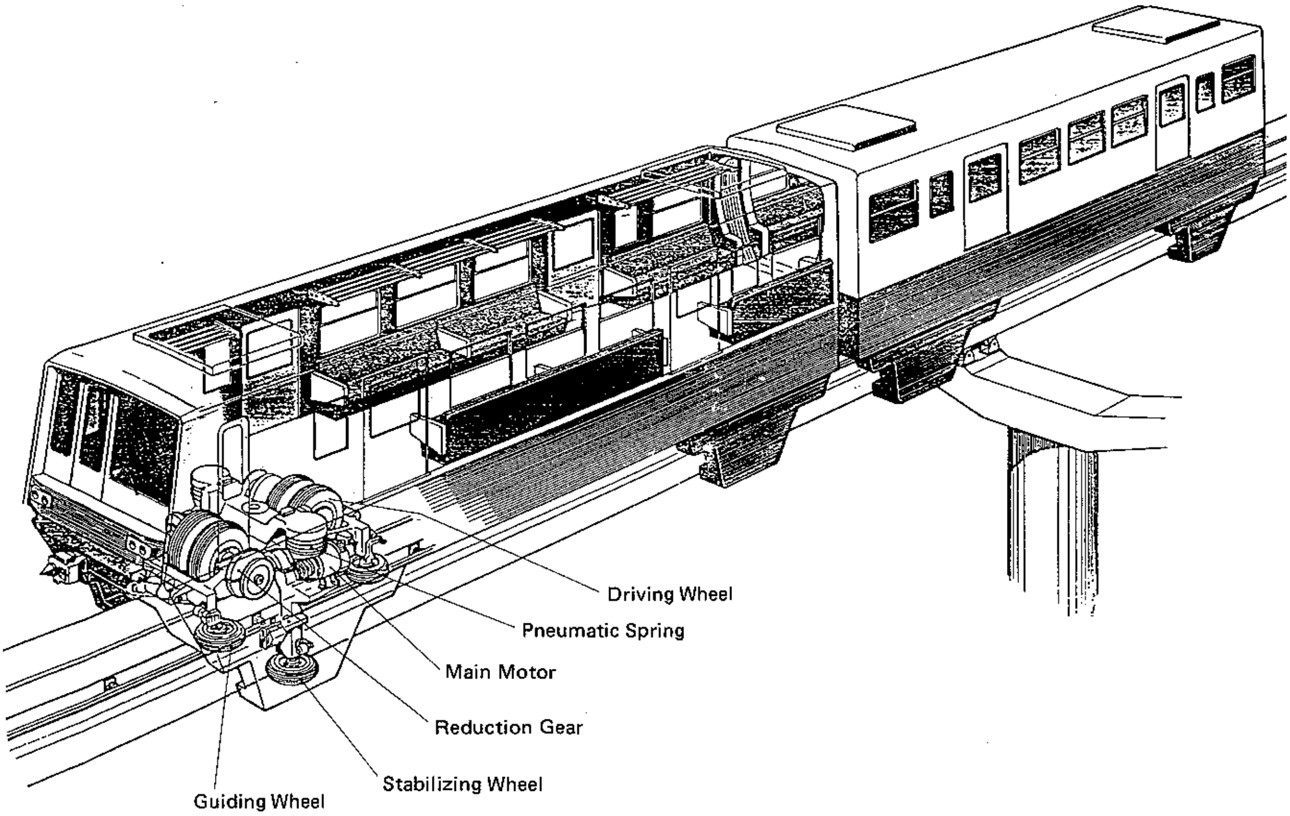


Fig. 3–Perspective view of monorail car

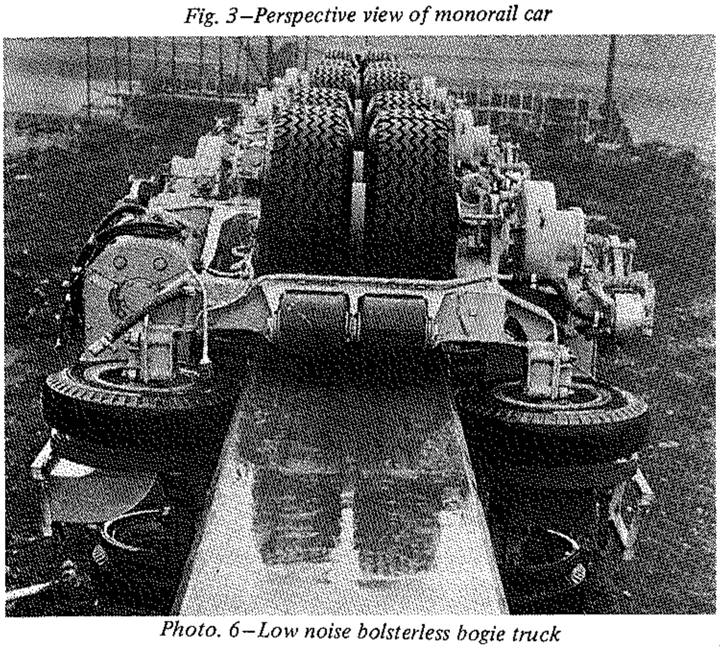
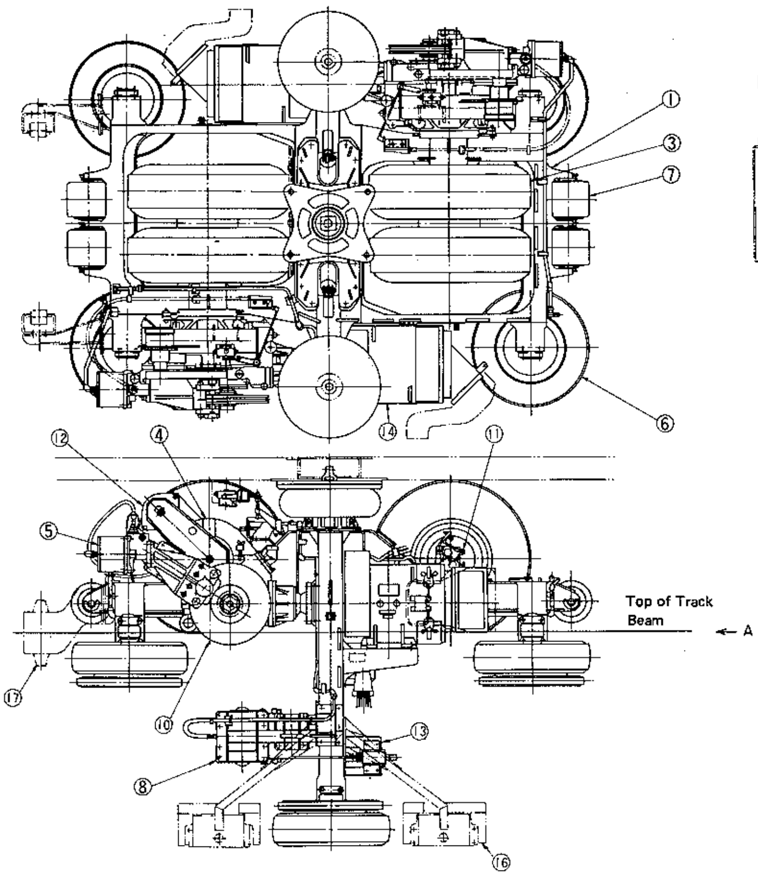
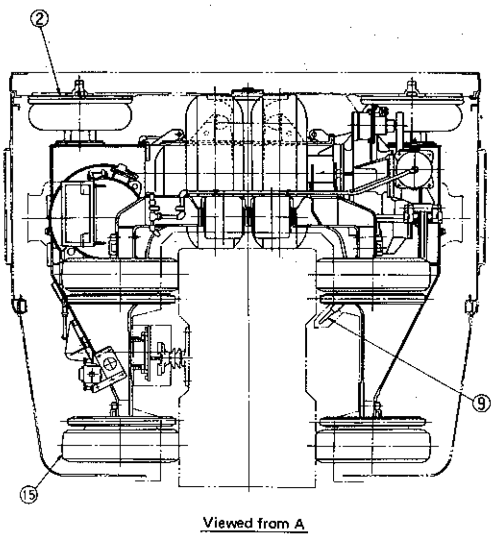


Photo. 6–Low noise bolsterless bogie truck





1	Truck Frame	10	Brake Disc
2	Carbody Suspension	11	Delector of Tire Burst
3	Driving Wheel	12	Tachogenerator
4	Driving Gear	13	Pautoyraph Unlocking Device
5	Brake Equipment	14	Main Motor
6	Guide Wheel	15	Stabilizing Wheel
7	Auxiliary Wheel	16	IR Antenna
8	Collecting Apparatus	17	ATP/TD Truck-mount Detector
9	Grounding Apparatus		

Fig. 4—General view of bogie truck

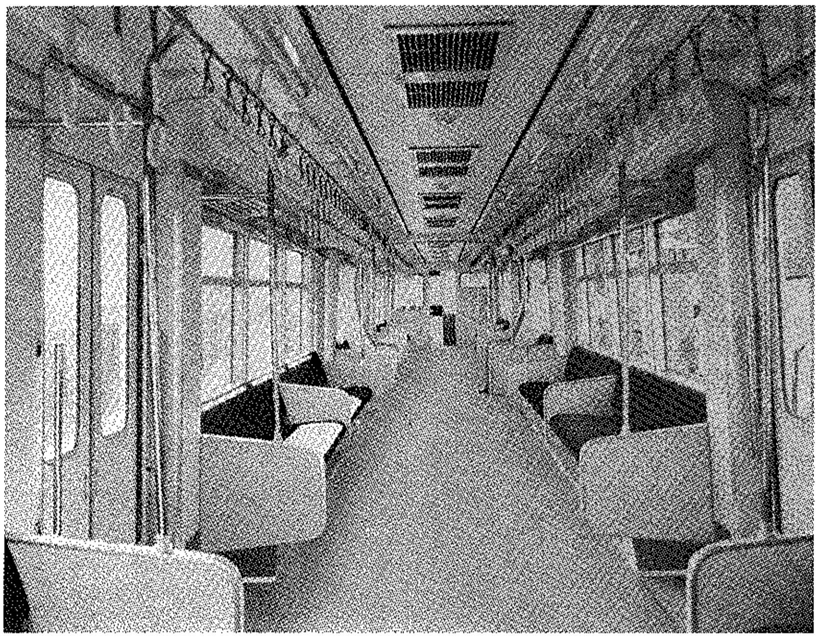


Photo. 7—Passenger room interior of monorail car

2-6 Can Be Built on Narrow Street

(1) Needs less area for construction site and narrower width for aerial structure

To make the best of the limited space in a city, the monorail system is constructed with pylons erected on a median strip of street to support whole structure. The pylons are of reinforced concrete with square section, each side of which is as small as 1 to 1.5m in length. The width of the structing for double track is about 5m which is the smallest in the various existing tracked transportation systems. [Fig. 5, Photo. 8, Photo. 9, Photo. 10]

