5.2.5. Designing of Tower Foundation

(1) Present condition of tower foundation on transmission line

Except for special cases, pad and chimney type foundation is generally used as tower foundation on transmission line in East Java. The standard shape of this type is a square, but circular shape foundation is sometimes seen when the form is made of bamboo.
In case that the foundation is a weak stratum, the piles such as steel pile, Cakar Agam, etc. were used to ensure the bearing capacity.
Recently in Central Java, in order to cope with steel pile, the micro pile (long pile) has been studied and is going to be developed with national technology.
Above mentioned is the general present condition of tower foundation. Since the actual execution of tower foundation on transmission line is made based on the contracts between PLN and the local contractors, the details of designing and applicable scope are not clearly found, except the foundation designing recommended by Consultants.
For the standardization of the tower foundation in the future, it is necessary to standardize the design criteria and to settle the applicable scope of work after check of construction cost estimation and technical difficulty in construction.
In this Report, the comparative study of tower foundation on transmission line was made to get the basic data for standardization of foundation in the future.

(2) Comparison between square shape foundation and circular shape foundation

Table 5.2-27 shows the design formula to get the compression stability and uplift stability of square shape foundation and circular shape foundation. Comparative study was made from the above results.

(a) Compression

As seen in Table 3.2-16, the coefficients (α) for determing the maximum compression at pad are only different ones between square and circular shape foundations in the relative formula between load of compression and ultimate bearing capacity of the soil. But, since this difference is generally very small, ultimate bearing capacity for compression of circular shape foundation is regarded as same as that of square shape foundation with an equivalent area. Therefore, if both shape foundations have same depth and same thickness of pad, concrete volume required for these 2 foundations will be almost equal. Designing of N-type and M-type foundations is determined by ultimate bearing capacity. So, work volume will be effected very little by the replacement from square to circular type foundation.

(b) Uplift

The relation between load of uplift and ultimate uplift capacity of foundation is shown in Table 5.2-27. Earth cone volume is calculated from the following expression to get the earth cone weight of effective soil. Difference in earth cone volume is found in the calculation between square shape foundation and circular shape foundation. When earth cone volumes of square shape foundation and circular shape foundation are expressed at Ve and Ve', respectively, they are calculated as below.

$$Ve = h \left(B^2 + 2Bh \tan \Theta + \frac{4}{3}h^2 \tan^2 \Theta\right)$$

$$Ve' = \frac{\pi}{4}h \left(B'^2 + 2B'h \tan \Theta + \frac{4}{3}h^2 \tan^2 \Theta\right)$$

Supposing that both foundations have the same base area and same depth of the pad.

$\frac{\pi}{4}B'^2 = B^2$,   Therefore, $B' = B\sqrt{\frac{4}{\pi}}$

When this is substituted for Ve', Ve' is computed as below.

$$Ve' = \frac{\pi}{4}h\ (B^2 \cdot \frac{4}{\pi} + 2B\sqrt{\frac{4}{\pi}} \cdot h\ \tan\Theta + \frac{4}{3}h^2\ \tan^2\Theta)$$

$$= h\ (B^2 + 2B\sqrt{\frac{\pi}{4}}h + \frac{4}{3} \cdot \frac{\pi}{4}h^2\ \tan^2\Theta)$$

$$= h\ (B^2 + 2Bh \times 0.886 + \frac{4}{3}h^2\ \tan^2\Theta \times 0.785)$$

$$< Ve$$

The result of the above calculation shows that the ultimate uplift capacity of circular foundation is considerably lower in case of same base area and same depth of the pad. Generally, the designing of L-type foundation is determined by load of uplift. The comparative study between square and circular shapes was made to the L-type foundation for AA, BB and CC steel towers which were applied at East Java 3rd Stage. In case that L-type circular foundation for AA steel tower has the same base area and same depth of pad as the square foundation, the designing examples are as shown in Table 5.2-28. L-type circular foundation for BB and CC steel towers was designed in the same manner as above mentioned, and compared with square foundation already designed, as for the measurement and cost for foundation, etc. This comparison is shown in Table 5.2-29, according to which the circular foundation have much more base width of pad, concrete volume and excavation volume than the square foundation.

For the comparison of work volume, the relation between the ratios (concrete volume and excavation volume for circular foundation to those for square foundation) and each allowable load of uplift is indicated in Fig. 5.2-16. As seen in the Figure, the ratio becomes smaller with the increase of foundation area. But in general, work volume of circular foundation is about 1.1 to 1.2 time of that of square foundation. Therefore, in case of L-type foundation, the square foundation is generally advantageous because of less work volume required.

If the circular shape foundation is applied with bamboo forms, further cost study will be required to check whether increased work volume can be covered by the bamboo form.

The reason why circular foundation is applied in Japan is to perform the under-cut excavation with circular steel pile i.e. to reduce the excavation volume and to reinforce the load of uplift of the foundation. (Fig 5.2-17)

(3) Foundation of weak stratum with deep hard layer

The existing transmission line route in East Java is mostly occupied by plain areas, some of which are rice fields having weak stratum. 20% to 30% of the transmission line routes to be projected in the future will also be occupied by the weak stratum, and special foundation will be required, accordingly.

As seen in the actual examples in north-east part of Surabaya City, these weak stratums are expected to have the hard layer of more than 10m. When the construction of steel tower foundation is required in such weak stratum, shallow type foundation with large diameter steel pile is applied in general. However, large diameter steel piles are not producted in Indonesia, but have to be imported from aboroad. This will affect the construction schedule and financial schedule of the transmission line.

Therefore, it will be difficult to adopt large diameter steel pile in the future. The aim of this Report is to study the weak stratum foundation fully suitable for the future transmission line construction in East Java, without adoption of large diameter steel pile.

(a) Pile foundation

Pile foundation had been used since old time as a foundation of transmission line. Pile foundation can expect comparatively little temporary facilities and much better effect with easy execution. This is the most popular foundation with hard layer weak stratum. Piles are roughly divided into 2 kinds : one is a manufactured pile, the other concreting pile at site. They have a merit and demerit, each other. The manufactured pile has generally guaranteed quality but suffers much restriction in transportation and pile connection. Especially, it is strongly influenced by vibration, noise, etc. On the other hand, the concreting pile at site requires high technique in the execution but little restriction in transportation and pile connection. In East Java, the suitable as manufactured pile is seemed to be the large diameter steel pile, and as concreting pile, the micro pile. Steel piles have no problem because of many actual results of use in East Java. But, micro piles have been developed by National technology in order to cope with the steel pile, and are still on the way of study. As seen in Fig. 5.2-18, micro piles are of simple structure, cheaper material cost and can get the big bearing capacity by mortar grouting. If pile placing is executed without problems, the micro pile is considered most suitable for clayey stratum. However, there still remain the problems in execution of micro pile, whether pile placing can be made successfully and whether mortar pressure can prevent the soil sliding occurring by pile placing. It is also seemed difficult to know the section performance of the pile for designing. Most attractive point of the micro pile is to be the long pile developed by national technology. Careful and continuous study are required for the future practicability.

The recommendable improvement is to revise the end structure of the pile, as shown in Fig. 5.2-19. By this improvement the piling efficiency will become higher, and pile placing will be more straight, because cross-section of the pile becomes circular.
Designing examples of the actual foundation by use of steel pile and micro pile are indicated in Table 5.2-30 and Table 5.2-31, respectively.

<u>Design condition</u>

Load of uplift : 180 tons
Load of compression : 200 tons
Horizontal force : 4 tons
Soil : Clayey soil
N-value at the standard penetration test : 4
Frictional stress between soil and pile : 20 tons/m^2
Length of pile : 16m
(Sukolilo Kenjeran 4 RD type steel tower load)

(b) Floating foundation

Floating foundation is one of the mat foundation, having a shallow and wide base. This kind of foundation is used in Japan when firm hard layer is laid at the very deep portion or when it is requested to prevent the unbalanced settlement of tower's four legs by the consolidation of clayer layer.
In Indonesia, as the case may be, the floating foundation will be useful as well as pile foundation, even if the hard layer is not so deep. Table 3.2-21 shows the designing example of floating foundation at the same design conditions as applied to the pile foundation.
The Table indicates that the floating foundation requires no piles but concrete volume reaches to 8 times in comparison with pile foundation. However, the execution of floating foundation is very simple and any

special technique is not required. Economical construction will be expected by floating foundation with large sized civil work machinery.
In case that big differences are found in the load conditions to the tower between horizontal longitudinal load and horizontal transverse load, 2 legs 1 body foundation is often used to support the higher load in parallel. And if the ground includes a lot of spring water, it will be one of the methods to level up the foundation base and to lessen the depth of excavation.
Various kinds of foundation can be designed by the ground condition including spring water and load condition.
At the actual designing of floating foundation, sufficient reinforcement by tower is needed for foundation, because the base is too thin in comparison with large base area. Therefore, the most important is to ensure the sufficient hardness of the foundation with thin reinforcing bars to be arranged in the short interval.

(4) Summary

The study was made to the foundation of steel towers in East Java, of which results are summarized as follows.

(a) In case that foundation base and body are of circular shape, it requires 1.1 to 1.2 time of work volume for square shape foundation. This means that the circular shape foundation is not more advantageous except for special case.

(b) Large diameter steel pile had been used in Indonesia for long pile foundation. But recently, micro pile was developed by national technology. Careful and continuous study will be required for the future practicability.

(c) Floating foundation is considered applicable to the deep foundation with firm and hard layer. From the view-points of workability, the floating foundation is considered competitive with long pile foundation.
Further study is needed whether floating foundation is applicable or not in East Java.

(d) The increase of multi-circuit steel tower is expected in East Java, because of the land restriction for transmission line route.
In order to meet the increase of foundation load for multi-circuit, it is considered necessary to design the firm and economical foundation.
Sufficient ground investigation has to be made to collect necessary data for designing, especially to the weak stratum.

