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モロッコ王国カサブランカ新高架交通システム建設計画

調査報告書

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（付属資料）

1987年7月

国際協力事業団
JICA

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1 SURVEY OF NATURAL CONDITIONS

1. SURVEY OF NATURAL CONDITIONS

The survey was carried out on natural conditions such as geology, hydrology, meteorology and occurring sinisters.
Collected information will be a usuful basis for determining the selection of the route, the layout of the structure and the planning as well as the achievement of the works.

1.1 Geotechnical Survey

The geotechnical survey, as one of the most important ones carried out among the natural conditons, has a close relationship with the preliminary design of infra-structures and has, thus, an important effect on the investment level.

(1) Outline of Geology in Morocco

Considering the fact that the Kingdom of Morocco is rich in mining resources such as iron, coal and phosphate (of which Morocco holds 70 per cent of the World's reserves), the Ministry of Energy and Mining has since long ago conducted geological surveys.

The land of Morocco can be divided into four geological areas as indicated on the map Fig. 1.1.

① Anti-Atlas and Sahara zones where deposits of continental shields stretch out and Precambrian rocks emerge here and there.

② High Atlas and Medium Atlas zones where primary grounds strongly folded by Hercynian motion are covered by Permian and Jurassic fields deformed by alpine orogenetic motion.

③ Plain and Plateau zones, called Meseta, which was stabilized after Hercynian motions.

④ On the chain of Rif Mountains, where both north and south meet, a numerous group of Nappes is found; showing the effects of the most violent orogenic motions.

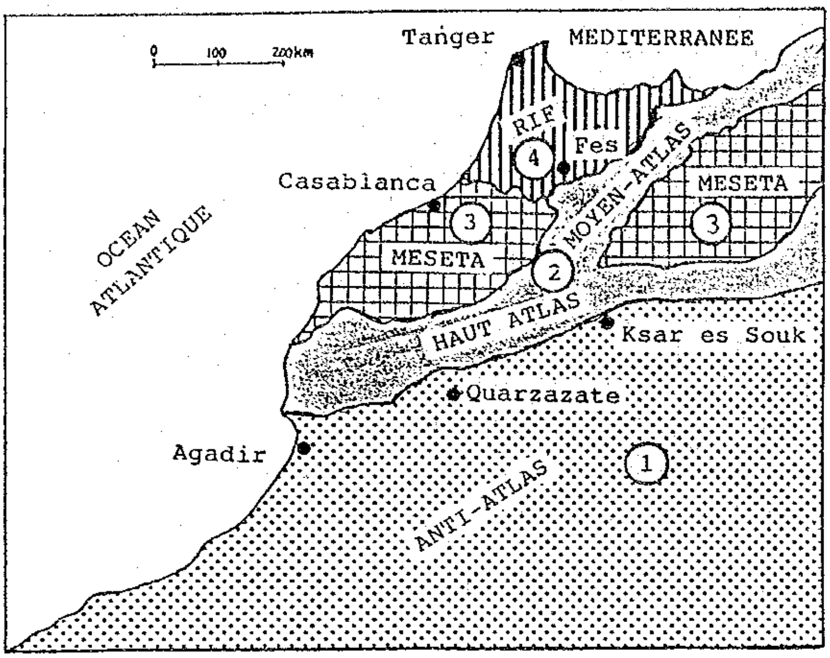


Fig. 1.1 Outline of Geology in Morocco

(2) Outline of Topography and Geology in Casablanca

The quaternary geology of CASABLANCA was formed by the marine transgressions that are shown in Fig. 1.2 and 1.3. Six epoches were produced after the end of the Villafranchian. They had extended over the length and breadth of the areas which were covered 15 km away from the present sea-side of CASABLANCA after the following Moghrebian epoch. The ocean sediments such as sand, conglomerates and shells, which were caused by the marine transgressions, piled up in the first place except in the early epoches. Such sediments formed the sand-hills that are parallel with the shore line which consisted in sand and shells after the ensuing marine regression.

Later on, they solidified and produced calcareous sandstones or limed sandstones with an inclined bedding. Ground depressions in the sand-hills buried by sediments originated from the continent. Definite boundaries were settled by the ocean level movements after the end of the Villafranchian. They were marked by every movement at the bottom of their strata as notches on the marine criff.

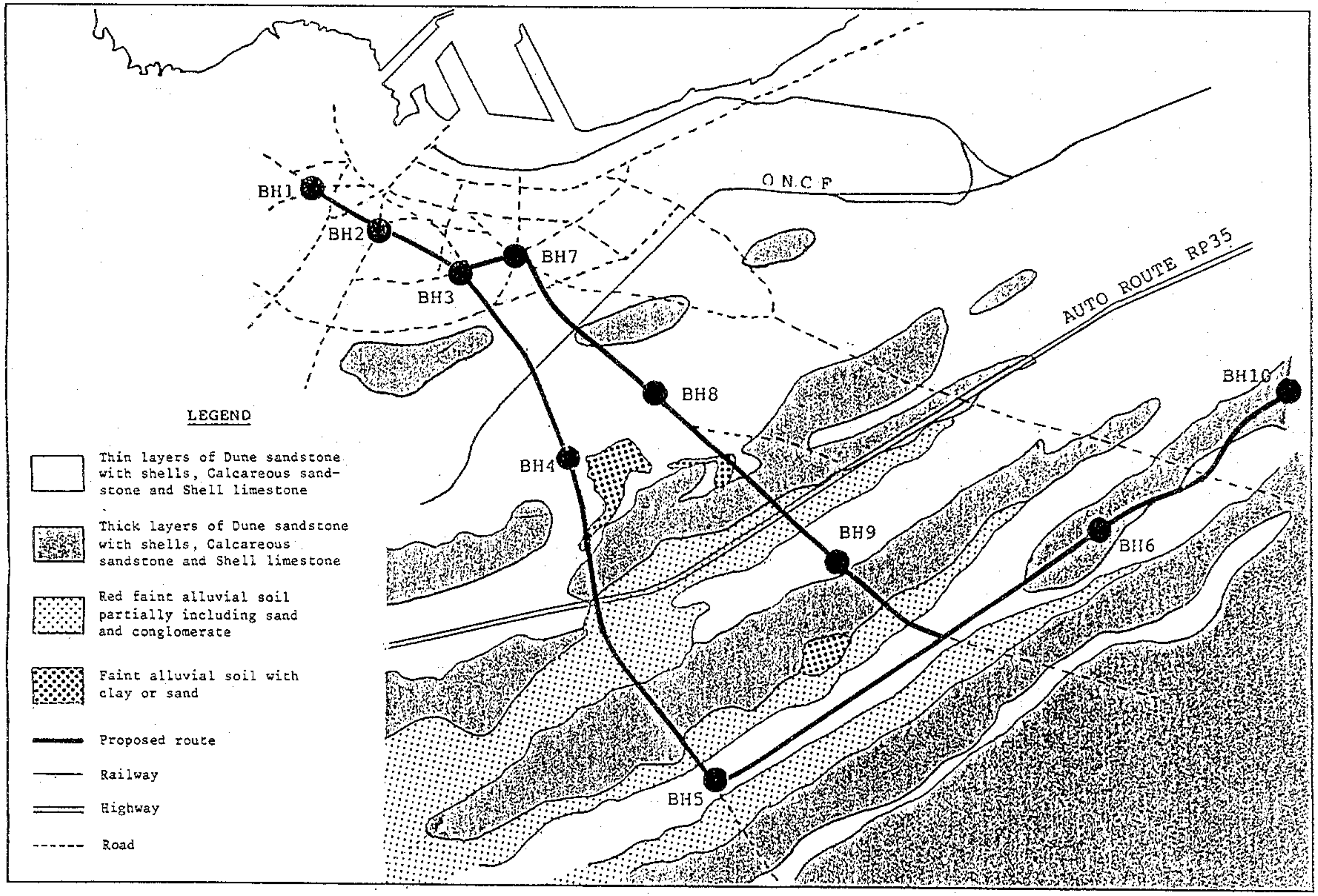
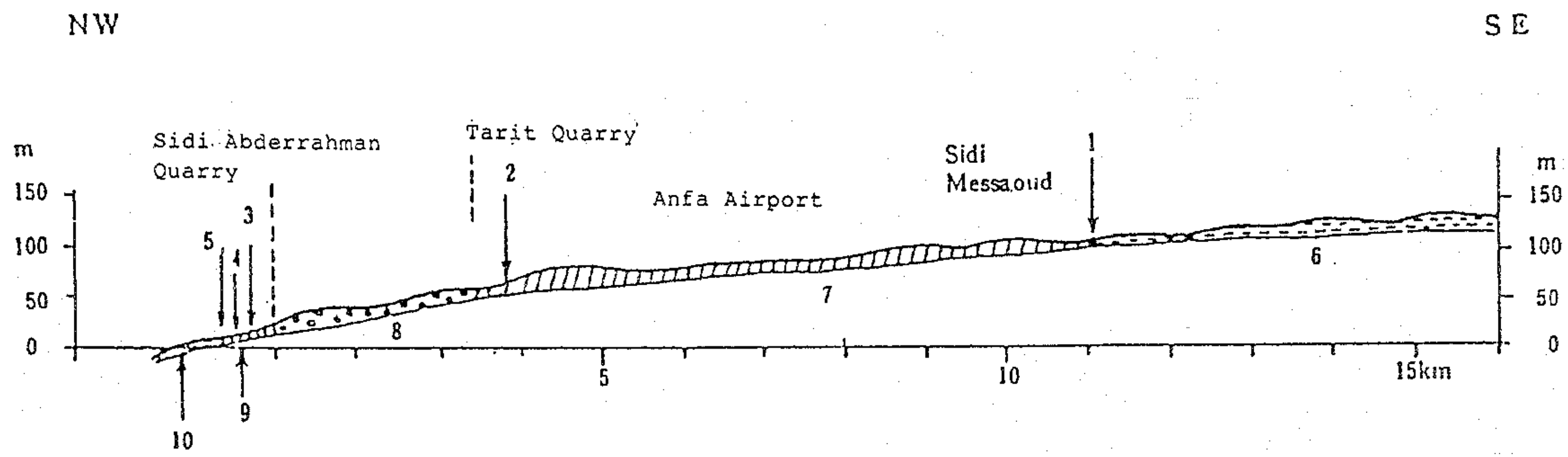


Fig. 1.2 Geographical Map in Casablanca (S = 1/50,000)



1 Messaoudien Stage Boundary

2 Maarifien Stage Boundary

3 Anfatien Stage Boundary

4 Harounien Stage Boundary

5 Ouljien Stage Boundary

6 Moghrébien Stage (sand-hill of Villafranchien Stage which was re-drifted)

7-10 Deposits resulted from a series of transgression (ex. Messaoudien Stage), and the sand-hill was re-drifted due to regression (ex. sand-hill of Messaoudien Stage)

Fig. 1.3 Topographical and Geographical Section of Quarternary Deposit in Casablanca (Sourse: Beaudet 1969 and Biberson 1970)

Table 1.1 Stratigraphy of Quarternary in Morocco

(Source: A. Beaudet, 1969; C. Arambourg, 1969; G. Choubert et A. Faure-Muret, 1970)

	Ocean Stage	Continent Stage	Alpine Quarternary	Mediterranean Quarternary	Absolute Ages
Holocene epoch		Rharbien			
End of Pleistocene epoch	Mellahien		"Atlantique" (Flandrien)	Versilien	6,000
		Soltanien	Würm		12,000 75,000
	Ouljien			Néotyrrhénien	80,000
Middle of Pleistocene epoch		Tensifitien*	Riss		
	Rabatien (Harounien)		Riss	Eutyrrhénien	110-140,000
	Anfatien			Paléotyrrhénien	200-270,000
		Amirien	Mindel		500,000
	Maarifien			Milazzien	700-1,000,000
Beginning of Pleistocene epoch (End of Villafranchien)		Salétien	Günz		1,750,000
	Massaoudien			Sicilien	2,000,000
		Régréguien	Danube		
Villafranchien	Moghrébien	Moulouyen		Villafranchien	
				Calabrien Villafranchien	4,000,000

* According to the G. Beaudet's interpretation, P. Biberson's Présoltanien has not been mentioned in this table.

Stratigraphy of quaternary in Morocco is shown on Table 1.1. Each marine regression in Morocco corresponds to the glacial epoch in Eurpoe. In the same way, each marine transgression corresponds to the span of the glacial epoch. The glacial epoch of Würm, for instance, made a descent of sea level about 150 m down. On the other hand, it seems that the ascending sea level resulting from the marine transgression could not reach the present sea level after the end of the Villafranchian excepting the Anfatian epoch. Current heights of these sediments were mainly influenced by the orogenic movements of these coastal areas.

(3) Policy of the Geotechnical Investigation

1) Location of drilling holes

The locations of drilling holes have been defined taking into consideration the following elements:

- The survey concerns the areas which were not subject to the surveys carried out formerly.
- The survey is aimed at areas that particularly refer to different programmes such as the selection of the route, station planning, transport planning, the planning of car-shed complex as well as carrying out civil-engineering works.
- At last, the survey especially aims at areas where terminus, terminals and principal inter-sections are scheduled, as well as the car-shed complex and areas where curve raduses are relatively small.

Ten locations have been selected for the geotechnical investigation in view of the above mentioned remarks (see Fig. 1.4).

2) Geotechnical Survey and Survey Items

Besides the fact that this survey helps get an idea about the present formations, it also consists in carrying out site and laboratory tests.

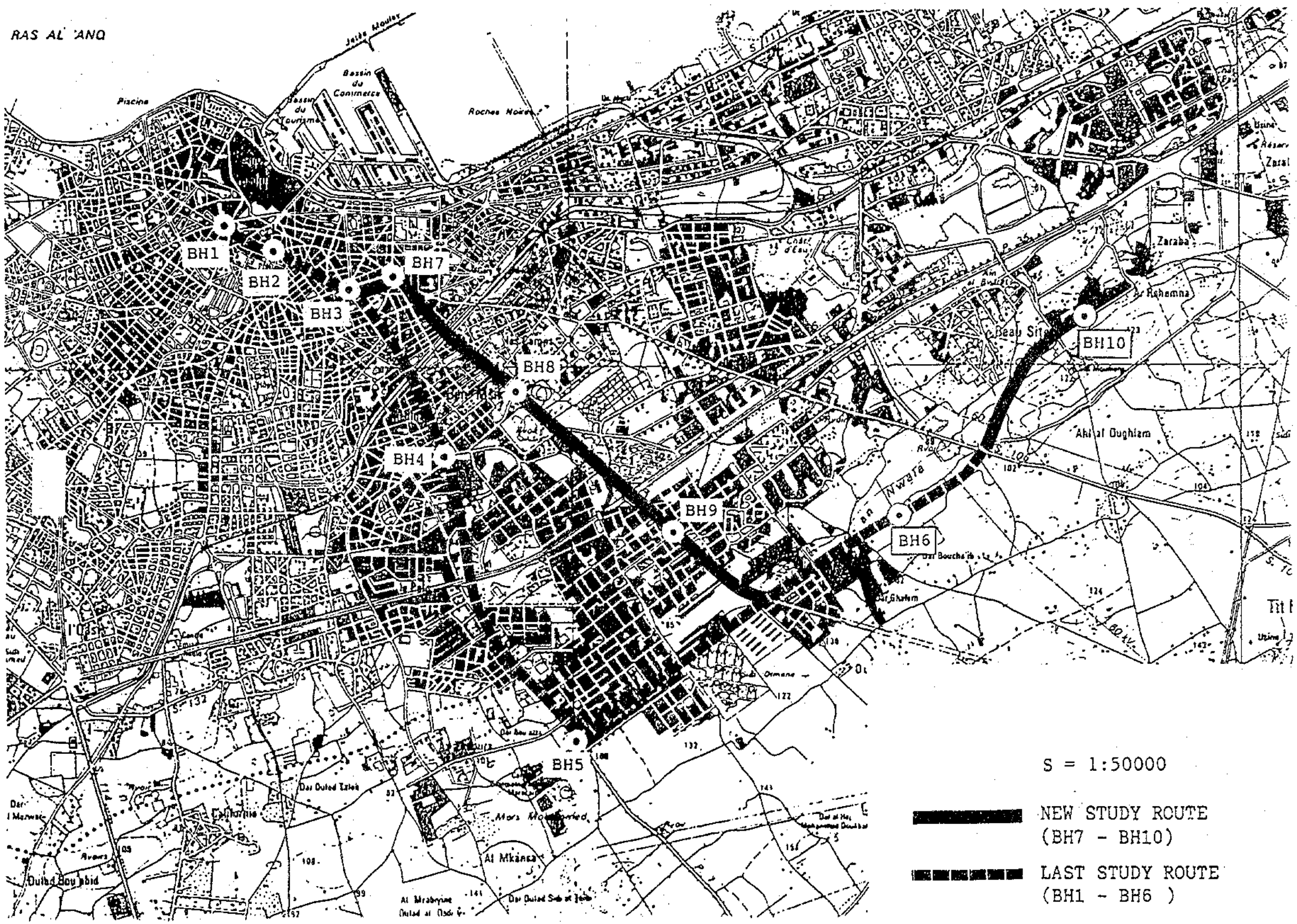


Fig. 1.4 Location of Drilling Holes

This aims at evaluating the soil nature and soil strength, on one hand, and the phreatic ground-water together with the effects exerted on such formations, on the other.

① Tests on site:
- Standard Penetration Tests are carried out at all boring locations.

② Physical tests in laboratory
- Specific gravity test
- Water content test
- Grain size analysis
- Atterberg limit test
- Permeability test

③ Mechanical tests in laboratory
- Unconfined compression test
- Consolidation test

(4) Examination of Soil Investigation Results

Ten boring tests along the proposed routes were performed in this study. But the number of the boring tests remains few when compared with the length of the route. Therefore, several existing boring tests would be applied to analyze the soil investigation results. The formation of the main soil strata found out from the above tests is listed below top layers to the bottom ones.

- Backfill
- Sandy tuff
- Sand with conglomerates
- Calcareous dune sandstone (Non-solidification to solidification)
- Black sandy silt
- Silty marl
- Schist

1) Schist

There is the paleozoic schist in Casablanca as the basement rock. It consists of sandy and muddy crystalline schist belonging to the Cambrien and Ordovicien eras. Yet, its upper part, which had practically undergone a metamorphosis, is not completely made of schist. Schist stretches widely in Casablanca as the basement rock and the level of the upper part of schist is ascent together with the ground height. That is, the upper part of schist follows a slow descent towards the sea. Yet, it is so hard to classify it as the hard rock. Hence, there will be no problem in supporting the heavy structures on schist.

2) Silty marl

Silty marl with great water content lies on the upper part of the schist stratum on BH2, BH3, BH4 and BH7.
Marl is a rather soft stratum consisting of faint carbonate and clayey minerals in the Cenomanian age of the Cretaceous period in the Mesozoic era. There is a lot of conglomerates of schist and sandstones in the silty marl. Therefore, it seems that N values of Standard Penetration Tests were quite high because of the striking of these conglemorates.

Silty marl is observed on BH2, BH3, BH4 and BH7 only and these areas are topographical recesses. Therefore, it seems that marl is formed within limited areas. Furthermore, hard calcareous sandstone is surmounted on the marl stratum. Such soil formation has turned out to be typical of calcareous areas. And the following theory will be anticipated. The small scale of karst topography was formed due to the solution of lime stones and marl was deposited on the spot. In other theories, marl was deposited on the ground depressions in the sand hills.

Silty marl is not suitable enough to support the structure designed with a spread foundation since it is a soft stratum. It is, then, preferable to select the pile foundation and pile should be penetrated through the marl stratum into the schist strutum. Yet, as mentioned above, hard calcareous sandstone is surmounted on the silty marl.

It is conceivable that the spread foundation should be designed on the top of its calcareous sandstone. Thus, it is difficult to design the foundatin on the areas of marl stratum.

Therefore, further investigations should be carried out to design the foundation of the structure when marl is observed during the boring campaign.

- Range and thickness of marl stratum.
- Geotechnical tests for marl such as consolidation test, triaxial compression test, horizontal loading test and so on.
- Range and thickness of the upper layer of calc sandstone.
- Plate bearing test of the upper layer of calc sandstone.

3) Black sandy silt

Black sandy silt is discovered on BH4 only and the layer of 3.2 m thick with height from the surface of 2.6 m to 5.8 m deep. It seems natural that black sandy silt was deposited with the soft layer and having high water cotent, since the location of BH4 shows a topographical depression.

Therefore, this silt layer seems to be deposited with a lens shape because of the recess among sand-hill areas. The layer is as soft as marl and the N value of the Standard Penetration Test show small figures. Consequently, the black sandy silt should be penetrated by pile while constructing the structure of this area.

4) Calcareous dune sandstone

The dune sandstone contains about 90 per cent of lime. The nature of this calcareous dune sandstone has variable characteristics such as loose layer with non-solidification to hard layer with solidifcation which depends on the depth and the location.

Such variety of soil nature seems to be caused by the lime quality in the sandstone, by the dissolving action of the underground water and by the chemical cementation action. Calcareous dune sandstone is classified as follows:

① Nodule of sandstone within sand matrix
② Non-solidified sandstone
③ Hard sandstone with compact sand
④ Solidified sandstone

① The nature of sandstone is similar to the sand layer and sand matrix. It also belongs to the loose deposit; and this layer may bring about a ground subsidence when the structure is built on the layer.

② Sandstone shows a porous nature resulting from the dissolution of lime by underground water. Therefore, this type of sandstone has a permeability and is easy to be weathered.

Designing the foundation of the struture on these soil conditions seems rather difficult than selecting either the pile or the spread foundation. It is possible to select the spread foundation once this sandstone is quite thick. It is advisable, however, that grouting with cement milk will be filled into the pore of sandstone.

③ It is preferable to select the spread foundation for the structure on this hard sandstone with compact sand. If this sandstone shows a thin layer together with a soft layer underneath, such geotechnical survey as the palte bearing test would seem necessary to carry out for the selection of the foundation of the structure.

④ There is no problem to select the foundation type since this solidified sandstone is strong enough to bear the structure.

Calcareous sandstone is classified as stated above. However, some sandstone cannot be classified as such since it has got some variable natures like the cemented or semi-cemented sandstone, and also an alternation of strata with sand and sandstone. As a result, the type of the foundation of the structure should be selected carefully, for the calcareous sandstone has wide soil nature and wide strength.

5) Sand with conglomerates

This type of soil exists only in the suburbs of Casablanca on BH5, BH8 and BH9. Sand is quite compact except for the upper part of this layer. Therefore, it is possible to support the structure with the spread foundation since the N value of the Standard Penetration Test shows big figures.

6) Sandy tuff

This layer exists just near the ground surface. Soil nature of this layer is believed to decline its strength when water fills into the layer. Hence, this is not suitable for the foundation of the structure. Sandy tuff should be abolished before the construction.

7) Backfill

As it is the case with the sandy tuff mentioned above, the backfill layer should be ablished before construction.

(5) Examination of the Foundation of the Structure

Based on the above boring test results, some views regarding the construction of the structure along the proposed route are described here.

1) Examination of the foundation along Route A

There will raise no problem from selecting the spread foundation along the route from place Qued El Makhazine (BH1) to 0 k 500 m since schist appears which 5 m deep from the ground surface.

The depth of schist stretches out deeper from the location of 0 k 500 m. The old bed rock of Bouskoura River might lie near BH2; that's why the vicinity of this area forms a topographical depression.

Therefore, the soft layer of silty marl is deposited on these areas. Pile foundation might be required for the structure of about 400 m long along the route between 0 k 500 m and 0 k 900 m. The solidified calcareous sandstone is surmounted on the silty marl and also this section lies in the centre of the city. Consequently, cast-in-place concrete pile should be selected for the construction without big noise.

The silty marl is found in Place La Voctoire (BH3). Yet, it is envisaged that the marl layer has got a limited extent and is formed with a lens shape. In addition, the marl is to be cemented with a lot of conglomerates as well as the solidified sandstone which is surmounted on the marl more than 4 m thick. Therefore, the pile may not be required for the foundation of the structure. That is, the spread foundation will be applied for the structure in the section between 0 k 900 m and 3 k 400 m.

In case of an underground alternative in the section between Place Qued El Makhazine and Place de la Victoire, a great manpower will be required for the construction because of the excavation of hard rock such as schist. Under such soil conditions, the earth retaining wall with timbering or sheet pile will not be applied for the excavation and open-cut method with steep slope might be selected for the construction.

During the construction of the underground, problems of the groundwater, which may come through the porous sandstone, will be raised. In such a case, the drainage will be required to build deeper than the bottom of the excavation. Pumping and deep well methods are examples of drainage.

There is another topographical depression near Boulevard El Fida (BH4) like BH2. Soft layers such as black sandy silt and silty marl seem to be as deposited as a lens shape.

Therefore, the pile foundation is required to drive into the schist of this area. The length of the pile section along the route cannot be defined since the number of the boring surveys was not quite enough for holding an adequate discusison around this area. It is envisaged, however, that the section of the pile foundation will be extended between 3 k 400 m and 4 k 300 m.

The soft ground with a small figure of N value of the Standard Penetration Test exists only near the surface course after the 4 k 300 m till the end of the route. Therefore, the spread foundation will be adopted for the structure after removing the soft ground. Despite the fact that the pile foundation will be applied within this section, only short pile should be required.

2) Examination of the foundation along Route B

Section between Place oued el Makhazine (BH1) and Place de la Victoire (BH3) is the same route as Route A as described above.

The deep silty marl with 13 m thick deposit is found in Rond-point Dakar (BH7). It is envisaged that marl was deposited on the ground depressions in the sand hills since this area is topographical recess. Therefore, the marl layer has got a limited extent and is formed with a lens shape.

Pile foundation might be required for the structure of about 500 m long along the route between 2 k 000 M and 2 k 500 M. The solidified carcareous sandstone is surmounted on the silty marl and this section lies in the centre of the city. Consequently, cast-in-place concrete pile should be selected for the construction without big noise.

After the 2 k 500 M till the end of the route, the soft ground with a small figure of N value of the Standard Penetration Test exists only near the surface course. Therefore, the spread foundation will be adopted for the structure after removing the soft ground. Despite the fact that the pile foundation will be applied within this section, only short pile should be required.

Soft layer of 6 m deep with small N value is lain at the terminal (BH10), however, any heavy structure is not planned at this area but only for the car shed complex.