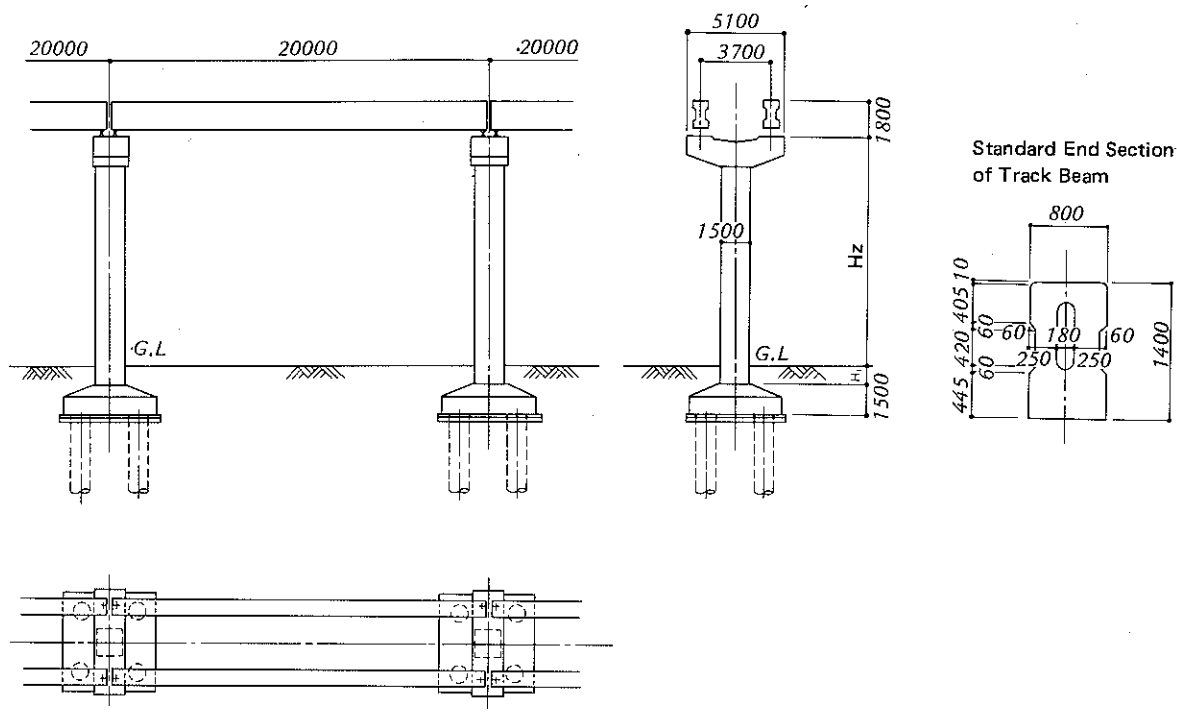


Fig. 5—Standard track

Photo. 8—Pylons erected on median strip (Kita-Kyushu Monorail)

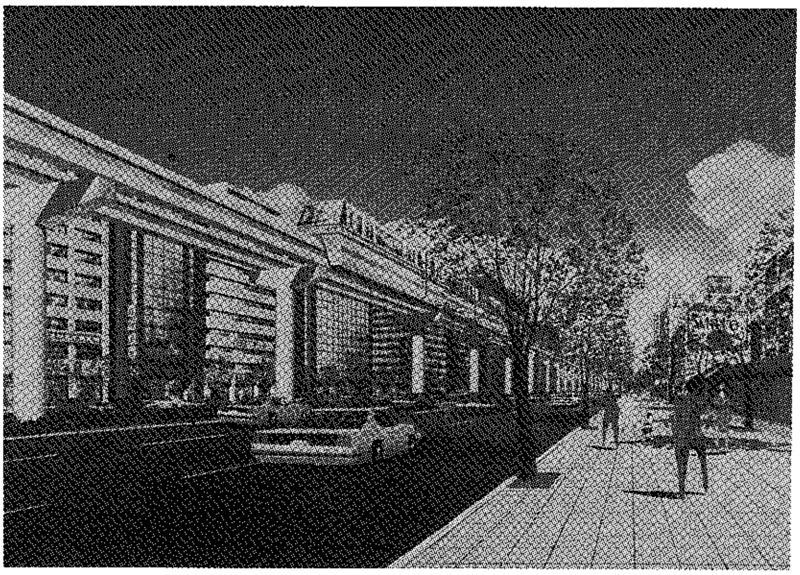


Photo. 9–Artist's rendering of monorail train

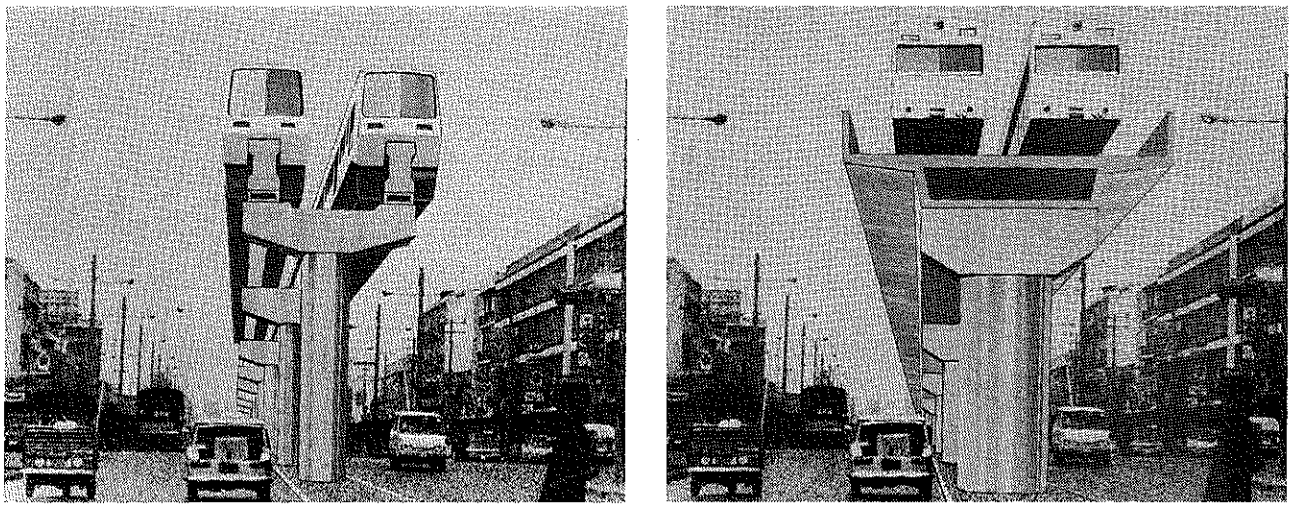


Photo. 10–Comparison of monorail system (left) and elevated railroad (right)

(2) Efficient utilization of land can be accomplished by constructing the monorail system together with elevated highway or in common with adjacent building. [Photo. 11, Photo. 12, Photo. 13, Photo. 14]

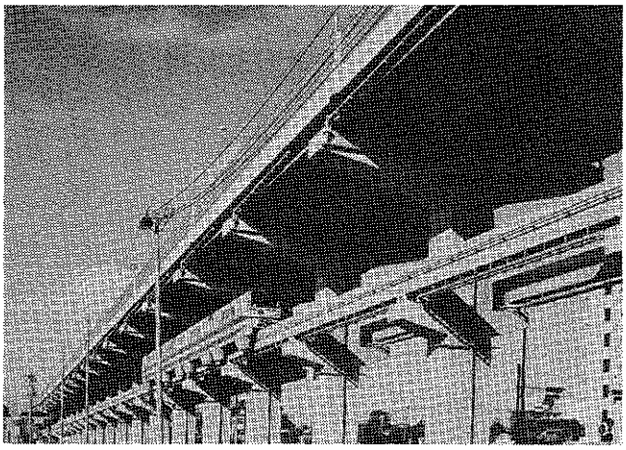


Photo. 11–Monorail system built united with highway (Kita-Kyushu Monorail)

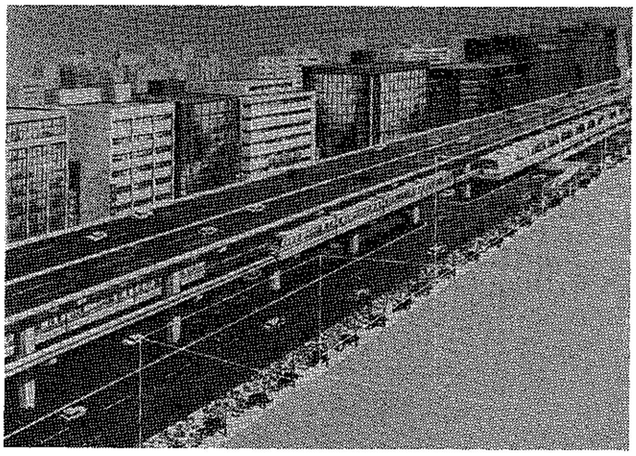


Photo. 13–Artist's rendering of monorail system and highway built on common structure

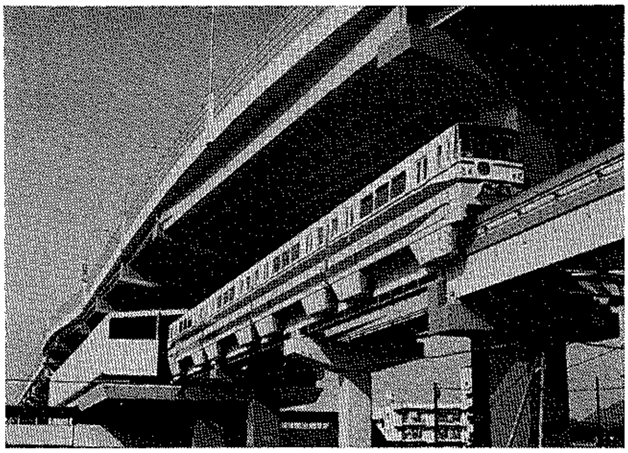


Photo. 12–Monorail train running under highway built together (Kita-Kyushu Monorail)

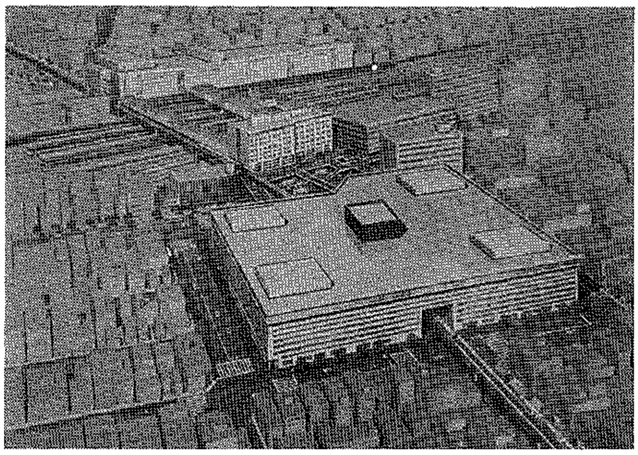


Photo. 14–Imaginary picture of monorail running through a building

(3) Practicable operation of monorail train on steep grade or sharp curve facilitates the routing in crowded cities.

The monorail train, on account of the adoption of rubber tire and bogie truck, can negotiate a grade of 100‰ and a curve of 30m in radius.

2-7 Easy Construction Work at Site

As small sized footing and foundation pile are needed for the pyron, the extent or interference with the traffic on the street adjacent to the construction site is limited.

And as the track beam is of precast construction, it can be manufactured in the beam casting yard near the construction site and it can be delivered to the site at night causing no road traffic problem. [Photo. 15]

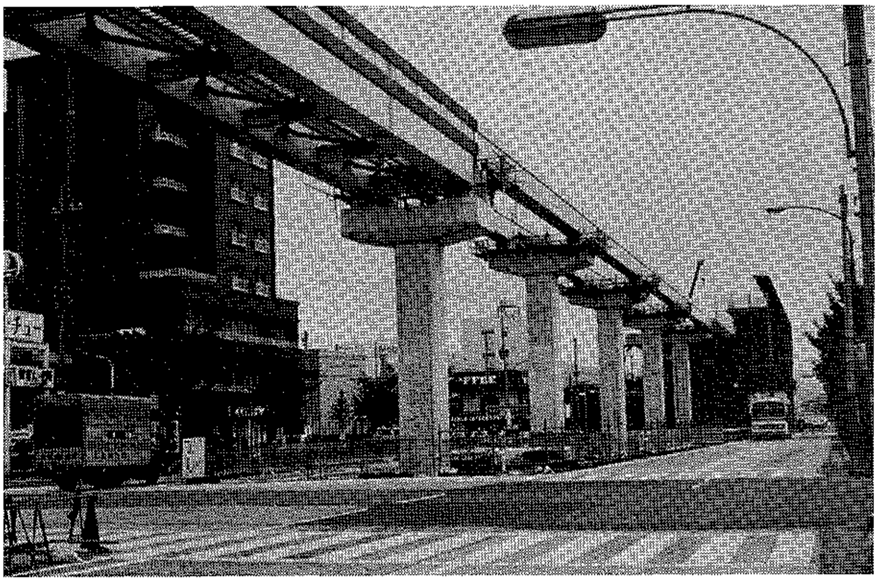


Photo. 15–Monorail structure under construction on median strip of street

3. Construction and Specifications of Kita-Kyushu Monorail

With reference to the Kita-Kyushu Monorail as a concrete example, which was put in operation in 1985, the construction and specifications of the monorail system are described below.