Table 5.2-1 Comparison of Wind Load

	France Loan	E.J.P. Ⅰ～Ⅲ
Maximun mean wind Velocity(m/s)	25	25
Tower Load (kg/m²)	120	110
Wire Load (kg/m²)	45	40
Insulator String Load(150kV,kg/st)	60	60

Table 5.2-2 Climate of Surabaya (Number of Years-20)

	J	F	M	A	M	J	J	A	S	O	N	D	Year		
													Max	Min	Mearn
Mean Temperature(°C)	26.6	26.4	26,8	26.9	26.6	26.6	26.0	26.1	26.9	27.8	28.0	26,8	31.1	23.5	26.8
Mean Air Pressure(M.Bar)	1009.1	1007.8	1007.2	1007.7	1008.2	1008.6	1009.3	1003.3	1009.9	1009.4	1007.7	1008.2	—	—	1008.1

Table 5.2-3 Wind Load of Conductors

	d(mm)	D(mm)	d/D	Re	Cx	P(Kg/m²)
50mm² Cu	1.8	9.0	1/5	1.46	1.23	46.4
Pigeon	4.25	12.75	1/3	2.07	1.14	43.0
Ostrich	2.73	17.28	1/6.3	2.84	1.05	39.6
Hawk	3.44	21.80	1/6.3	3.54	0.97	36.6
330mm² ACSR	4.0	25.30	1/6.3	4.11	0.93	35.1
55mm² G.S.W.	3.2	9.6	1/3	1.56	1.19	44.9

ν : 1.54×10^{-5} (m^2/s) at. 23°C 756mmHg

ρ : 0.1208 ($kg.s^2/m^4$) "

Table 5.2-4 Comparison of Material Standard

	France Loan	NEW-JEC Standard
Tower-Member	°AFNOR E 36(Yield Point36)	°JIS-SS55(Yield Point41)
	Main Members	L70×6 or more
	°AFNOR E 24(Yield Point24)	°JIS-SS41(Yield Point25)
	Bracings	Less than L70×6
-Bolt	°AFNOR E 24(Yield Point24)	°JIS-SS50(Yield Point29)
	Three Dimensions of Diameter	M20, M22
		°JIS-SS41(Yield Point25)
		M16
-Minimum Size	°Member	°Member
	Thickness of angles-	Leg members and arm members
	Less than 3mm	L60×5
	°Bolt 14mm	°Bolt M16
Conductor-Code Name	°ASTM "Hawk"	°JIS C 3110
No. & Dia of Al. wire	26 × 3.44mm	30 × 3.2mm
No. & Dia.pf St. Wire	7 × 2.68mm	7 × 3.2mm
Sectional Area of Al	241.6mm²	241.3 mm²
Sectional Area of St.	39.5mm²	56.29mm²
Weight per KM	976kg	1,110kg
Ultimate B.S.	8,818kg	10,210kg
Over all Diameter	21.80mm	22.4mm
Insulator-Type	°Glass-IEC 305/74	°Porcelain-ANSI-C29.5
Diameter	255mm	254mm (10")
Height	146mm	146mm ($5\frac{3}{4}$")
Leakage Length	292mm	292mm ($11\frac{1}{2}$")
Impulse	130kV	125kV
Mechanical St.	12,000kg	11,340kg or (25L.B)
Earth Wire-Code Name	°NF C34.125 AACSR59.7mm²	° AW 55mm²
No. & Dia. of Wire	19/2.0mm (AA)	7 x 3.2mm (AW)
Sectional Area	59.7mm²	56.29mm²
Diameter	10mm	9.6mm

Table 5.2-5 Electric Power Loss

(In %)

Item \ Country	*P.L.N.(East Java) 1983	**JAPAN 1982	P.L.N / JAPAN
Power Station Loss	3.95	3.4	1.2
Transmission Line, Substation Loss	4.71	2.7	1.7
Distribution Line Loss	12.35	3.3	3.7
Total	21.0	9.4	2.2

Note

* P.L.N.(East Java) Loss based on P.L.N. 1983 (From April to December) data.

** JAPAN Loss based on average loss ratio of a Electric Power Companies.

Table 5.2-6 Planning of Additional 2nd Circuit

Item \ Year	1 (n)	......	n (1)	n+1 (0)
Investment	◎			⊗
O & M	○	......	○	
Depreciation		○	......	○
Revenue		○	......	○
Electric Peak current on T/L	I(n)		I(1)	Io(o)

Note

◎ : Investment of early stage

⊗ : Investment of normal stage

Io : Current carrying capacity

Table 5.2-7 Base Cost of Electric Power

Voltage \ Base Cost	Base Cost	
	Rp/KWH	¥/KWH
150KV Bus bar	71.44	16.93
*(70KV) "	(74.28)	(17.61)
20KV "	77.11	18.28

Note

* 70KV Bus bar : Average between 150KV Bas.cost and 20KV Bas.cost

1 Rp = 0.237¥

Table 5.2-8 Unit Costs of T/L & S/S

	Currency	Unit Cost (F.C:$,L.C:$10^3$Rp)			"(10^3¥)
		Direct Cost	*Others	Total	Total
150KV Additional 2nd Circuit (/KM)	F.C	16,830	2,977	19,797	5,665
	L.C	3,731	544	4,275	
70KV Additional 2nd Circuit (/KM)	F.C	8,320	1,473	9,793	2,956
	L.C	2,296	469	2,765	
150KV Additional T/L Bay (/Bay)	F.C	279,102	49,401	328,503	114,979
	L.C	138,080	21,403	159,483	
70KV Additional T/L Bay (/Bay)	F.C	146,068	25,854	171,922	69,074
	L.C	104,790	16,243	121,033	

Note

* Others : Physical Contigency + Consultant Fee

US$ = 992Rp = 235¥

Table 5.2-9 150KV 330mm^2 ACSR (1/2) Growth Rate 16.5%/Y

Year	Reak Current (Ip)	Average Current (Ip)x0.67=(Iave)	Loss Reduction 3/2 $Ip^2 R^* x 0.515 x 10^{-3}$(KW/KM)	Revenue (10^3¥/KM/Y) (KW/KM)x8.760x16.93
(0)	740.0	495.8	35.6	5,282
(1)	635.2	425.6	26.2	3,892
(2)	545.2	365.3	19.3	2,867
(3)	468.0	313.6	14.2	2,113
(4)	401.7	269.2	10.5	1,557
(5)	344.8	231.0	7.73	1,147
(6)	296.0	108.3	5.70	845
(7)	254.1	170.2	4.20	623
(8)	218.1	146.1	3.09	459
(9)	187.2	125.4	2.28	338
(10)	160.7	107.7	1.68	249
(11)	137.9	92.4	1.24	183
(12)	118.4	79.3	0.91	135
(13)	101.6	68.1	0.67	99.6

NOTE *R: 0.0842 Ω/KM

70KV 300MCM ACSR (2/2)   Growth Rate 16.5%/Y

Year	Reak Current (Ip)	Average Current (Ip)x0.67=(Iave)	Loss Reduction 3/2 $Ip^2 R^* x 0.515x10^{-3}$(KW/KM)	Revenue (10^3¥/KM/Y) (KW/KM)x8.760x17.61
(0)	440.0	294.8	28.42	4,383
(1)	377.7	253.0	20.94	3,230
(2)	324.2	217.2	15.43	2,380
(3)	278.3	186.4	11.37	1,754
(4)	238.9	160.0	8.38	1,292
(5)	205.0	137.4	6.17	952
(6)	176.0	117.9	4.55	701
(7)	151.1	101.2	3.35	517
(8)	129.7	86.9	2.47	381
(9)	111.3	74.6	1.82	280
(10)	95.5	64.0	1.34	206
(11)	82.0	54.9	0.985	152
(12)	70.4	47.2	0.726	112
(13)	60.4	40.5	0.535	82.6
(14)	51.7	34.8	0.392	60.5
(15)	44.5	29.8	0.290	44.8
(16)	38.2	25.6	0.214	33.0

NOTE *R: 0.190 Ω/KM

Table 5.2-10 Discount Rate Calculation

150KV 330mm^{2}ACSR Growth Rate 16.5%/Y, n=10, 10^3¥

	1	2	3	4	5	6	7	8	9	10	11
Investment	5,665										Δ5,665
Depreciation		498	455	415	378	345	314	287	262	239	218
O & M	85	85	85	85	85	85	85	85	85	85	
COST (C)	5,750	583	540	500	463	430	399	372	347	324	Δ5,447
Revenue (R)		249	338	459	623	845	1,147	1,557	2,113	2,867	3,892
(R) - (C)	Δ5,750	Δ334	Δ202	Δ41	160	415	748	1,185	1,766	2,543	9,339

70KV 300MCM ACSR Growth Rate 16.5%/Y, n=10, 10^3¥

	1	2	3	4	5	6	7	8	9	10	11
Investment	2,956										Δ2,956
Depreciation		260	237	216	197	180	164	150	136	125	114
O & M	44	44	44	44	44	44	44	44	44	44	
COST (C)	3,000	304	281	260	241	224	208	194	180	169	Δ2,842
Revenue (R)		206	280	381	517	701	952	1,292	1,754	2,380	3,230
(R) - (C)	Δ3,000	Δ98	Δ1	121	276	477	744	1,048	1,574	2,211	6,072

Table 5.2-11 Total Cost (10^3 ¥/KM)

	150 KV 330mm ACSR			70 KV 300MCM ACSR		
	30 KM	45 KM	60 KM	30 KM	45 KM	60 KM
T/L Cost (10^3 ¥/KM)	5,665	5,571	5,540	2,956	2,908	2,891
S/S Bay cost (")	7,652	5,110	3,834	4,593	3,070	2,302
Total Cost (")	13,317	10,681	9,374	7,549	5,978	5,193
O & M Cost (1.5%)	200	160	141	113	90	78

Table 5.2-12 **Tripout Records of T/L**

(1983/11 ~ 1984/6)

Items of T/L				Causes of Fault (1983/11 ~ 1984/6)					* 1982 ~ 1983
Vg	c.c.t.	Route Length (km)	Tripout	Human Work	Climate: Bad. Weather	Climate: Lightning	Unknown	Total	
150kV	1/2cct	380.43	1cct	1	6	1	0	8	-
	2/2cct	463.99	1cct	4	8	3	13	28	-
			2cct	1	3	0	0	4	-
	Total	844.42	-	6	17	4	13	40	9
70kV	1/2cct	169.2	1cct	0	2	1	3	6	-
	2/2cct	631.7	1cct	19	19	9	12	59	-
			2cct	9	6	0	3	18	
	Total	800.9	-	28	27	10	18	83	86

Note
* 1982/11 ~ 1983/6

Table 5.2-13 2CCT T/L Tripout Rate Records Per 100KM Per Rainy Season

Item / Vg	Route Length (km)	[1983/11~19884/6] A			*[1982~1984] Average B			Japan (Per Year)
		1cct	2cct	Total	1cct	2cct	Total	
150kV	463.99	6.04	0.86	6.90	3.70	0.53	4.23	----
70kV	631.7	9.34	2.85	12.19	9.51	2.90	12.41	7.64

Note * Average 150kV : $B = A \times \frac{24.5}{40}$ $24.5 = \frac{40 + 9}{2}$

70kV : $B = A \times \frac{84.5}{83}$ $84.5 = \frac{83 + 86}{2}$

Table 5.2-14 Schedule of Tripout Records

In (%)

Item / Region	Vg	Climate			Human Work	Unknown	Total
		Bad Weather	Ice Load	Lightning			
East Java	70kV	32.5	0	12.1	33.7	21.7	100
*Japan	66~77kV	7.2	10.9	55.6	10.9	15.4	100