3) Examination of the foundation along Av. des F.A.R. which is alternative route

Place Zallaga (in front of Safir Hotel) is the ground depresison with 5.90 m above the sea level along Av. des F.A.R. Therefore, old Bouskoura River might flow out to the sea somewhere here. As the groundwater flow along the old bed rock of the river, the problem of groundwater filled in the porous sandstone will be raised during the construction. However, no underground structure is planned but the elevated structure is required in this route. Consequently, construction by water pump up will be applied since the excavation is on a small scale.

1.2 Hydrological Survey

(1) Precipitation

The annual precipitation in Casablanca is low, reaching only 462 mm during the last 30 years shown in Fig. 1.5. No river exists in the city. Consequently, the hydrological survey focused on investigating the groundwater rather than the surface water or the pluviometric height.

The average quantity of the rainfall in July reaches only some millimeters; and it is probable that almost no rain falls during July. But in December, the average rainfall has reached 95 millimeters in the last 31 years (1950 - 1980) shown in Fig. 1.6.

(2) Groundwater

The underground water has a close relationship with the soil formation besides the precipitations described in the previous section. As it is shown in Fig. 1.3, both of the topographical level and the soil formation of Casablanca are formed around the inclination. According to the geotechnical survey, calcareous dune sandstone and metamorphic schist seem to be aquifers while schist is clearly formed as the non-aquifer. Therefore, the direction of the groundwater is mostly influenced by the formation of schist. Consequently, the direction of the groundwater will generally flow either to the North of North-West as it corresponds to the schist formation.

Calcareous dune sandstone with lime presents the porous nature because of the dissolving action of the groundwater and due to the chemical cementation action. The pores of sandstone produce the variety of the hydraulic motions. Therefore, it sounds quite difficult to measure the groundwater with a quantitative analysis. Yet, the coefficient of permeability has been presumed by the following methods based on the geotechnical data and tests described in Fig. 1.7.

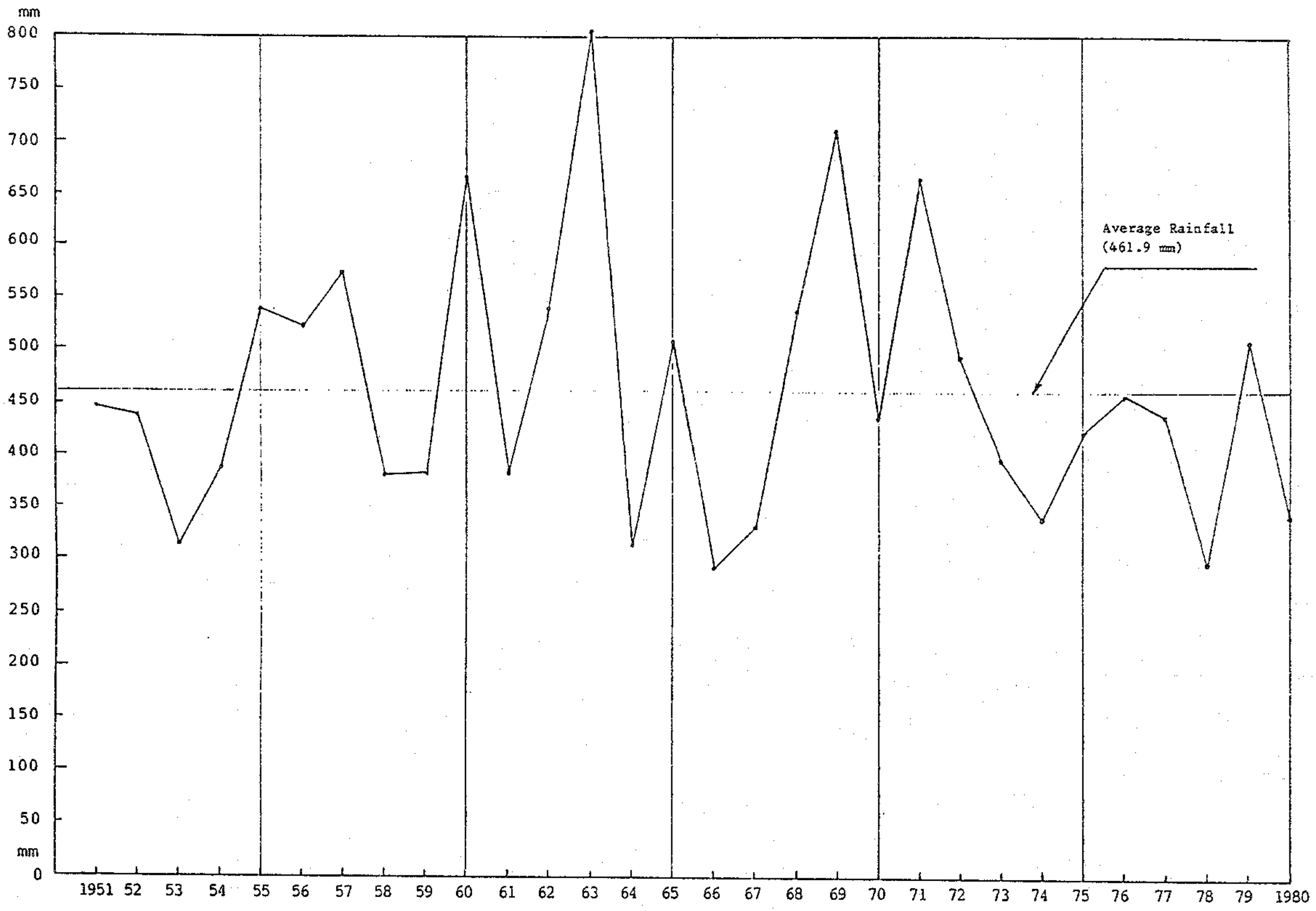


Fig. 1.5 Annual Rainfall Record in Casablanca

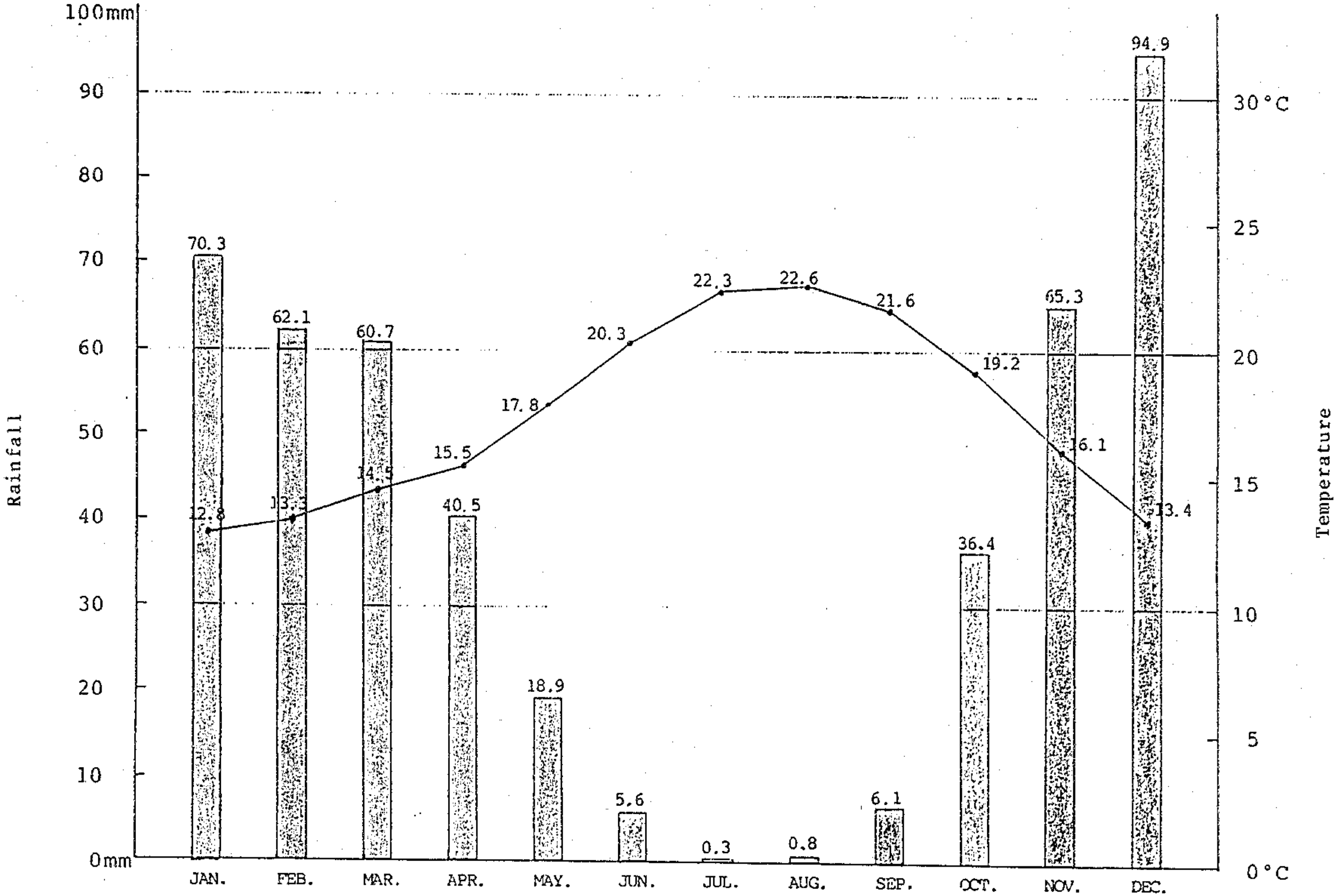


Fig. 1.6 Rainfall and Temperature Diagram (1950 - 1980)

1) Presumption of the coefficient of permeability by grain size analysis

Test results given by the geotechnical survey area drawn in the grading curve shown in Fig. 1.9. The effective grain size D_{20} has been found by means of the grading curve. Then the coefficient of permeability will be given by the Table 1.2. According to the above Creager Method, the coefficients of permeability are estimated as follows:

Calcareous sandstone $k = 5.1 \times 10^{-3}$ cm/sec
Sandy silt $k = 1.8 \times 10^{-3}$ cm/sec

2) Presumption of the coefficient of permeability by previous test data

Pumping test data at the centre of the city in Casablanca shown in Fig. 1.7 are collected and analyzed as follows:

Aquifer	Numbers of data	Coefficient of permeability (cm/sec)		
		Max.	Min.	Mean
sandstone and schist	7	1.12×10^{-2}	3.07×10^{-4}	4.1×10^{-3}
metamorphosed schist	3	2.01×10^{-3}	5.48×10^{-4}	1.4×10^{-3}

The figures mentioned above are only the outcome of this analysis.

3) Conclusions

As anlayzed above, the coefficients of permeability are listed as follows:

Aquifer	Coefficient of permeability (cm/sec)
sandsotne	4.1×10^{-3} - 5.1×10^{-3}
metamorphosed schist	1.4×10^{-3}
sandy silt*	1.8×10^{-3}

* Sandy silt is found only at BH4.

A neat examination of the groundwater survey shows that there is no confined groundwater in Casalbanca. Fluctuations of the groundwater level may have been influenced by the precipitation.

The groundwater exists in such aquifers as calcareous dune sandstone, metamorphosed schist and sandy silt. The flowing direction of the groundwater is mostly influenced by the formation of schist which is non-aquifer. (see Fig. 1.8)

An examination of the above coefficient of permeability shows that no groundwater problem will be raised during the construction. Pumping method or deep well method will be manipulated for excessive groundwater. However, if the construciton site is situated near seaside, or if the rainfall reaches more than usual, the countermeasures for the groundwater will be carried out during the construction.

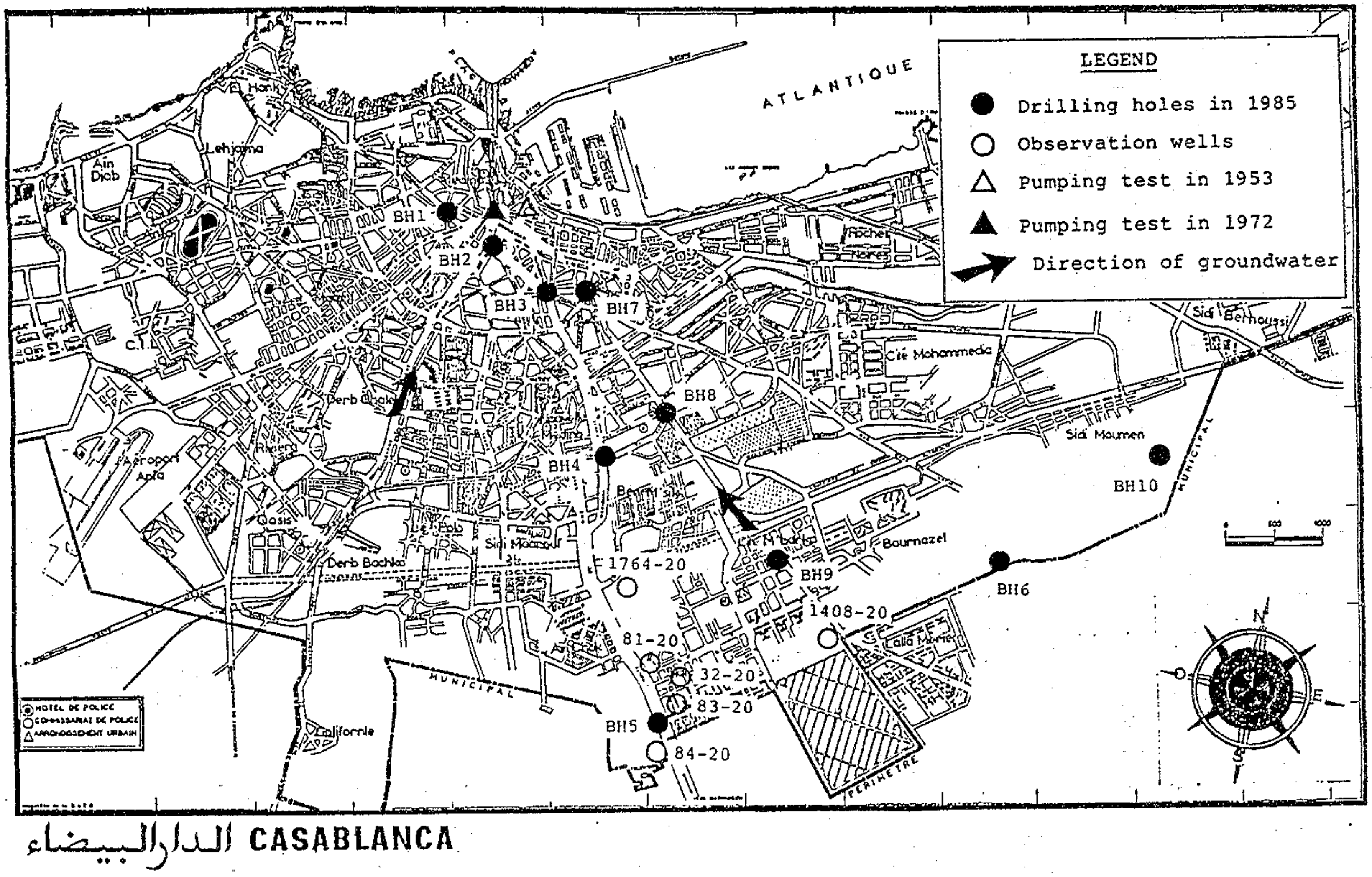


Fig. 1.7 Location of Groundwater Survey

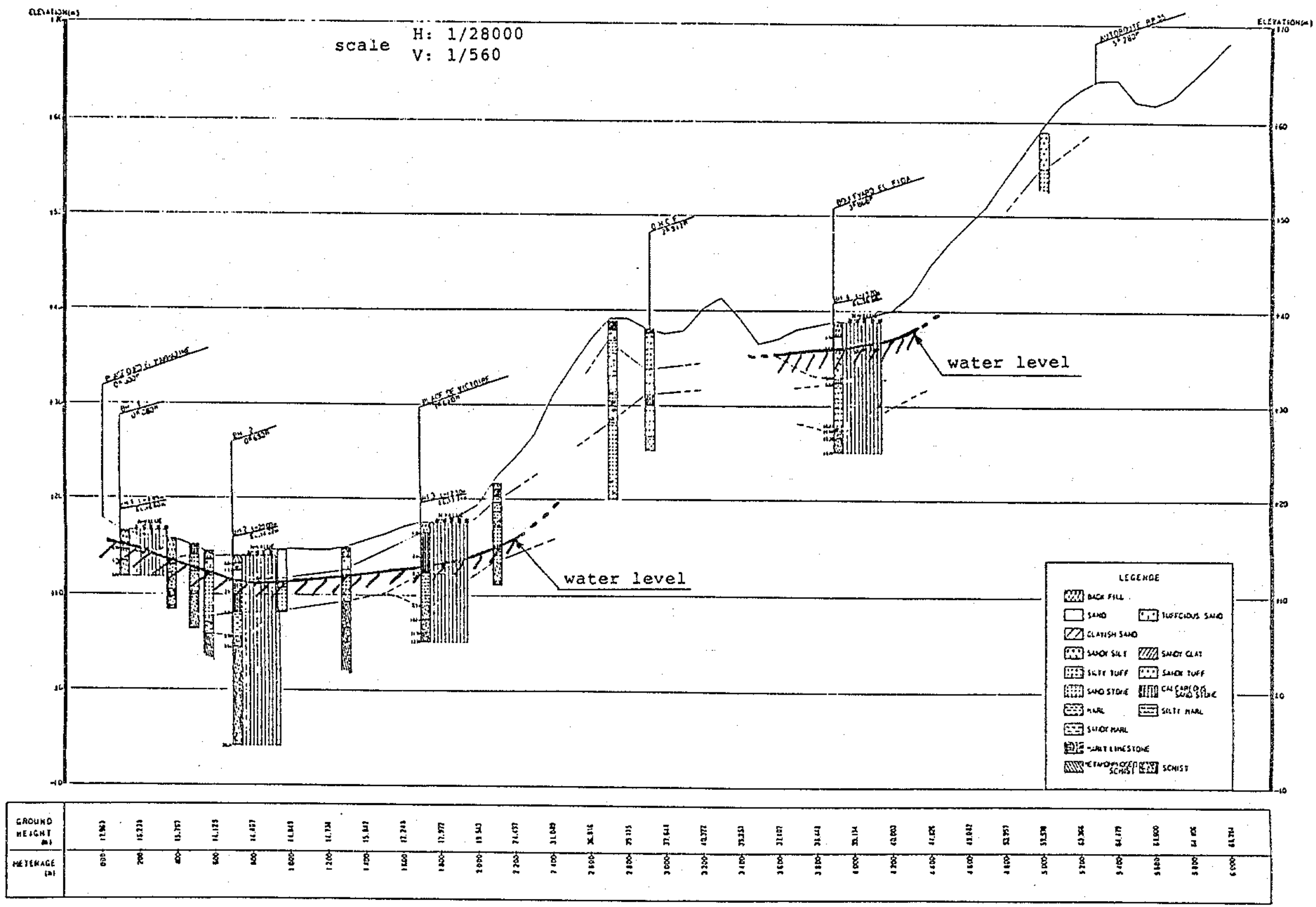


Fig. 1.8 Groundwater Level Profile

Table 1.2 Relation between D_{20} and Coefficient of Permeability (k) given by Creager

D_{20} (mm)	k (cm/sec)	Classification	D_{20} (mm)	k (cm/sec)	Classification
0.005	3.00×10^{-4}	coarse clay	0.18	6.85×10^{-3}	
0.01	1.05×10^{-5}	fine silt	0.20	8.90×10^{-3}	fine sand
0.02	4.00×10^{-5}		0.25	1.40×10^{-2}	
0.03	8.50×10^{-5}	coarse	0.3	2.20×10^{-2}	
0.04	1.75×10^{-4}	sand-silt	0.35	3.20×10^{-2}	
0.05	2.80×10^{-4}		0.4	4.50×10^{-2}	middle sand
0.06	4.60×10^{-4}		0.45	5.80×10^{-2}	
0.07	6.50×10^{-4}	very	0.5	7.50×10^{-2}	
0.08	9.00×10^{-4}	fine sand	0.6	1.10×10^{-1}	
0.09	1.40×10^{-3}		0.7	1.6×10^{-1}	
0.10	1.75×10^{-3}		0.8	2.15×10^{-1}	coarse sand
0.12	2.6×10^{-3}		0.9	2.8×10^{-1}	
0.14	3.8×10^{-3}	fine sand	1.0	3.60×10^{-1}	
0.16	5.1×10^{-3}		2.0	1.80	fine gravel

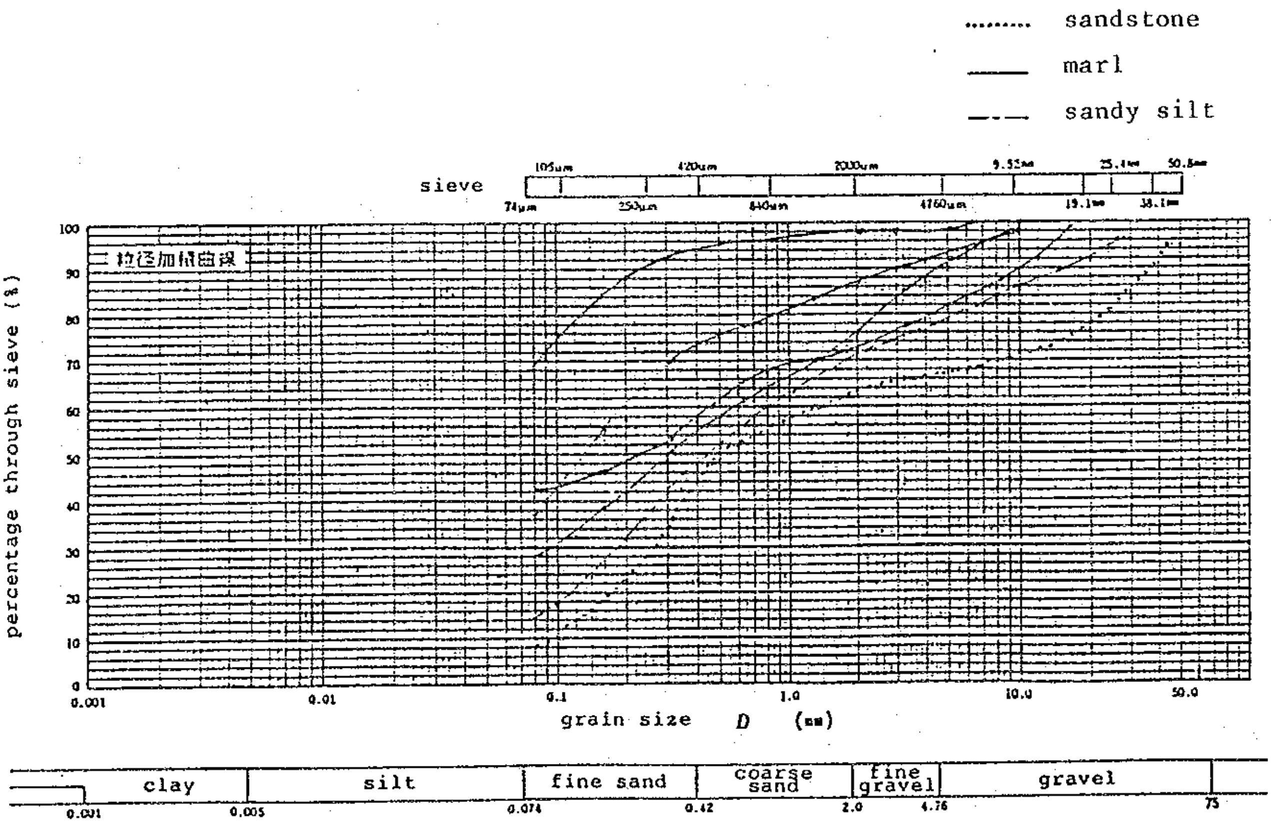


Fig. 1.9 Grading Curve

1.3 Meteorological Survey

(1) Wind Velocity and Direciton

In Winter, the wind blows in the Southwest, and it changes to the Northwest in Spring in Casablanca In Summer, most winds come fromt he North, and in Autumn they shift either to the West of Northward again. In Winter, they blow anew in the Southwest. From Spring to Summer, the wind is rather high, but relatively moderate all year long. The average velocity of wind ranges between 1.0 m/s and 5.0 m/s. From 1943 to 1975 and during a period of 33 years the maximum point in wind velocity was over 50 m/s for twice only. Wind-rose of Casablanca is shown in Fig. 1.10.

(2) Climate

Being at 9.5°C in average, the diurnal amplitude in Casablanca is relatively large.