3-1 Outline of Route

3-2 Principal Specifications

3-3 Outline of Facilities

(1) Track
(2) Switch
(3) Passenger station
(4) Car shed and facilities for inspection and maintenance of car
(5) Signal and protection facilities
(6) Monorail car
(7) Method of passenger evacuation in an emergency
(8) Safety and communication
(9) Power facilities
(10) Power feed facilities
(11) Total administration system

3-1 Outline of Route

The Kokura Line of Kita-Kyushu Monorail is a newly built monorail route of 8.7km in total length linking the Kokura station of Japanese National Railways to the southern residential area of Kokura district to serve as a trunk line of urban transit for the district which is a nucleus of the Kita-Kyushu City.

Formerly, this area was serviced by street car and bus, but their service became paralysed due to growing congestion caused by increasing traffic volume. To cope with such condition, the monorail system is introduced to provide the residents of the district with an reliable, rapid, convenient and novel means of transportation. And a large sized monorail car is selected for this purpose. [Fig. 6]

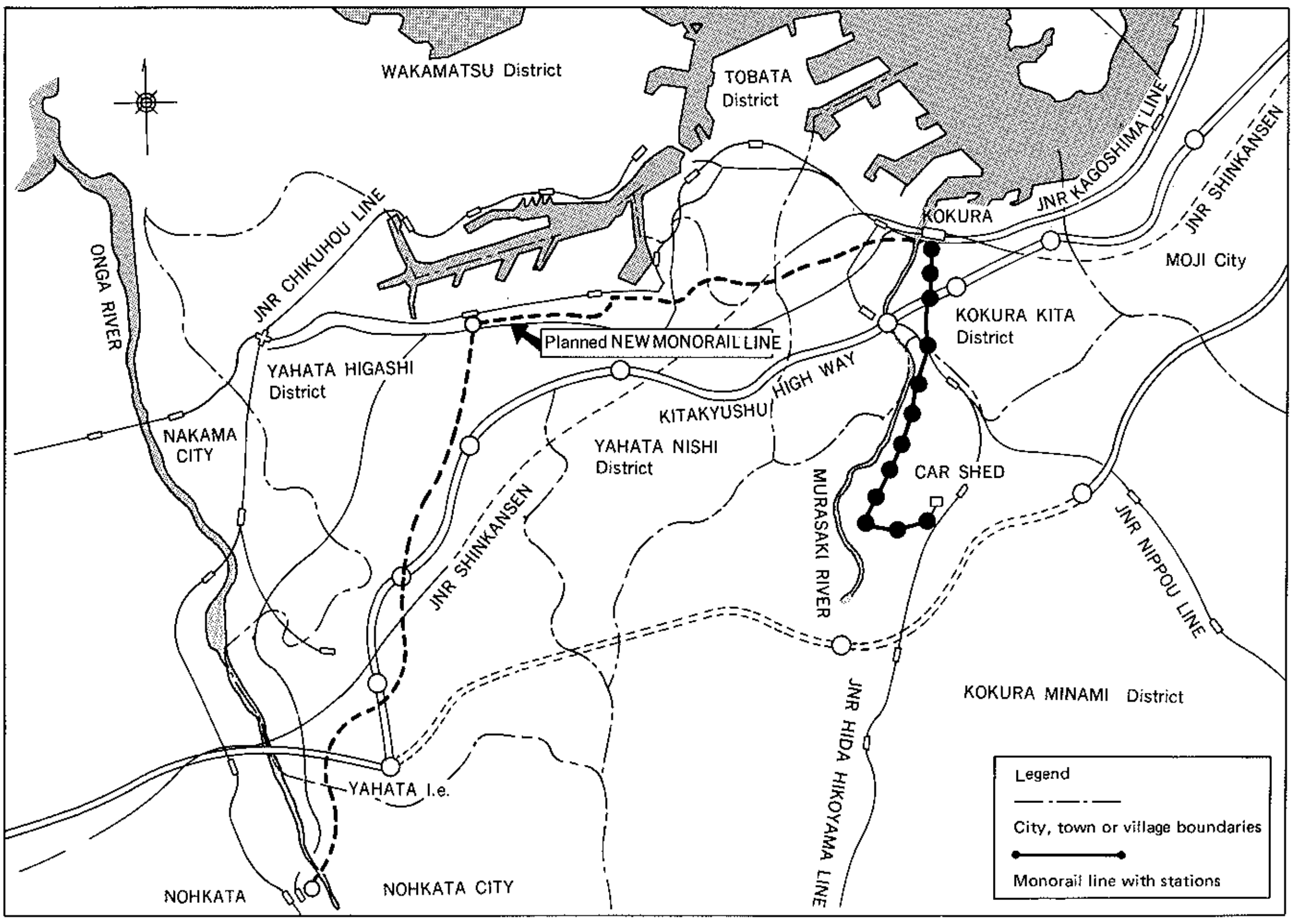


Fig. 6—Route map

3-2 Principal Specifications

TABLE 4 PRINCIPAL SPECIFICATIONS

Item				Description	Remarks
GENERAL	Total Kilometrage			8.7 km	
	Kilometrage for revenue service			8.4 km	
	No. of stations			12	
	Average interval of stations			787m	
	Demand	Full day		85,000 passengers 10,000 passengers/km	at the beginning of putting in service
		Peak hour (Max.)		7,000 passengers/h	
MONORAIL CAR	Size			Large	
	Type			Electric car with double axle bogie truck	
	Composition			4 car permanently coupled	
	Feeder voltage			DC 1,500V	
	Track dimensions			PC track beam 850mm W 1,500mm H	
	Axle load			11 ton	
	PERFORM-ANCE	Acceleration		3.5 km/h/sec	
		Deceler-ation	Normalcy	4.0 km/h/sec	
			Emergency	4.5 km/h/sec	
		Balanced speed		80 km/h	
	Max. grade			40/1000	
	Min. curve radius			50m (at center of crosstie)	
	Main motor			16 x 75 kW/train	
	Control system			Armature chopper control	
	Bracking system			Electropneumatic brake with regenerative brake	
	Driving system			Right angle Cardan drive	
	Signal and protection system			Continuous train detecting system, Cab signal system, ATP	
	Operating system			ATO	
	Train crew			One motorman	
	Train Radio			150 MHz band FM	
	Automatic inspections function			Provided	
	Principal dimensions	Length	Head and tail cars	15,500 mm	
			Intermediate cars	14,600 mm	
			Train	60,200 mm	
		Overall width		2,980 mm	
		Overall height		3,640 mm	
	Nominal No. of passengers	Head car	Seating	34 passengers	
			Standing	56 passengers	
			Total	90 passengers	
		Inter-mediate car	Seating	40 passengers	
			Standing	60 passengers	
			Total	100 passengers	
		Train	Seating	148 passengers	
			Standing	232 passengers	
			Total	380 passengers	

Item				Description	Remarks
CAR	Carrying capacity	Filled up	Max. No. of passengers	1,078 passengers	
			Congestion rate	281%	
			Max. per hour	10,700 passengers	Headway: 6 min.
	Major part	Car shell		Aluminum alloy welded construction	
		Low voltage power source	Equipment	Motor generator	
			Capacity	65 kVA	
			Unit/train	2	
			For power failure	Battery	
		Air conditioning		Heat pump type, 32,000kcal/h	
Car shed and maintenance facilities	Track	Overall length		2,040 m	
	Switch			4 units of 3-way switch	
	Automatic diagnostic equipment			Provided	
Station and its facilities	Staff	Supervising system		All Stations are manned	
		Super-vising station	No.	3 stations	
			No. of staffs	2	
		Ordinary station	No.	9 stations	
			No. of staffs	1	
	Station automation equipment			Provided	
Station facilities	Escalator			Provided (2 units/station)	
Electric power facilities	No. of substations			3	
	Receiving	No. of substations		2	
		Voltage		66 kV	
		No. of circuits		2 each	
	Substation	Capacity		2,000 kW x 2 units x 3 stations with inverter for regenerative brake	
		Feeder voltage		DC 1,500V	
	Feeder	Type		Double solid feeder	
		No. of feeders		2	
Signal and protection facilities	Blocking			Cab signal blocking	
	Signaling	System	Operating section	Cab signal	
			Car shed	Color light permanent signal	
	Train detection	System		Continuous transmission and reciving with high frequency	
		Transmission		Signal transmission from cab	
	Train protection			Automatic train protection	
	Relay interlocking equipment			Provided	
Communication facilities	Train radio			150 MHz band FM	
	Telephone	for instruction		Frequency selective system	
		for business		Automatic dialing system	
	Information display			Automatic and independent display by operation control system	
	Public address at station			Automatic broadcasting equip.	
	ITV equipment			Monitoring center and every station office	
Total administration system	Transportation control system			Operation control	
				Power control	
				Station and disaster alarm facilities control	
	Automatic train operation system			Automatic speed and stop control	
	Car shed control system			Automatic inspection	

3-3 Outline of Facilities

(1) Track

To reduce construction cost, track beam is of prestressed concrete (PC) and pylon is of reinforced concrete (RC). However, in case of need, steel track beam and steel pylon are adopted for longer span beam and taller pylon respectively. [Fig. 7, Fig. 8, Fig. 9, Photo. 16, Photo. 17]