Note * Records in Japan : 1966 ~ 1971

Table 5.2-15 Forecast of Tripout Rate Per 100KM Per Year

Installation System / Stroke To / Number of Circuit / Vg	Standard Insul.				Unbalanced Insul.				High Insul.			
	Tower		Cond.	Total	Tower		Cond.	Total	Tower		Cond.	Total
	1cct	2cct	1cct		1cct	2cct	1cct		1cct	2cct	1cct	
150 kV	0.228	0.787	0.70	1.715	0.873	0.142	0.64	1.655	0.147	0.313	0.58	1.040
70 kV	0.311	2.079	0.98	3.37	2.259	0.131	1.02	3.410	0.264	1.203	1.07	2.537

Table 5.2-16 Tripout Rate Records of 150 kV 2cct. T/L by Climate

(Per 100KM Per Rainy Season)

	Route Length	[1983/11 ~ 1984/6] C			* [1982 ~ 1984] Average D			Average / Forecast
		1cct	2cct	Total	1cct	2cct	Total	
150 kV	463.99	2.37	0.65	3.02	1.45	0.40	1.85	1.12

Note * Average 150 kV : $D = C \times \frac{24.5}{40}$ $24.5 = \frac{40 + 1}{2}$

Table 5.2-17 Tripout Records In Japan (275kV T/L)

	Fault Phase												Reclose Success Ratio	
1L	A	A	A B	A	A B	A B	A B C	A B	A B	A B C	A B C	A B C	To Total Tripouts	To 2cct Tripouts
2L		A		B	A	A B		C	B C	A	A B	A B C		
K Company	239*	33*	43*	6	8	4	4*	2	2	3	1	2	0.92	0.54
C Company	50*	8*	5*		1	6					1		0.89	0.50

Note * Reclose Success

Table 5.2-18 150kV 1/2cct T/L Tripout Records

	Route Length (KM)	[1983/11 ~ 1984/6] Records		
		Tripouts	Rates/100KM	Ratio
IKL 100	298.03	5	1.68	1.21/1.68 = 0.72
IKL 70	82.4	1	1.21	

Table 5.2-19 T/L Conductor Characteristics

70 KV T/L

Age	H.D.C.C.	A.C.S.R.
1929	———	Pigeon - 85mm^2(6/4.25, 1/4.25)
1932 ~ 1943	50mm^2 (unknown)	———
1961 ~ 1967	50mm^2 (unknown)	Pigeon - 85mm^2(6/4.25, 1/4.25)
1975 ~	———	Piper - 152mm^2(30/2.54, 7/2.54) Ostrich-152mm^2(26/2.73, 7/2.12)

150 KV T/L

Age	H.D.C.C.	A.C.S.R.
1971 ~	———	JIS-330mm^2(26/4.0, 7/3.1) HawK-242mm^2(26/3.44, 7/2.67) JIS-160mm^2 (30/2.6, 7/2.6)

Table 5.2-20 Comparison of Conductor Characteristics and Construction Unit Costs (In US$ x 10^3)

Item \ Conductor	$330mm^2$ ACSR	$240mm^2$ ACSR
Conductor Characteristic		
System	Metric (26/4.0,7/3.1)	Inch Pound (26/3.44, 7/2.68)
D.C. Resistance, /KM	*1 0.0888,20°C	*2 0.1964 /Mile 0.12235 /KM,25°C
Construction Unit Cost (/KM)		
2cct. Tower	*3 15.296	15.296 x *4 0.93 = 14.225
1cct. Conductor	9.595	*5 8.343 x *6 $\frac{673}{812}$ + *7 1.252 = 8.167
1 Earth Wire	1.298	1.298
1cct. Insulator	3.645	3.645
F.C. Total	29.834	27.335
L.C. (Tower Cons. Cost)	*8 17.850	17.850 x 0.93 = 16.601
F.C. + L.C.	47.684	43.936
(F.C. + L.C.)-(47.684)	0	- 3.748

NOTE

* 1 JIS C3110 1978

* 2 Transmission Line Reference Book 345KV and Above by E.P.R.I.

* 3 Unit Cost Estimated by JICA - Category B

* 4 Ratio of Another Conductor T/L Tower Weight to $330m^2$ ACSR T/L one - From Fig. 5.2-9

* 5 Conductor Cost of T/L

* 6 Conductor Cost in Japan (Yen/m) $\frac{240mm^2 ACSR}{330mm^2 ACSR}$

* 7 Accessory Cost

* 8 Tower Construction Cost Estimated by JICA Category B
X-0.292, Y-0.527, Z-0.181 ——— Madura Island

Table 5.2-21 Calculation of Benefit

No.	Year	Demand / 1988 Demand	Benefit (A^2 x 0.6765 IN US$) 1	4	5	6	7	8
1	1988	1	0.6765	11	17	24	33	43
2		1.1325	0.8676	14	22	31	43	56
3		1.2826	1.1129	18	28	40	55	71
4		1.4525	1.4273	23	36	51	70	91
5		1.6450	1.8306	29	46	66	90	117
6	1993	1.8632	2.3485	38	59	85	115	150
7		2.0781	2.9215	47	73	105	143	187
8		2.3177	3.6340	58	91	131	178	233
9		2.5899	4.5202	72	113	163	221	289
10		2.8830	5.6229	90	141	202	276	360
11	1998	3.2154	6.9942	112	175	252	343	448
12		3.5527	8.5386	137	213	307	418	546
13		3.9254	10.4240	167	261	375	511	667
14		4.3372	12.7258	204	318	458	624	814
15		4.7922	15.536	249	388	559	761	994
16	2003	5.2954	18.970	304	474	683	930	1,214
17		5.8408	23.079	369	577	831	1,131	1,477
18		1.4425	28.079	449	702	1,011	1,376	1,797
19		7.1060	34.160	547	854	1,230	1,674	2,186
20		7.8379	41.559	665	1,039	1,496	2,036	2,660
21	2008	8.6453	50.562	809	1,264	1,820	2,478	3,236
22		9.5271	61.403	982	1,535	2,211	3,009	3,930
23		10.4989	74.568	1,193	1,864	2,684	3,654	4,772
24		11.5698	90.556	1,449	2,264	3,260	4,437	5,796
25	2012	12.7499	109.972	1,760	2,749	3,959	5,389	7,038

COST : BASE
BENEFIT : CASE11

Table 5.2-22 INTERNAL ECONOMIC RATE OF RETURN

(USD X1000)

NO	YEAR	COST: EXP.PROG. INVESTMENT	COST: TOTAL	BENEFIT	BENEFIT: TOTAL	PRESENT WORTH: COST	PRESENT WORTH: BENEFIT	E.I.R.R. 11.40 % FACTOR
1	1987	3743	3743	0	0	3743	0	1.0000
2	1988	0	0	33	33	0	30	0.8976
3	1989	0	0	43	43	0	35	0.8058
4	1990	0	0	55	55	0	40	0.7233
5	1991	0	0	70	70	0	45	0.6493
6	1992	0	0	90	90	0	52	0.5828
7	1993	0	0	115	115	0	60	0.5231
8	1994	0	0	143	143	0	67	0.4696
9	1995	0	0	178	178	0	75	0.4215
10	1996	0	0	221	221	0	84	0.3784
11	1997	0	0	276	276	0	94	0.3397
12	1998	0	0	343	343	0	105	0.3049
13	1999	0	0	418	418	0	114	0.2737
14	2000	0	0	511	511	0	126	0.2457
15	2001	0	0	624	624	0	138	0.2205
16	2002	0	0	761	761	0	151	0.1980
17	2003	0	0	930	930	0	165	0.1777
18	2004	0	0	1131	1131	0	180	0.1595
19	2005	0	0	1376	1376	0	197	0.1432
20	2006	0	0	1674	1674	0	215	0.1285
1987 - 2006		3743	3743	8992	8992	3743	1972	
2007 - 2012		0	0	21003	21003	0	1771	
1987 - 2012		3743	3743	29995	29995	3743	3743	

PRESENT WORTH

	DISCOUNT RATE (%)	(4.0)	(6.0)	(8.0)	(10.0)	(12.0)	(14.0)	(16.0)
COST	EXP.PROG. INVESTMENT	3743	3743	3743	3743	3743	3743	3743
	TOTAL	3743	3743	3743	3743	3743	3743	3743
BENEFIT		13571	9361	6568	4690	3409	2523	1901
	TOTAL	13571	9361	6568	4690	3409	2523	1901
	B/C	3.626	2.501	1.755	1.253	0.911	0.674	0.508
	B-C	9828	5618	2825	947	-334	-1220	-1842

Table 5.2-23 Demand Forecast By PLN

Year \ Item	East Java		Madura	
	Demand For.	Growth Rate	Demand For.	Growth Rate
1984/85	2,550.7 MW		112.9 MW	
		18.5%		22.63%
1988/89	5,026.6 MW		255.3 MW	
		16.2%		20.95%
1993/94	10,637.7 MW		660.8 MW	

Table 5.2-24 Ratio of Demand Forecast to 1983/84 Demand

	East Java		Madura	
	PLN	JICA	PLN	Modified Ratio
1983/84	1	1	1	1
1988/89	2.335	2.100	2.772	2.772
1993/94	4.942	3.921	7.175	5.175

$$1993/94 \text{ Target of Ratio in Madura} = 3.921 \times \frac{7.175}{4.942} = 5.693$$

Table 5.2-25 Demand Forecast in Madura (1988/89)

(In MW)

	Gili.Timur	Bangkalan	Sampang	Pamekasan	Sumenep
Macro Plan	0.13	1.41	2.00	2.30	1.92
Modified Plan	0.17	1.86	2.64	3.04	2.53

$$\text{Modification Factor of 1988/89 Demand in Madura} = \frac{2.772}{2.100} = 1.32$$

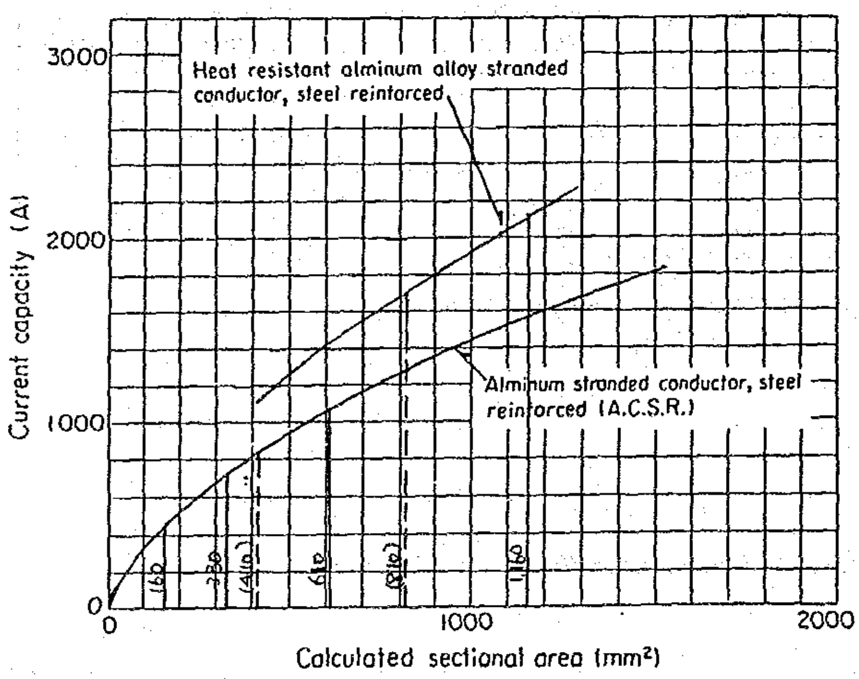
Table 5.2-26 Standard A.C.S.R. of T/L in JAPAN