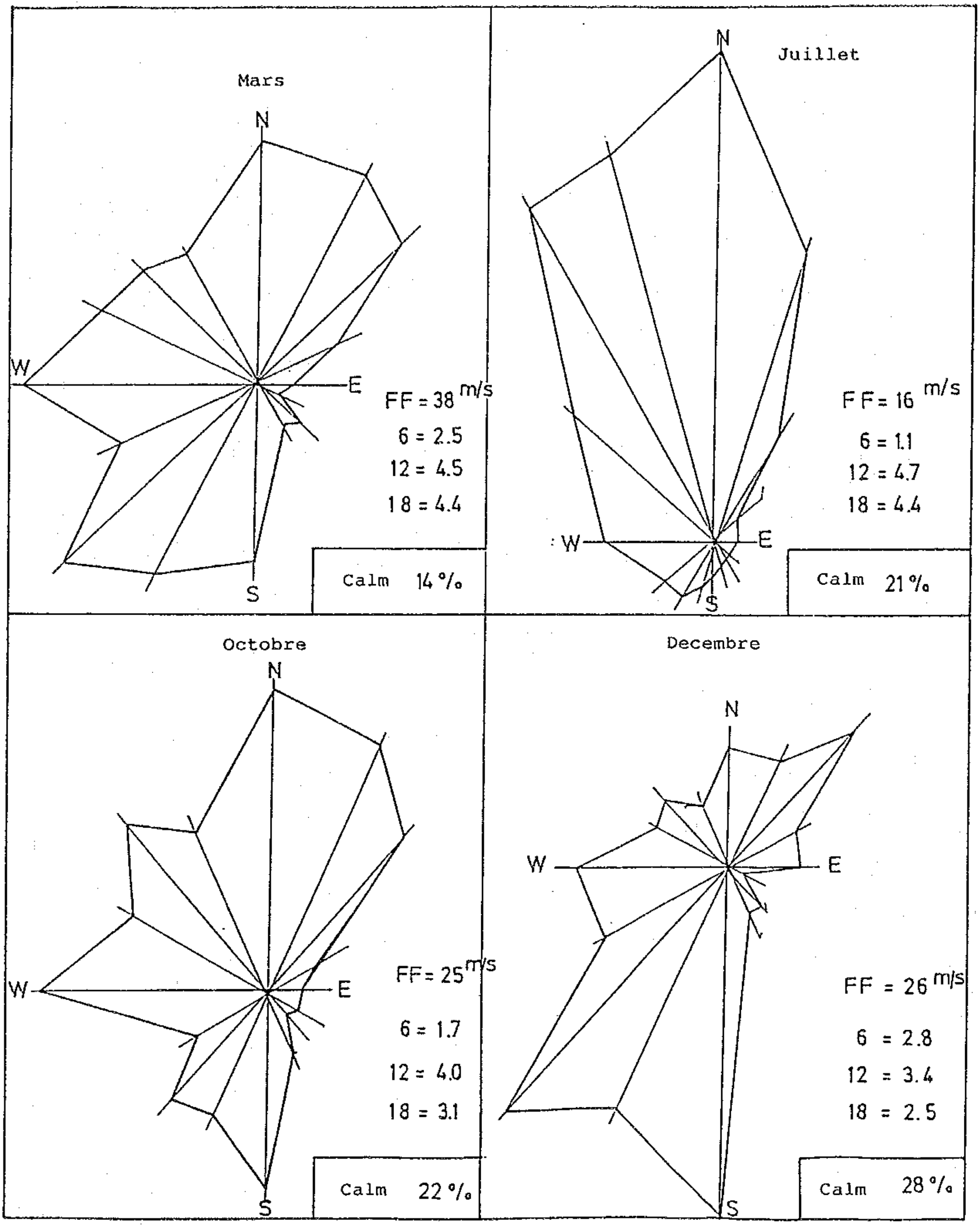
As the average tempertures in summer and in winter are 22°C and 13°C respectively, no wide difference between them can be noticed. However, the highest temperature has ever gone up to 46°C in summer, whereas in winter the lowest temperature is minus 3°C. The air is a bit damp, and at six o'clock in the morning the indication of humidity reaches its highest point, that is 85 per cent as average, then goes lower till 70 per cent in the day-time, but practically not less than 60 per cent. Temperature diagram of Casablanca is shown in Fig. 1.6 and the meteorological data of Casablanca are shown in Table 1.3.

1.4 Occuring Sinisters

Sinisters such as earthquake, storm and tidal-wave hardly occurred in Casablanca. And this has been confirmed by the sinisters report issued by the meteological service of the Ministry of Transportation. Historical seismic data in Morocco are shown in Fig. 1.11.

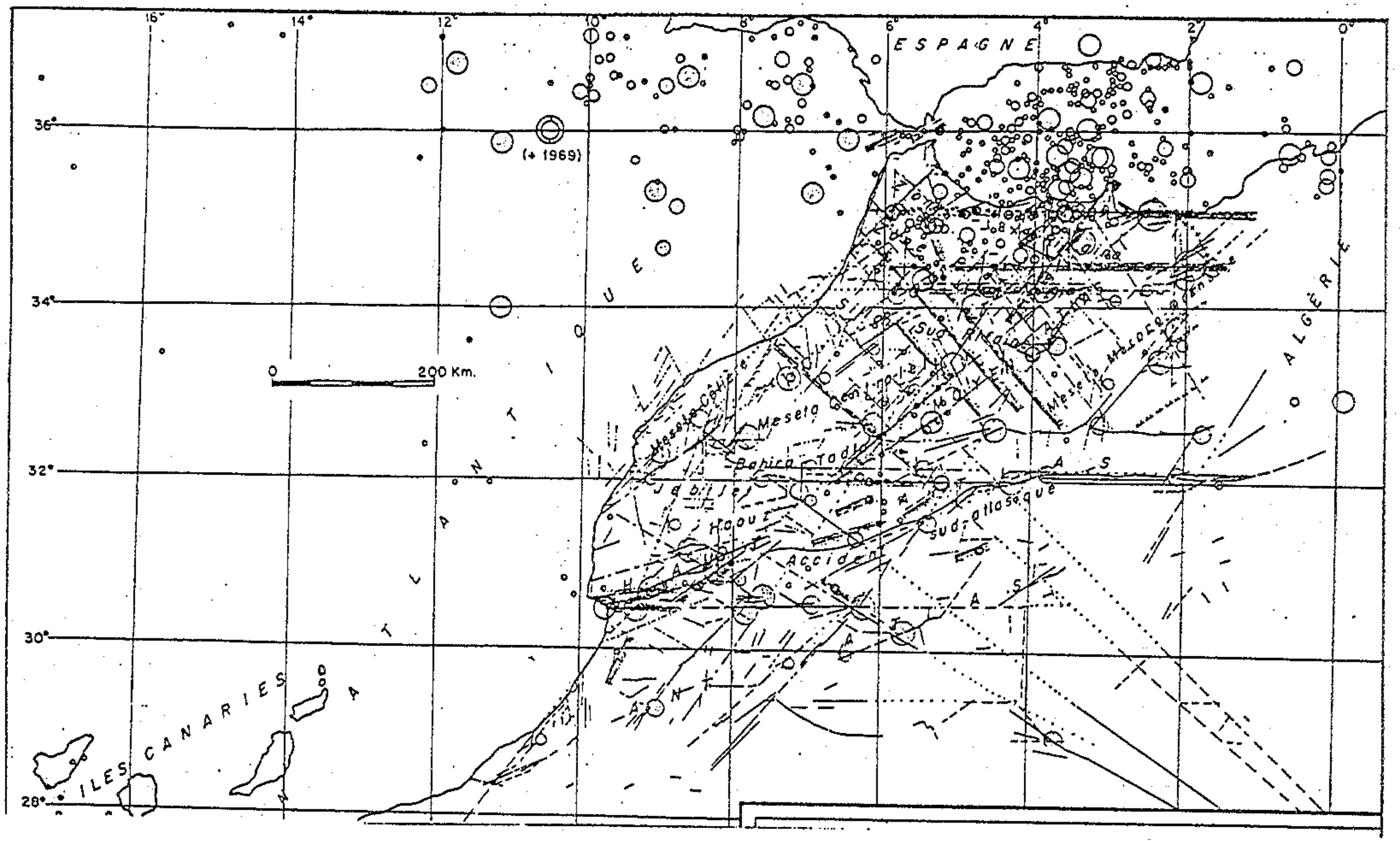
Table 1.3 Meteorology Data in Casablanca (1951 - 1980)

MONTH	TEMPERATUE (°C)			HUMIDITY (%) 6h + 12h + 18h			AIR PRESSURE (Mb) 6h + 12h + 18h			WIND (M/S) 6h + 12h + 18h		RAINFALL (MM)		
	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX	MEAN TOTAL	Greates in 24h	MEAN DAYS
JANUARY	12.8	17.3	8.3	81	95	64	1013.8	1019.0	1006.5	2.8	31	70.3	49.6	9.7
FEBRUARY	13.3	17.8	8.8	79	95	59	1012.4	1019.3	1005.6	3.3	43	62.1	42.5	8.3
MARCH	14.5	18.9	10.1	78	94	58	1016.4	1016.4	1005.9	3.6	38	60.7	42.0	9.3
APRIL	15.5	19.7	11.3	78	95	59	1009.2	1013.3	1004.7	3.7	24	40.5	50.2	7.3
MAY	17.8	21.5	14.0	77	93	63	1009.3	1012.3	1006.8	3.7	21	18.9	50.7	5.1
JUNE	20.3	23.5	17.0	79	94	63	1009.9	1012.0	1007.6	3.6	22	5.6	4.8	1.6
JULY	22.3	25.5	19.1	79	95	61	1009.4	1011.5	1007.5	3.4	16	0.3	0.5	0.2
AUGUST	22.6	25.9	19.2	77	96	63	1008.7	1010.3	1006.5	3.3	23	0.8	10.6	0.5
SEPTEMBER	21.6	25.3	17.8	79	95	63	1009.9	1012.2	1007.5	3.1	50	6.1	17.2	2.4
OCTOBER	19.2	23.4	14.9	78	94	52	1013.3	1013.2	1006.5	3.0	25	36.4	46.6	7.4
NOVEMBER	16.1	20.7	11.5	79	93	58	1011.6	1015.6	1006.4	2.7	27	65.3	44.7	8.8
DECEMBER	13.4	17.8	9.0	81	94	64	1013.2	1018.7	1008.0	2.8	26	94.9	50.2	11.1
MEAN TOTAL	17.4	21.4	13.4	79	94	61	1011.4	1014.5	1006.6	3.3	29	461.9	-	71.7



_The observation period is from 1943 to 1975. (33 years)
_FF : Maximum absolute wind velocity.
_6. 12.18 shows the time of the observation a day.

Fig. 1.10 Wind Rose in Casablanca



Legend

⟨ Magnitude ⟩

- 7.0
- 6.0 - 6.9
- 5.0 - 5.9
- 4.0 - 4.9

⟨ Tectonic geology ⟩

- category 1
- category 2
- category 3
- category 4

Structure alignments

- Very clear alignments
- Clear alignments
- Alignments described in gravitative map only
- General direction of alignments
- Alignments relation between hypocenter and Medium and High Atlas Zones and Rif Mountains

Fig. 1.11 Relations between Structure Alignments and Hypocenters in Morrocco (Hypocenter observed in 1901-1975: Based on the map given by J. Duverge and map given by Institute of Geophysics)

2 TRANSPORT PLAN

2. TRANSPORT PLAN

2.1 Train Operating Plan

Rolling stock performance will be determined by the following premises among those affecting the train operating plan.

(1) Rolling Stock Performance

Table 2.1 Rolling Stock Performance

Item / Type of wheel		Steel wheels	Rubber tires	Monorail
Amount of rolling stock (unit) per formation		4	4	4
Length of formation (m)		64	55	56
Maximum speed (km/h)		80	80	80
Acceleration (km/h/sec)		3.0	3.5	3.5
Deceleration (km/h/sec)	Service use	2.5	3.5	3.5
	Emergency (use)	3.0	4.0	4.0
Nominal passenger (persons/car) capacity		96	92	90

(2) Speed Limits

1) Curve sections

Table 2.2 Restricted Speed Limits (km/h)

Radius of curve / Type of wheel	Steel wheels	Rubber tires	Monorail
over 450 m	80		
over 400 m	75		
over 350 m	70	80	
over 300 m	65	75	80
over 250 m	60	65	70
over 200 m	55	60	65
over 150 m	50	50	55
over 125 m	45	45	50
over 100 m	40	40	45
below 100 m	30	35	40

2) Turnout

. Steel wheels .... 45 km/h
. Rubber tires, monorail .... 30 km/h

3) Downhill grade sections

. 40 ‰ (all systems) .... 70 km/h
. 60 ‰ (rubber tires, monorail) .... 65 km/h

Running speed in downhill grade sections is determined by the braking distance for the train. The emergency braking distance for an emergency stop, in particular, is related to the interlocking device, etc. It is therefore necessary to determine the basic requirements for the train's operation. The emergency braking distance in the concerned section here, has been determined to be 600 m or less.

The appropriate value will be determined with the inclusion of a consideration of normal train operation and handling.

4) Correction of acceleration and deceleration, in graded sections

$\alpha c = \alpha L \pm 0.032\gamma$

αc: Corrected acceleration or deceleration (km/h/sec)

αL: Acceleration or deceleration on level section (km/h/sec)

γ : Grade (‰)

(3) Standard Operation Time and "Train hour(s)"

The standard operation time between each stations will be set, for the operation time determined from the train operation diagram, in 10-second units. In the ordinary train operation section, however, this will be determined in 15-second units.

Table 2.3 shows the standard operation time, etc., classified by individual alternative plans.

(4) Train Operating Plan

The train operating plan, classified by individual alternative plans, is shown in Table 2.4.

(5) Required Rolling Stock

The amount of rolling stock needed for each alternative plan, is as shown in Fig. 2.1.

2.2 Operation Safety System

(1) Electronic Interlocking

An electric relay interlock has already been used, in ONCF. An outline of the new electronic interlocking system which will be adopted, is shown in Fig. 2.2.

This electronic interlocking system will also constitute a portion of the total control system.

Basic functions of electronic interlocking:

The electronic interlocking system has the following functions, in addition to the functions of electric relay interlocking.

1) Rolling stock tracing function

The accuracy of the information on the location of rolling stock will be evaluated, and the improvement of safety and control efficiency will be achieved at the same time as the assessment of problems with the location detection function.

2) Functions related to operability, etc.

. Automatic course re-positioning function

This function does automatic re-positioning of the route in the direction of traffic, for trains or rolling stock, prior to their runs.

. Automatic assessment function for content of operations, with the use of a control panel.

Checking and indication, etc., when it is impossible to construct a route, due to errors in operation or conflict between the operating route and the route previously determined.

. This function prevents mishandling when maintenance work, etc., is done.

When the plan for maintenance work, etc., is input into the system in advance, this system will display the plan on a CRT, and will function to prevent mishandling.

. Idling and switching functions, etc., for the point lever system

This has the function of re-switching, in cases where the point lever system does not function satisfactorily.

. Functions of movement recording and assessment of mechanical problems.

3) Other, additional functions

The addition of the following functions will be examined, using the man-machine system (universal computer) and the computer for the PRC, which is constructed separately.

. Automatic route-setting function

This will provide the determination of a route for the operation of a train or of rolling stock, in the yard, and when incoming or outgoing the rolling stock shed; the setting of a route for rolling stock when changes are made; and automatic judgement and control of priorities when there is a conflict between the above operations, on the basis of train numbers (utilization numbers).

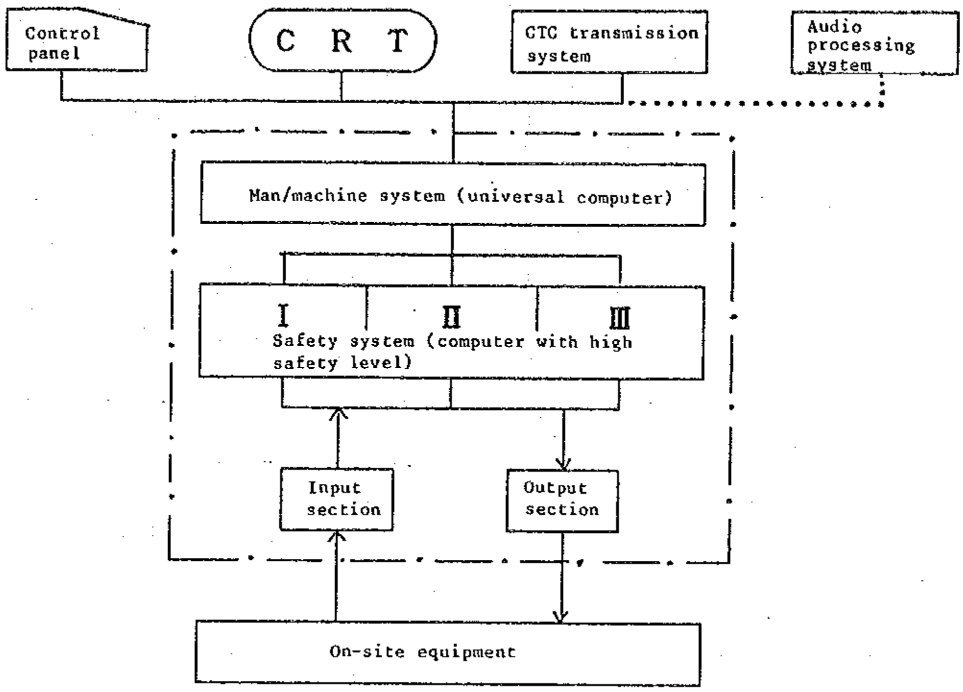


Fig. 2.2 Diagram of Components of Electronic Interlocking System Components

(Computer in man-machine system; mini-computer)

- Input of information for control
- Conversion of information for control, to information for route, and transmission to the safety system
- Output to display, of various items of information
- Information for maintenance and other service functions

(Computers for safety system: triple system)

- On-site input of information
- Interlocking processing using both information from the site, and information from the man-machine system
- Output for control of on-site equipment
- Tracing of rolling stock, etc.

(2) Various ATS Methods

Fig. 2.3 shows each type of ATS.

2.3 Total Control System

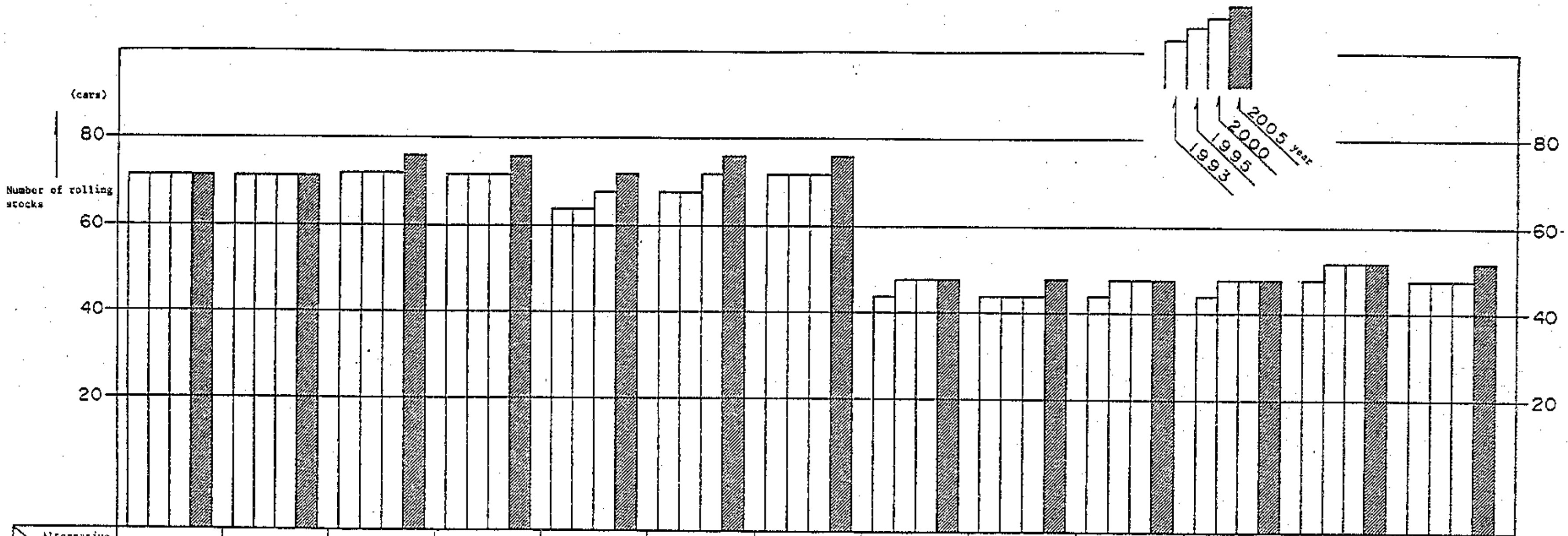
Table 2.5 shows the content of the system.

When the results of examination are correlated, relative to the over-all transportation plan, above, the result is as shown in Table 2.6.

Table 2.3 Standard Operating Time, Train Hour of Each System

Station No.	A－1 Monorail			A－2 Monorail			A－3 Rubber			A－4 Steel			A－4' Steel			A－5 Steel			A－6 Monorail		
	km	Down	Up	km	Down	Up	km	Down	Up	km	Down	Up	km	Down	Up	km	Down	Up	km	Down	Up
1–2	.6	1:00	1:20	.6	1:10	1:20	.6	1:20	1:20	.6	1:20	1:20	.6	1:00	1:20	.9	1:20	1:40	.9	1:30	1:40
2–3	.5	1:00	1:00	.5	50	50	.5	1:00	1:00	.5	1:00	1:00	.5	1:00	1:00	.8	1:30	1:20	.8	1:20	1:30
3–4	.5	1:00	50	.4	50	50	.4	50	50	.4	50	50	.5	1:00	1:00	.7	1:20	1:20	.7	1:10	1:10
4–5	.5	1:00	50	.6	1:10	1:10	.6	1:10	1:10	.6	1:00	1:00	.5	1:00	1:00	.5	1:00	1:00	.5	1:00	50
5–6	.7	1:10	1:10	.7	1:10	1:10	.7	1:10	1:10	.5	1:00	1:00	.6	1:10	1:10	.7	1:20	1:10	.7	1:10	1:10
6–7	.6	50	50	.5	60	50	.5	50	50	.7	1:10	1:10	.4	50	50	.5	1:00	1:10	.5	50	50
7–8	.5	50	50	.5	50	50	.5	50	50	.5	50	50	.5	1:00	1:00	.6	1:00	1:00	.5	50	50
8–9	.7	1:10	1:00	.7	1:10	1:00	.7	1:10	1:00	.7	1:10	1:00	1.0	1:30	1:20	.7	1:10	1:10	.7	1:10	1:00
9–10	1.0	1:30	1:20	1.0	1:30	1:20	1.0	1:30	1:20	1.0	1:30	1:20	.9	1:20	1:20	1.0	1:30	1:20	1.0	1:30	1:20
10–11	.8	1:20	1:10	.8	1:20	1:10	.8	1:20	1:10	.8	1:20	1:10	1.6	2:00	1:50	.8	1:30	1:10	.8	1:20	1:10
11–12	.7	1:00	1:00	.7	1:00	1:00	.7	1:00	1:00	.7	1:00	1:00	1.2	1:50	1:50	.7	1:00	1:10	.7	1:00	1:00
12–13	1.2	1:40	1:40	1.2	1:40	1:40	1.2	1:50	1:50	1.2	1:50	1:50	1.3	1:40	1:40	1.2	1:40	1:40	1.2	1:40	1:40
13–14	1.3	1:30	1:40	1.3	1:30	1:40	1.3	1:30	1:40	1.3	1:30	1:40	.9	1:20	1:20	1.3	1:40	1:40	1.3	1:30	1:40
14–15	1.0	1:20	1:20	1.0	1:20	1:20	1.0	1:20	1:20	1.0	1:20	1:20	1.2	1:40	1:40	1.0	1:20	1:20	1.0	1:20	1:20
15–16	1.2	1:30	1:30	1.2	1:30	1:30	1.2	1:30	1:30	1.2	1:30	1:30	1.3	1:40	1:40	1.2	1:30	1:40	1.2	1:30	1:30
16–17	1.3	1:30	1:30	1.3	1:30	1:30	1.3	1:30	1:30	1.3	1:30	1:30	1.2	2:10	1:50	1.3	1:30	1:40	1.3	1:30	1:30
17–18	1.2	2:00	1:50	1.2	2: 00	1:50	1.2	2:10	2:00	1.2	2:10	2:00				1.2	2:00	1:40	1.2	2:00	1:50
Total	14.2	21:20	20:50	14.2	21:20	21:00	14.2	22:00	21:30	14.2	22:00	21:30	14.2	22:10	21:50	15.0	23:20	23:00	15.0	22:20	22:00
Stopping time		8:00	8:00		8:00	8:00		8:00	8:00		8:00	8:00		7:30	7:30		8:00	8:00		8:00	8:00
All Total		29:30	29:00		29:30	29:00		30:00	29:30		30:00	29:00		30:00	29:30		31:30	31:00		30:30	30:00

Station No.	B－1 Monorail			B－1' Steel			B－2 Rubber			B－3 Monorail			B－4 Rubber			B－5 Steel		
	km	Down	Up	km	Down	Up	km	Down	Up	km	Down	Up	km	Down	Up	km	Down	Up
1																		
	.8	1:10	1:20	.8	1:00	1:20	.6	1:10	1:20	.8	1:20	1:30	.8	1:20	1:30	.8	1:10	1:30
2																		
	.5	50	50	.5	1:00	1:00	.5	50	50	.5	50	50	.5	50	50	.5	1:00	1:00
3																		
	.4	50	50	.4	50	50	.4	50	50	.7	1:10	1:10	.7	1:20	1:20	.7	1:20	1:20
4																		
	.4	50	50	.4	50	50	.4	50	50	.5	1:00	50	.5	1:00	50	.5	1:00	1:00
5																		
	1.3	1:50	1:50	.5	1:00	1:00	1.3	1:50	2:10	.5	1:10	1:10	.5	1:00	1:20	.5	1:10	1:00
6																		
	.7	1:10	1:10	.8	1:10	1:10	.7	1:10	1:10	.7	1:10	1:10	.7	1:20	1:20	.7	1:20	1:20
7																		
	.8	1:10	1:10	.9	1:30	1:20	.8	1:10	1:10	.7	1:10	1:10	.7	1:10	1:10	.7	1:10	1:10
8																		
	.5	50	1:00	.7	1:10	1:10	.5	50	1:00	.8	1:10	1:10	.8	1:10	1:10	.8	1:10	1:10
9																		
	.9	1:30	1:20	.6	1:00	1:00	.9	1:30	1:20	.5	50	1:00	.5	50	1:00	.5	1:00	1:00
10																		
	.6	1:10	1:00	.9	1:30	1:20	.6	1:10	1:00	.9	1:30	1:20	.9	1:30	1:20	.9	1:30	1:20
11																		
	.8	1:20	1:10	.7	1:20	1:10	.8	1:20	1:10	.6	1:10	1:00	.6	1:10	1:00	.6	1:10	1:10
12																		
	.8	1:20	1:10	.7	1:10	1:10	.8	1:20	1:10	.8	1:20	1:10	.8	1:20	1:10	.8	1:20	1:20
13																		
	1.2	1:30	1:30	.8	1:10	1:10	1.2	1:30	1:30	.8	1:20	1:10	.8	1:20	1:10	.8	1:20	1:20
14																		
	1.3	1:30	1:30	1.2	1:40	1:30	1.3	1:30	1:30	1.2	1:30	1:30	1.2	1:30	1:30	1.2	1:40	1:40
15																		
	1.2	2:00	1:50	1.3	1:50	1:40	1.2	2:10	2:00	1.3	1:30	1:30	1.3	1:30	1:30	1.3	1:40	1:40
16																		
				1.2	2:00	1:40				1.2	2:00	1:50	1.2	2:10	2:00	1.2	2:10	1:50
17																		
18																		
Tota	12.0	19:00	18:30	12.0	20:10	19:20	12.0	19:30	19:00	12.5	20:00	19:30	12.5	20:30	20:30	12.5	21:10	20:50
Stopping time		7:00	7:00		7:30	7:30		7:00	7:00		7:30	7:30		7:30	7:30		7:30	7:30
All Total		26:00	25:30		28:00	27:00		26:30	26:00		27:30	27:00		28:00	28:00		29:00	28:30