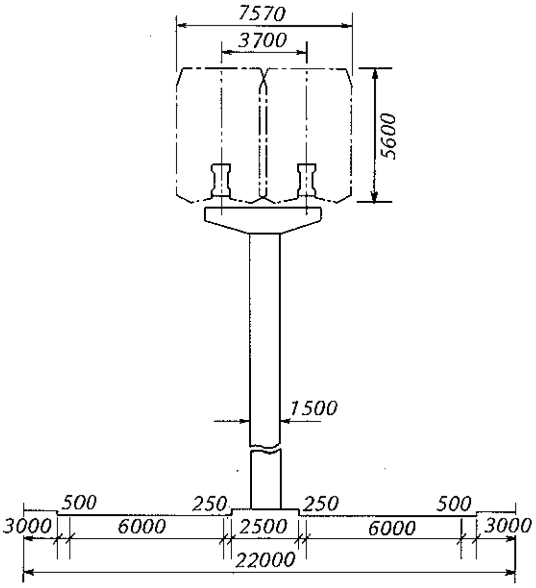


Fig. 7–PC track beam and RC pylon

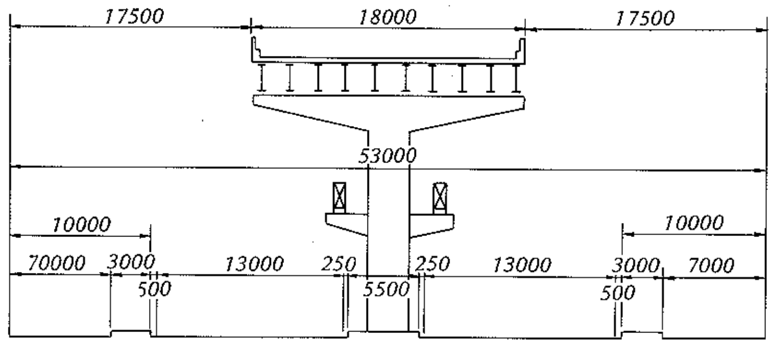


Fig. 8–Monorail system constructed together with highway

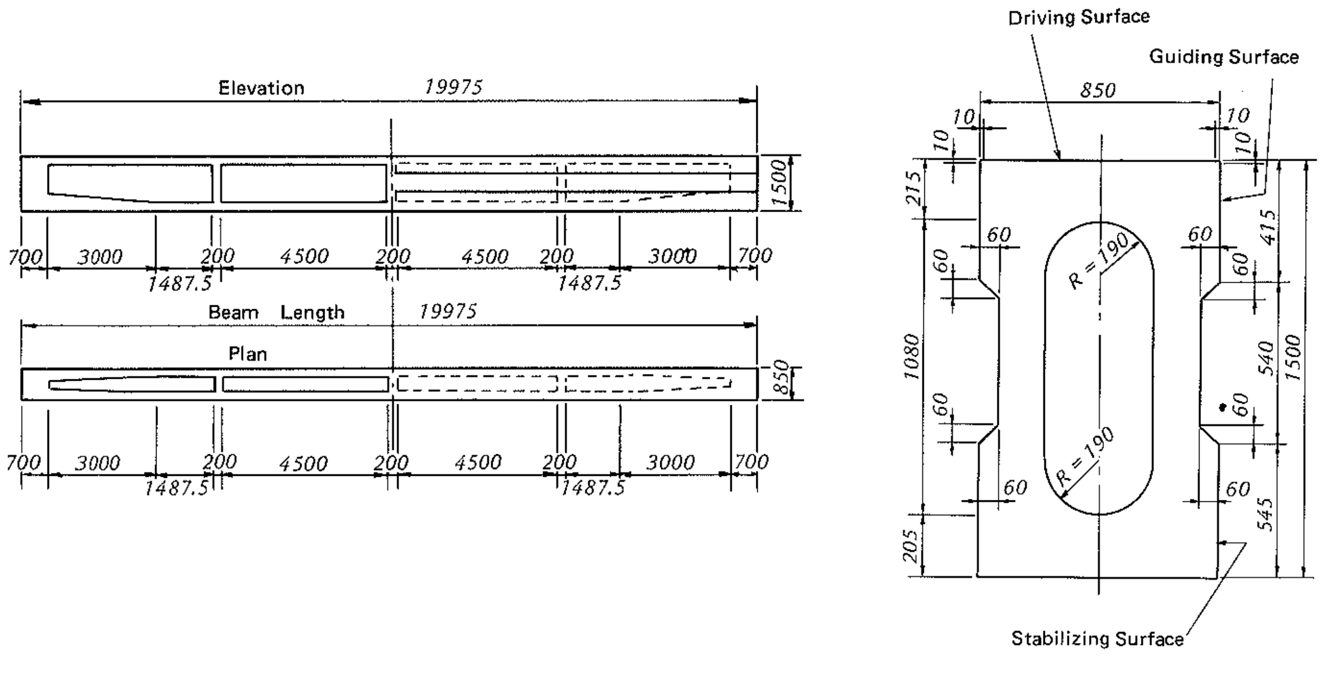


Fig. 9–Dimensions and section of PC concrete beam

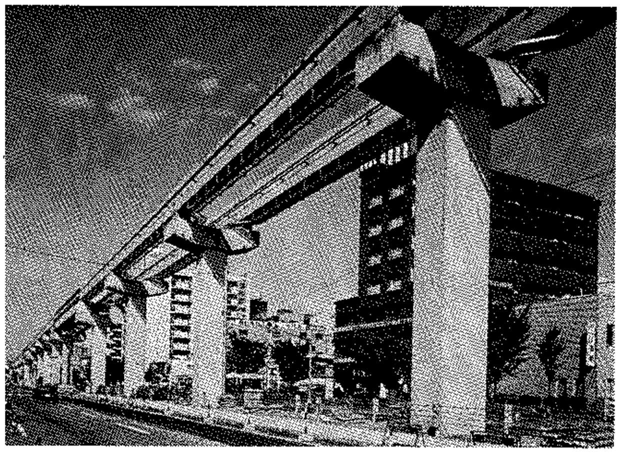


Photo. 16–PC concrete track beam and RC pylon

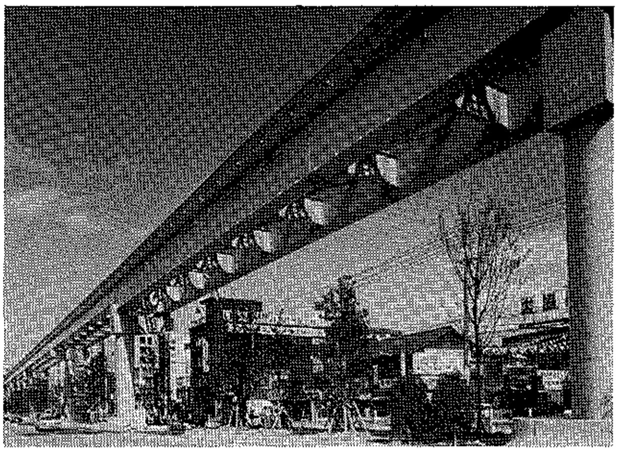


Photo. 17–Steel track beam and steel pylon

(2) Switch

The switch of the Straddle Type Monorail is of a type utilizing track beam itself as switching beam by moving one end of the beam. The switching beam is supported securely by movable truck, and its operation is electrically controlled at control center remotely as well as on the spot independently. The switch is so constructed as to be trouble free and highly reliable, and is capable of completing a switching operation within about ten (10) sec. not to hinder smooth train operation.

Two kinds of switch are applied, one is flexible joint type for main line use (the sides of switching beams form a smooth curved plane) and the other is simple joint type applicable to the lower speed section of track like one in car shed (the sides constitute a series of flat planes but not a smooth curved plane). A switch is composed of four (4) units of 5m long track beam jointed together, and each of them is moved through motor, reduction gear and pinion for a length predetermined respectively.

The arangement of switches in the Kokura Line of Kita-Kyushu Monorail is shown below. [Fig. 10, Fig. 11, Photo. 18, Photo. 19]

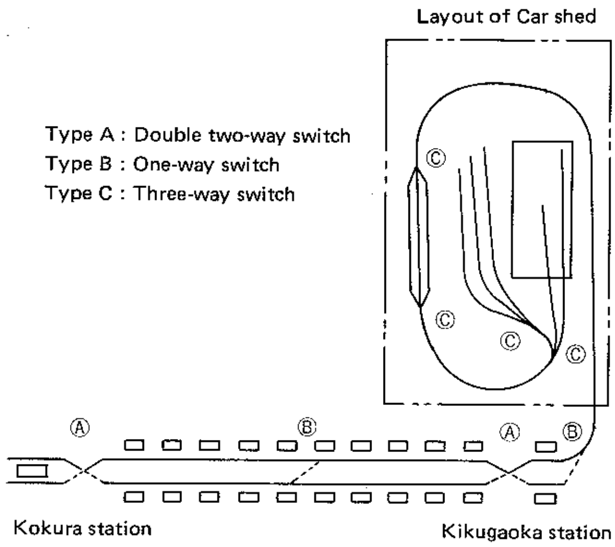


Fig. 10–Layout of monorail line

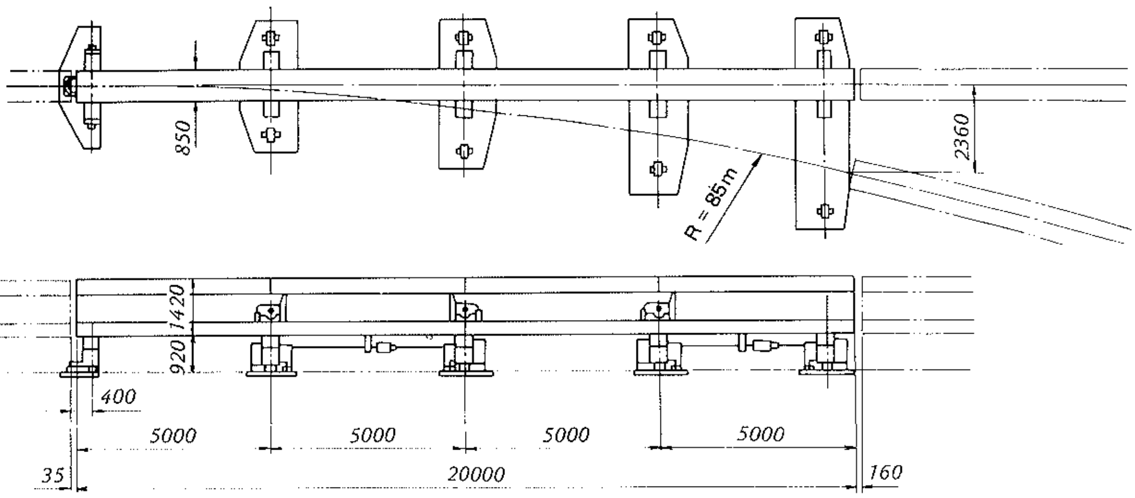


Fig. 11–One-way switch

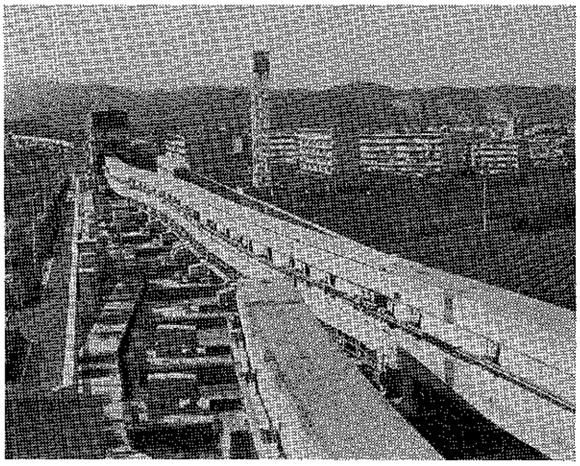


Photo. 18–Double two-way switch

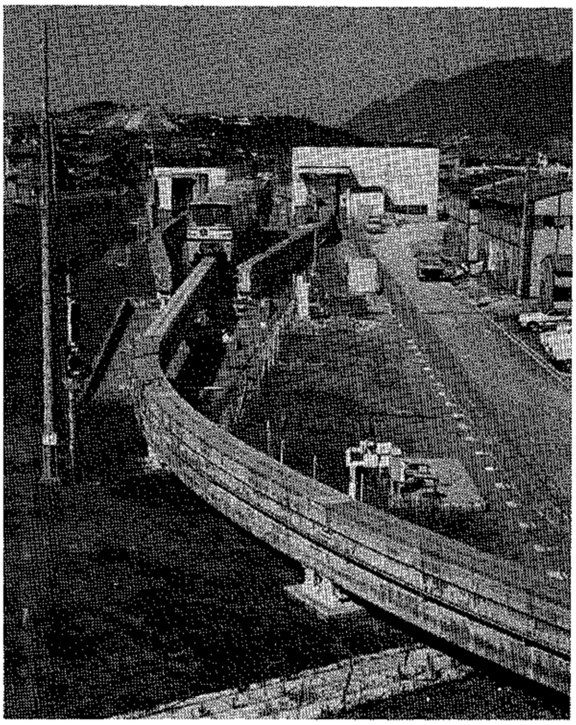
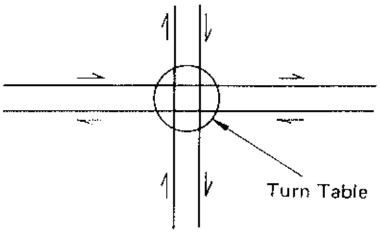


Photo. 19–Three-way switch

The track arrangement for crossing as described below is being examined to meet occasional demands.