(K.Company)

77 kV , 154 kV			275 kV , 500 kV		
Size(mm^2)	Current Carrying Cap(A)	Ratio	Size(mm^2)	Current Carrying Cap(A)	Ratio
160	455	0.6	410	835	1
330	720	1	A810	1,670	2
610	1,075	1.5			
*A1,160	2,135	3.0			

Note *A: Heat resistant alminum alloy

Current Carrying Capacity



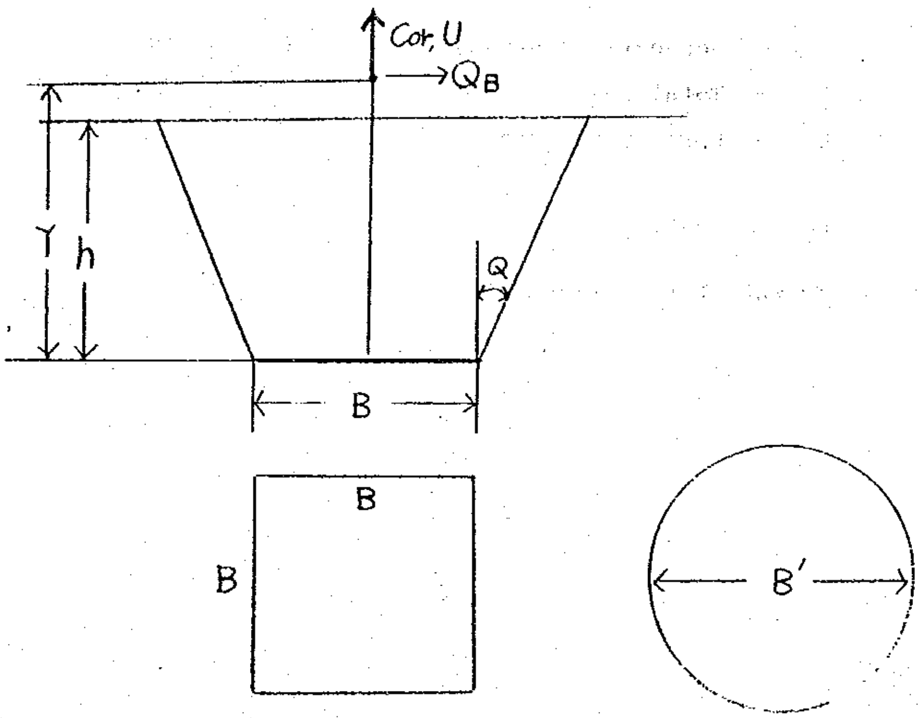
Calculating condition:

Ambient temperature ....40°C
Allowable temperature rise ....50°C
Solar radiation energy ....0.1 W/cm²
Wind velocity ....0.5 m/sec
Surface coefficient.................................0.9
Frequency ....60 Hz

But as for the conductors used heat resistant aluminum alloy wire, allowable temperature rise is 80°C, other constants are equal to the above.

Table 5.2-27 Foundation Stability Formula

	Square Type Foun.	Circular Type Foun.
Compression Stability	$\frac{q}{S.F.} \geqq \alpha \frac{C+Wc+Wec}{A}$	
Uplift Stability	$U \leqq \frac{Wc+We}{S.F.}$	
Earth Cone Volume Formula	$h(B^2+2Bh\tan\theta+\frac{4}{3}h^2\tan^2\theta)$	$\frac{\pi}{4}h(B'^2+2B'h\tan\theta+\frac{4}{3}h^2\tan^2\theta)$



q : Ultimate bearing capacity of the soil (t/m^2)

c : Load of compression (t)

Wc : Weight of Concrete of foundation (t)

Wec : Volume of soil on the pad (t)

A : Area of the pad (m^2)

α : Coefficient for determing the maximum compression at pad

- Square type foundation

$$\alpha = 1 + \frac{6e}{B} \qquad \text{for } e \leq \frac{B}{6}$$

- Circular type foundation

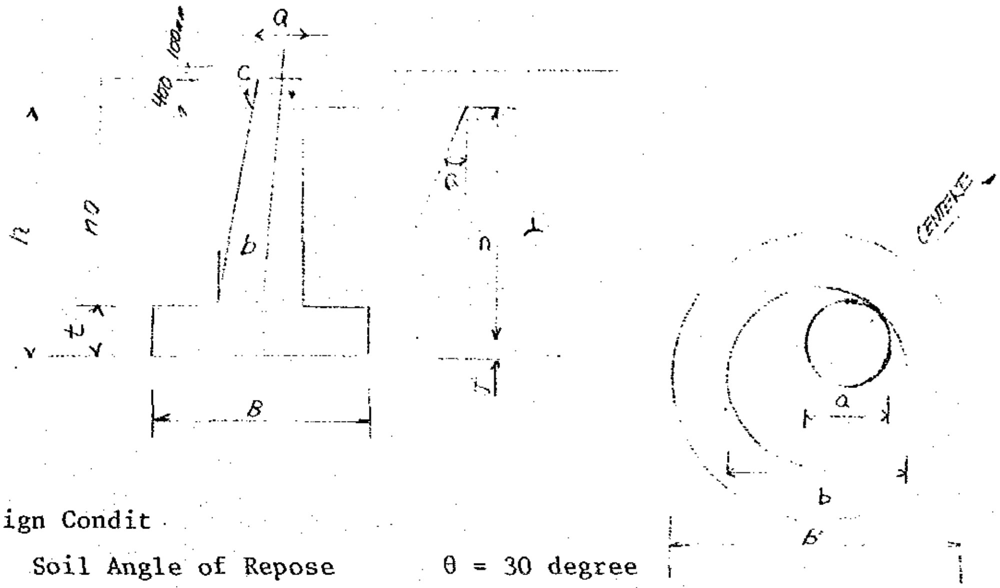
$$\alpha = 1 + \frac{8e}{B} \qquad \text{for } e \leq \frac{B}{8}$$

e	-	eccentric distance	$e = Q_B \cdot Y/P$
P	-	Total compression	$P = C + Wc + Wec$
Q_B	-	Horizontal Load	

U : Load of uplift

We : Weight of effective soil

Table 3.2-17 Foundation of Type AA-L



Design Condit

Soil Angle of Repose	θ = 30 degree
Soil Unit weight	γe = 1,600 kg/m^3
Con Unit Weight	γc = 2,300 kg/m^3
Safety factor	≧ 2.0

$$U \leq \frac{Vc.\gamma c + Ve.\gamma e}{S.F.} = \frac{Wc + We}{S.F.}$$

Where U : Load of uplift (kg)

Vc : Volume of concrete

$$Vc = \frac{\pi B^2}{4} \cdot t + \frac{\pi he}{12}(a^2 + ab + b^2) \quad (m3)$$

Ve : Effective Volume of Soil

$$Ve = Ve' - Vc' \quad (m^3)$$

Ve' : Volume of Cone

$$Ve' = \frac{\pi}{4}j(B^2 + 2Bj\tan\theta + \frac{4}{3}j^2 \cdot \tan^2\theta)$$

Vc' : Volume of Concrete included in Cone

$$Vc' = Vc - \frac{\pi 0.4}{12}(\alpha^2 + a \cdot c + c^2) - \frac{\pi B^2}{4} \cdot f$$

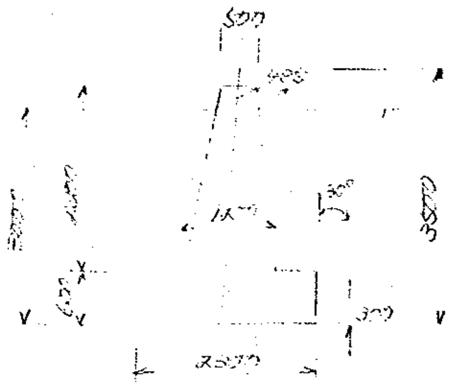
Wc : Weight of Concrete of Foundation

$$Wc = Vc \cdot \gamma c \quad (kg)$$

We : Weight of Effective Soil

$$We = Ve \cdot \gamma e \quad (kg)$$

I. AA-L TYPE UPLIFT STABILITY



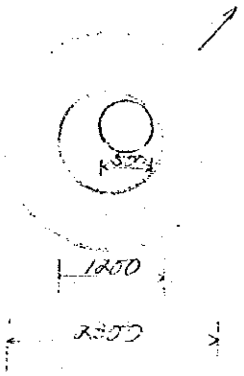
$U = 27,510$ kg

$$Vc = \frac{\pi B2}{4}t + \frac{\pi ha}{12}(a^2 + ab + b^2)$$

$$= \frac{3.14x2.3^2}{4} \times 0.6 +$$

$$\frac{3.14x28}{12}(0.5^2 + 0.5x1.2 + 1.2^2)$$

$$= 4.16 \ m^3$$



$$Ve' = \frac{\pi}{4}j(B^2 + 2Bj\tan\theta + \frac{4}{3}\cdot j^2\cdot\tan^2\theta)$$

$$= \frac{3.14}{4} \times 2.7 \ (2.3^2 + 2x2.3x2.7x0.577$$

$$+ \frac{4}{3} \times 2.7^2 \times 0.577^2)$$

$$= 33.26 \ m^3$$

$$Vc' = Vc - \frac{0.4}{3}(a^2 + ac + c^2) - \frac{\pi B2}{4}\cdot f$$

$$= 4.16 - \frac{\pi 0.4}{12}(0.5^2 + 0.5 \times 0.565 \times 0.565^2) -$$

$$\frac{3.14 \times 2.3^2}{4} \times 0.3$$

$$= 2.82 \ m^3$$

$$Ve = Ve' - Vc'$$

$$= 33.26 - 2.82 = 30.44 \ m^3$$

$$We = Ve\cdot\gamma e = 30.44 \times 1.6 = 48.70 \ t$$

$$Wc = Vc\cdot\gamma c = 4.16 \times 2.3 = 9.56 \ t$$

$$U \leq \frac{Wc + We}{S.F.}$$

$$U = 27.51 \ t < \frac{9.56 + 49.96}{2.0} = 29.13 \ t$$

II. AA-L TYPE COMPRESSION STABILITY

ULTIMATE BEARING CAPACITY $q = 60\ t/m^2$

$$\sigma max = \alpha \cdot \frac{C + \gamma cVc + \gamma eVec}{\frac{\pi}{4} \cdot B^2}$$

$$\geqq \alpha \cdot \frac{C + Wc + Wec}{\frac{\pi}{4} \cdot B^2}$$

$$\frac{q}{S.F.} \geqq \sigma max$$

Where,

C : Coad of Compression (kg) (C = 33.63 t)