Item \ Alternative plan	A − 1	A − 2	A − 3	A − 4	A − 4'	A − 5	A − 6	B − 1	B − 1'	B − 2	B − 3	B − 4	B − 5
	Monorail		Rubber tire		Steel tire		Monorail		Steel tire	Rubber tire	Monorail	Rubber tire	Steel tire
1993	72 (18)	72 (18)	72 (18)	72 (18)	64 (16)	68 (17)	72 (18)	44 (11)	44 (11)	44 (11)	44 (11)	48 (11)	48 (12)
1995	72 (18)	72 (18)	72 (18)	72 (18)	64 (16)	68 (17)	72 (18)	48 (12)	44 (11)	48 (12)	48 (12)	52 (13)	48 (12)
2000	72 (18)	72 (18)	72 (18)	72 (18)	68 (17)	72 (18)	72 (18)	48 (12)	44 (11)	48 (12)	48 (12)	52 (13)	48 (12)
2005	72 (18)	72 (18)	76 (19)	76 (19)	72 (18)	76 (19)	76 (19)	48 (12)	48 (12)	48 (12)	48 (12)	52 (13)	52 (13)

Required rolling stock (cars)
( ): Number of formation

Fig. 2.1 Required Rolling Stock for Each Alternative Plan with Year

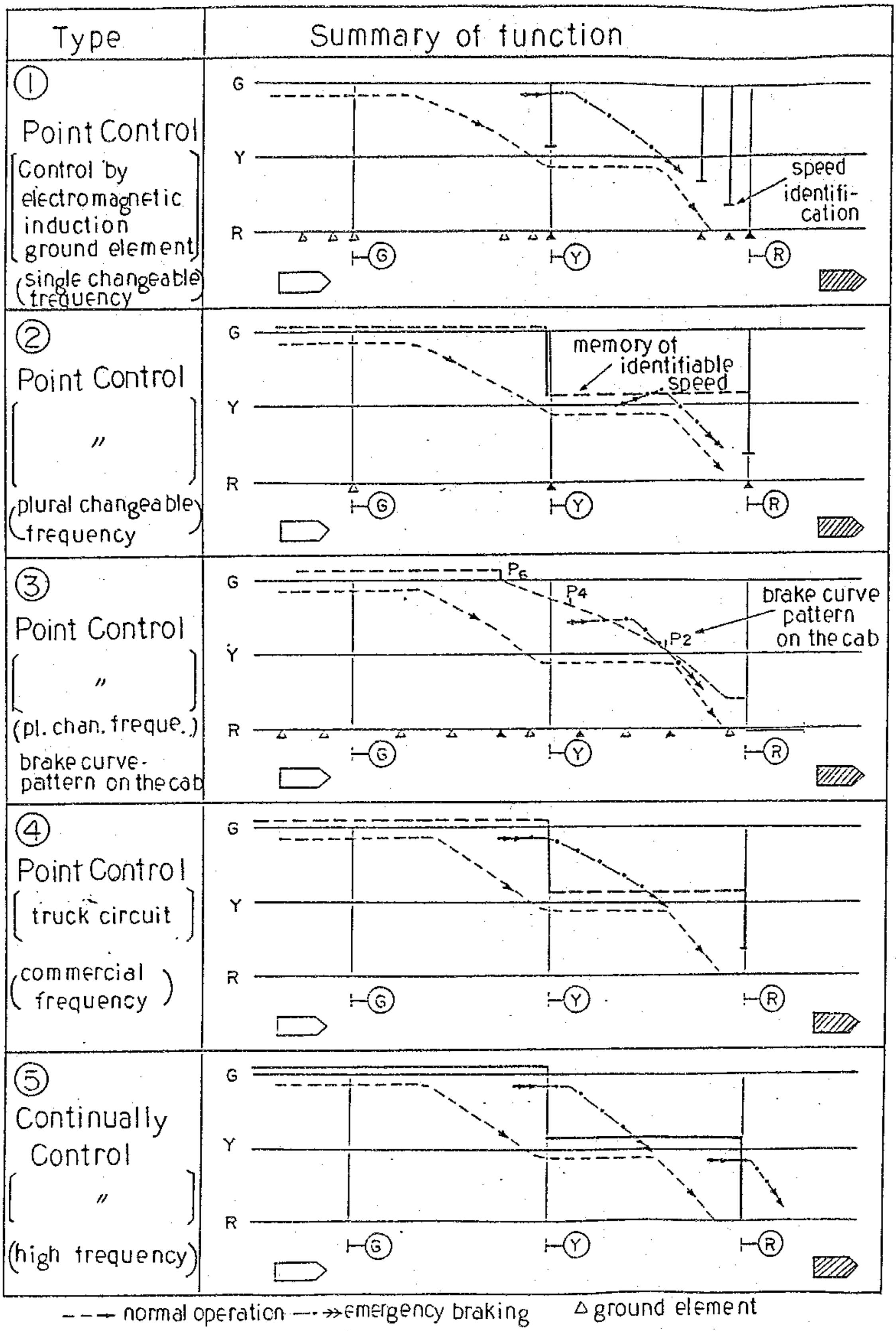


Fig. 2.3 Each Type of ATS

Table 2.4 Train Setting for Rush Hour (7:00 - 8:00)

Item	Alternative plan	A-1	A-2	A-3	A-4	A-4'	A-5	A-6	B-1	B-1'	B-2	B-3	B-4	B-5
	System	Monorail		Rubber		Steel		Monorail	Monorail	Steel	Rubber	Monorail	Rubber	Steel
1993	Transport volume (passengers/hr.)	8,590	8,590	8,590	8,590	8,590	8,590	8,590	5,610	5,610	5,610	5,610	5,610	5,610
	Number of scheduled trains (trains/hr)	13	13	13	13	12	12	13	8	8	8	8	8	8
	Nominal passenger capacity (passengers/hr.)	4,680	4,680	4,784	4,784	4,608	4,608	4,680	2,880	3,072	2,944	2,880	2,944	3,072
	Boarding efficiency (%)	184	184	180	180	186	186	184	195	183	191	195	191	183
1995	Transport volume (passengers/hr.)	8,890	8,890	8,890	8,890	8,890	8,890	8,890	5,730	5,730	5,730	5,730	5,730	5,730
	Number of scheduled trains (trains/hr)	13	13	13	13	12	12	13	9	8	9	9	9	8
	Nominal passenger capacity (passengers/hr.)	4,680	4,680	4,784	4,784	4,608	4,608	4,680	3,240	3,072	3,312	3,240	3,312	3,072
	Boarding efficiency (%)	190	190	186	186	193	193	190	177	187	173	177	173	187
2000	Transport volume (passengers/hr.)	9,150	9,150	9,150	9,150	9,150	9,150	9,150	5,900	5,900	5,900	5,900	5,900	5,900
	Number of scheduled trains (trains/hr)	13	13	13	13	13	13	13	9	8	9	9	9	8
	Nominal passenger capacity (passengers/hr.)	4,680	4,680	4,784	4,784	4,992	4,992	4,680	3,240	3,072	3,312	3,240	3,312	3,072
	Boarding efficiency (%)	195	195	191	191	183	183	195	182	192	178	182	178	192
2005	Transport volume (passengers/hr.)	9,420	9,420	9,420	9,420	9,420	9,420	9,420	6,030	6,030	6,030	6,030	6,030	6,030
	Number of scheduled trains (trains/hr)	14	14	14	14	14	14	14	9	9	9	9	9	9
	Nominal passenger capacity (passengers/hr.)	5,040	5,040	5,152	5,152	5,376	5,376	5,040	3,240	3,456	3,312	3,240	3,312	3,456
	Boarding efficiency (%)	187	187	183	183	175	175	187	186	175	182	186	182	175

Note: Maximum passenger section; A-Route No. 11 - 12 station, B-Route No. 7 - 8 station but A-4' Route, No. 10 - 11 station.

Table 2.5 Summary of Functions of the Total Traffic Control System (TTC)

System		Item	Functional content	Remarks
Operation control system	CTC (centralized traffic control) system	. Collection, and centralized indication, of various types of information . Transmission of information for control . Input and output of display information and information for the making of judgements, to and from the PRC	. Information on train positions, route information, and equipment information, related to hazard prevention, will be transmitted and displayed cyclically, using a central display. . Does transmission of information, provides control for manual route control, train operation control, switching between manual and automatic control, etc. . Provides input and output of various types of information, such as train numbers and information of locations, etc., to and from the PRC.	. The CTC transmission system becomes basic to all systems.
	PRC (programed route control) system	. Tracing of trains . Automatic route control . Adjustment of operation, judgement and control of priorities. . Control of departures . Statistical processing of train operation data	. Train tracing, and output of shift indications, by train number and by information on locations, and the centralized display of this information on the CTC display panel. . Route control output will be done automatically, based on train diagram information at times when individual trains are near a station or departing from a station. . Output of decisions for priority control, and displays indicating alarms, etc., will be provided when a train has been delayed, and when a conflict of routes occurs. . Decisions and signals indicating departure will be output, according to the departure time of the first train, or the location of the previous train, etc. . Processing of the data collected regarding kilometers of train runs, delay times, etc., will be done, and a printout will be done if necessary.	. Indication of suggestions, by CRT according to the authorization and operation, done by the dispatcher sending the orders.
Rolling stock utilization control system		. Rolling stock utilization control processing . Statistical processing of data on running kilometers of rolling stock . Administration of history of inspections and repairs of rolling stock . Control of lines within yard for rolling stock	. Preparation of daily plans for rolling stock utilization, and the data processing of actual records, will be done, and printouts will be made. . The totalling of running kilos for each unit of rolling stock, will be processed, and printouts will be done. . Administrative data on the history of the rolling stock, will be printed out according to the data on running kilometers for rolling stock, and according to the data on inspections and repairs, etc. . Orders for movements into and out of the rolling stock shed, and storage plan data, will be output, based on the rolling stock utilization control and processing data, and on data from the history of inspections and repairs of rolling stock, etc.	. Interfacing of this system will be done, with the electronic interlocking universal computer.
Electrical power-signal control system		. Remote surveillance and manual control . Automatic control of electric power equipment . Restoration of power after power failure, and processes for the restoration of the receiving of electrical power. . Statistical processing of data on electrical power	. The status of the electrical power systems in the substation will be indicated on the electrical power system control panel. Control signals for the switching on and off of equipment, will be output as needed. . Signals indicating that electrical power equipment is not under automatic control, will be sent according to the daily equipment control pattern. . Automatic procedures will be carried out each time an irregularity has occurred, in accordance with the treatment procedure to be followed when an irregularity occurs, and the treatment procedures for the restoration and receiving of electrical supply. . Engages in collecting processing data such as electric power volume.	. Includes central surveillance of signal wave transmission status, etc.
Office work control system		. Station duty data control . Transmission of data on administrative work	. Processing for the totalling of revenue and of the numbers of passengers boarding and disembarking, etc., for all stations, will be done according to the input data on the number of tickets issued at each station, etc. . The transmission of various orders and items of information, will be done.	. Data from booking machines in each station, will be centrally processed.

Table 2.6 (1) Transport Plan

Item / Running level / System (Alternative plan)		A − 1	A − 2	A − 3	A − 4	A − 4'	A − 5	A − 6
Running level		Elevation	Underground, elevation	Underground, elevation	Underground, elevation	Underground, elevation, ground	Elevation	Elevation
System		Monorail	Monorail	Rubber-tire	Rubber-tire	Steel-wheel	Steel-wheel	Monorail
Commercial distance (km) ( ): underground section		14.2	(1.9)+12.3=14.2	(1.9)+12.3=14.2	(3.3)+10.9=14.2	(6.8)+7.4=14.2	15.0	15.0
Number of stations (stations)		18	18	18	18	17	18	18
Train hour (min.: sec.)	Down	29:30	29:30	30:00	30:00	30:00	31:30	30:30
	Up	29:00	29:00	29:30	29:30	29:30	31:00	30:00
Commercial speed (km/hr.)		28.9	28.9	28.4	28.4	28.4	28.6	29.5
Rush hour Number of scheduled trains (trains/track-hr.) (min: sec): headway	1993	13 (4:40)	13 (4:40)	13 (4:40)	13 (4:40)	12 (5:00)	12 (5:00)	13 (4:40)
	1995	13 (〃)	13 (〃)	13 (〃)	13 (〃)	12 (〃)	12 (〃)	13 (〃)
	2000	13 (〃)	13 (〃)	13 (〃)	13 (〃)	13 (4:40)	13 (4:40)	13 (〃)
	2005	14 (4:20)	14 (4:20)	14 (4:20)	14 (4:20)	14 (4:20)	14 (4:20)	14 (4:20)
Boarding efficiency at rush hour (%)	1993	184	184	180	180	186	186	184
	1995	190	190	186	186	193	193	190
	2000	195	195	191	191	183	183	195
	2005	187	187	183	183	175	175	187
total of scheduled trains (up + down) (trains/day)	1993	156	156	156	156	152	152	156
	1995	164	164	158	158	152	152	164
	2000	166	166	164	164	160	160	166
	2005	178	178	178	178	176	176	178
Required of rolling stock (cars) ( ): number of formations	1993	72 (16+2=18)	72 (16+2=18)	72 (16+2=18)	72 (16+2=18)	64 (14+2=16)	68 (15+2=17)	72 (16+2=18)
	1995	72 (〃)	72 (〃)	72 (〃)	72 (〃)	64 (〃)	68 (〃)	72 (〃)
	2000	72 (〃)	72 (〃)	72 (〃)	72 (〃)	68 (15+2=17)	72 (16+2=18)	72 (〃)
	2005	72 (〃)	72 (〃)	76 (17+2=19)	76 (17+2=19)	72 (16+2=18)	76 (17+2=19)	76 (17+2=19)

Table 2.6 (2) Transport Plan

Item / Running level / System / Alternative plan		B – 1 Underground, elevation Monorail	B – 1' Underground, elevation, ground Steel-wheel	B – 2 Underground, elevation Rubber-tire	B – 3 Elevation Monorail	B – 4 Elevation Rubber-tire	B – 5 Elevation Steel-wheel
Commercial distance (km) ( ): underground section		(2.6)+9.4=12.0	(3.7)+8.3=12.0	(2.6)+9.4=12.0	12.5	12.5	12.5
Number of stations (stations)		16	17	16	17	17	17
Train hour (min.: sec.)	Down	26:00	28:00	26:30	27:30	28:00	29:00
	Up	25:30	27:00	26:00	27:00	28:00	28:30
Commercial speed (km/hr.)		27.7	25.7	27.2	27.3	26.8	25.9
Rush hour Number of scheduled trains (trains/track-hr.) (min: sec): headway	1993	8 (7:30)	8 (7:30)	8 (7:30)	8 (7:30)	8 (7:30)	8 (7:30)
	1995	9 (6:40)	8 (〃)	9 (6:40)	9 (6:40)	9 (6:40)	8 (〃)
	2000	9 (〃)	8 (〃)	9 (〃)	9 (〃)	9 (〃)	8 (〃)
	2005	9 (〃)	9 (6:40)	9 (〃)	9 (〃)	9 (〃)	9 (6:40)
Boarding efficiency at rush hour (%)	1993	195	183	191	195	191	183
	1995	177	187	173	177	173	187
	2000	182	192	178	182	178	192
	2005	186	175	182	186	182	175
total of scheduled trains (up + down) (trains/day)	1993	124	124	124	124	124	124
	1995	126	124	126	126	126	124
	2000	126	124	126	126	126	124
	2005	128	128	128	128	128	128
Required of rolling stock (cars) ( ): number of formations	1993	44 (9+2=11)	44 (9+2=11)	44 (9+2=11)	44 (9+2=11)	48 (10+2=12)	48 (10+2=12)
	1995	48 (10+2=12)	44 (〃)	48 (10+2=12)	48 (10+2=12)	52 (11+2=13)	48 (〃)
	2000	48 (〃)	44 (〃)	48 (〃)	48 (〃)	52 (〃)	48 (〃)
	2005	48 (〃)	48 (10+2=12)	48 (〃)	48 (〃)	52 (〃)	52 (11+2=13)

Table 2.6 (3) Transport Plan

Item / Running level / Alternative plan / System		A − 4" Underground, elevation, ground Steel-tire	B − 1 + (side line) Underground, elevation Monorail		B − 5 + (side line) Elevation Steel-tire	
Commercial distance (km) ( ): underground section		(7.6)+6.6=14.2	(2.6)+9.4=12.0	+ [3.1] =15.1	12.5	+ [3.1] =15.6
Number of stations (stations)		18	16+3=19		17+3=20	
Train hour (min.: sec.)	Down	30:30	26:00	6:30	29:00	6:30
	Up	30:30	25:30	6:30	28:30	6:30
Commercial speed (km/hr.)		27.9	27.7	28.6	25.9	28.6
Rush hour Number of scheduled trains (trains/track-hr.) (min: sec): headway	1993	12 (5:00)	10 (6:00)	3 (20:00)	9 (6:40)	3 (20:00)
	1995	12 (〃)	10 (〃)	3 (〃)	9 (〃)	3 (〃)
	2000	13 (4:40)	11 (5:30)	3 (〃)	10 (6:00)	3 (〃)
	2005	14 (4:20)	11 (〃)	4 (15:00)	11 (5:30)	3 (〃)
Boarding efficiency at rush hour (%)	1993	186	171	160	179	150
	1995	198	176	165	184	155
	2000	183	172	178	177	167
	2005	175	183	143	172	179
total of scheduled trains (up + down) (trains/day)	1993	152	144	72	142	72
	1995	152	144	72	142	72
	2000	160	150	72	144	72
	2005	176	150	74	148	72
Required of rolling stock (cars) ( ): number of formations	1993	68 (15+2=17)	52 (11+2=13)	8 (2)	52 (11+2=13)	8 (2)
	1995	68 (〃)	52 (〃)	8 (2)	52 (〃)	8 (2)
	2000	72 (16+2=18)	56 (12+2=14)	8 (2)	56 (12+2=14)	8 (2)
	2005	76 (17+2=19)	56 (〃)	8 (2)	60 (13+2=15)	8 (2)

3 STATION PLAN

3. STATION PLAN

3.1 An Example of the Average Distance between Stations

The distance between stations of the urban railway is generally said to be about 1,000 m. Below is an example of the distance of the existing stations.

Table 3.1 Average Distance between Stations of the Japanese Urban Transportation System

Item / System	Name of line	Length (km)	Number of stations	Average distance between stations(m)
. Underground subway				
Eidan subway	Ginza line	14.3	18	841
Tokyo subway	Asakusa line	18.3	20	963
Nagoya subway	Higashiyama line	17.5	22	833
Osaka subway	Line No. 1	19.5	17	1,219
Kobe subway	Nishigami-Yamanote line	10.0	8	1,429
. Rubber tire				
Sapporo subway	Nanboku line	14.3	16	953
. Monorail				
Kitakyushu Monorail	Kokura line	8.4	12	764
. Tramway				
Hiroshima Dentetsu line	Miyazima line	16.1	17	1,006
			Average	1,001 (m)

Table 3.2 Average Distance between Stations of the Urban Transportation System in the World

City	Name of the company	Length (km)	Number of stations	Average distance between stations (m)
London	Transport corporation	387.9	248	1,564
Paris	Régie autonome des transports Parisients	190.8	359	531
Stockholm	Transport corporation	103.6	94	1,102
West Berline	Transport corporation	100.9	111	909
Madrid	Underground subway company	94.5	133	711
Moscow	Underground subway	184.0	115	1,600
New York	Transport corporation	371.1	458	810
Mexico	Mass transport corporation	78.3	80	879
			Average	1,026(m)

4 ELECTRIC FACILITY PLAN

4. ELECTRIC FACILITY PLAN

4.1 Calculation on Voltage Drop

4.1.1 Prerequisite

Feeding System	DC 1500 V Parallel Feeding
Short Circuit Capacity	235 MVA
Rectifier	2,000 kW, Voltage regulation rate 6%
1 set or 2 set	
Full-Load Voltage	1500 V
Contact Line System	
Underground	
Rigid Contact Line System	
Contact Wire	GT 110 mm^2
Support	Al-T type 2100 mm^2
Ground or Elevated	
Simple Catenary System	
Contact Wire	GT 110 mm^2
Messenger Wire	St 90 mm^2
Feeder Wire	Al 510 mm^2
Feeding System Structure	
Shown in Fig. 4.1	
Train Interval	
Under 4 Minutes Headway	2 km
Train Load Current	
Maximum Starting Current	1350A
Powering Current	675A

The load distribution on up and down direction lines are the same.
A starting and a powering in every two trains.

Rail

50 kg Rail with 30% Leakage Current

4.1.2 Resistance

Power Source		0.00957 Ω
Rectifier	1 set	0.06750 Ω
	2 set	0.03375 Ω

Line Resistance

Rigid Contact Line System	0.0270Ω/km
Simple Catenary System with Feeder	0.0556Ω/km