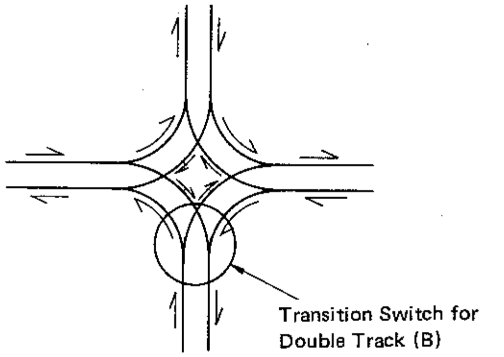
a. Straight crossing

Two (2) lines cross each other on a same plane without transition to another line.



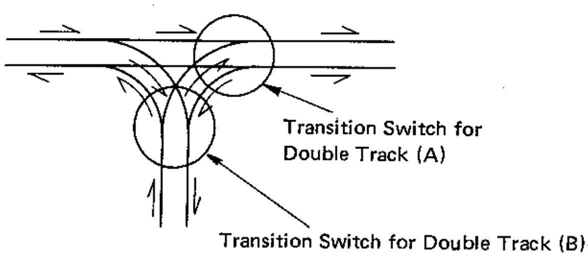
b. Diamond-shaped crossing

Two (2) lines cross each other for reciprocal transition to another line only.



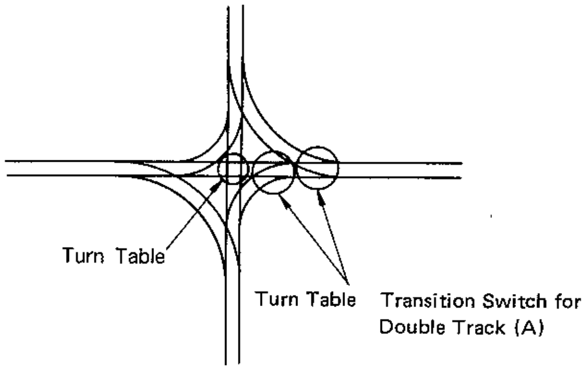
c. T-shaped crossing

Three (3) lines cross each other for reciprocal transition to other lines.



d. Combination of straight and diamond-shaped crossings

Two (2) lines are capable of crossing straight (a) and reciprocal transition to another line (b).



(3) Passenger station

As the monorail station is usually constructed above public road, it exerts a great effect on the environment along the route. Therefore, the station should be considered, like monorail car, to best match with the urban view by applying soothing design and color. At the same time, the surface structure on the street, such as telephone and electric light poles, should also be contained in a common underground duct to clear the street. Further, by making the structure of station as much as compact while maintaining the necessary function of station, the aerial space above the street can be reserved. Based on these ideas, terminal and intermediate stations were planned.

1) For terminal, island type platform was adopted because of a large number or passengers and of operating shuttle train. The length of platform is set at about 70m leaving 10m allowance to the train length of 60m. Concourse (serving pedestrian bridge as well) is built at the both ends of platform, and besides stairways, escalator exclusive for up passengers can be installed to connect the ground with the concourse and the latter with the platform.
2) For intermediate station, opposed platforms were adopted, and the concourse is furnised at one end of platform. The escalator is provided between concourse and platform only.

As for station interval, about 1km was taken as a standard in planning, considering the walking distance of patrons. Each station is located after synthetic survey of other locating factors like connection service with other means of transportation, patrons' convenience taking into account of the development plan in future, compatibility with the construction standards, and so forth.

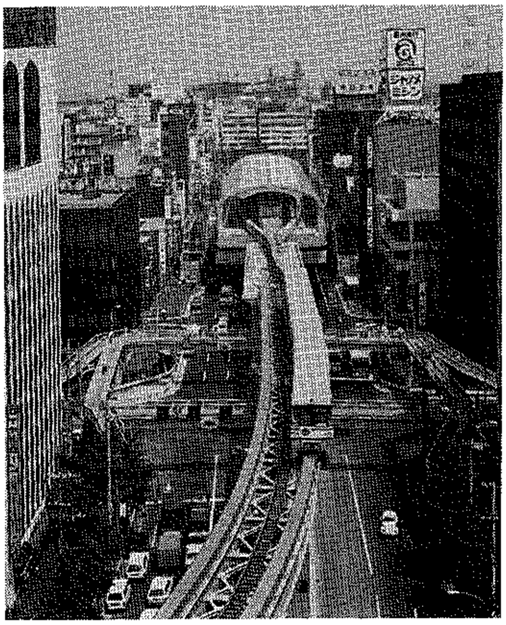


Photo. 20–Kokura terminal station

In the Kokura Line, 12 passenger stations are provided and their average interval is 787m. (Photo. 20, Photo. 21]

(4) Car shed and facilities for inspection and maintenance of car

Car shed is located in a site of about 55,600m^2 (350m x 160m) and connected to the main line before the terminal, Kikugaoka station, by single track with a 2-way switch. In the car shed, train inspection yard, monthly inspection yard, yard for essential parts and general inspection, painting shop, car washing facilities, tire replacing facilities, traverser and car storage yard (max. capacity 72 cars) are arranged. Further, an administration building to control business function, centralized operation control function, substations for supplying power to the main line and car shed, and signal equipment of the Kokura line is situated at a cornor of the site as well as the office for track facilities for maintaining track and so forth. The monthly inspection yard is equipped with an automatic inspection facilities to conduct synthetic and efficient functional test of car-mounted equipment. [Photo. 22, Photo. 23]

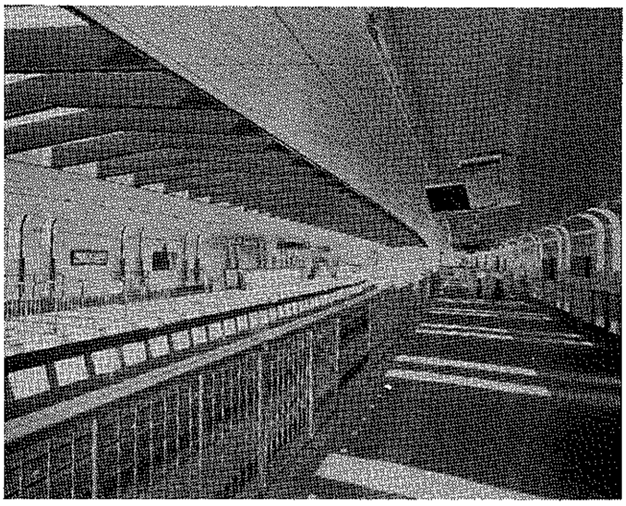


Photo. 21–Platform of a monorail station

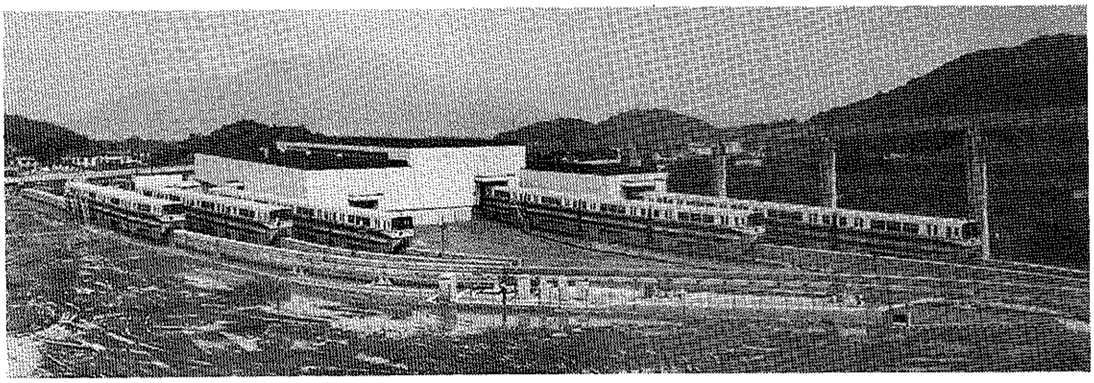


Photo. 22–Yard for car storage and inspection

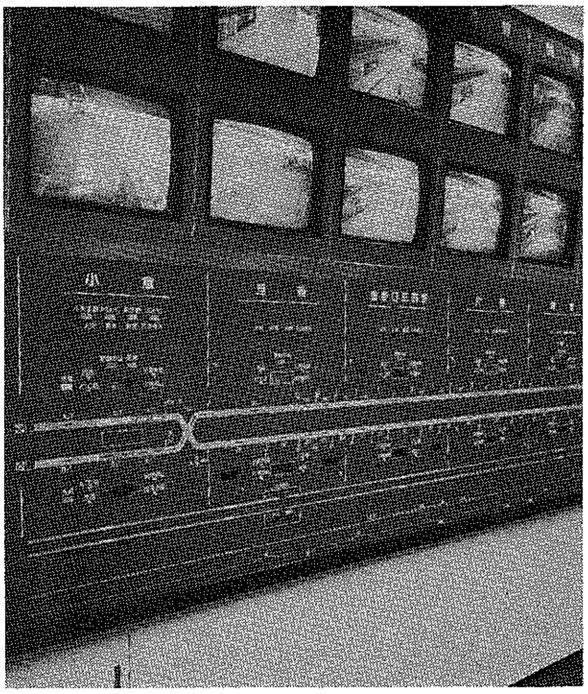


Photo. 23– Comprehensive display panel

(5) Signal and protection facilities

The signal and protection facilities of the Kita-Kyushu monorail are composed of train detecting device, automatic train protection device and relay interlocking device. The route control at each station is performed at the control center through centralized train control system. The outline of its component devices is given below. [Fig. 12] [Photo 23]

① Blocking system

Normal blocking system

Cab signal blocking system

Substitutive blocking system

Command or directive command system

Corresponding blocking system

Messenger system

② Signal system

Cab signal system is applied to the operating section of trains and automatic train protection system (ATP) is provided. Shunting of the train is directed by standing colored lamp signal (on the ground).

③ Train detection device (TD)

a) Detection Method

Two kinds of train detecting signal transmitted from the head and tail of train are received by the loop provided in each train detecting section. By this system, the presence of trains is continuously detected. Further, a fail-safe function is given by applying a system in which the presence of a train is cleared when the tail signal of the train passed the blocking boundary under normal condition by interrelating the normal conditions of the transmitters of the train detectors provided at the head and trail of a train.

b) Transmission route

The loop provided at each blocking section or its division occasionally formed by demand, is used in common by the train detection device (TD) and the automatic train protection system (ATP). (ATP. [Fig. 12]

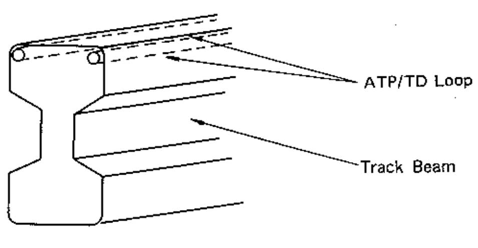


Fig. 13–Loop for ATP/TD buried in PC track beam

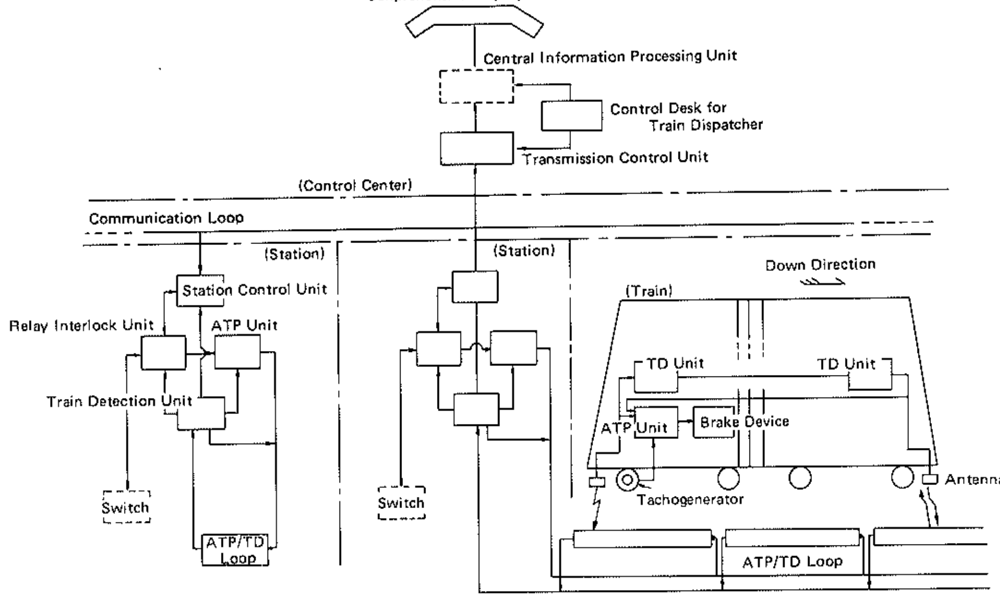


Fig. 12–Arrangement of component devices

④ Automatic Train Protection system (ATP)

a) Control system

Cab signal.

b) Signal indication step

Standard signal indications are 65, 40, O_1 (allowable stop signal or proceedable after confirming stop signal) and O_2 (absolute stop signal). In case of need, other signal indication can be provided. All signal indications are made by indicator. When no signal is indicated, absolute stopping is applied by judging that the equipment is in trouble or train is out of the section equipped with signal loop.