Vec : Volume of soil on the slab

$$Vec = \frac{\pi B^2}{4} \cdot h - Vc''$$

Vc'' : Volume of concrete under the ground

$$Vc'' = Vc - \frac{0.4}{3}(a^2 + ac + c^2)$$

α : Coefficient for determining the maximum compression at slab

$\alpha = 1 + 8e/B$ FOR $e \leqq B/8$

e : Eccentric distance

$e = Q_{B'} \cdot Y/P$

P : Total Compression

$P = C + Wc + Wec$ (kg)

Q_B : Horizontal Load (kg) (Q_B = 1.37 t)

Wec : Weight of soil on the slab (kg)

$Wec = Vec \cdot \gamma e$

σmax : Maximum Compressive Stress (kg/m^2)

q : Ultimate bearing capacity of the soil (t/m^2) ($q = 60 t/m^2$)

$C = 33.63$ t

$Vc'' = Vc - \frac{\pi 0.4}{12}(a^2 + ac + c^2)$

$= 4.16 - \frac{3.14 \times 0.4}{12}(0.5^2 + 0.5 \times 0.565 + 0.565^2) = 4.07 \ m^3$

$Vec = \frac{\pi B^2}{4} \cdot h - Vc''$

$= \frac{3.14 \times 2.3^2}{4} \times 3 - 4.07 = 8.38 \ m^3$

$Wec = Vec \cdot \gamma e$

$= 8.38 \times 1.6 = 13.42$ t

$P = C + Wc + Wec$

$= 33.63 + 9.56 + 13.42 = 56.61$ t

$e = \frac{Q_{B'} . Y}{P}$

$= \frac{1.37 \times 3.5}{56.44} = 0.085$

$\alpha = 1 + \frac{8e}{B}$

$= 1 + \frac{8 \times 0.085}{2.3} = 1.295$

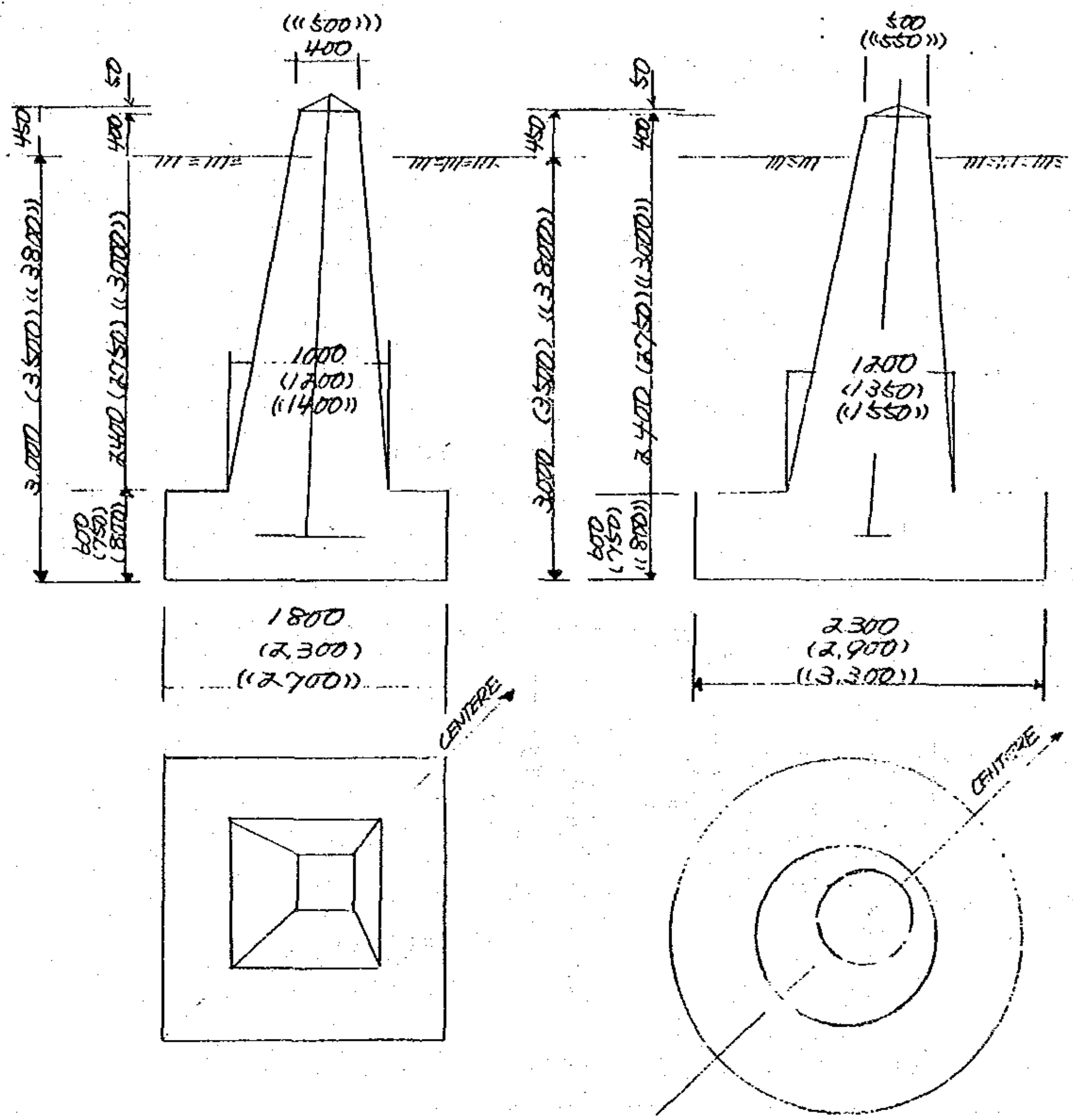
$\sigma max = \alpha \cdot \frac{C + Wc + Wec}{\frac{\pi}{4} B^2} = \alpha \cdot \frac{P}{\frac{\pi}{4} B^2}$

$= 1.295 \times \frac{56.61}{\frac{3.14}{4} \times 2.3^2} = 17.6 \ t/m^2$

$\frac{q}{S.F.} \geqq \sigma max$

$\frac{60.0}{2.0} = 30 \ t/m^2 > 17.6 \ t/m^2$

Table 5.2-29 **Foundation of Type L**



QUANTITY LIST

TYPE		EXCAVATION (m³)	CONCRETE (m³)	BACK FILLING (m³)	U(t)	C(t)
AA-L	SQUARE	17.60	3.40	14.28	27.510	33.63
	CIRCLE	20.69	4.16	16.62		
BB-L	SQUARE	31.45	6.37	25.20	49.85	57.89
	CIRCLE	35.40	7.35	28.13		
CC-L	SQUARE	45.52	9.13	36.51	69.57	77.67
	CIRCLE	49.02	10.13	39.01		

Table. 5.2-30 STEEL PILE FOUNDATION

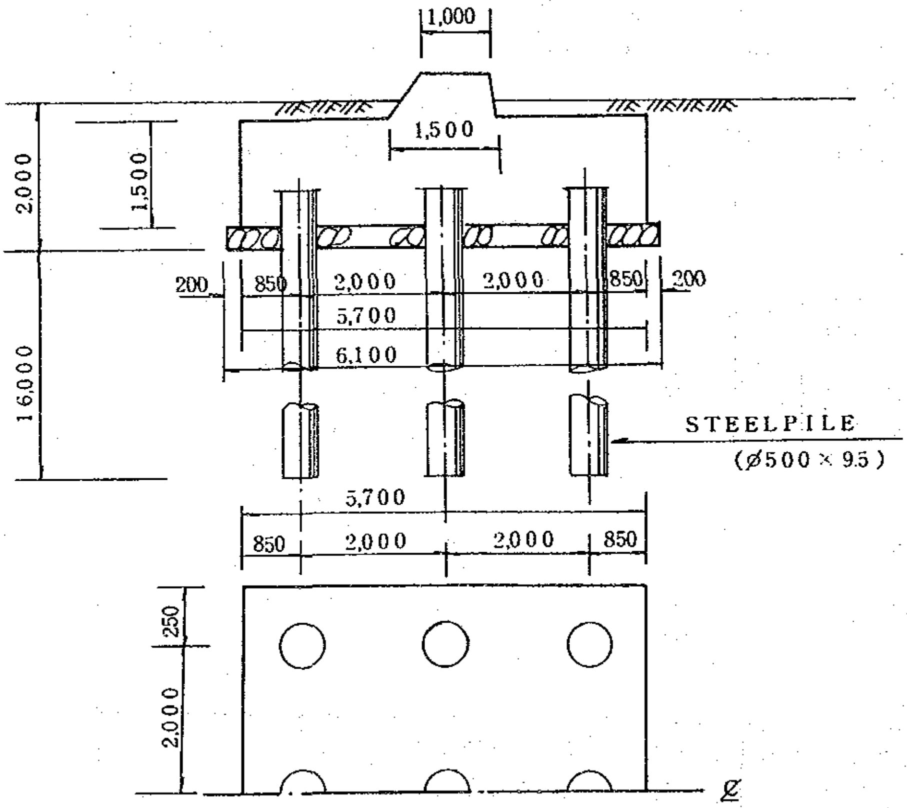
DESING CONDITION

$U = 180t$ $\quad N = 4$

$C = 200t$ $\quad f_{sf} = 2.0\ t/m^2$

$Q_B = 4t$ $\quad L = 16m$

SCALE 1:100
UNIT mm



QUANTITY LIST

EXCAVATION	CONCRETE	COBBLE STONE	STEEL PILE
75.0 m^3	50.0 m^3	12.0 m^3	148.5 m

UPLIFT CAPACITY OF A PILE

$$R_{aty} = \frac{\pi DL \cdot fst}{1.5SF} \qquad (fst = 2.0\ t/m^2)$$

$$= \frac{3.14 \times 0.5 \times 16.0 \times 2.0}{1.5 \times 2} = 16.7\ t/pile$$

$$R_{1i} = \frac{T - (\frac{Wc_f + We_f}{1.5})}{n} + \frac{M \cdot ji}{\Sigma xj^2}$$

$$= \frac{180 - (\frac{68.23 + 5.8}{1.5})}{9} + \frac{4 \times 2.2 \times 2}{24}$$