4.1.3 Load Condition

1) Normal Condition	See Fig. 4.2 - 4
2) In Case of Failure	See Fig. 4.5 - 8

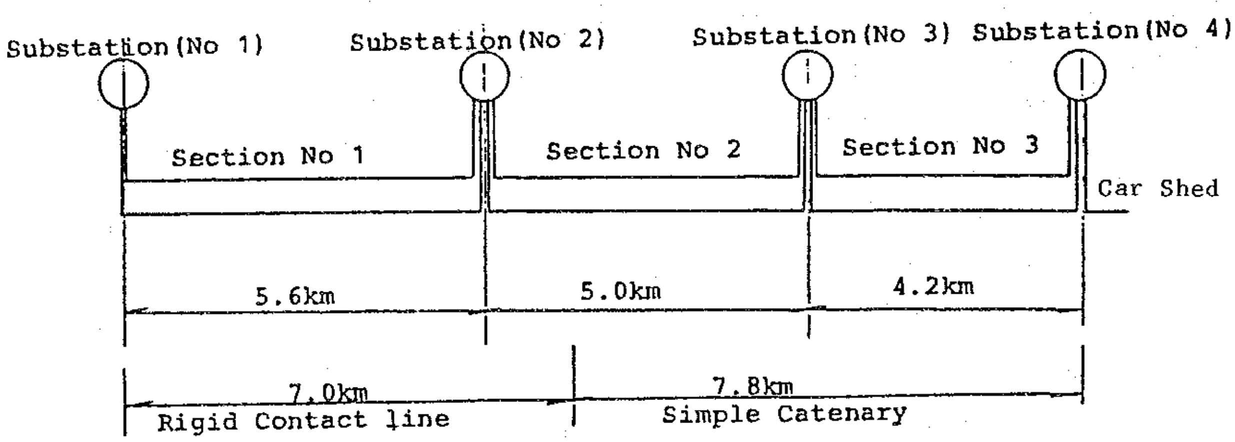


Fig. 4.1 Feeding System Plan

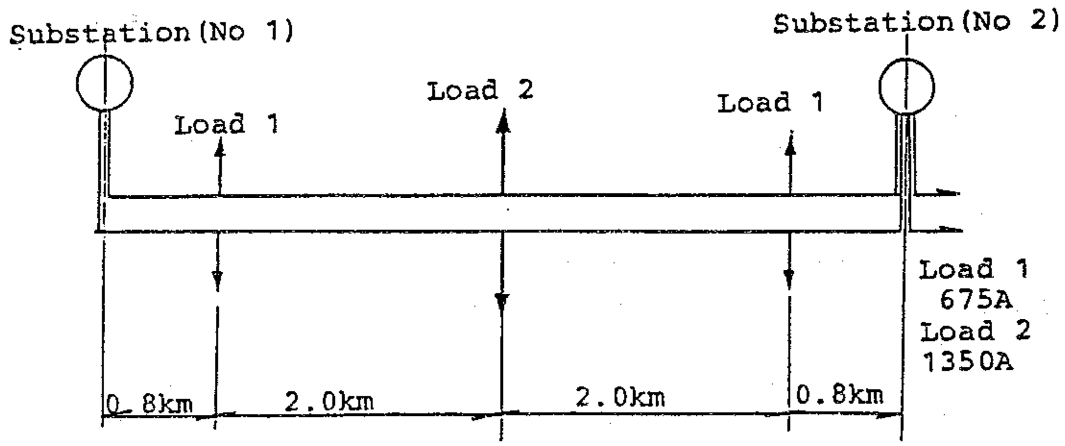


Fig. 4.2 Load Condition Section No. 1 Normal

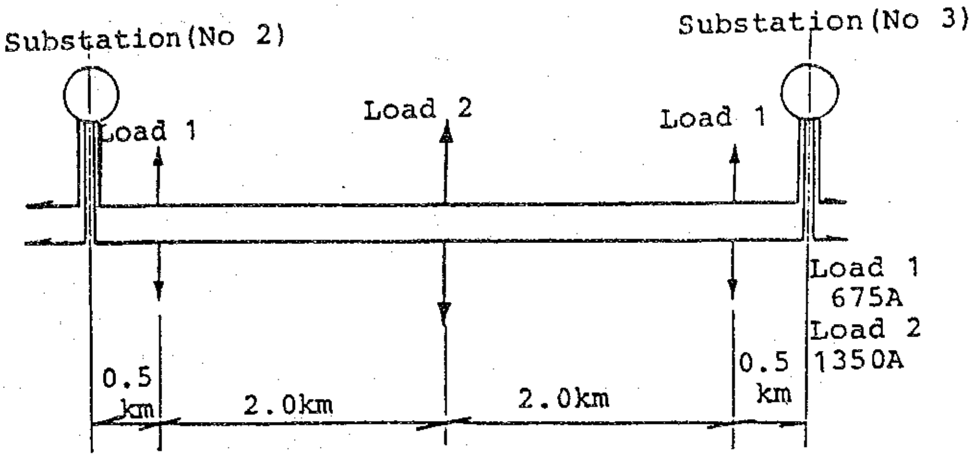


Fig. 4.3 Load Condition Section No. 2 Normal

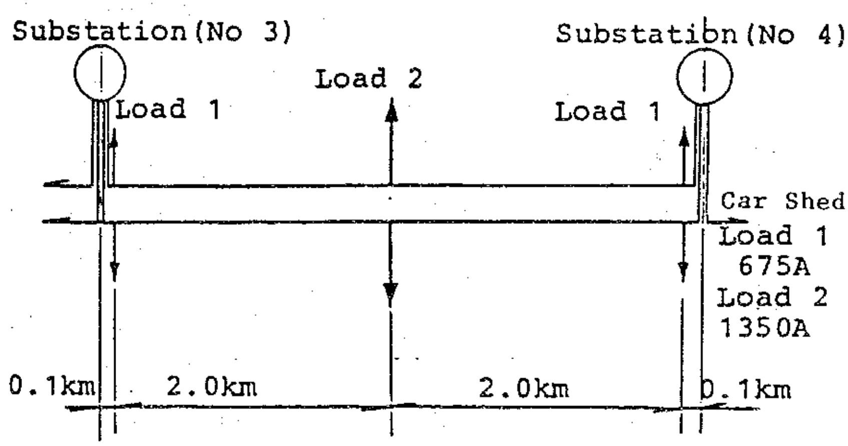


Fig. 4.4 Load Condition Section No. 3 Normal

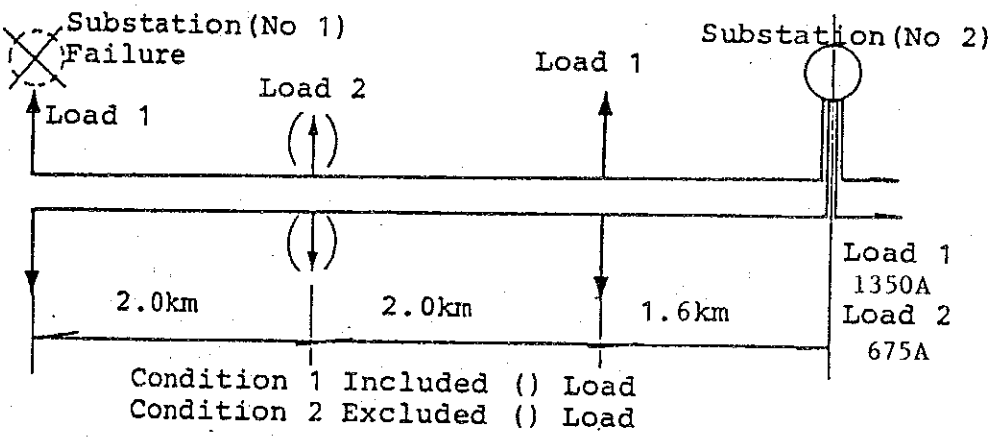


Fig. 4.5 Section No. 1 in Case of Failure

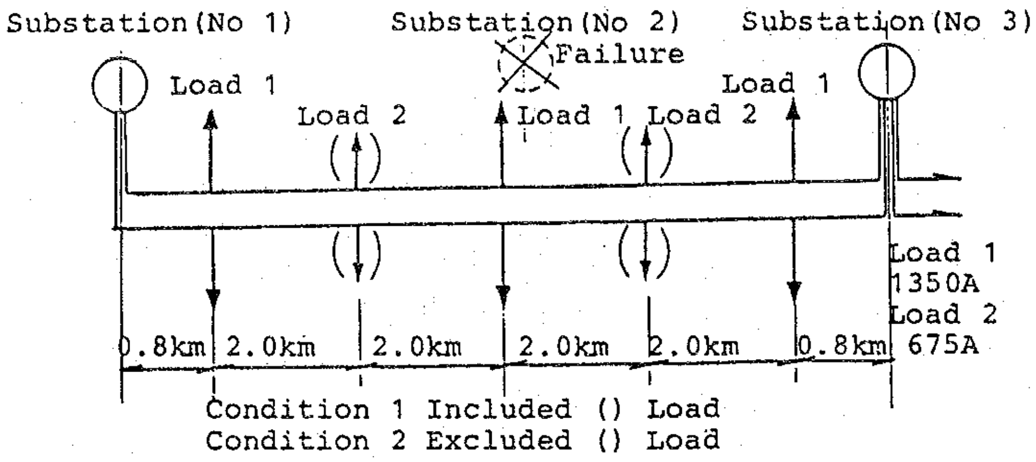


Fig. 4.6 Section No. 1 and No. 2 in Case of Failure

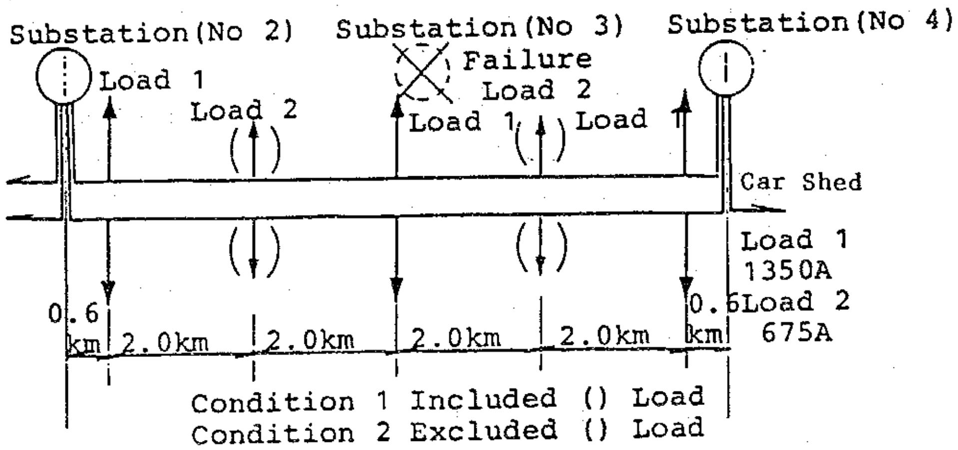


Fig. 4.7 Section No. 2 and No. 3 in Case of Failure

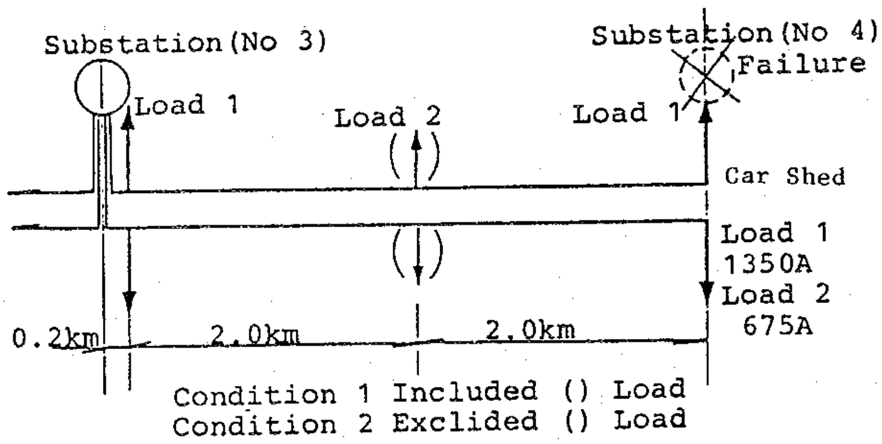


Fig. 4.8 Section No. 3 in Case of Failure

4.1.4 Calculation Result

Under the condition mentioned above, estimated minimum voltage in Contact line system is shown in Table 4.1.

Table 4.1 Minimum Contact Line Voltage (V)

<table>
<tr><th rowspan="2">Condition</th><th rowspan="2">Normal Condition (SR x 1)</th><th colspan="2">Failure in Substation 1 SR x 2</th><th colspan="2">Failure in Substation 2 SR x 2</th><th colspan="2">Failure in Substation 3 SR x 2</th><th colspan="2">Failure in Substation 4 SR x 2</th></tr>
<tr><th>Condition 1</th><th>Condition 2</th><th>Condition 1</th><th>Condition 2</th><th>Condition 1</th><th>Condition 2</th><th>Condition 1</th><th>Condition 2</th></tr>
<tr><td>Section 1</td><td>1225</td><td>No good (880)</td><td>1004</td><td>No good (983)</td><td>1066</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Section 2</td><td>1190</td><td></td><td></td><td></td><td></td><td rowspan="2">No good (972)</td><td rowspan="2">1121</td><td></td><td></td></tr>
<tr><td>Section 3</td><td>1210</td><td></td><td></td><td></td><td></td><td>No good (925)</td><td>1068</td></tr>
</table>

4.1.5 Conclusion

Outline of the result is shown below.

(1) Under normal condition, the system has no problem concerning about voltage drop.

(2) The load limitation is necessary even if two sets of rectifiers are operated in case of failure. However prerequisite load condition is a heavy condition, therefore, the train is expected to be operated under light load limitation.

4.2 Estimation of Rectifier Capacity

Rectifier capacity is calculated below concerned about optimum plan A4'. For example, the calculation about other alternative plans are also shown below.

4.2.1 Prerequisite

(1) Power Consumption Rate

Steel Wheel	86 kWh/1000 t-km
Monorail, Rubber Tire	132 kWh/1000 t-km

(2) Train Headway

Route A	4 minutes
Route B	6 minutes

(3) Car Weight (Weight of Train Set)

Steel Wheel	148 t (175% passengers)
Monorail	143 t (187% passengers)
Rubber Tire	134 t (183% passengers)

4.2.2 Consumed Power in Peak One Hour

(1) One Hour Average Maximum

Pt(kW) = Feeding distance (km) x 60 min./Train headway (min)
x 2 x Weight of train set (1000 t)
x Power consumption rate (kWh/1000 t-km)

(2) Instantaneous Maximum

$Z(kW) = Pt + C\sqrt{Pt}$ (Equation based on experience in Japan)

$C = 1.7\sqrt{Im}$

Im = Maximum current of one train set

Steel Wheel	1350A
Monorail	1500A
Rubber Tire	

4.2.3 Result

Feeding distance is 5.3 km for No. 2 substation in plan A4'. And for other alternatives, standard feeding distance of one substation is 5 km for Route A and 6 km for Route B. Calculation result is shown in Table 4.2.

Note: Over load rating of a rectifier is assumed as 300 per cent in one minute according to Japan National Railway's standard.

4.2.4 Conclusion

Rectifier is selected to have a capacity more than one hour maximum load and more than instantaneous maximum load/2.5 (divide by 2.5 with surplus to over load rating of 300 per cent).

Arranged to upper nearest value, estimation result is shown in Table 4.2

Table 4.2 Rectifier Capacity (kW)

Alternative	A4'	A4	A2	A6	B1	B1'	B5
One Hour Average Maximum	1873	2512	2680	2831	2265	1510	1573
Instantaneous Maximum	4610	5812	5913	6334	5398	3937	4050
Rectifier Capacity	2000	3000	3000	3000	2500	2000	2000

4.3 Influence on Power Source

4.3.1 Estimation of Voltage Fluctuation Rate

Maximum consumption power (instantaneous) is 4610 kW at No. 2 substation in the plan A4'. If power factor is presumed as 0.9, maximum consumption power PL (kVA) is shown below;

$$PL = 4610/0.9\ (\cos\theta) = 5122\ \text{kVA}$$

Voltage drop rate (ΔV) is shown below;

$$\Delta V = PL/PS \times \sin\theta = 0.0095 \ (\fallingdotseq 1\%)$$

PS: Short Circuit Capacity of Power source 235 MVA

Maximum voltage drop rate is about 1 per cent. Voltage fluctuation rate is less than voltage drop rate, then there is no problem.

4.3.2 Estimation of High Harmonics

Influence of high harmonics on power source is estimated below.

(1) Prerequisite

Maximum consumption power (PL) is 5122 kVA, same as 4.3.1.
Fundamental harmonic (I_1) is;

$$I_1 = 5122kVA/20kV/\sqrt{3} = 147.9A$$

High harmonic currents contained in load current vary greatly depending on circuit conditions.

This calculation is done under the prerequisite that the rectifier has 10 per cent commutation reactance.

(2) Calculation Formula

1) Impedence of power source applied to fundamental harmonic (Xo)

$$Xo = V^2/PS = (20\ kV^2)/235\ MVA = 1,702\Omega$$

V; Source Voltage

2) Each harmonics distortion

$$\Delta Vi = \frac{2 \times Xo \times Ii}{V}$$

i: Harmonic number

Ii: ith harmonic current

3) Total distortion ($\Sigma\Delta V$)

$$V = \sqrt{\Sigma \Delta Vi^2}$$

Number of rectification pulses calculated are 6, 12 and 24.

(3) Calculation result

Calculated values, containing rate of each harmonic against fundamental harmonic, each harmonic current and distortion factors are shown in Table 4.3.

Table 4.3 Estimation of High Harmonics

		Number of high harmonic								Total
		5th	7th	11th	13th	17th	19th	23th	25th	--
6 pulse	containing rate	17.5%	11.0	4.5	3.0	1.5	1.25	0.75	0.75	--
	each harmonic current	Δ 25.86A	Δ 16.20	Δ 6.66	Δ 4.43	Δ 2.22	Δ 1.84	1.11	1.11	--
	distortion factor	Δ 1.10%	0.97	0.62	0.49	0.32	0.30	0.23	0.23	1.88
12 pulse	containing rate	2.0%	1.5	4.5	3.0	0.2	0.15	0.75	0.75	--
	each harmonic current	2.96A	2.21	Δ 6.66	Δ 4.43	0.30	0.22	1.11	1.11	--
	distortion factor	0.13%	0.13	0.62	0.55	0.04	0.03	0.23	0.23	0.91
24 pulse	containing rate	2.0%	1.5	1.0	0.75	0.2	0.15	0.75	0.75	--
	each harmonic current	2.96A	2.21	1.48	1.11	0.30	0.22	1.11	1.11	--
	distortion factor	0.13%	0.13	0.13	0.13	0.04	0.03	0.23	0.23	0.42

Note Δ: exceed Japanese Standard

(4) Conclusion

Short circuit capacity of 235 MVA is comparatively small as a power source for traction substation. Therefore, according to the result described before, a few distortion factor of 6 pulse exceed Japanese standard and some current values of 6 and 12 pulse exceed the standard.

If the rectifier is used without counter measures against high harmonics, more than 24 pulse rectification is required. However 24 pulse rectification is difficult to be done by a set of rectifier because the connection method of transformer become complicated causes the raise of manufacuting cost.

As a conclusion, 12 pulse rectifier is used for the MRT Plan with high harmonic counter measures. And in the actual implementation stage, farther discussion with RAD should be held concerned about standard values, calculation methods and etc. since this calculation was done based on Japanese standards.

4.4 Signalling Safety Equipment

4.4.1 Outline

In introducing MRT in Casablanca and operating it in safety, on time and at high speeds, a plan is studied and formed for the provision of signalling safety equipment based on the transportation plan shown in 10.2 main body.

Alternative systems proposed are:

a. Steel wheel system
b. Monorail system
c. Rubber tire system

The signalling safety equipment required for these systems comprise:

a. Train detection device in the cases of the monorail and rubber tire systems

b. Signal equipment in the cases of the monorail, rubber tire and steel wheel systems

c. Interlocking device in the cases of the monorail, rubber tire and steel wheel systems

d. Track circuit equipment in the case of the steel wheel system

e. Automatic Train Control (ATC) system in the cases of the monorail and rubber tire systems

f. Automatic Train Stop (ATS) system in the cases of the monorail, rubber tire and steel wheel systems

g. Turnout machine in the cases of the monorail, rubber tire and steel wheel systems

h. Centralized Traffic Control (CTC) system in the cases of the monorail, rubber tire and steel wheel systems

i. Level crossing protection device in the case of the steel wheel system

j. Electric power source in the cases of the monorail, rubber tire and steel wheel systems

k. Distribution line equipment in the cases of the monorail, rubber tire and steel wheel systems

4.4.2 Train Operation Safety System

(1) Block System

In the cases of the monorail and rubber tire systems, the automatic block system -- a check-in and check-out count system of transmitting signal from train and receiving it on the ground to detect the moving of the train -- is adopted, since the track short circuit block system is not allowed to be used.

In the case of the steel wheel system, the automatic block system, the system of detecting the existence and movement of a train with the wheel axle and continuous track circuit, is adopted.

Fig. 4.13 shows the Impedance Bond equipped on the boundary between track circuits.

(2) Signal System

In the cases of the monorail and rubber tire systems, the cab signal system is adopted.

Compared with the ground signal system, the cab signal system has the following advantages. As the system uses electronic devices, however, it is necessary to pay close attention to the designing for the enhancement of reliability.

a. Signal indications can always be identified, since they receive no influence of weather conditions, such as haze, mist or fog, track curve, grade, and others that obstruct their visibility.

b. Misidentification of signal indications for those of other signals, as in the case of ground signal system, can by no means be made.

c. The block section can be settled up as calculated theoritically without consideration of identification of signal compared to the pole mounting under the ground signal system.

d. Essential parts of ground machines and devices can be so concentrated they can be more easily maintained and protected.

Not only the cab signal system with electronic devices used is more advantageous over the ground signal system, but it can be combined with ATC system with ease.

In the case of the steel wheel system, the ground signal system is adopted.

The ground signal system has shown good performance, used in many cases and highly reliable. It is possible to increase the number of block sections with ease by erecting additional signals between stations. This system is suitable for the highly dense operation of trains. For deciding the system, however, it is necessary to take into account the number of block sections, the locations of signal, the operation of trains and the condition of tracks.

Fig. 4.9 shows home and starting signal in the underground section. Fig 4.10 shows block signal, Fig. 4.11 shows shunting signal and Fig. 4.12 shows shunting signal and route indicator in the ground and elevated section.

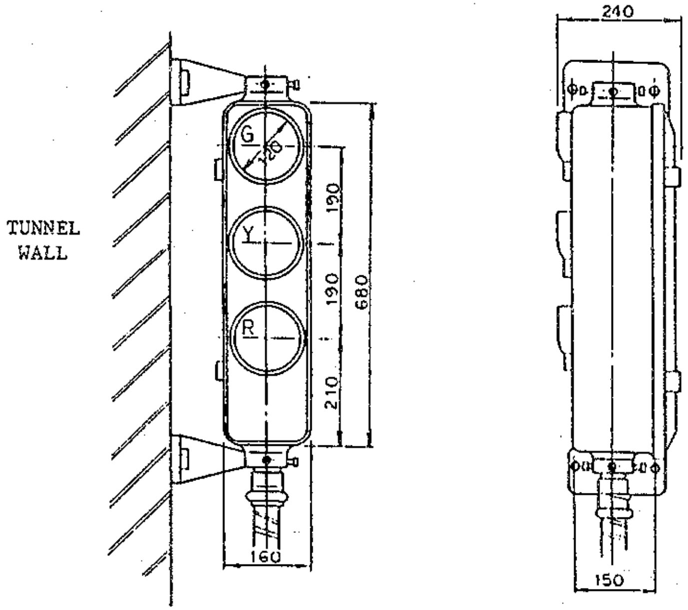


Fig. 4.9 Home and Starting Signal
(Underground Section)

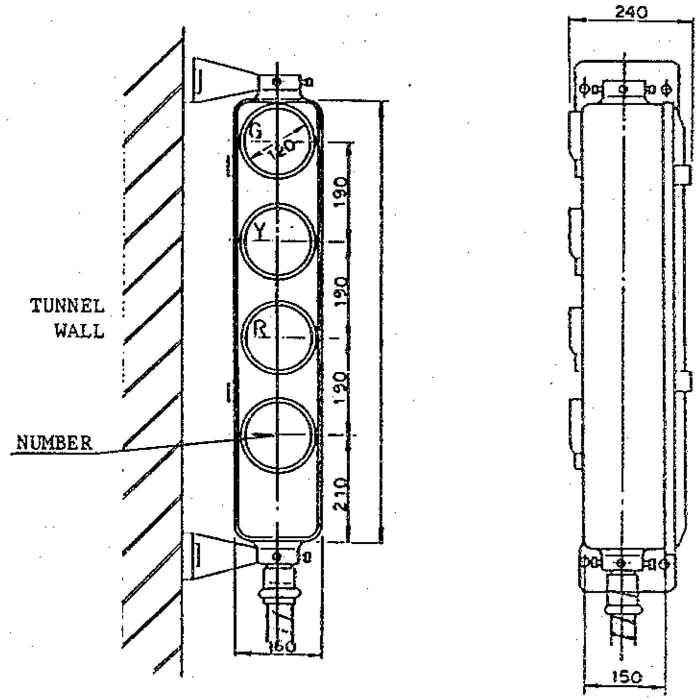


Fig. 4.10 Blocking Signal
(Underground Section)

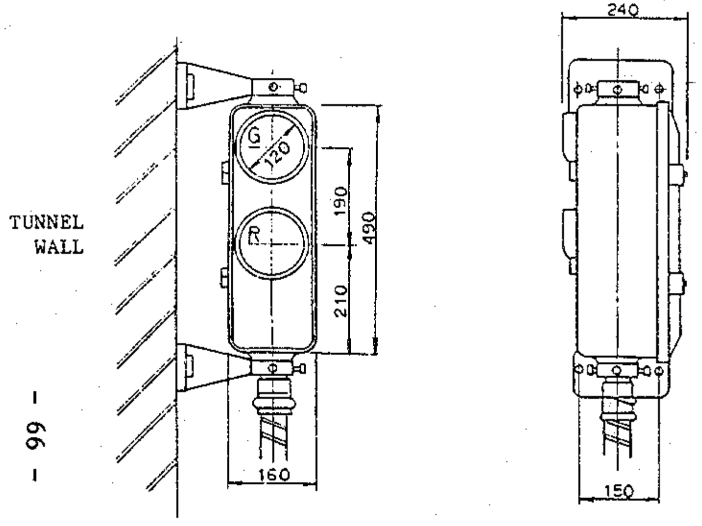


Fig 4.11 Shunting Signal (Underground Section)

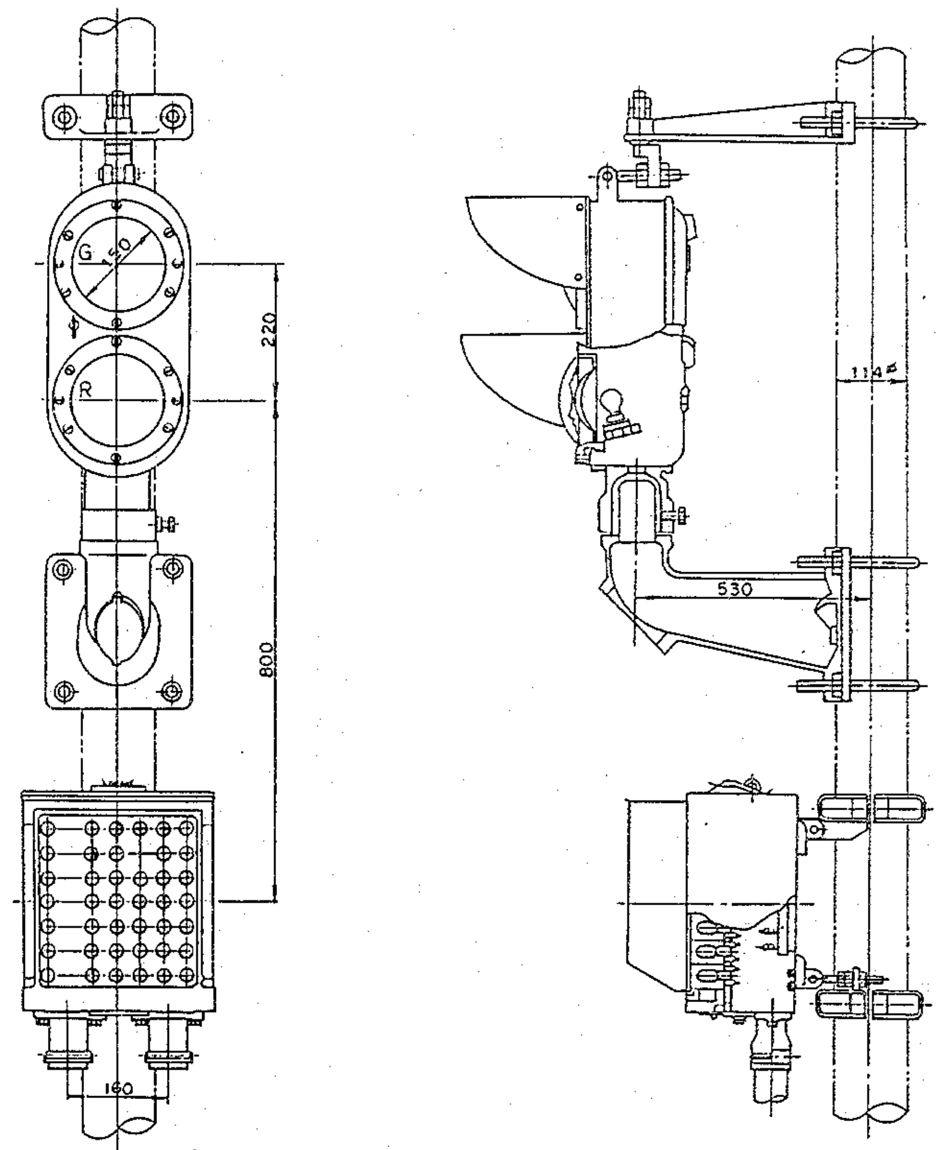


Fig 4.12 Shunting Signal and Route Indicator
(Ground Section)

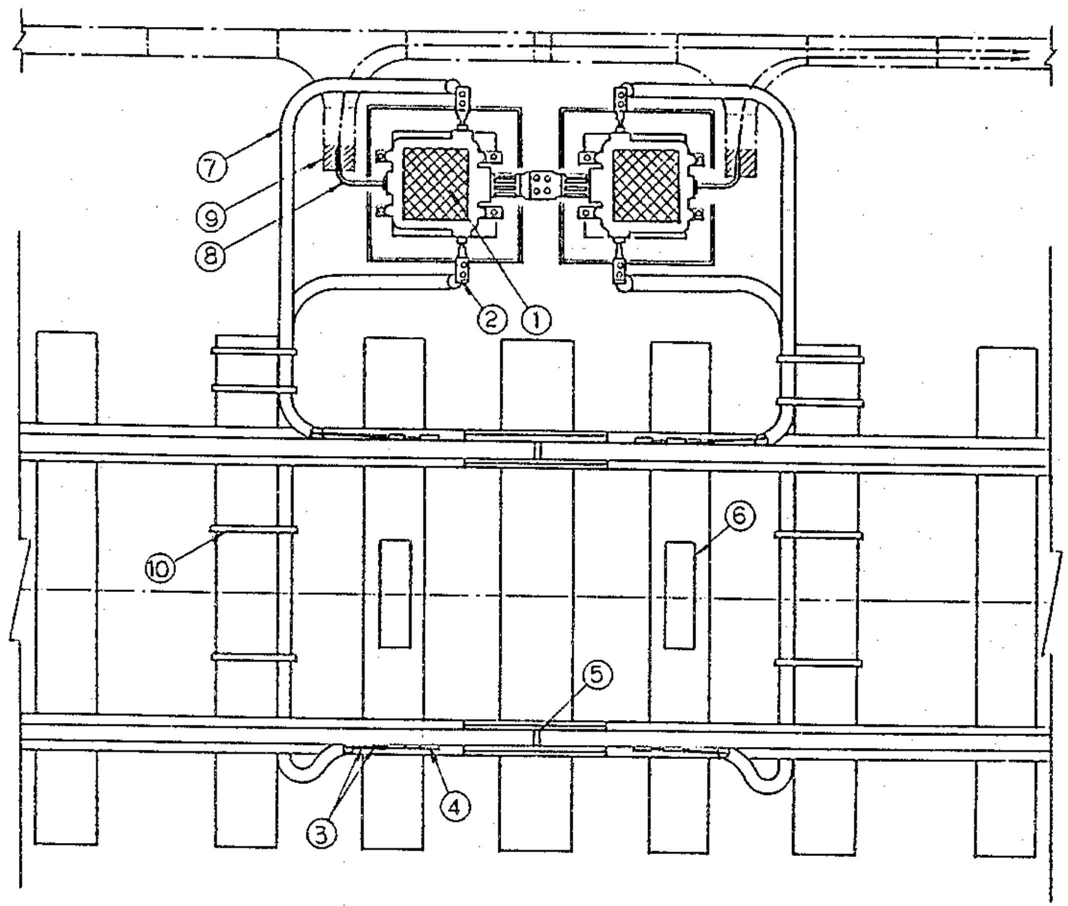


Fig. 4.13 Construction of Impedance Bond Installation

(3) Train Control System

There are three systems to automatically control the operation of trains: ATS system that functions to automatically stop a train by stop signal; ATC system that functions to reduce the speed of a train or stop it when it has entered a section by caution or stop signal; and ATO system that has functions, in addition to those of the ATC system, to control the powering of the train and to stop the train at a fixed place at station.

a. ATS system

In the automatic signal system under the plan introduced are the track circuit equipment, train detection device, automatic ground or cab signal, electric turnout machine and relay interlocking device for the safe operation of trains. Therefore, trains operate in safety as far as they observe the indications of signals; however, it is feared that if the driver happens to fall sick all of a sudden or ignores the signal carelessly, the train might give rise to a serious accident, such as collision or derailment.