⑤ Relay interlocking system

Route selection type, class 1 electrical relay interlocking system are installed at Kokura, Race Track, and Kikugaoka stations and at the administration building in the Kikugaoka car shed.

The control center built in the Kikugaoka car shed conducts remote route selection control of Kokura, Race Track and Kikugaoka stations.

(6) Monorail car

① General

The monorail car is a large sized electric car with 2-axled bogie truck and a train is composed of four (4) cars permanently connected. The car is furnished with chopper controlling equipment and air conditioning equipment. The car is 15m long by 2.9m wide by 3.7m high and a car can carry 135 nominal passengers and 262 passengers when fully loaded.

Car body is mainly of welded construction of light metal to reduce its weight, and large curved glass is applied to create smart appearance. [Photo. 24, Fig. 14, Table 5]

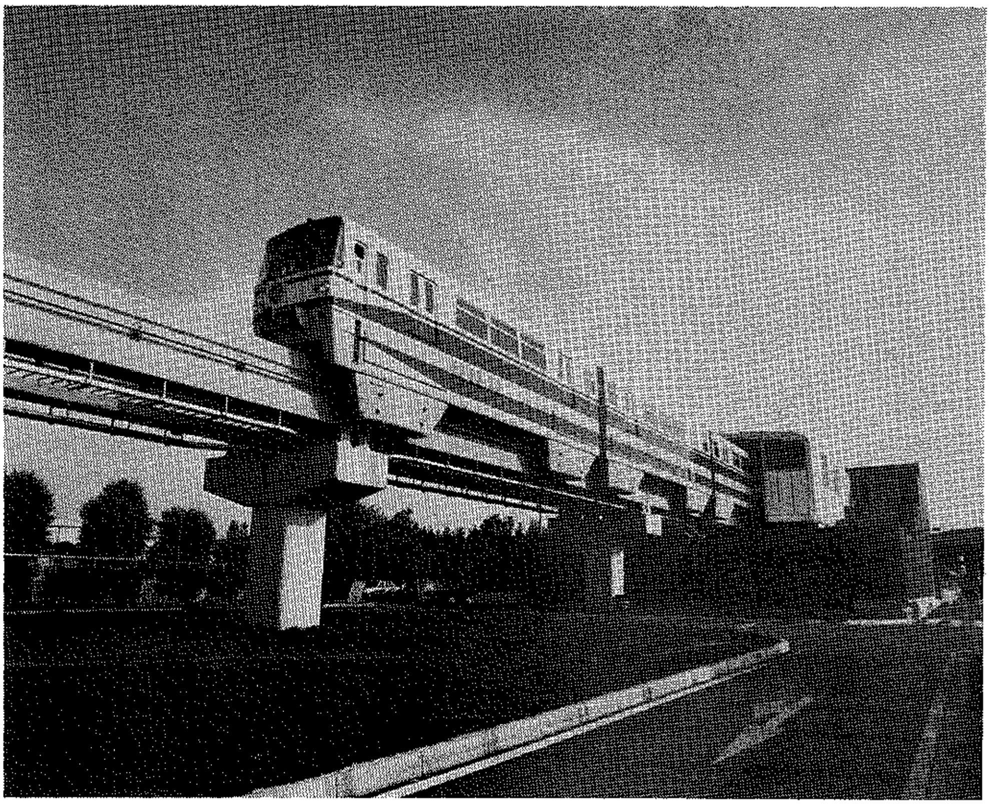


Photo. 24–Kokura line monorail train

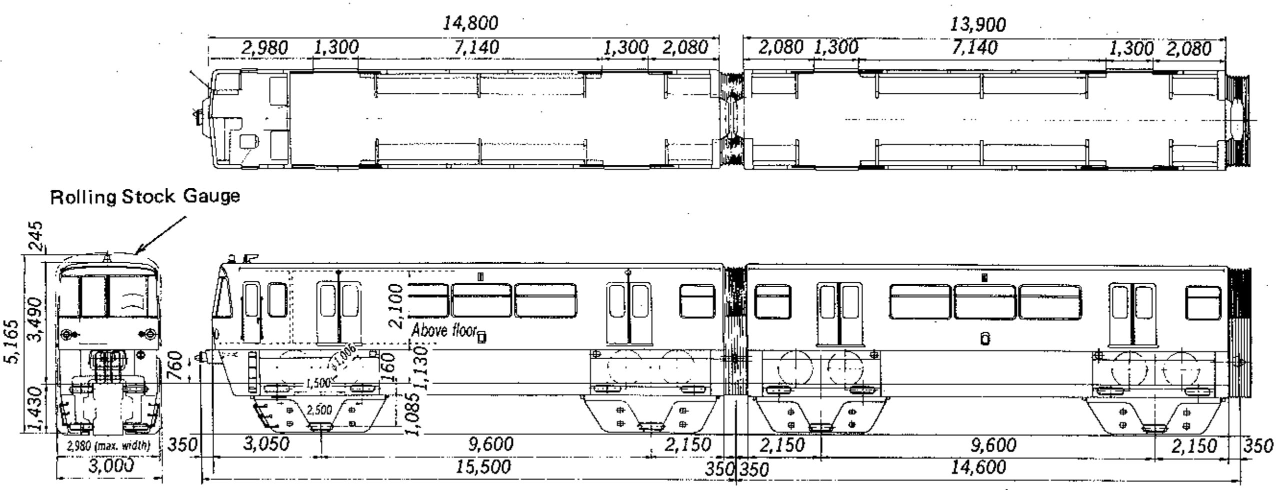


Fig. 14—General view of Kokura line monorail cars

② 4 cars permanently coupled (MC_1-M_2-M_1-MC_2 formation) approx. 60m in length

TABLE 5 SPECIFICATIONS FOR A TRAIN COMPOSED OF 4 CARS

Type		Large size		Remarks
Train formation		4 cars (Mc-M-M-Mc)		
No. of seats		Head car (Mc)	Intermediate car (M)	
		34	40	
Passenger room area		32.86 m^2	36.24 m^2	
Area for standing passengers [I] (250mm deducted in front of seats)		18.83 m^2	21.20 m^2	
Area for standing passengers [II] (100mm deducted in front or seats)		20.64 m^2	23.79 m^2	
Nominal carrying capacity	Seating	148 passengers		$\frac{\text{Passenger room area } (m^2)}{0.35\ (m^2/\text{person})}$
	Standing	232 passengers		
	Total	380 passengers		
No. of passengers, operation plan		718 passengers		No. of seats + $\frac{\text{Standing area [I] } (m^2)}{0.14\ (m^2/\text{person})}$
No. of passengers, fully loaded		1,078 passengers		No. of seats + $\frac{\text{Standing area [II] } (m^2)}{0.10\ (m^2/\text{person})}$
Overall length		60.2 m		Between coupling faces
Overall width		2.98 m		Max. width
Overall height		3.49 m		Above top of track beam
Axle load		11 t		
Tare weight		108 t/train		

③ Construction of monorail car

Monorail car adopts a new construction so that it can demonstrate its ability as monorail system for urban transportation to the utmost by materializing greater carrying capacity, power saving, and improved quality of service to passengers.

a) Betterment to increase passenger carrying capacity
- (i) Reduction of car weight by adoption of all light metal alloy car shell of welded construction
- (ii) Increase of the volume of passenger room by flattening its floor
- (iii) Smoothing passenger flow by application of biparting side doors and longitudinal seats

b) New functions to improve environment
- (i) Design of train head shape with large curved glass well matched with urban scene
- (ii) Maintaining uniform room temperature during cooling and heating by using heat pump type air conditioning equipment
- (iii) Improvement of interior vista of train by adoption of through-the-train gangway and large hood at car ends
- (iv) Lowered noise by lessening noise made by equipment and by absorbing and arresting of sound around the source of noise

c) Measures taken for saving power and energy
- (i) Application of regenerative brake realized by adoption of chopper controlling system
- (ii) Possible one man operation by utilizing automatic train operation system
- (iii) Weight reduction and improvement of heating efficiency by adoption of heat pump type air-conditioning equipment and abolition of electrical heating
- (iv) Rationalization of maintenance and inspection by introduction of automatic inspection device
- (v) Adoption of imspection-from-the-side system for equipment mounted under the car floor
- (vi) Simplified construction and reduced weight of car shell by using large size shaped material. [Fig. 15]

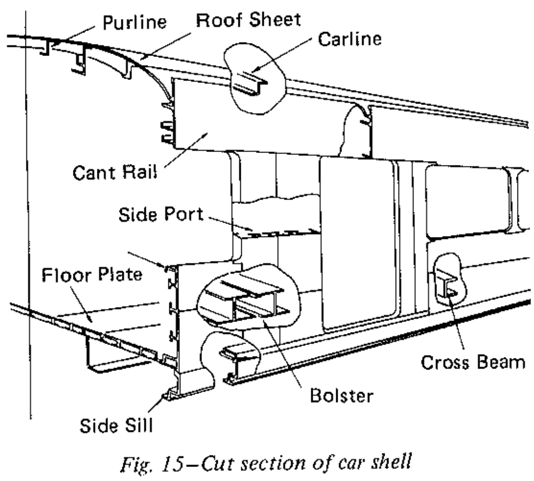


Fig. 15–Cut section of car shell

In addition to the adoption of large size shaped material to side sill and cant rail, shaped material is used for wainscot panel and floor plate to reduce the number of structural members.