$$= 14.5 + 0.74 = 15.2\ t/pile$$

$R_{aty} \geqq R_{1i}$

16.7 t/pile > 15.2 t/pile

COMPRESSION

DOWN BEARING CAPACITY

$$RCY = \frac{40N}{1.5 \times FS} AP$$

$$= \frac{40 \times 50}{3.0} \times 0.196 = 130\ t/pile$$

$$RCi = \frac{C + Wc + Ws}{n} + \frac{M \cdot xi}{\Sigma xj^2}$$

$$= \frac{200 + 116.9 + 9.1}{9} + 0.74 = 36.9\ t/pile$$

RCY = 130 t/pile RCi = 36.9 t/pile

Table 5.2-31 MICRO PILE FOUNDATION

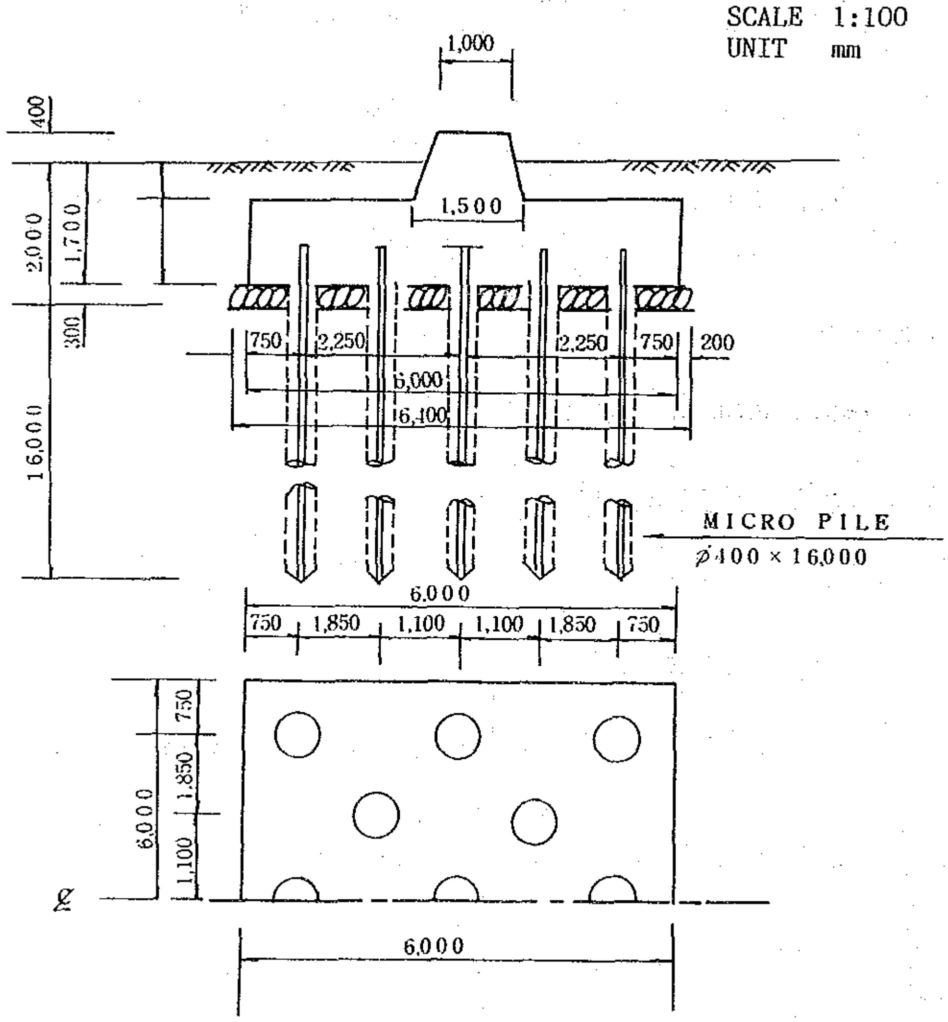
DESIGN CONDITION

U = 180 t N = 4

C = 200 t f_{st} = 2.0 t/m^2

Q_B = 4.0 t L = 16 m

SCALE 1:100
UNIT mm



QUANTITY LIST

EXCAVATION	CONCRETE	COBBLE STONE	MICRO PILE
82.7 m^3	45.0 m^3	13.0 m^3	214.5 m

MICRO PILE

(1) UPLIFT

$$R_{aty} = \frac{\pi DL \cdot f_{st}}{1.5st}$$

$$= \frac{3.14 \times 0.4 \times 16 \times 2}{3.0} = 13.0 \text{ t/pile}$$

$$Vc = 6^2 \times 1.3 + 1.3^2 \times 0.9 = 44.72 \text{ m}^3$$

$Wc_f = Vc \times 1.4 = 62.6$ t $Wc = Vc \times 2.4 = 107.3$ t

$$Ve = 6^2 \times 1.7 - Vc = 16.5 \text{ m}^3$$

$We_f = Ve \times 0.9 = 14.8$ t $We = Ve \times 1.4 = 23.1$ t

$$R_{ti} = \frac{T - \left(\frac{Wc_f + We_f}{1.5}\right)}{n} + \frac{M \cdot ji}{\Sigma xj^2}$$

$$= \frac{180 - \frac{62.6 + 14.8}{1.5}}{n} + \frac{4 \times 2.2 \times 2.25}{6 \times 2.25^2 + 4 \times 1.1^2} = 9.87 + 0.5 = 10.4 \text{ t/pile}$$

Raty ≧ Rci

Raty = 13.0 t/pile > Rci = 10.4 t/pile

(2) COMPRESSION $C = 5 \text{ t/m}^2$ $N = 15$

$$RCY = \frac{\alpha \cdot CNc + Df\gamma \cdot Ng}{1.5\ fF} = \frac{1.3 \times 5.3 \times 5 + 16 \times 0.9 \times 3}{3} = 25.8 \text{ t/pile}$$

$$Rci = \frac{Wc + We + C}{n} + \frac{M \cdot xi}{\Sigma xj}$$

$$= \frac{107.3 + 23.1 + 200}{13} + 0.5 = 25.4 \text{ t/pile}$$

RCY = 25.8 t/pile > Rci = 25.4 t/pile

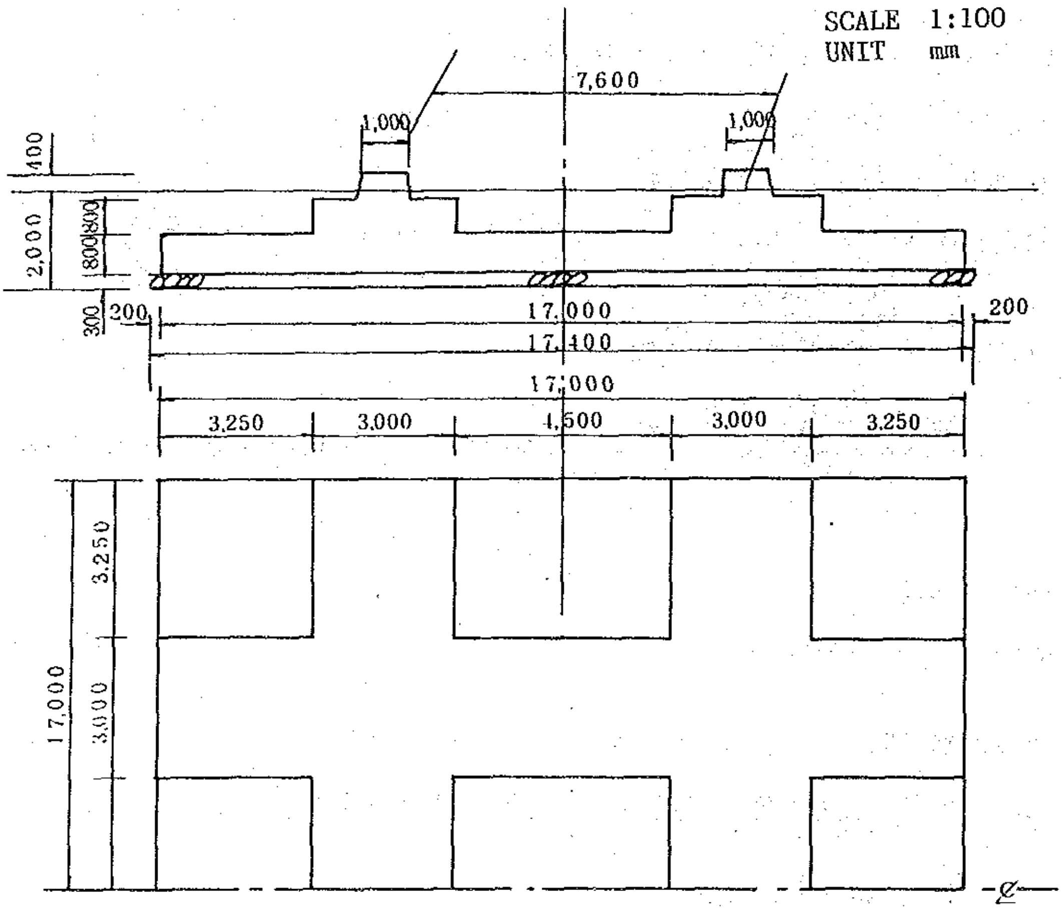
Table. 5.2-32 FLOATING FOUNDATION

DESIGN CONDITION

$U = 130$ t $\quad N = 4$

$C = 200$ t $\quad q = 10\ t/m^2$

$Q_B = 4$ t



QUANTITY LIST

EXCAVATION	CONCRETE	COBBLE STONE	BACK FILLING
606.0 m^3	369.0 m^3	91.0 m^3	146.0 m^3

FLOATING FOUNDATION

U = 180 t C = 200 t Q_B = 4 t B = 17 m Y = 2.2 m

N = 4 C = 2.5 t/m²

(1) COMPRESSION

$$M = \frac{b}{2}(2U + 2C) + 4Q_BY$$

$$= \frac{7.6}{2}(180 \times 2 + 2 \times 200) + 4 \times 4 \times 2.2 = 2888 + 35.2 = 2923.2 \text{ t/m}$$

$$Vc = 17^2 \times 0.8 + (2 \times 17 \times 3 + 11 \times 3 \times 2) \times 0.8 + 1.3^2 \times 0.5 \times 4$$
$$= 368.98 \text{ m}^3$$

$$Wc = Vc \times 2.4 = 885.5 \text{ t}$$

$$Ve = 17.2 \times 1.7 - (Vc) = 123.0 \text{ m}^3$$

$$We = Ve \times 1.4 = 172.6 \text{ t}$$

$$W = Wc + We = 1058.1 \text{ t}$$

$$e = \frac{M}{W} = \frac{2,923.2}{1,058.1} = 2.76 \text{ m} < \frac{B}{6} = 2.8 \text{ m}$$