It is necessary, therefore, to install an ATS system that functions to automatically stop a train when it approaches a stop signal or receive a stop signal an alarm of warning rings and yet the driver fails to apply the brakes within the fixed time, on a heavy traffic section.

b. ATC system

This system transmits the high-frequency current modulated according to the signal indication to the loop line and makes it information for the automatic control of train -- a system of high-frequency, continuous induction ATC and cab indication.

The information is on modulated waves, using as carrier waves more than 10 kHz. The kinds of the information are 80, 65, 45, 30, 0 and X in six steps.

High-frequency current transmitters/receivers are concentrated in the equipment room provided at appropriate intervals. The concentration area is appropriate to be about 10 km, 5 km on either side of the equipment room. The on-board device functions to receive the high-frequency current flowing in the track circuit or loop line with its receptor through eletromagnetical induction effect, compares the signal output selected out from the receiver with the speed generator output at the speed checking part, and, when the train speed exceeds the limit speed, automatically reduce it under that limit speed or stop the train.

The purpose of using this system is to automatically control the speed of a train according to the signal condition, track curve, route, branch, grade, etc.

c. Comparison between cab signal ATC system and ground signal system

Compare the operation of trains under the cab signal ATC system with that under the ground signal system. In the case of the latter, according to the signal indication, the train must operate under the speed represented by that signal indication when passing the signal concerned; therefore, the driver confirms the signal indication before the signal, applies the brakes if necessary, and must reduce the speed under the represented limit speed before passing the signal.

Therefore, it is necessary for the visibility to be long enough to reduce the speed to the limit speed when the driver has confirmed the signal indication before passing the signal. Actually, it is not so easy to choose a place for erecting a signal post where a good visibility is available.

In the case of the former, on the contrary, when a train is beginning to enter a section, it receives the signal for that section indicated in the cab.

When the train enters the lower speed section, it automatically reduces the speed and releases the brakes when it comes down under the indicated limit speed, then allowed to continue operating at or below that speed.

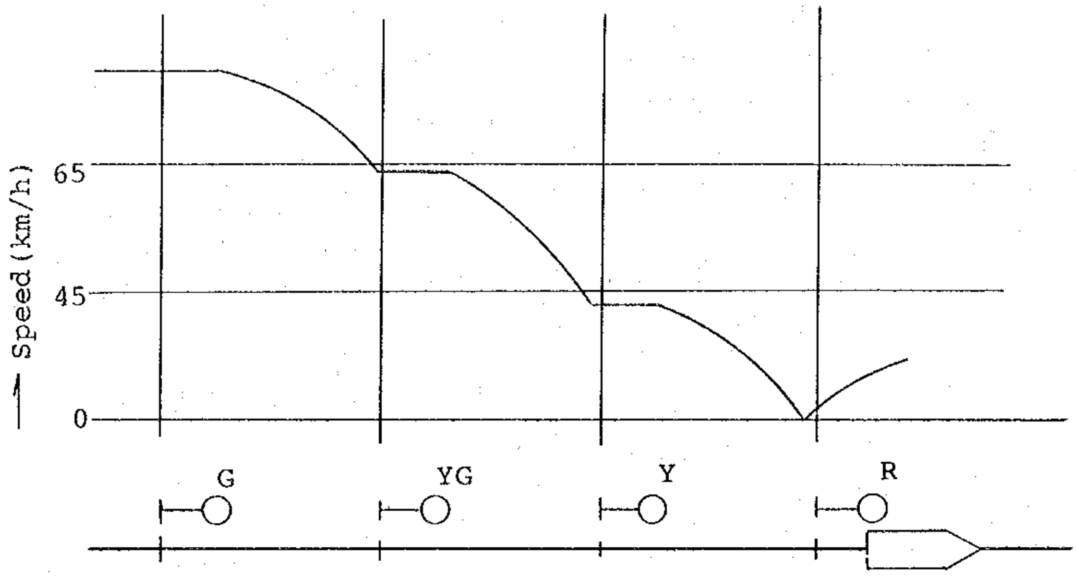


Fig. 4.14 Run Curve (Ground Signal)

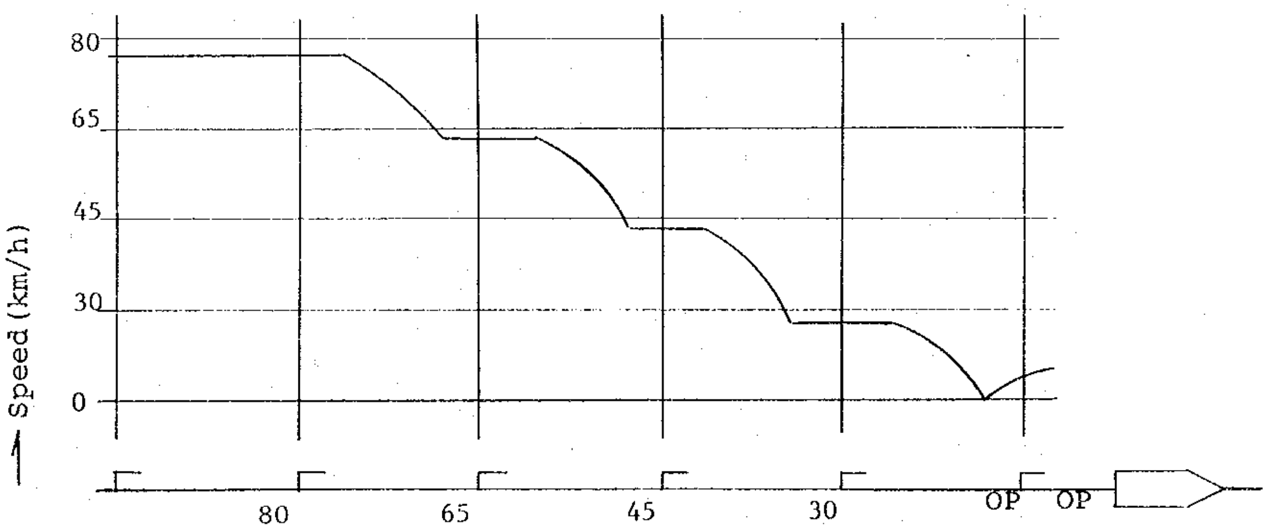


Fig. 4.15 Run Curve (Cab Signal)

OP signal that stops a train within the OP signal section at a fixed deceleration speed; confirmation can be made within the OP signal section only, the train allowed later to operate at speeds lower than 15 km/h.

As can be seen from the foregoing, the ATC system may save manpower. For the time being, however, an efficient handling of train crew will be taken into account. A plan for this system will be formed in the future when required for saving more manpower.

Fig. 4.14 shows an example of train operation curve in the case of ground signal, and Fig. 4.15 that in the case of cab signal and ATC system.

4.4.3 Station Yard Operation Safety System

(1) Interlocking Device

In the station yard adopted is the electric relay interlocking device that uses electric turnout machine and turnout switch detector. Consideration has been given to adopt and electronic interlocking device in a large station yard.

In the cases of the monorail and rubber tire systems, the cab signal is adopted, with no ground signals, such as home and starting signals, provided. Traffic levers are provided in the console concerned to control the home and starting signals in the cab, and, by means of these levers, train detection and turnout switching on the protected route are performed. Under these conditions, cab signal codes corresponding to main signal indications are transmitted to the loop line. For shunting of cars in the station yard, ground shunting signals are used.

In the case of the steel wheel, ground signals are adopted with home and starting signals provided. To control these signals, route levers are provided in the console concerned. Train detection and turnout switching in the protected route are performed by means of these levers, and, under these conditions, the indications of main signals are given. For shunting of cars in the station yard, ground shunting signals are used as in the case of the monorail.

(2) ATC and Others in the Station Yard

Absolute signal sections with OA codes are provided at the places where home or starting signals are assumed to be erected, and stopping post indicators are installed at the point which it is considered necessary to indicate for the train to stop.

Manual signal substitutes are also provided at the places where home signals are assumed to be erected for reducing the labor of indicating manual signal when the safety system is put out of order.

4.4.4 Total Train Operation Control System

For the modernized train operation and management, this system is adopted to automatically indicate train signals, route control, supervise and record train operations and troubles if any, because of dense train headway of 4 minutes under the plan in the rush hour.

(1) System Construction

This system, a total system, consists mainly of CTC and CPU. The basic construction of this system is as shown in Fig. 10.2.11 of the main body of this Report.

(2) Principal Thought on the System

a. The total system with CPU used as a center is constructed to enhance its efficiency.

b. Color display and others are used from the point of smooth man-machine interface and well-studied-and-designed operation board and console as well.

c. Train detection numbers are information indispensable for the system to restore the train services put out of order. On-board pattern is adopted to facilitate the working of the system at the start.

d. Normally, the system functions to automatically set up train routes; however, automatic route setting device by train is provided as a back-up to ensure the operation of trains to a certain extent when the system is put out of order including CTC.

e. Substitute block system is used for the following reason:

In the cases of the monorail and rubber tire systems, when a on-board device is put out of order, the block section boundary is not clear due to the cab signal system and trains are to operate by substitute block system only. It is not advisable to operate trains by telecommunication method only; therefore, it is desired to operate trains by means of the device that indicates the existence of no trains between stations.

(3) System Function

Fig. 4.16 shows the function of the system.

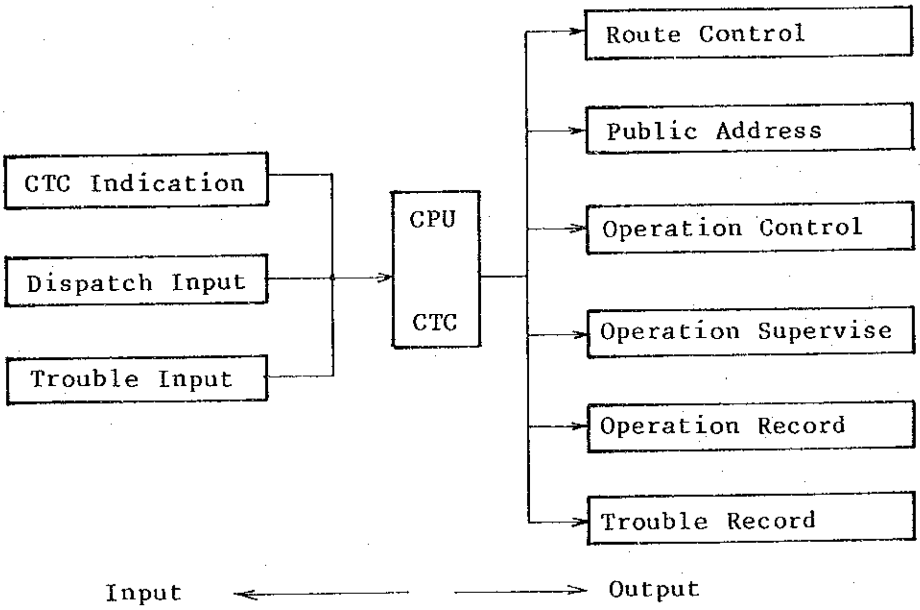


Fig. 4.16 Total Train Operation Control System

4.4.5 CTC

(1) Conditions

a. In the conventional CTC system control has priority, but the CTC planned is for automatic control by computer. It is required therefore that the indications, preconditions to control, be as reliable as control information.

b. It is necessary to provided equipment with large capacity because the number of pieces of information per equipment room is increased due to the adoption of concentrated equipment, such as cab signal and ATC devices, and a variety of information systems.

c. Whereas the volume of information is increased, it is desired that transmission delays be as shortest as possible.

d. It is desired that the CTC be easily combined with other equipment, such as the central processor, be of non-contact system (electronic), from the view of cost and reliability.

Fig. 4.17 shows total construction of the system, Fig. 4.18 shows the component of the control equipment and Fig. 4.19 shows the construction of the station equipment.

(2) Comparison

Compare the constructions of 1:1 and 1:n systems. Each has its own advantages and disadvantages. In the case of the MRT line, combination with CPU, it is considered favorable to adopt the 1:n system because no total CPU input equipment is required between CTC and CPU.

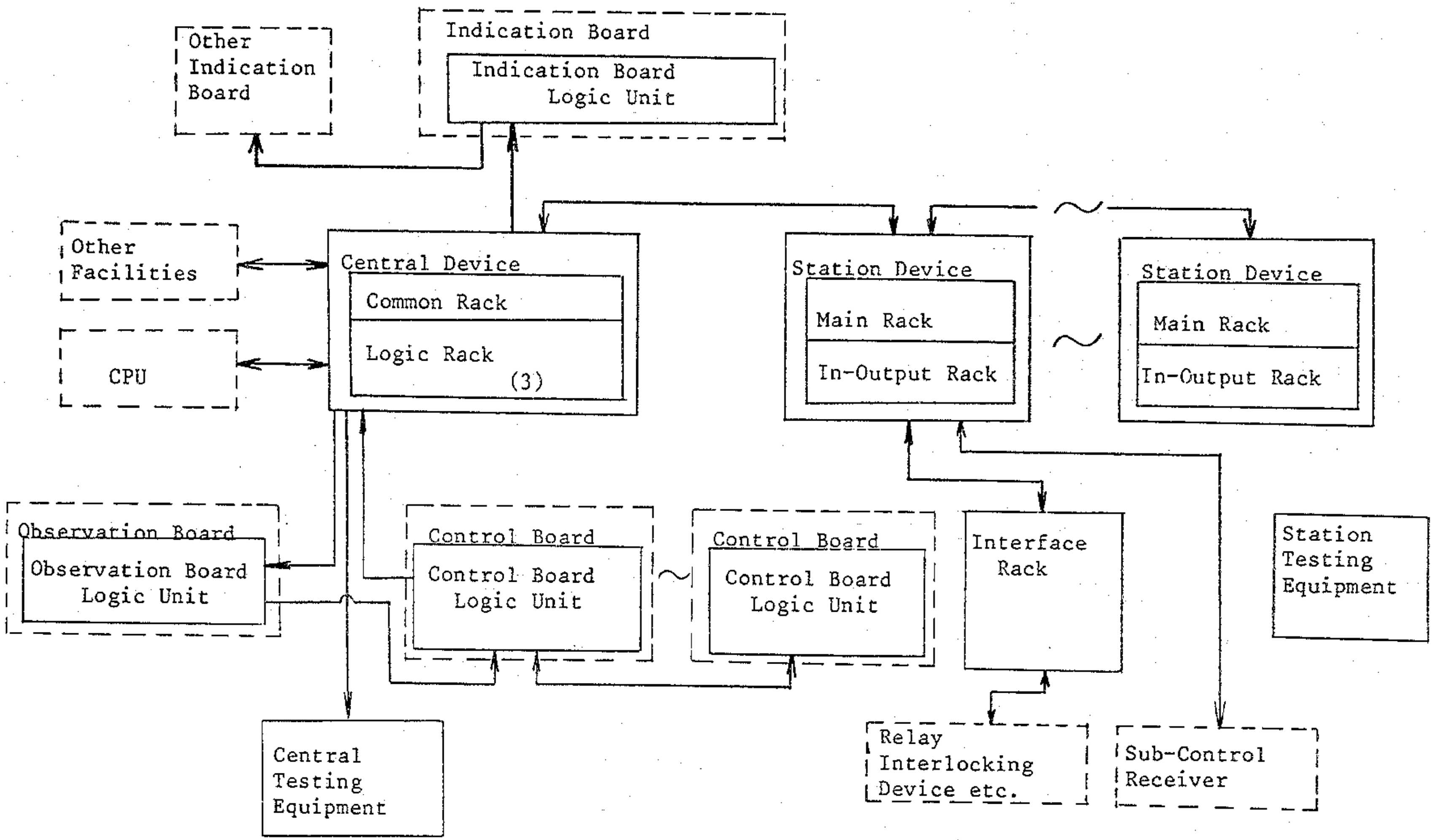


Fig. 4.17 Total CTC System Construction

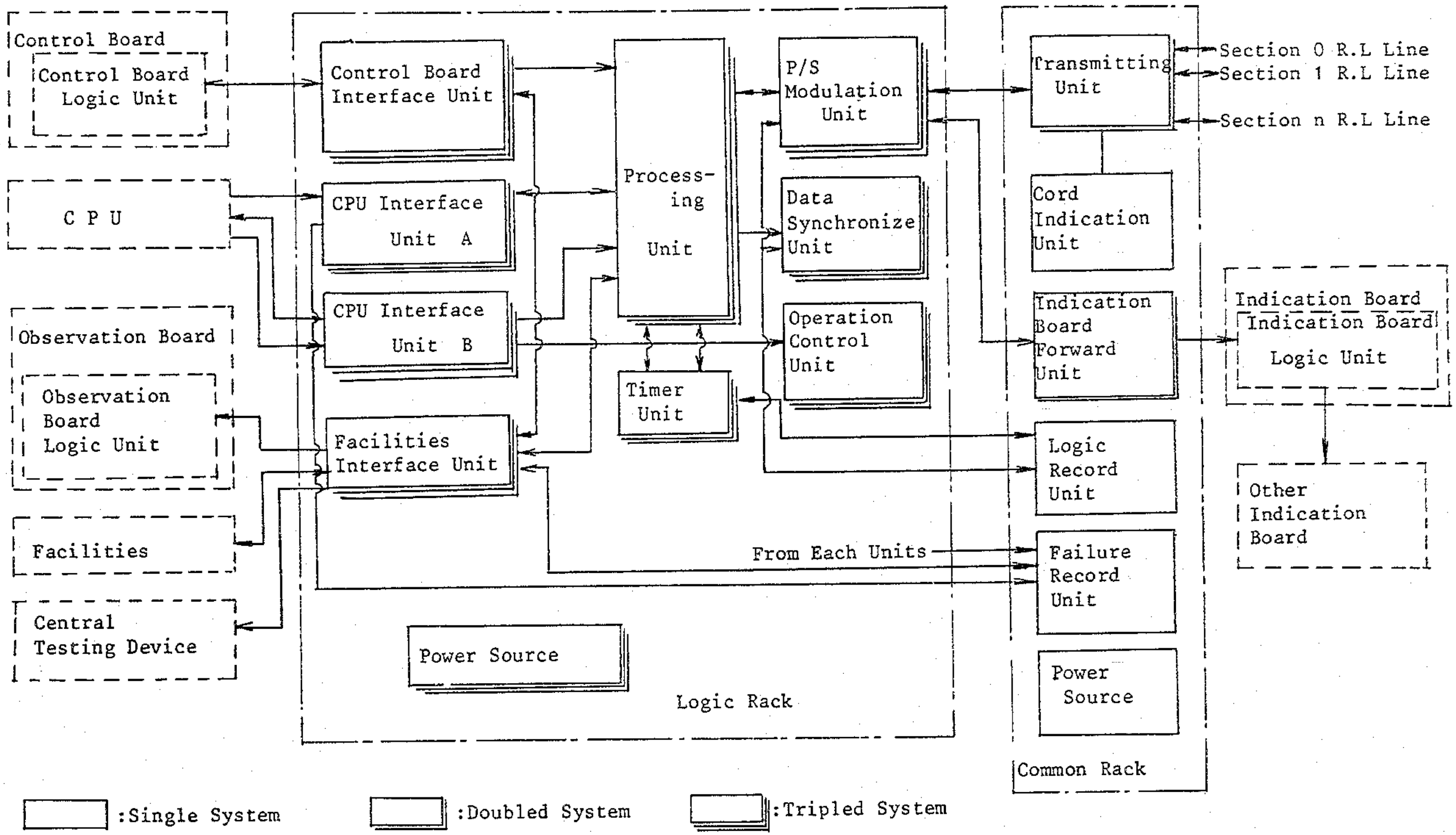


Fig. 4.18 Central Device Construction

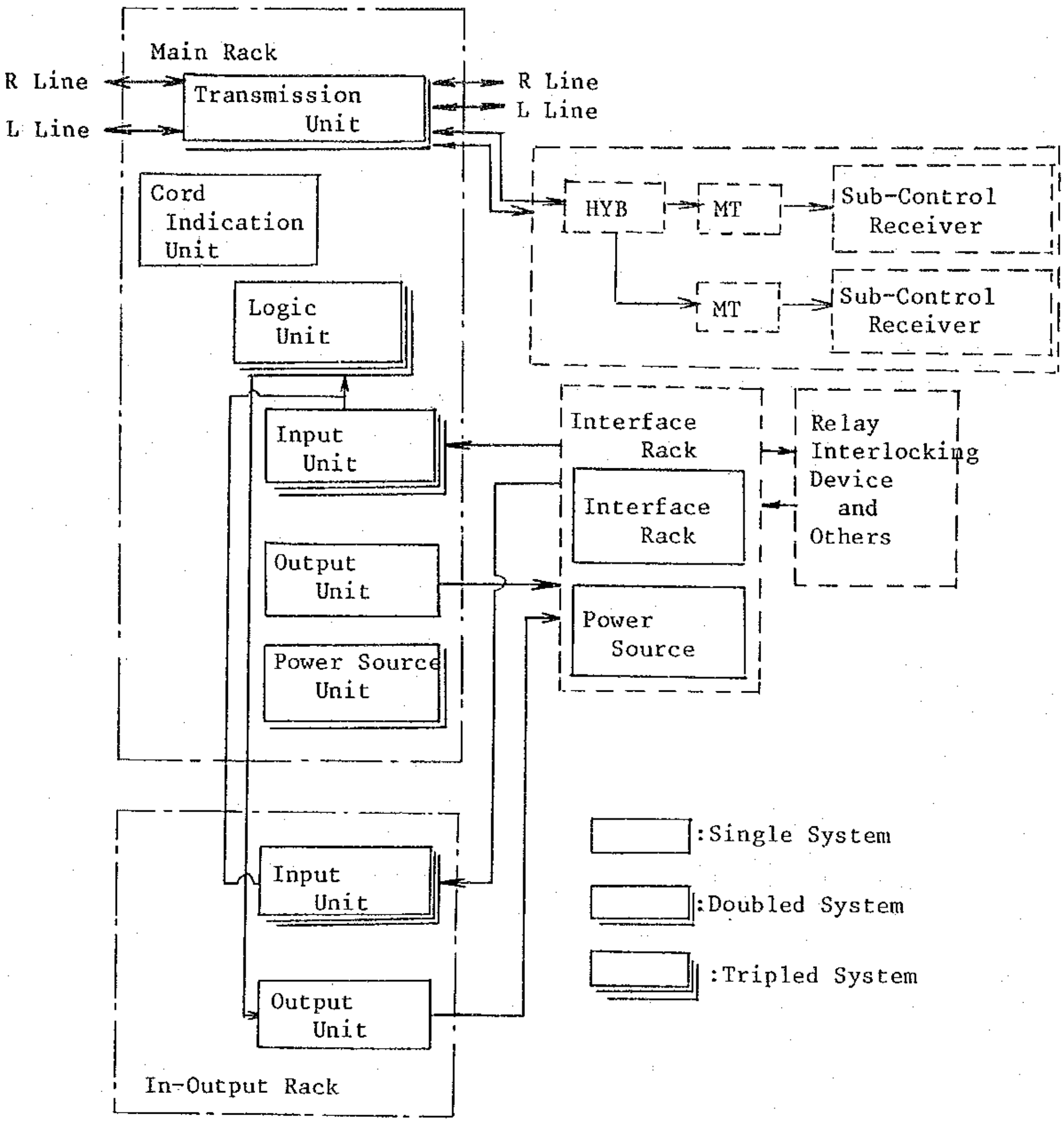


Fig. 4.19 Station Device Construction

4.4.6 Outline of Equipment

Signalling equipment planned for the MRT line is outlined as below:

a. CPU: central processor, exterior memory, electric power source equipment, etc.

b. CTC: logic rack, indication rack, indication device, control board, electric power source equipment, station device, etc.

c. Cab signal equipment room: train detection racks, cab signal transmission racks, electric power source equipment, etc.

d. Cab signal field equipment: matching transformer, loop line, etc.

e. Track circuit equipment: impedance bond, rail insulation, rail bond, etc.

f. Relay interlocking device: relay interlocking machine, main signal, shunting signal, electric turnout machine, turnout switch detector, etc.

g. Telecommunication line: cable, cable trough, cable rack, etc.
Table 4.4 shows the kinds of signalling cable.

h. Others: manual signal substitute, block system substitute, indicators, etc.

i. Level crossing protection device: level crossing warning device, crossing barrier, etc.
Fig. 4.20 and Fig. 4.21 shows the installation of devices.