④ Driver's cab

Driving stand is arranged based on human engineering to facilitate the adoption of automatic train operation system. [Photo. 25]

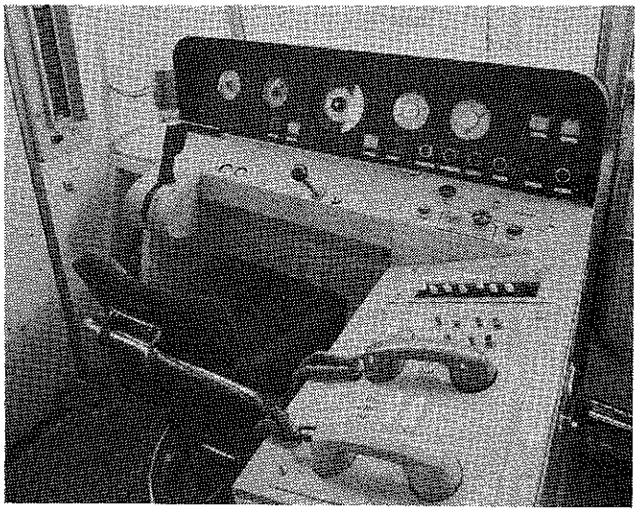


Photo. 25–Driver's cab

⑤ Car interior

Car floor is flat to facilitate passenger flow. [Photo. 26]

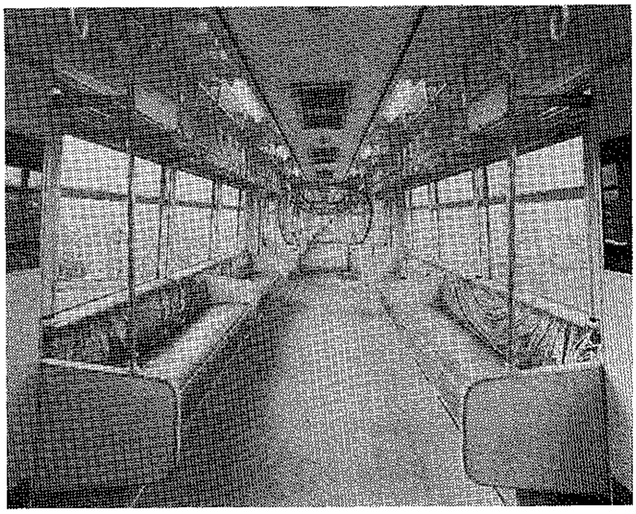


Photo. 26–Interior view

⑥ Arrangement of underfloor equipment

Major equipment are arranged underfloor by body-mount method to allow easy inspection from the side. They are made compact in size and light in weight to be suitable for monorail. [Photo. 27]

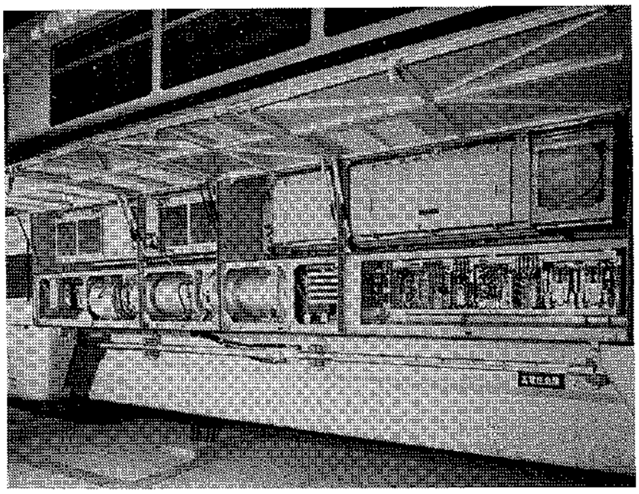


Photo. 27–Arrangement of underfloor equipment

⑦ Bogie truck

Lightweight bogie truck is realized by adoption of bolsterless truck aimed at improved maintainability. Each component or driving mechanism like main motor, reduction gear, tire is manufactured to make less noise. [Photo. 28]

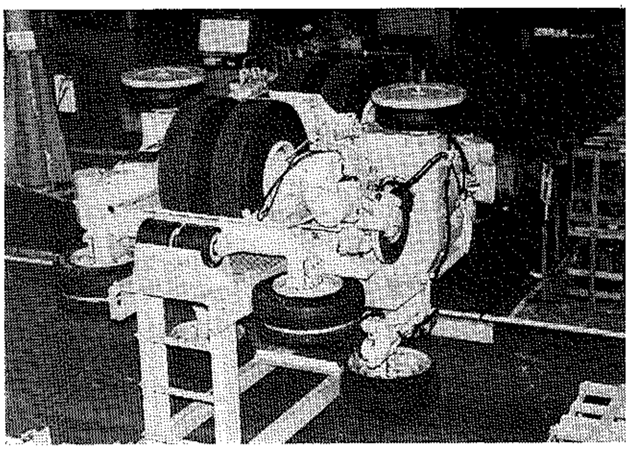


Photo. 28–Less noisy bolsterless bogie truck

⑧ Heat pump type air conditioning equipment

Heat pump type air conditioning equipment for underfloor arrangement developed exclusively for monorail keeps passenger room temperature uniform both in heating and cooling. [Photo. 29]

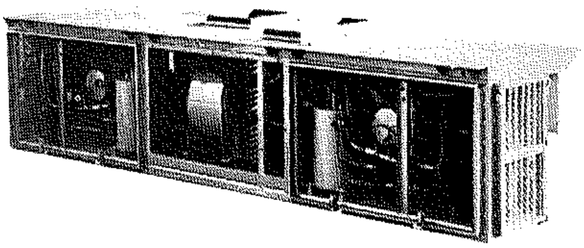


Photo. 29 Heat pump type air conditioning equipment

⑨ Chopper controlling equipment

On account of the following advantages, chopper control system is adopted.

a) Elimination of the ill effect of heat generated by resister
b) Energy saving
c) Improvement of riding quality
d) Man-power saving in maintenance work (maintenance free)

The equipment is made compact in size and light in weight to be applicable to urban monorail car. [Photo. 30]

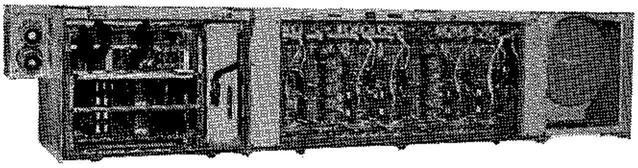


Photo. 30–Chopper controlling equipment

⑩ Automatic train control system

Automatic train control system consists of ATP (Automatic Train Protection), TD (Train Detector), ATO (Automatic Train Operation), IR (Induction Radio) and so on, and its control command is transmitted by the electromagnetic coupling of the loop coil laid down at both top shoulders and bottom of track beam and the transmitting and recieving coils on the cab. One complete set of these equipment are mounted on a train and their installation is shared by the two driver's cabs at the head and tail of train. The height of equipment behind driver's seat is limited to allow the driver to have unobstructed view of passenger room when the train has only one driver on board.

a) Starting control

After all conditions are satisfied both on the train and on the ground, the train starts upon pushing the starting button by train crew, then the train is subject to starting acceleration control.

b) Constant speed control

Constant speed control performs speed control to follow the ATO (Automatic Train Operation) target speed which is set based on ATP (Automatic Train Protection) signal.

c) Deceleration control

By memorizing a point for deceleration control (P_5) before entering the section where limitation of operating speed is permanently needed on account of the presence of curve, grade, and switch, the speed is controlled under the limited value. Accordingly, ATP brake is not applied and riding confort improves.

d) Control for stopping at preset point

To control the train to stop at the preset point of the station, points for such control (P_1 through P_4) are provided. According to the pattern generated or corrected by the information from these points, the train is controlled to stop at predetermined point.

e) Automatic control of public address
After leaving a station, the next station is introduced to passengers, and before arriving the station, the arrival is forecast automatically through the public address system.

f) Control under abnormal operation
When ATP brake is applied during ATO operation depending on the train location, control by ATP has priority to ATO command to secure safety. Also when the train speed becomes excessively higher than the deceleration pattern in the process of control for stopping at preset point, ATP system stops the train by directing application of emergency brake.

g) Control of opening side of passenger door
To secure passenger safety, doors not facing to platform will not be opened even when the door switch for these doors is erroneously pushed. [Fig. 16]

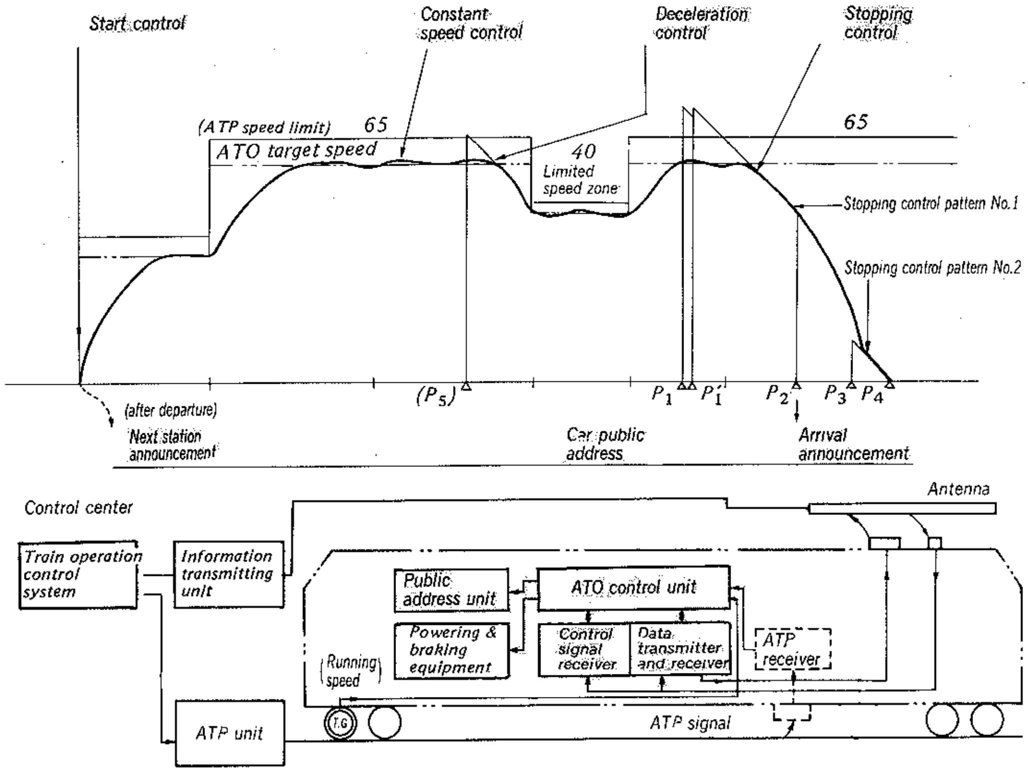


Fig. 16–Composition of automatic train operation

(7) Method of Passenger Evacuation in an Emergency

① In case of some mishap and passenger evacuation is needed, the monorail train will continue to run as far as the next station to unload passengers as a standard procedure. As an average station interval is approximately 1km and a train arrives at the next station in about 2 min., proceeding to the next station is the most quick, safe and reliable way of evacuation in most cases.

② Should the train disabled in-between stations, the most suitable evacuation method for the situation is to be selected among the following.

a) Longitudinal evacuation
In this method, rescue train is attached to the disabled train and passengers are inducted via through-doors at the ends of both trains.

b) Lateral evacuation
In case of double track line, a rescue train is brought to a stop alongside the stuck train and passengers are transferred to the rescue train using step plate with handrail.

c) Vertical evacuation (Slow Down)
Passengers are lowered safely to the ground by a rope being held by band or bucket attached to it or through canvas evacuation chute. This method is similar to that used for rescueing in building fire.

d) Rescue from the ground
Rescue work is readily performed by utilizing the aerial ladder of fire engine or the gondola of Schnorkel type work vehicle.

(8) Protection and Communication

Protection and communication facilities are described in the following table.