$$\sigma max = \frac{W}{B^2}(1 + \frac{6e}{B})$$

$$= \frac{1058.1}{17^2}(1 + \frac{6 \times 2.76}{17}) = 7.2 \text{ t/m}^2$$

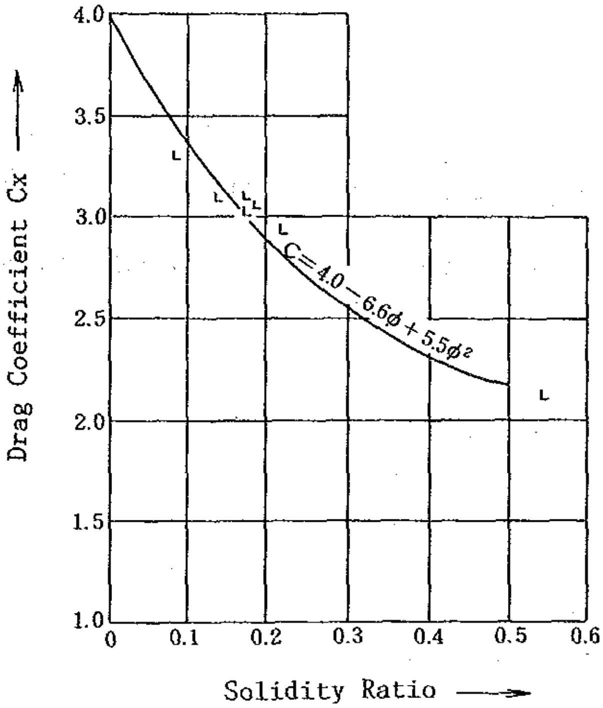
q' : By Terzaghi Formula

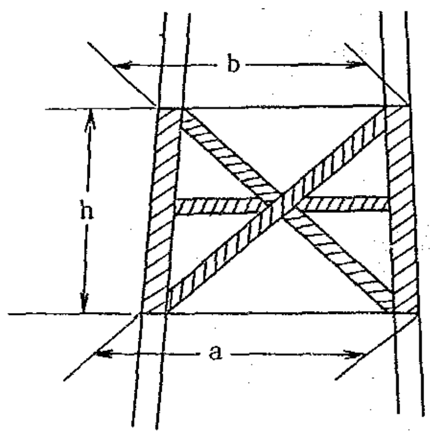
$$q' = \frac{\alpha \cdot CNc + D_f \cdot \gamma \cdot Ng}{1.5 \times sf} = \frac{1.3 \times 5.3 \times 2.5 + 2 \times 0.9 \times 3}{1.5 \times 2}$$

$$= \frac{17.2 + 5.4}{3} = 7.5 \text{ t/m}^2$$

$$q' = 7.5 \text{ t/m}^2 > \sigma max = 7.2 \text{ t/m}^2$$

Fig 5.2-1 Drag Coefficient Characteristic for Solidity Ratio



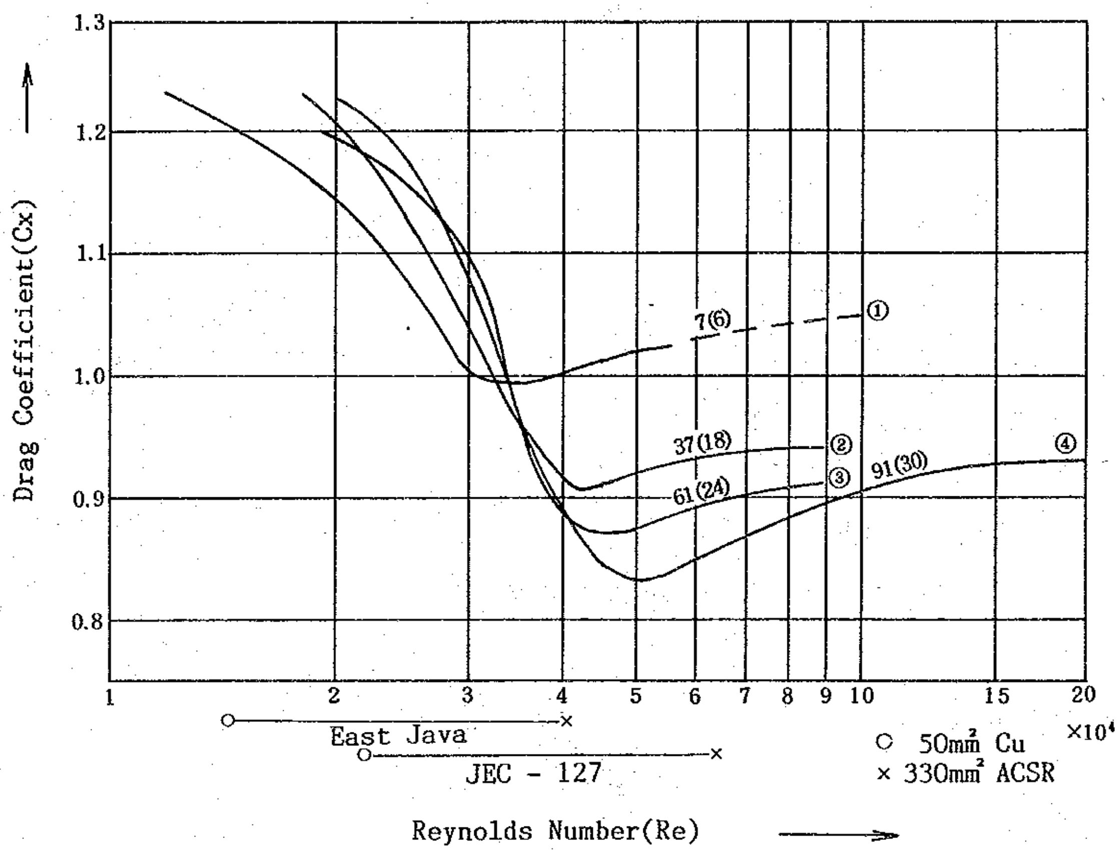


$$\text{Solidity Ratio} = \frac{A'}{A}$$

$$A = \frac{1}{2}(a+b)h$$

A' = ▨ Area

Fig. 5.2-2 Strand Composition and Cx-Re Characteristic of Standard Conductor



	No.of Wire	Layers	Strand Dia/Outsid Dia
①	7	1	1/3
②	37	3	1/7
③	61	4	1/9
④	91	5	1/11

Fig 5.2-3 D.R. Annual Average Current Characteristic

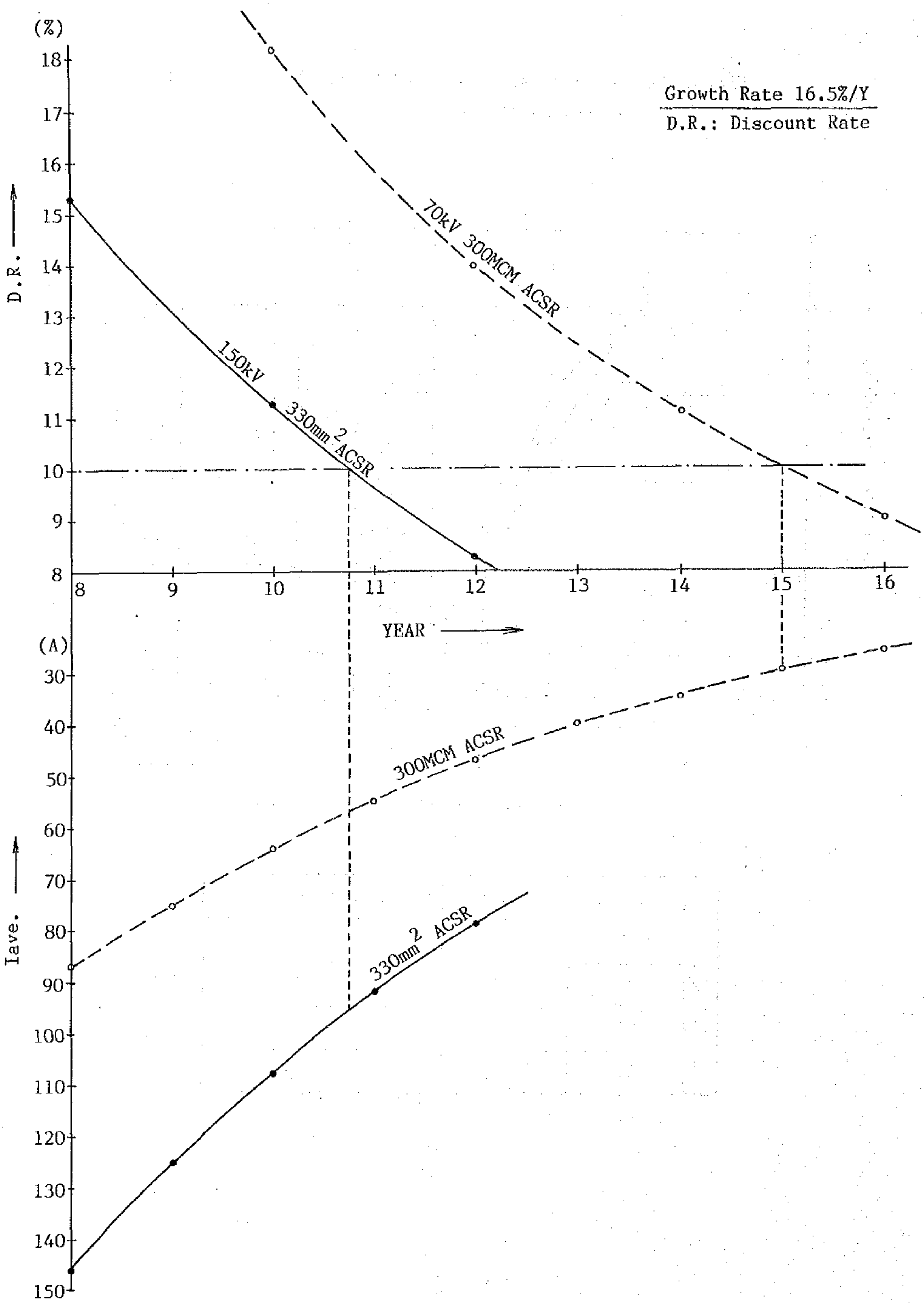
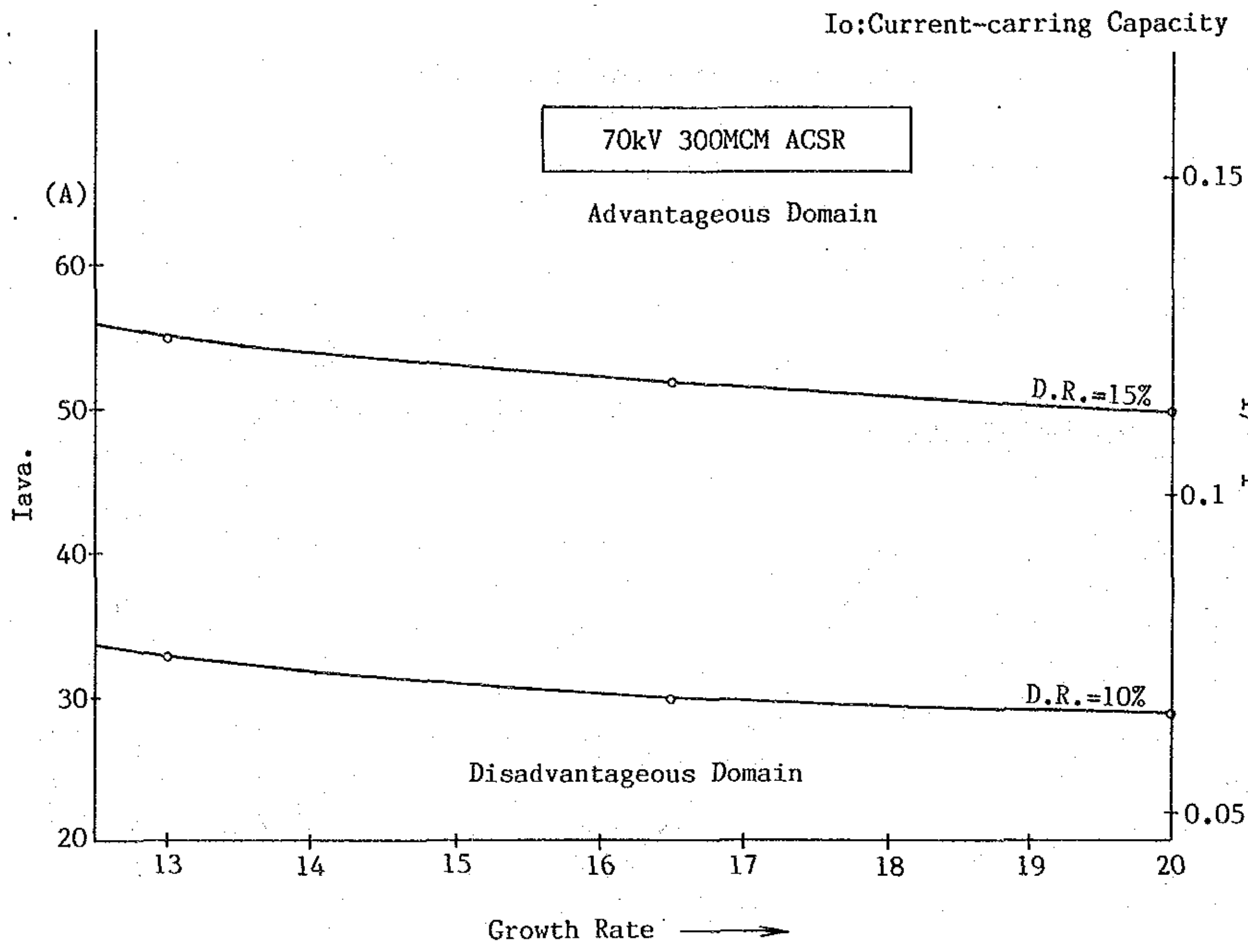