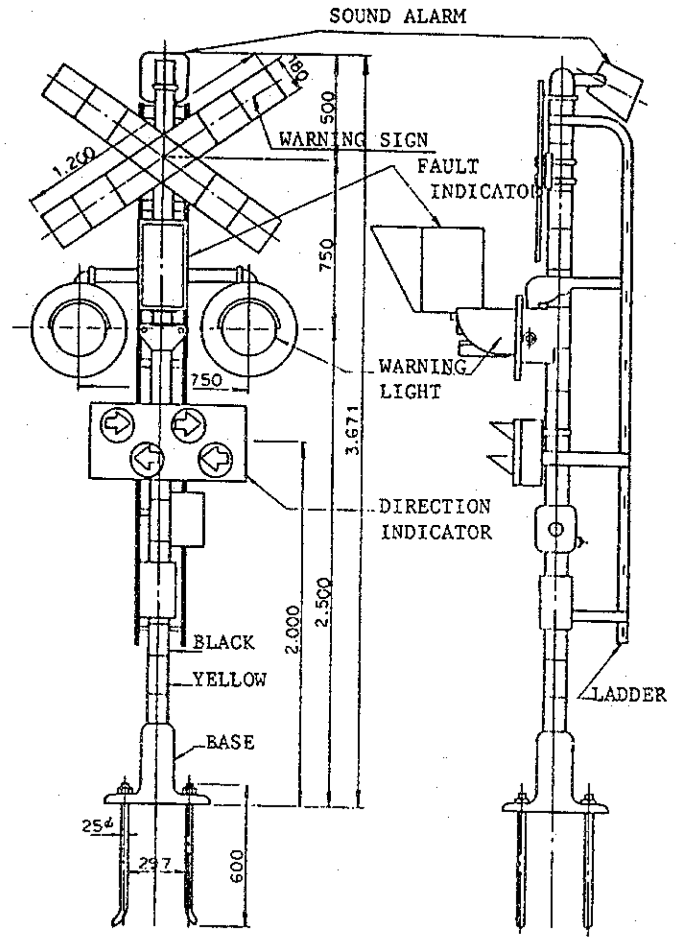


Fig. 4.20 Installation of Warning Device

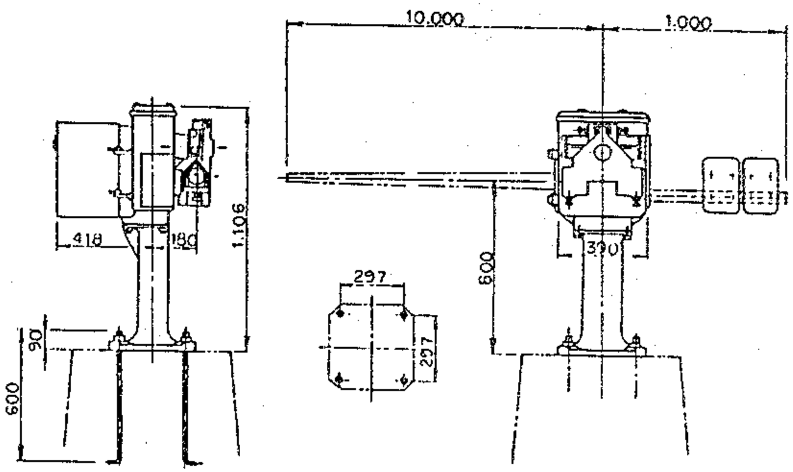


Fig. 4.21 Installation of Crossing Barrier

Table 4.4 Kinds of Signalling Cable (Vinyl)

Kinds	Mark	Nominal Section mm^2	Conductor/ Component mm	Number of Core	Usage
Signalling Vinyl Cable	SVV	30	19/1.4	2	Usually laid in trough
		10	19/0.8	2.4	
		2	7/0.6	2.4.6.8. 12.19.30	
Signalling Steel Armored Vinyl Cable	SVV-TA	30	19/1.4	2	Mainly burried in soil directly
		10	19/0.8	2.4	
		2	7/0.6	2.4.6.8 12.19.30	
Signalling Steel Armored Vinyl Anti-Corrosion Vinyl Cable	SVV-TAZV	30	19/1.4	2	Mainly burried in soil directly for anti-corrosion
		10	19/0.8	2.4	
		2	7/0.6	2.4.6.8 12.19.30	
Signalling Self-Support Vinyl Cable	SVV-SS	30	19/1.4	2	Mainly used as overhead cable
		10	19/0.8	2.4	
		2	7/0.6	2.4.6.8. 12.19.30	

4.5 Telecommunication Equipment

4.5.1 Outline of Telecommunication Systems

In the telecommunication equipments that transmits information are exclusive telecommunication systems and devices, as given below:

(1) System for train operation

a. Train dispatch line
b. Electric power dispatch line
c. Train radio system
d. Line for management communication or for exchange subscribers

(2) System for passenger service

a. Public address system

b. Master clock system

c. Line for bell and other indications

(3) System for equipment maintenance

a. Line for track maintenance

b. Line for electrical equipment maintenance

c. Radio wave system

d. Line for disaster prevention information

(4) System for supervision and management

Subscriber telephone line other than in the foregoing (1), (2) and (3).

Figs. 10.5.16 and 10.5.17 in 10.5.7 in this Report main body show the telecommunication systems and devices considered necessary for the operation of Casablanca MRT.

Table 4.5 shows the kinds of telecommunication cables.

Table 4.5 Kinds of Telecommunication Cable (Common use)

Name of Cable	Core diameter	Number of pairs
City Quad Unit Cable	0.4 mm, 0.65 mm, 0.9 mm	10P, 20P, 30P, 50P, 100P, 200P
City Quad Unit Self-Support Cable	0.65 mm, 0.9 mm	10P, 20P, 30P, 50P,
City Quad Unit Colgate Sheath Cable	0.65 mm, 0.9 mm	10P, 20P, 30P, 50P, 100P, 200P
City Quad Unit Colgate Sheath Self-Support Cable	0.9 mm	10P, 20P, 30P
City Quad Unit Colgate Sheath Self-Support Transfer Combination Cable	0.9 mm	20P+(2P), 30P(3P)
City Quad Unit Aluminum Sheath Cable	0.65 mm, 0.9 mm	10P, 20P, 30P, 50P, 100P, 200P
City Quad Unit Transfer Combination Cable	0.9 mm	20P+(2P), 30P+(3P), 50P+(3P), 100P+(3P), 200P+(2P)
City Quad Unit Transfer Combination Self-Support Cable	0.9 mm	20P+(2P), (30P)+(3P), 50P+(3P)
City Quad Unit Transfer Combination Colgate Sheath Cable	0.9 mm	20P+(2P), 30P+(3P), 50P+(3P), 100P+(3P), 200P+(2P)
City Quad Unit Transfer Combination Aluminum Sheath Cable	0.9 mm	20P+(2P), 30P+(3P), 50P+(3P), 100P+(3P), 200P+(2P)
City Quad Cable	0.9 mm	2P, 6P
City Quad Colgate Sheath Cable	0.9 mm	2P, 6P

4.5.2 Train Radio Equipment

Train radio system can be divided into two as shown below:

(1) SR System (Space Radio System)

This system uses the space radio waves, 150 MHz or 400 MHz band. It is usually adopted for the railway with trains and radio stations located within the visible area.

There are many cases where ground railways are equipped with this system. In the case of tunnels, leakage coaxial cable (LCX) are used.

(2) IR System (Inductive Radio System)

The system uses radio waves, 100-250 kHz, for communication by electromagnetically connecting the train antenna with the induction line laid along the rail track, mainly used in underground system.

(3) Selection of Train Radio System

For selection of the optimum system, the following items are studied and taken into account:

a. Adaptability
b. Capability
c. Reliability
d. Economy

The SR system is planned for Casablanca MRT.

4.5.3 Telephone Exchange Equipment

It is considered that there are service telephones exclusively used for railway business and ordinary subscriber telephones by ONPT. Since the number of ONPT subscriber telephone lines required is small, separate subscriber telephones are planned, not included in the exchanger.

In the future, if required to include them in the exchanger, they will be included in the service exchanger. Therefore, the service exchanger is planned to be capable of being usable with PBX.

4.6 Study of Radio Wave Jamming

A study has been made on jamming to TV reception along the planned route. The underground running of trains raise no problem.

The causes of reception hindrance include:

a. Screening or reflection by structures
b. Screening or reflection by running rolling stock
c. Electric noise generated from rolling stock, etc.

As for the above b, the hindrance arises due to high-speed changes in the wave intensity seen from the receiver side by the screening or reflection of the running rolling stock.

The running speed of the planned MRT is comparatively low, maximum 80 km/h, and therefore problems are hardly considered to arise since the change in the wave intensity is considerably slower than the time constant of AGC (Automatic Gain Control) set in the receiver.

The electric noise mentioned in the above c includes that due to the electric discharge from the high-voltage line, but has few problems in the plan, though high-voltage transmission lines, far higher than the feeding voltage DC 1500 V under the plan, usually causes many problems.

It is said that the noise that arises from the rolling stock is due mainly to the spark discharge caused by lose contact happening between the pantograph and the contact line.

No special study on this point is required since the speed of trains under the plan is slow and few lose contact are considered.

As regard the above a, the elevated structures of MRT hinder waves. However, it is difficult to correctly forecast the degree of hindrance because it varies with the intensity of waves in the area concerned, the location of broadcasting station, geology, the height and composition of structures and etc.

The elevated structures of MRT under the plan have a large space between supporting parts and therefore do not necessarily cause hindrance. It is considered that the effect of the reflection or screening of station buildings is larger than that of elevated structures between stations.

In the center of Casablanca are already many buildings higher than the elevated structures of MRT. Therefore, problems of MRT elevated structures lowering the reception level is out of question.

The area of Cité Jemaâ is quite near the broadcasting station, the reception level being considered high. Even if the reception level is lowered by MRT elevated structures, no hindrance will be hardly conceivable.

In ares other than the foregoing, there might be places that would lower the reception level due to the locations of buildings, possible to give rise to hindrance.

In any way, it is difficult to accurately forecast the effect of hindrance from the beginning; measures, such as setting up a common antenna, must be taken to meet the actual conditions after the construction is completed.

4.7 Estimation of Electromagnetic Induction Disturbances

Under the MRT plan in Casablanca, electromagnetic induction disturbances on telecommunication lines adjacent to MRT are estimated, one case is DC steel wheel electric railway with overhead contact line and rail and the other is DC operated monorail.

Induced noise disturbances caused by high harmonic currents contained in DC feeding currents on both systems are roughly estimated. The values on route A are calculated as a typical condition.

4.7.1 Steel Wheel Case

(1) Calculation Prerequisite

1) Prerequisites are, elevated section, hight of the structure is 7 m and telecommunication cable is buried underground by the depth of 1 m. (See Fig. 4.22.)

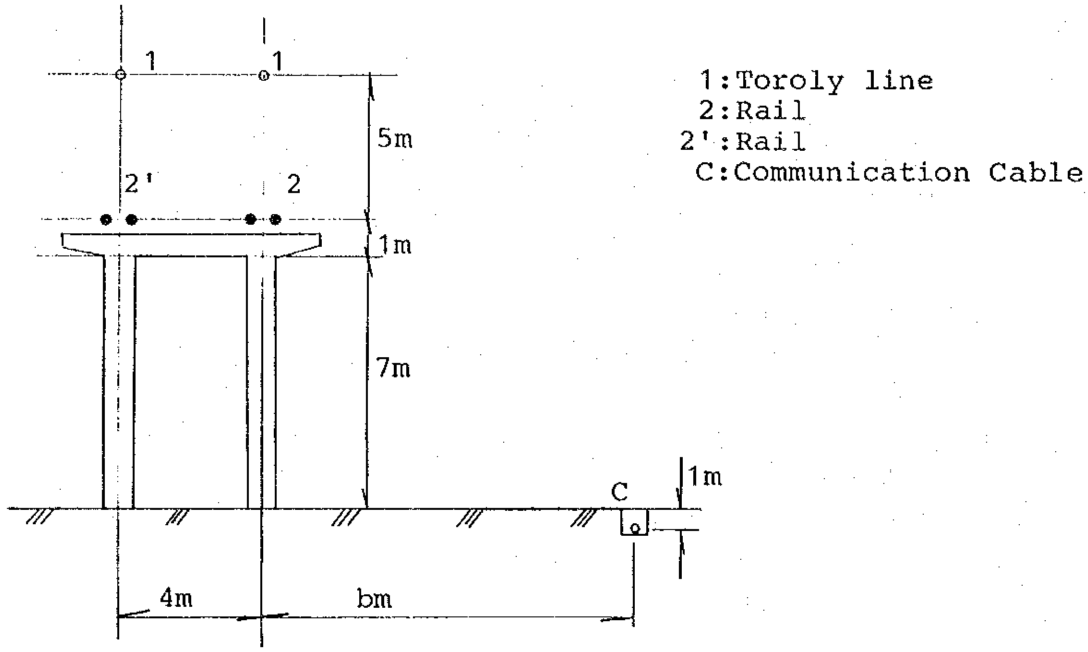


Fig. 4.22 Layout of Feeding Circuit and Telecommunication Cable (Steel Wheel)

2) Route length of the MRT systems is 15 km and 4 substations are placed every 5 km.

3) 12 pulse rectifier is used in substations and the high harmonic voltages are presumed as a value of heavy duty load shown below.

f	600 Hz,	1200 Hz,	1800 Hz,	2400 Hz,	3000 Hz
V	45 V	22 V	15 V	11 V	9 V

Equivalent disturbance voltage

$$Vp = \sqrt{\sum (VfSf)^2} = 44 \text{ (V)}$$

Sf = Psophometric factor

4) Internal inductance of each substation is $Ls = 1$ mH

Inductance of train load is $Lr = 3$ mH (constant)

Inductance of feeding circuit is $L = 1.5$ mH/km

5) Earth conductivity is assumed $\delta = 0.001$ s/m
Small value due to the rock underground.

(2) Calculation Method

Induced line noise voltage (V) is described below on telecommunication line cable (C), length of 1 (km), running side of electric railway feeding circuit when the current 1[A] 800[HZ] flows through contact line (1).

$$V = W_{800}\,(M1c - n1M2c - n2M'c) \quad [V] \qquad (1)$$

here

M1c; Mutual inductance between contact line (1) and telecommunication cable (C) [H/km]

M2c; Mutual inductance between rail (2) and telecommunication cable (C) [H/km]

M2'c; Mutual inductance between rail (2') and telecommunication cable (C) [H/km]

$$n1 = \frac{I2}{I1} = \frac{Z22Z12 - Z22'Z12'}{(Z_{22})^2 - (Z_{22})^2}$$

$$n2 = \frac{I2'}{I1} = \frac{Z22Z12' = Z22'Z12}{(Z_{22})^2 - (Z_{22'})^2}$$

here

Z22; Self impedance of rail [Ω/km]

Z22'; Mutual impedance between rail (2) and rail (2') [Ω/km]

Z12; Mutual impedance between contact line (1) and rail (2) [Ω/km]

Z12'; Mutual impedance between contact line (1) and rail (2') [Ω/km]

Calculation result is shown in Fig. 4.24 .

4.7.2 Monorail Case

(1) Calculation Prerequisite

1) Layout of contact line system of monorail and telecommunication cable are shown in Fig. 4.23.

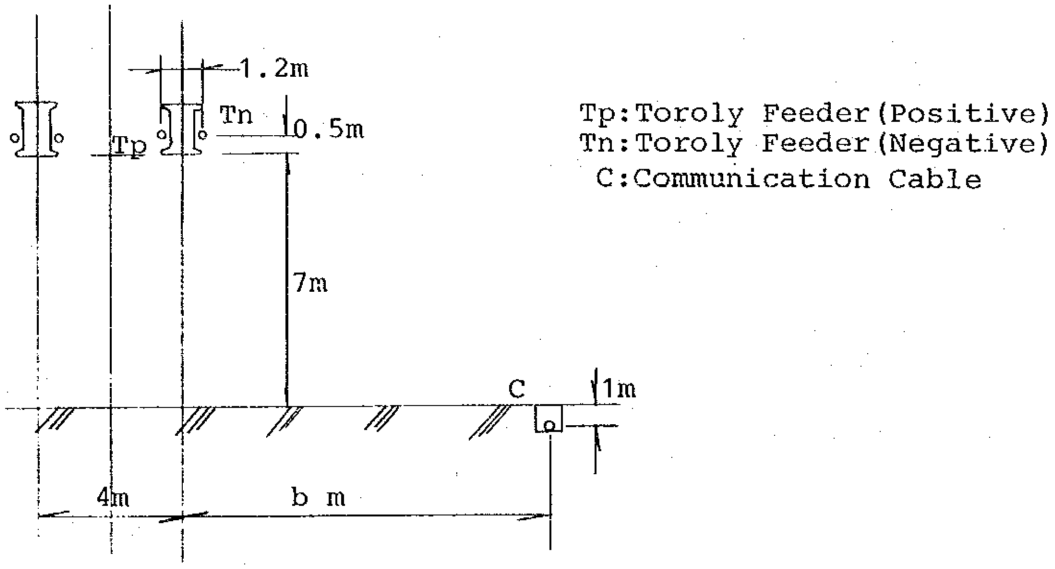


Fig. 4.23 Layout of Feeding Circuit and Telecommunication Cable (Monorail)

Route length of monorail, location and impedance of substations, high harmonic voltages, train load impedance, feeding circuit impedances, location of trains and others are presumed same as steel wheel case.

Calculation is done in accordance with the method used in steel wheel case. Calculation results are shown in Fig. 4.24.

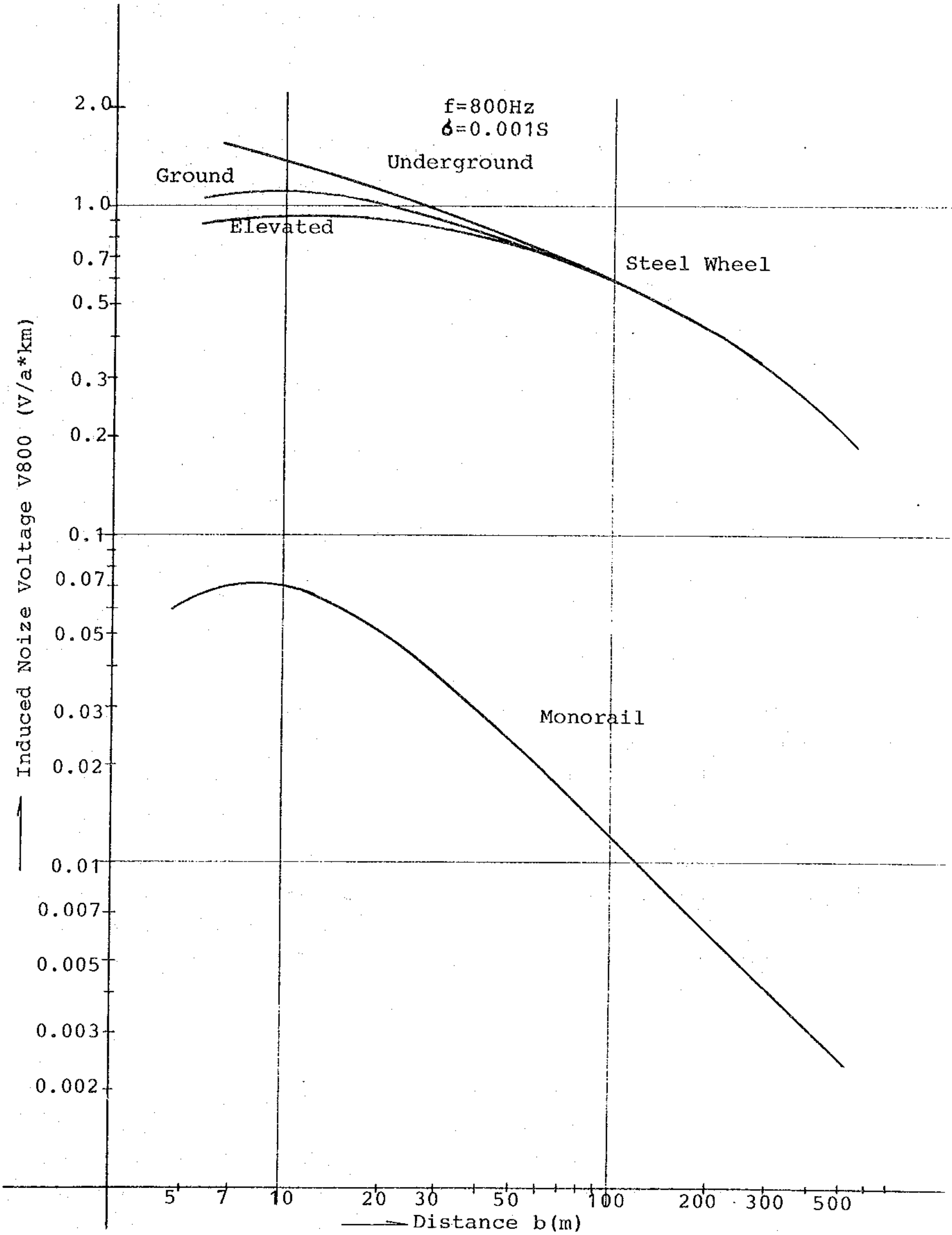


Fig. 4.24 Induced Noise Voltage

4.7.3 Conclusión

(1) Steel Wheel Case

Case with the effect of the shielding of communication cable (shield factor k = 0.4) is presumed. Communication cable runs side by side of feeding circuit with the distance of 10 - 20 m (side of the road) and the cable is connected with telephone exchanger means bad balance between pairs (λ= 46 dB).

In this case, noise voltage (V) between telecommunication cable circuits becomes large value about 5.1 mV when the circuits go parallel in one section (between substations) about 5 km with electric railway. Even if shielding effect of varied metals (water pipes, gas pipes and etc.) is taken into account, this value means the possibility of generating noise disturbances. According to C. C. I. T. T. recommendation, the limit of maximum noise voltage between circuits of telecommunication line cable is 1 mV as a induced noise voltage. The voltage at a telephone terminal is 0.5 mV.

In addition to above, the area suffered by induced noise disturbances seems wide because of assumption of small earth conductivity (0.001 S/m). Therefore, installation of DC side filter for decreasing high harmonic currents is required in each substation. The comparison of induced line noise voltage among feeding circuits, elevated section, underground and surface is also described in Fig. 4.24.

When separation distance is small like 10 - 30 m, the noise voltage in underground section is as big as 1.1 to 1.5 times of elevated section, 1.05 - 1.2 times of elevated section when surface. In surface section, considering no shielding effect of reinforcing bar it becomes as big as 2.0 - 1.7 times of elevated section.

(2) Monorail Case

In case of monorail, induced noise voltages are small compare to the steel wheel electric railway. In elevated section, the voltages are 1/13 - 1/18 of steel wheel case when separation distance is 10 - 20 m and decrease to about 1/80 when the distance is 300 m. However, considering expansion of noise voltage caused by high harmonic currents increase in DC side by following factors, DC side filter for decreasing high harmonic currents should better be installed. The factors are telecommunication cable without shield, bad receiving voltage wave form of substations, unbalance of power source voltages and etc.

4.8 Consideration of Electrolytic Corrosion Damage

4.8.1 Electrolytic Corrosion by DC Electric Railway

Under the ordinally electric railway, steel wheel is applied, rail is used as return circuit. Therefore electric potential rise against earth is occurred on the rail by the voltage drop by the current flows through the rail. Rail potential is positive around the load point and negative around the substation. A part of load current flowing through rail leak to earth around the load point and flows into buried metal like water pipe, gas pipe, cable and etc. and return to rail around substation through the earth. Generally in the case of flowing current from the metal positive electrode to medium, the metal is electrolyzed and smelt into medium, occurring of electrolytic corrosion. In the case of electric railway using rail as return circuit, the leaking current from rail to earth becomes up to 30 per cent of load current. If the load current is 1350A leakage current becomes about 405A.

4.8.2 Feeding Circuit Difference between Steel Wheel Railway and Monorail

As described before in 4.8.1., the electric railway using rail as a return circuit occurs electrolytic corrosion because of large leakage current from rail to earth.

In case of monorail, positive and negative contact lines are insulated from the earth, it means the contact line system is designed having remarkably small leakage current to the earth. Fig. 4.25 shows the feeding circuit of electric railway using rail as return circuit and Fig. 4.26 shows the circuit of monorail.

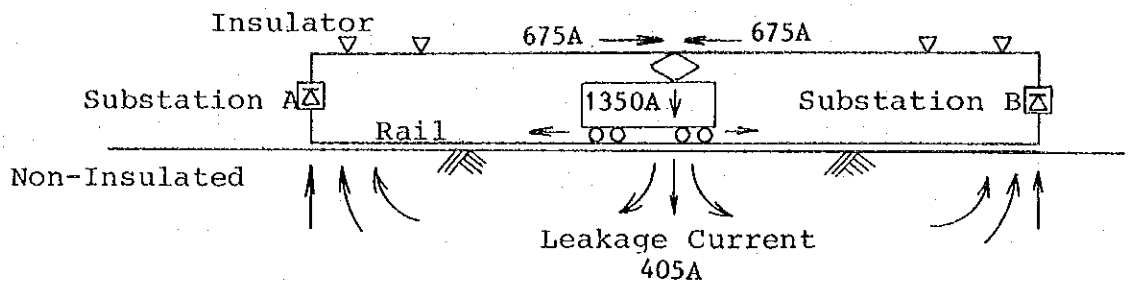


Fig. 4.25 Feeding Circuit (Steel Wheel)

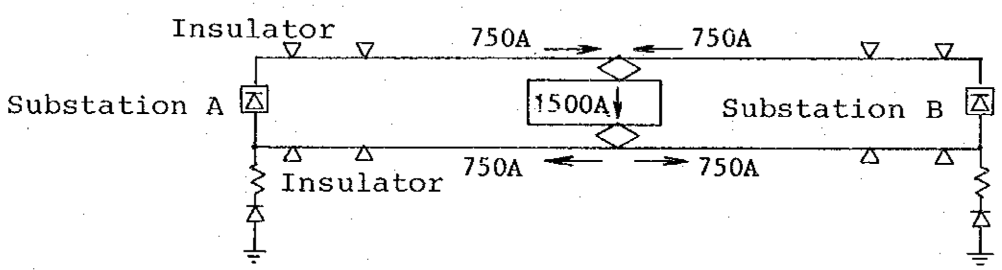


Fig. 4.26 Feeding Circuit (Monorail)

4.8.3 Leakage Current to Earth from Monorail Feeding Circuit

Leakage current to earth from monorail feeding circuit is minute because of insulation both positive and negative contact lines. Electrolytic corrosion is considered below with a assumption of the current.