Feeder rail, communication cable and power cable are laid down around the track beam. [Table 6, Fig. 17]

TABLE 6 DESCRIPTION OF PROTECTION AND COMMUNICATION

Description	Use	Remarks
Telephone	Operation instruction	Frequency selective type
	Power instruction	Frequency selective type
	Business communication	Automatic dialing type
Train radio	Communication between train dispatcher and crew	FM press talk type 150 MHz band
CCTV	Platform monitoring	Transmission by optical fiber
Public address	Passengers' guidance	Automatic broadcasting (normalcy), operatable manually
Clock	———	Collectively controlled by master clock
Anemometer	———	Indicated on comprehensive display panel
Emergency communication	Communication in an emergency	Stops trains and power supply in an emergency

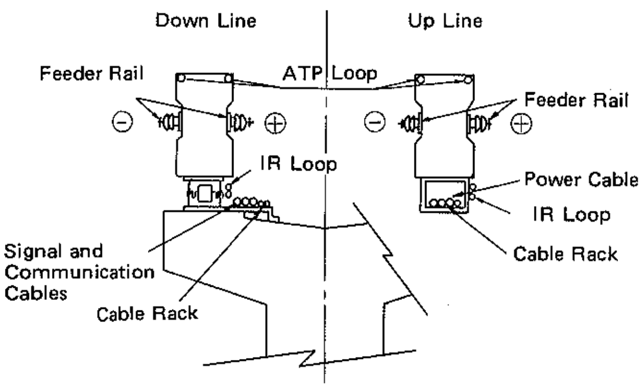


Fig. 17–Outline of laying cables

(9) Power Supply Facility

Altogether three (3) substations are installed in the whole system to feed for train operation in the section between Kokura and Kikugaoka stations and in the car shed and to supply auxiliary electrical power. Two (2) substations out of three (3) receive power of 66 kV and 60 Hz from the local utility company.

Silicon rectifier is installed in the substation to supply DC 1,500V current to the feeder rail for operating trains.

The substations are operated unattended and are monitored by the control center, in other words they are unmanned substations.

The substations are situated at an interval of about 4 km paying attention to voltage drop. [Fig. 18]

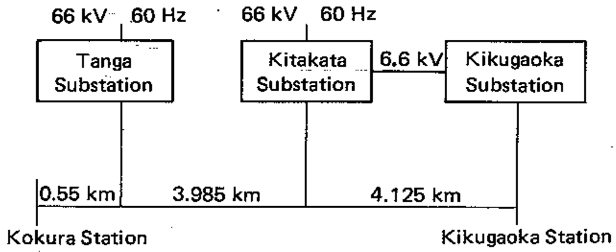


Fig. 18–Arrangement of substations

(10) Feeder Facilities

Feeder system is DC 1,500V parallel feeding, and power is supplied from substation to feeder rail through feeder line in the conduit tube buried in track beam. The feeder rail is of rigid and double feeder line type for sliding collection from the side, and is composed of T shaped aluminum alloy and trolley wire.

The standard interval of insulators to support the feeder rail is 2.5m. In case of steel track beam, insulating rubber plate is inserted between supporting insulator and steel track beam.

For the places like station where passengers have a possible chance to contact car body, body grounding plate is provided above negative feeder rail to discharge the electric charge in the car through grounding device on the car. [Fig. 19]

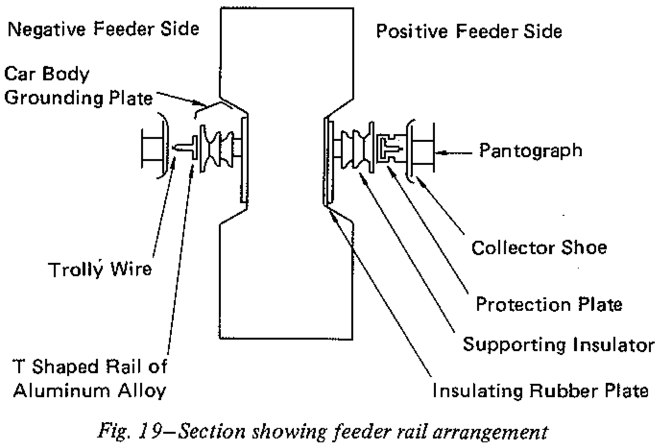


Fig. 19–Section showing feeder rail arrangement

(11) Total Administration System

This system is composed of the following subsystems controlled by computors.

① Transportation control system

a) Operation control

b) Power control

c) Station and disaster alarm facilities control

② Automatic train operation system

③ Car shed control system

The outline of the transportation control system, which forms a principal subsystem of the total administration system, is given hereunder.

Transportation control system comprises three subsystems, that is, the operation control that controls train operation, the power control that controls substations, and the station and disaster alarm facilities control that monitors functions of station facilities and alarm disasters inside stations. This system handles the business that needs instant disposition out of the business related to the train operation and station. Construction of the equipment and its relationship with other systems are shown below. [Fig. 20] [Photo 31]

① Operation control

a) Group control function of trains

(i) Train tracing and operation display

The location and operation code number, etc. of train are indicated on a comprehensive display panel.

(ii) Route control

The route of train is automatically controlled based on operation diagram and train location.

(iii) Operation restoration

To minimize the disorder of train diagram in the whole monorail system, the operation restoration system detects the symptom of disorder in its early stage, and then adjust the diagram automatically.

(iv) Communication with automatic train operation system

Information needed for the group control of trains are communicated with the IR unit on each train.

b) Public information function

(i) Public address at platform

To the passengers at each station, information is announced automatically according to the operating conditions of trains.

(ii) Information indication in stations

The operating conditions of trains are automatically indicated to the passengers in each station.

(iii) Control of bells for train departure

The bell ringer at platform is controlled according to the train departure time.

c) Record preparation function

Departing time, delayed departure, and arrival time at major stations, contents of operation performed by the train dispatcher, and equipment disorder, etc. are automatically recorded.

② Power control

a) Power supply control function

Number of rectifiers to be operated, switching operation of breakers are automatically controlled in accordance with a preset schedule.

b) Equipment control function

Operating conditions of equipment are indicated on display panel, and when a serious trouble takes place, it is automatically reported to the train dispatcher.

c) Record preparation function

Daily and monthly records of electric power supplied by each substation, occurrence of trouble, contents of equipment movement, and contents of operation by the train dispatcher are recorded automatically.

③ Station and disaster alarm facilities control function

Condition of major facilities of station such as air conditioning equipment, escalators, lighting, etc., and that of disaster alarm facilities like fire alarm are displayed and warning is given automatically.

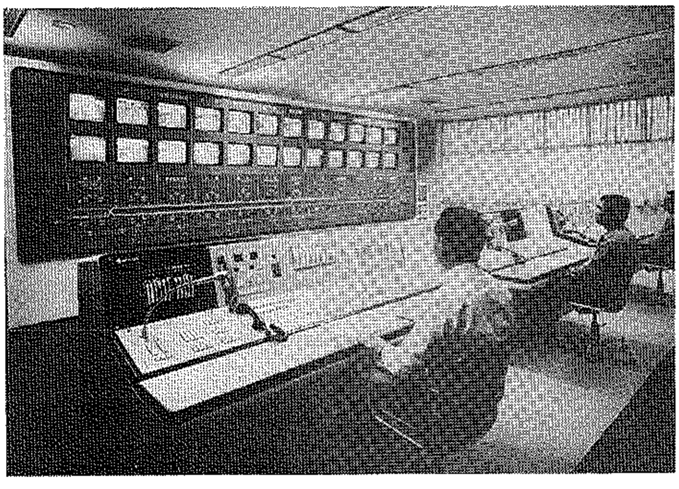


Photo. 31 – Control center

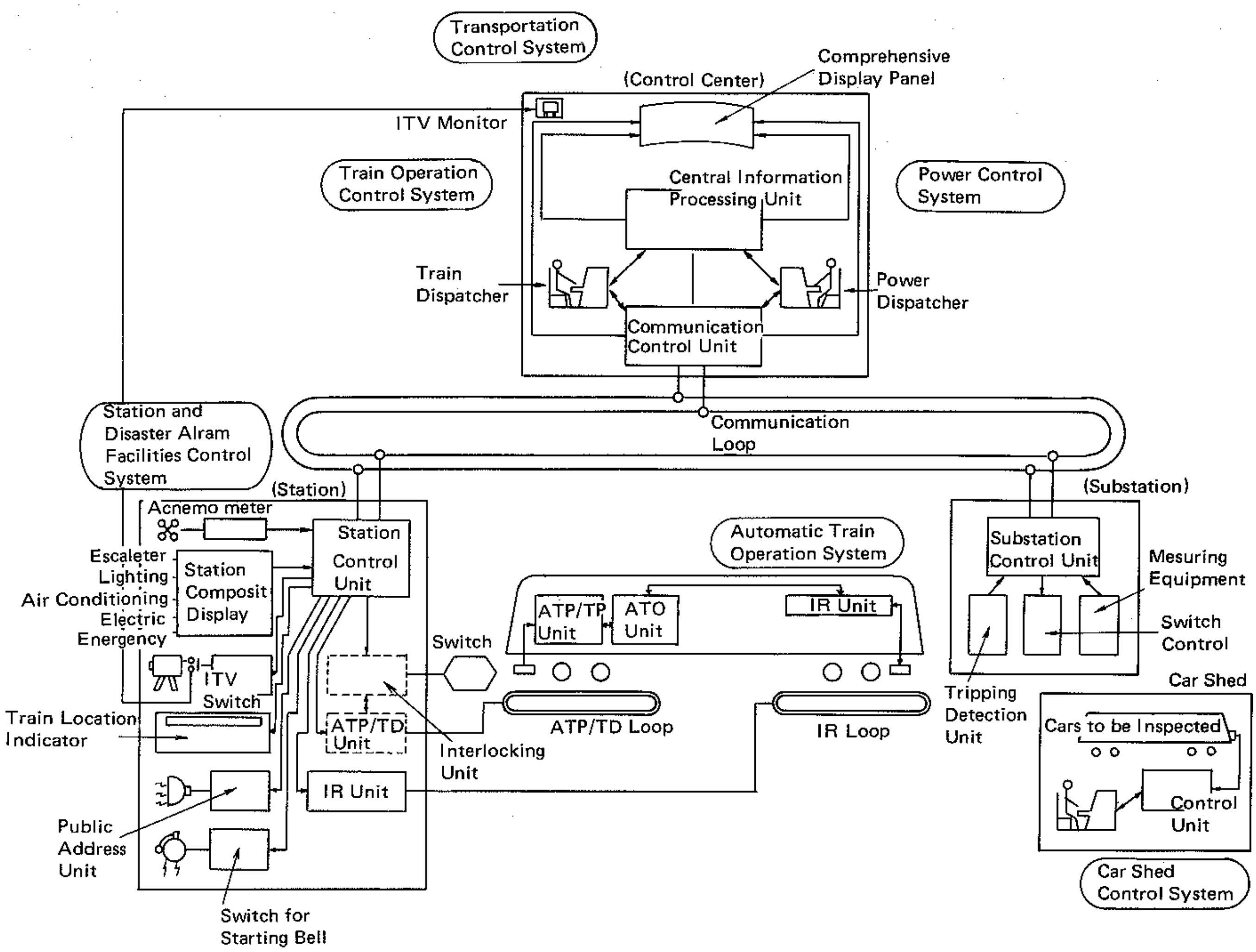


Fig. 20–Outline of System Composition

Summary

To summarize, the Straddle Type Monorail System is a well matured and reliable means of urban mass transit that can carry a large number of passengers rapidly,punctually and safely making the best use of the precious aerial space above city street with low construction cost.

More than twenty (20) years has passed since this monorail system was introduced by Hitachi, Ltd. The fact that there has been no bodily trouble at all for that entire period is of very great value in terms of "Safety", the first obligation of transit system.

To minimize the adverse effect on urban environment, the monorail system employs track beam and pylon which are cast as slender as possible. Further, a great deal of efforts are exerted for shortening construction period by the application of prefabrication method, for lessening noise and so forth. The above efforts are also contributing to lowering construction cost.

Following the remarkable technology innovation of late years, electronic technology including optical fiber and microcomputer technology, custom LSI, GTO, etc., is being anticipated to make tremendous progress in the near future. These superior technologies will be applied to and thereby will improve the Straddle Type Monorail System.

We, at Hitachi, Ltd., are very much confident that the Straddle Type Monorail System is definitely serviceable as an effective means for the resolution of urban traffic problems.

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