In the circuit shown in Fig. 4.26 negative bus bar of monorail substation is connected with the grounding mat through series connected resistance and diode.

The reasons are follows

1. Positive contact line voltage is kept as 1500 V against negative contact line and the negative contact line voltage is kept as 0 V against earth by voltage division effect of resistance.

2. To make the failure detection easy when one line grounding failure of positive contact line occurs.

Therefore leakage current when sound is considered to be only a leakage current from positive contact line to the earth via insulator.

According to Japanese regulation, the leakage current of contact line system for DC steel wheel type electric railway should be kept under the level described below. "For prolonged length of track not more than 10 mA/km in the DC overhead contact line system, not more than 100 mA/km in the other contact line system."

Based on this regulation, leakage current can be expected to be less than 0.1 A/km in case of monorail. Steel wheel case in this MRT plan, estimated leakage current is about 405A par one train then the current ratio of monorail is about 1/2000 when trains are operated with 2 km interval. In addition, currents in monorail case is widely distributed and the effect of electrolytic corrosion becomes much smaller compare to concentrated current.

4.8.4 Conclusion

Consideration result described before is summarized below.

(1) The reason electrolytic corrosion of ordinally electric railway affect on circumstances is because of using non-insulated rail as a return circuit and the return current leaks to the earth largely. Therefore following counter measures should better be taken into consideration.

   a. Raise the insulation level of rail
   b. Decreasing of return circuit resistance using longrail, rail bond at the rail joint and etc.
   c. Drainage connection

(2) Both positive and negative contact lines are insulated against earth in the feeding circuit of monorail, therefore the leakage current when sound is not more than 0.1 A/km and distributed then electrolytic corrosion is not a problem.

5 ROLLING STOCK AND CAR SHED COMPLEX

5. ROLLING STOCK AND CAR SHED COMPLEX

5.1 Rolling Stock Plan

(1) Running Condition

a. Present worldwide situation of MRT

Table 5.1 shows geogrpahical conditions (maximum gradient, minimum curve radius of curvature), electric system, car length, etc. of the world cities' MRT.

b. Adhesive characteristics of rolling stock

Fig. 5.1 shows the relation between speeds and adhesive coefficients of steel wheel railways and rubber tire systems. From this figure, it is found that the concrete beams of rubber tire systems (concrete beams are used mostly for monorail and rubber tire railway) have higher adhesive coefficients than these of steel wheel type, though they vary with climatic conditions.
In addition to the definition of adhesive coefficient, it is shown as the ratio of the critical tractive force (braking force), at which wheels begin to slip, to the force on wheels (axle load). The formula is as follows:

$\mu = F/W$ where,

μ : Adhesive coefficient
F : Tractive force (Braking force)
W : Force on wheels (Axle load)

(2) Characteristics of Rolling Stock

Table 5.2 shows the principal characteristics of rolling stock of various urban transport systems.
The figures in this table are mainly taken up from the representative examples of urban transport systems in Japan.

(3) Evaluation Items of Rolling Stock

Evaluation of rolling stock is performed from the point of view of riding comfort, noise level in car and ease of maintenance. The evaluation items, standards and the results of evaluation for 13 alternatives are as follows:

① Riding comfort

Table 5.3 Evaluation standard of riding comfort

Table 5.4 Car vibration-acceleration and evaluation

Table 5.5 Evaluation of alternatives (riding comfort)

Fig. 5.1 Scientific evaluation of riding comfort

② Noise level in car

Table 5.6 Evaluation standard of noise level

Table 5.7 Noise level in car (actual values) and evaluation

Table 5.8 Evaluaiton of alternatives (noise level in car)

③ Evaluation of ease of maintenance of rolling stock

Table 5.9 Evaluation standard of ease of maintenance

Table 5.10 Inspection/repair system and evaluation

Table 5.11 Evaluation of alternatives (ease of maintenance of rolling stock)

Table 5.1 Characterstics of World MRT (1)

System \ City		Route extension (km)	Track guage (mm)	Maximum gradient (‰)	Minimum radius of curvature (m)	Current collecting system (DC, Volt)	Car length/car (m) ( ) number of formations
Rapid Rail Transit	1.Athens	25.8	1435	40	160	600-750, ②	14.0/17.0
	2.Atlanta	40.0	1435	30	230	750, ②	23.0
	3.Baku	18.6	1524	40	300	825, ②	18.8
	4.Berlin(East)	17.6	1435	40	74	750, ②	12.1/18.1
	5.Berlin(West)	105.5	1435	40	74	750, ②	12.5/16.1
	6.Brussel	25.0	1435	62	100	750, ②	18.2 (2-5)
	7.Peking	35.0	1435	30	200	750, ②	19.0 (4-5)
	8.Budapest	25.3	1435	40	300	825, ②	20.0 (5)
	9.Calcutta	16.4	1676	20	300	750, ②	19.5 (4)
	10.Hamburg	89.4	1435	50	70	750, ②	13.0/14.0
	11.Helsinki	11.2	1524	35	300	750, ②	22.1 (6)
	12.Hong Kong	26.1	1435	30	300	1500, ①	22.8
	13.Kiev	30.6	1524	40	400	825, ②	18.8
	14.Kobe	10.0	1435	29	300	1500, ①	19.0 (4)
	15.Kyoto	6.9	1435	20	260	1500, ①	20.0 (4)
	16.Leningrad	66.1	1524	40	400	825, ②	18.8 (5-6)
	17.Lisbon	12.5	1435	40	100	750, ②	16.0 (4-6)
	18.London	388.0	1435	35	101	600, ②	16.0/18.0
	19.Madrid	100.0	1445	50	90	600, ①	14.5/17.5
	20.Manila	15.0	1435	40	250	750, ②	29.3 (1-2)
	21.Minsk	8.6	1524	40	400	825, ②	14.1 (6)
	22.Moscow	197.0	1520	40	196	825, ②	18.8
	23.New York	371.0	1435	48	27	650, ②	15.6/18.4
	24.Nuremberg	18.0	1435	40	100	750, ②	18.6 (2)
	25.Osaka	90.9	1435	35	120	750-1500, ①②	17.7/18.9
	26.Oslo	48.4	1435	50	200	750, ②	17.0
	27.Paris	192.0	1435	40	40	750, ②	15.5 (5)

Note: Current collecting system
① ... Overhead
② ... Third rail
③ ... Guidance rail

Table 5.1 Characterstics of World MRT (2)

System	City	Route extension (km)	Track guage (mm)	Maximum gradient (‰)	Minimum radius of curvature (m)	Current collecting system (DC, Volt)	Car length/car (m) ( ) number of formations
Rapid Rail Tran-sit	28. Philadelphia	38.7	1435	50	32	625, ②	16.8/20.6
	29. Rio deJaneiro	16.0	1600	40	500	750, ①②	21.9
	30. Rome	25.5	1435	40	100	1500, ①	17.8/19.1
	31. Rotterdam	34.9	1435	30	60	750, ②	14.9 (2)
	32. San Francisco	115.0	1676	40	120	1000, ②	22.9
	33. Sao Paulo	26.3	1600	40	300	750, ②	21.2
	34. Seoul	58.3	1435	40	400	1500, ①	19.5
	35. Stockholm	104.0	1435	48	200	750, ②	17.4
	36. Tashkent	20.4	1524	40	400	825, ②	18.8
	37. Tokyo	131.8	1435	35	94	700-1500, ①②	16.0/19.5
	38. Toront	56.9	1495	35	122	570, ②	17.4/22.7
	39. Vienna	32.2	1435	38	300	750, ②	18.4
	40. Washington	96.7	1435	40	198	750, ②	22.4
	41. Yokohama	11.5	1435	35	125	750, ②	18.0 (5)
Rubber-tired Rail Tran-sit	42. Lyons	14.0	1435	65	100	750, ③	18.0 (3)
	43. Marseille	13.0	1435	70	150	750, ③	16.0 (6)
	44. Mexico City	97.6	1435	70	105	750, ③	16.2 (9)
	45. Montreal	52.9	1435	65	140	750, ③	16.5 (3)
	46. Paris	192.0	1435	40	40	750, ③	15.1 (4-6)
	47. Santiago	25.5	1435	48	280	750, ③	16.0 (5)
	48. Sapporo	33.0	2180	43	200	750-1500, ②③	13.8/18.0
LRT	49. Antwerp	84.1	1000	60	18	600, ①	14.0 4axles
	50. Duisburg	10.9	1435	40	183	600, ①	19.8 4axles
	51. Helsinki	45.0	1000	70	17	600, ①	25.6 8axles
	52. Nantes	10.6	1435	60	20	750, ①	28.5 8axles
	53. Newark	6.9	1435	60	20	600, ①	20.0 6axles
	54. Stuttgart	115.0	1435	70	50	750, ①	28.5 6axles
LIM	55. Toront	7.2	1435	53	35	600, ③	12.7 (2-4)
	56. Vancouver	21.4	1435	60	75	600, ③	12.7 (2-4)

Note: Current collecting system ① ... Overhead
② ... Third rail
③ ... Guidance rail

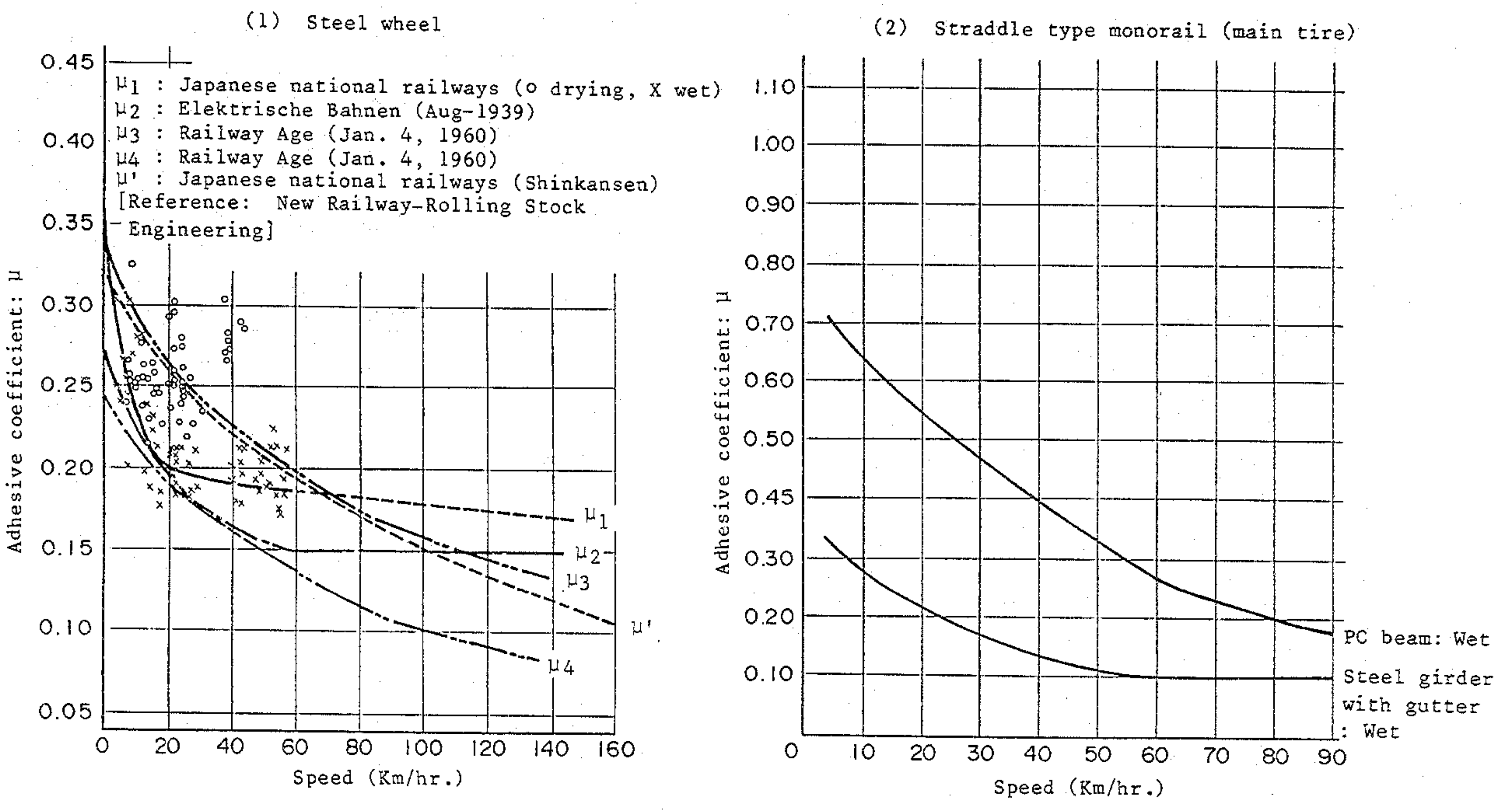


Fig. 5.1 Relation between Speeds and Adhesive Coefficients

Table 5.2 Characteristics of Rolling Stock of Various Transport Systems

System / Item	Rail way: Steel wheel: Standard	Rail way: Steel wheel: Small-size	Rail way: Rubber tire	Monorail: Straddle type: Large-size	Monorail: Straddle type: Standard	Monorail: Suspended type: Large-size	Monorail: Suspended type: Standard	Automated guided transit system	Linear motor steel wheel railway (in course of development)	LRT
Car dimension										
Overall length (mm)	19500	16000	13800	15100	14100	16500	13000	8000	12600	28500
Overall width (mm)	2800	2600	3030	2980	2980	2700	2600	2400	2470	2300
Overall height (mm)	3670	3490	3730	3640	3610	3700	3700	3300	2800	3250
Nominal riding (pass.)										
Control trailer										
Standing	88	58	50	54	50	48	34	43	37	108
Seating	48	36	32	36	34	42	36	28	28	60
Total	136	94	82	90	84	90	70	71	65	168
Intermediate										
Standing	90	54	54	58	54	52	38	48	40	-
Seating	54	44	42	42	40	48	40	32	34	-
Total	144	98	96	100	94	100	78	80	74	-
Tare weight of 4-cars (ton)	118	109	76	108	104	84	70	43	73	40
Axle load (ton)	14	11	7.9	11	10	9.5	7.5	9	7.5	-
Electric system (volt)	DC 1500	DC 600	DC 750	DC 1500	DC 1500	DC 1500	DC 1500	DC 750	DC 1500	DC 750
Current collecting system	Overhead	Third rail	Third rail	Double rigid	Double rigid	Double rigid	Double rigid	Double rigid	Overhead	Overhead
Gauge or distance between outboard guidances (mm)	1067	1435	110	850	800	1390	1390	2900	1067	1435
Distance between center plates (mm)	13800	10500	10900	9600	9000	11000	8000	5000	8600	10650
Guidance system	Steel wheel on steel rail	Steel wheel on steel rail	Central guidance	Central guidance	Central guidance	Central guidance	Central guidance	Outboard guidance with steering bogies	Steel wheel on steel rail	Steel wheel on steel rail
Output (KW) 4-cars	960	960	880	1200	1200	1120	1120	380	520	550
Traction control system	Rheostatic control, Super posed field excitation control	Chopper control	Chopper control	Chopper control	Chopper control	Chopper control	Chopper control	VVVF inverter with 3-phase AC induction motor	VVVF inverter with 3-phase AC induction motor	Chopper control
Braking system	Electrically commanded air braking to be applied together with regenerative braking		Combined regenerative and electromagnetic straight air brake	Electrically commanded air braking to be applied together with regenerative braking					Electro-air brake together with regenerative braking Electromagnetic rail brake	
Example	Tokyo -JNR	Tokyo -Subway	Sapporo -Subway	Kitakyushu - Monorail	Okinawa - Monorail (In planning)	Chiba-Monorail (under construction)	Shonan Monorail	Tokyo - New transportation system	Practical study	Nantes-LRT: 2 articulated cars

Note: Standing capacity: 0.35 m^2/passenger, but 0.16 m^2/passer for AGT, 0.25 m^2/passenger for LRT.

① Riding comfort

Table 5.3 Evaluation Standard of Riding Comfort

Coefficient of riding quality	Evaluation	Class	Evaluation
Below 1	Very comfortable	1	◎
1 - 1.5	Comfortable	2	
1.5 - 2	Fair	3	○
2 - 3	Bad	4	△
Over 3	Worse	5	▲

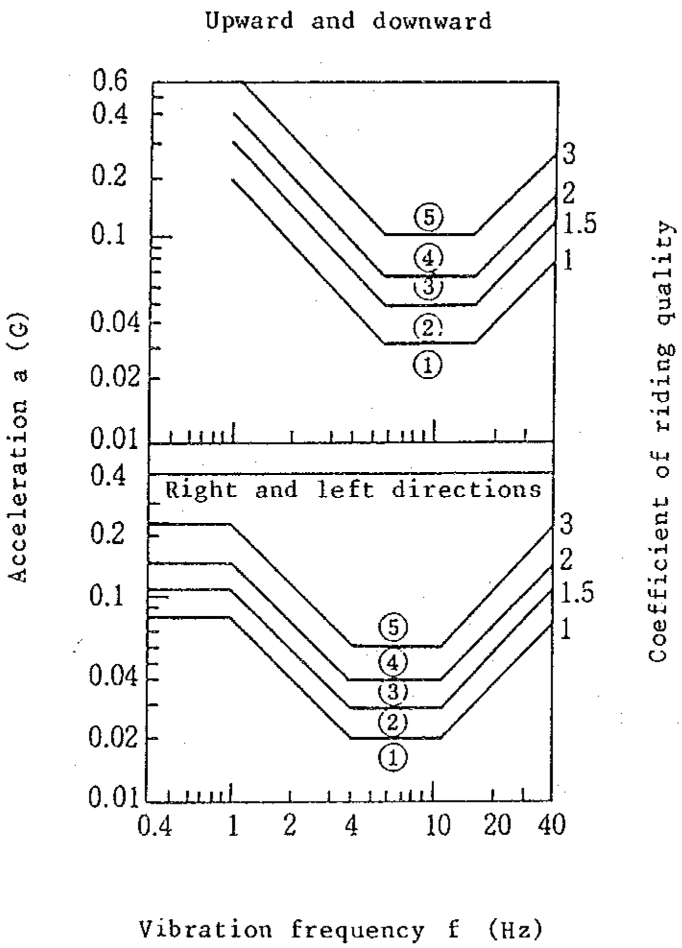


Fig. 5.2 Scientific Evaluation of Riding Comfort

Table 5.4 Car Vibration-acceleration (Actual Values) and Evaluation

Directions \ Frequency (Hz) \ System		Steel-wheel type	Rubber-tire type	Monorail
Upward and downward a: half amplitude (G)	bellow 6	0.02 - 0.08	0.02 - 0.07	0.02 - 0.06
	6 - 20	0.02 - 0.05	0.01 - 0.05	0.01 - 0.05
	Over 20	—	—	—
	Riding comfort class	①	①	①
Right and left directions a: half amplitude (G)	bellow 4	0.03 - 0.07	0.01 - 0.07	0.01 - 0.03
	4 - 12	—	0.01 - 0.03	0.01 - 0.03
	Over 12	—	0.01 - 0.02	0.01 - 0.02
	Riding comfort class	②	②	①
General evaluation		◎	◎	◎

Table 5.5 Evaluation of Alternatives (Riding Comfort)

Route	A							B					
Alternatives	A-1	A-2	A-3	A-4	A-4'	A-5	A-6	B-1	B-1'	B-2	B-3	B-4	B-5
System	Mono-rail	Mono-rail	Rubber tire	Rubber tire	Steel wheel	Steel wheel	Mono-rail	Mono-rail	Steel wheel	Rubber tire	Mono-rail	Rubber tire	Steel wheel
Evaluation	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎

② Noise level in car

Table 5.6 Evaluation Standard of Noise Level

Evaluation	Noise level (dB)	Evaluation
Excellent	Below 70	◎
Good	70 - 75	
Fair	75 - 80	○
Bad	80 - 85	△
Worse	Over 85	▲

. Measured at center of the car above the floor: 1.2 m

. Maximum speed: 70 - 80 km/hr.

Table 5.7 Noise level in Car (Actual values) and Evalaution

Item \ System	Steel-wheel type	Rubber-tire type	Monorail
Noise level : dB (A)	78 - 80	70	69 - 71
Evaluation	○	◎	◎

Table 5.8 Evaluation of Alternatives (Noise level in car)

Route	A							B					
Alternatives	A-1	A-2	A-3	A-4	A-4'	A-5	A-6	B-1	B-1'	B-2	B-3	B-4	B-5
System	Mono-rail	Mono-rail	Rubber tire	Rubber tire	Steel wheel	Steel wheel	Mono-rail	Mono-rail	Steel wheel	Rubber tire	Mono-rail	Rubber tire	Steel wheel
Evaluation	◎	◎	◎	◎	○	○	◎	◎	○	◎	◎	◎	○

③ Evaluation of ease of maintenance of rolling stock

Ease of maintenance will be determined based on the inspection/repair system of rolling stock.

Table 5.9 Evaluation Standard of Ease of Maintenance

Evaluation	Running kilometerage general overhaul interval	Evaluation
Excellent	Over 800 (thousand km)	◎
Good	600 - 800 (thousand km)	○
Fair	400 - 800 (thousand km)	△
Slightly bad	Below 400 (thousand km)	▲

Table 5.10 Inspection/Repair System and Evaluation

Item \ System		Steel wheel	Rubber tire	Monorail	Note
Inspection/ repair system	Inspection interval	General overhaul 8 years Intermediate overhaul 4 years Monthly inspection 4 months Daily inspection 3 days	G.O 6 years I.O 3 years M.I 3 months D.I 2 days	G.O 6 years I.O 3 years M.I 3 months D.I 2 days	
	Running kilometrage of general overhaul (thousand Km)	800	600	600	
Evaluation of ease of maintenance		◎	○	○	

Table 5.11 Evaluation of Alternatives (Ease of maintenance of rolling stock)

Route	A							B						
Alternatives	A-1	A-2	A-3	A-4	A-4'	A-5	A-6	B-1	B-1'	B-2	B-3	B-4	B-5
System	Mono-rail	Mono-rail	Rubber tire	Rubber tire	Steel wheel	Steel wheel	Mono-rail	Mono-rail	Steel wheel	Rubber tire	Mono-rail	Rubber tire	Steel wheel
Evaluation	○	○	○	○	◎	◎	○	○	◎	○	○	○	◎

5.2 Car Shed Complex

(1) Number of Cars Required Inspection/Repair and Number of Spots Required

Table 5.12 shows the number of cars scheduled to have inspection/repair which is calculated from inspection/repair system of rolling stock.

Table 5.12 Number of Cars Required Inspection/Repair

Route	System / Type of inspection	Steel wheel	Rubber tire	Straddle type Monorail	Note
A	Daily inspection (trains/day)	9	9	9	
	Monthly inspection (trains/month)	4.8	6.4	6.4	
	Intermediate overhaul (trains/year)	2.4	3.2	3.2	
	General overhaul (trains/year)	2.4	3.2	3.2	
	Occasional inspection (trains/year)	1	1	1	
	Rubber tire exchange or wheel reprofiling (trains/year)	9.5	3.7	9.5	
B	Daily inspection (trains/day)	4	6	5.5	
	Monthly inspection (trains/month)	3.3	4.4	4	
	Intermediate overhaul (trans/year)	1.7	2.5	2	
	General overhaul (trains/year)	1.7	2.5	2	
	Occasional inspection (trains/year)	0.6	0.6	0.6	
	Rubber tire exchange or wheel reprofiling (trains/year)	6.5	2.3	6	

Note: The frequency of occasional inspection is estimated 5 per cent of number of cars per year.

The capacities of inspection/repair for each spot (for 4-cars train) are as follows:

Daily inspection : 6 trains/day. spot
(Required work time: 1.5 hr./train)

Monthly inspeciton : 19 trains/month. spot
(Reguired work time: 1 day/train)

Intermediate overhaul: 5.4 trains/year. spot
(Required work time: 22 day/train)

General overhaul : 4.6 trains/year. spot
(Required work time: 26 day/train)

Occasional inspection: Common spot with tire exchange
(Required work time: 4 day/train)

Tire exchange : 1 train/day. spot
(Required work time: 3.5 hr./train)

As mentioned above, the number of required spots calculated from the capacities of inspection/repair is shown in Table 5.13.

Table 5.13 Number of Spots Required

Route	System / Type of inspection	Steel wheel	Rubber tire	Straddle type Monorail	Note
A	Daily inspection (Number of spots)	2	2	2	
	Monthly inspection (Number of spots)	1	1	1	
	Intermediate and general inspection (Number of spots)	1	1	1	
	Rubber tire exchange or wheel reprofiling (Number of spots)	1	1	1	
B	Daily inspection (Number of spots)	1	1	1	
	Monthly inspection (Number of spots)	1	1	1	
	Intermediate and general inspection (Number of spots)	1	1	1	
	Rubber tire exchange or wheel reprofiling (Number of spots)	1	1	1	

(2) Number of Storage Tracks
is shown in Table 5.14.

Table 5.14 Number of Storage Tracks

Place of car storage \ Route		A	B
Storage track	Storage tracks in the car shed complex	5 (5 x 2)	2 (2 x 2)
	Storage track in the station	1 (1)	1 (1)
For car inspection	Daily inspection track	2 (2)	1 (1)
	Monthly inspection track	1 (1)	1 (1)
	Car cleaning track	1 (1)	1 (1)
	Tire replacement or wheel reprofiling track	1 (1)	1 (1)
For car repair	Incoming & outgoing track at workshop	1 (1)	1 (1)
	Car repairing track	1 (1)	1 (1)
	Painting/cleaning track	1 (1)	1 (1)
	Test run track	1 (1)	1 (1)
Total		14 (20)	11 (13)

Note: Basic train formation; 4-cars train
Parenthesis ( ) indicates number of spots

(3) Required Area of Buildings

is calculated from the number of cars and the number of spots required as shown Table 5.15.

Table 5.15 Required Area of Buildings

(m^2)

Building \ System \ Route	A			B			Note
	Steel wheel	Rubber tire	Monorail	Steel wheel	Rubber tire	Monorail	
Headquarters' building	2,640	2,640	2,640	2,000	2,000	2,000	
Inspection shed	2,880	2,560	3,660	1,760	1,760	1,760	
Workshop	9,400	7,500	7,500	7,400	6,700	6,700	
Substation	1,750	1,750	1,750	1,750	1,750	1,750	
Others	1,985	2,200	2,200	1,885	2,200	2,200	Material store, Personnel office, Power supply room, etc.
Total	18,655	16,650	16,650	14,795	14,410	14,410	