Fig. 5.2-4 Economic Border Line



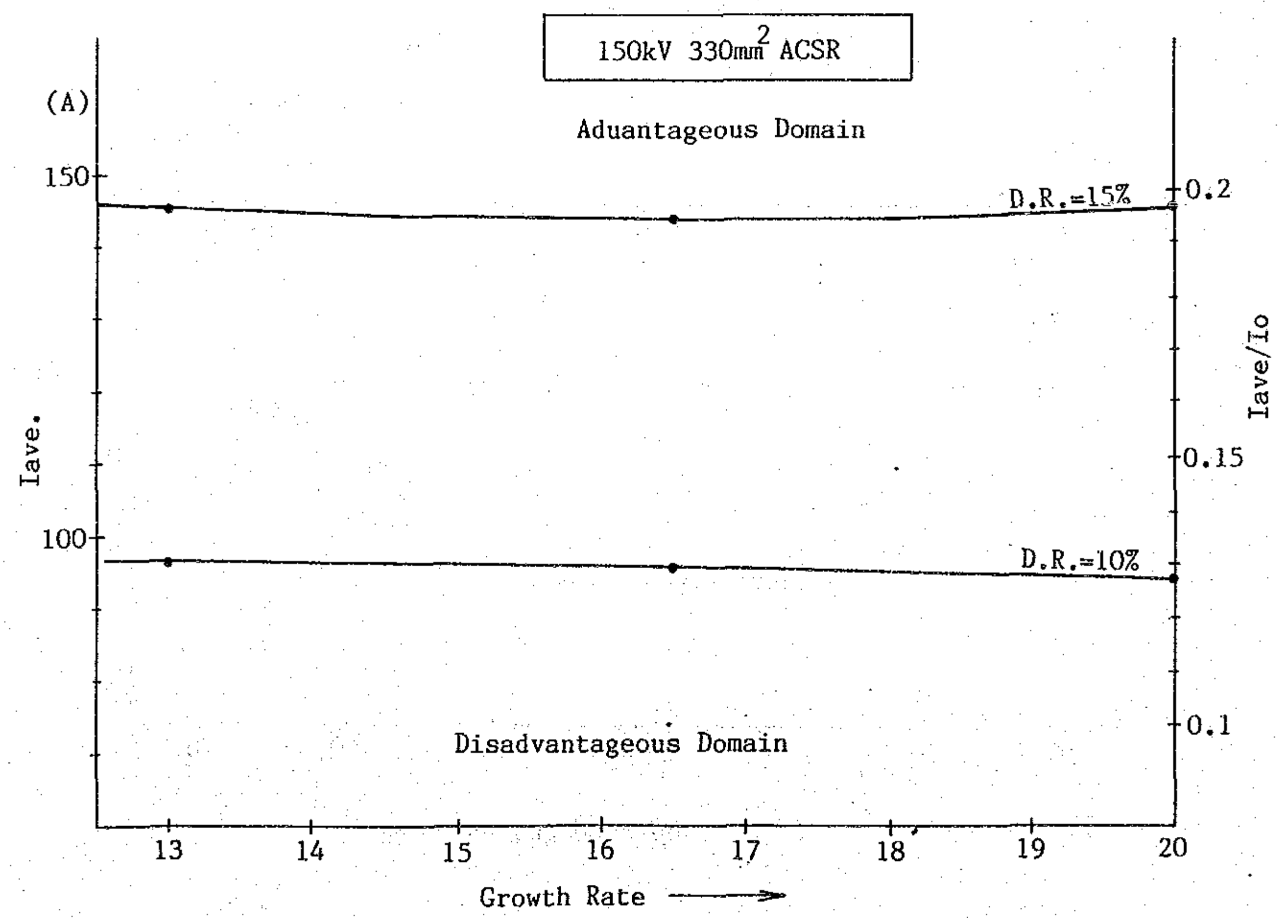


Fig. 5.2-5 (1/2) Economic Border Line

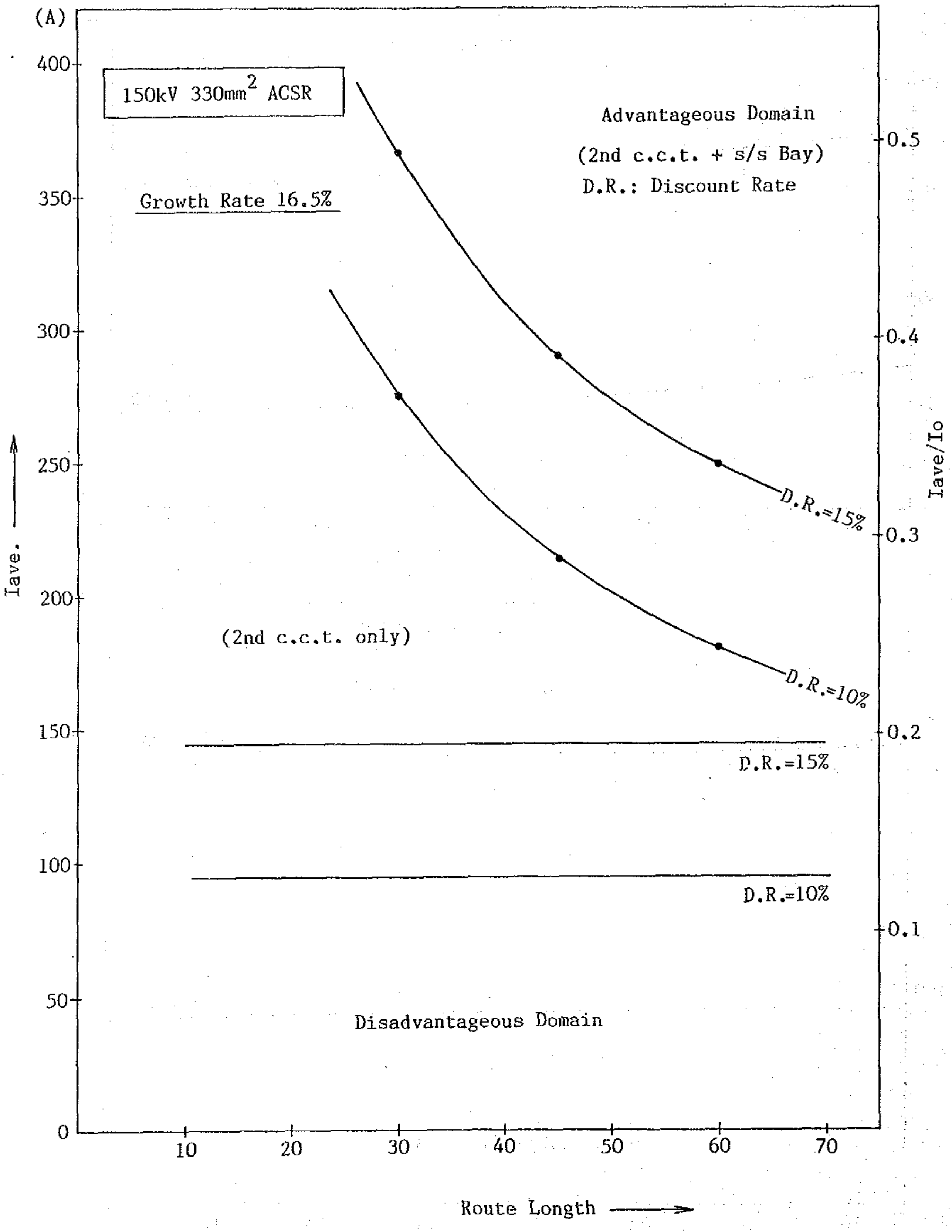


Fig. 5.2-5 (2/2) Economic Border Line

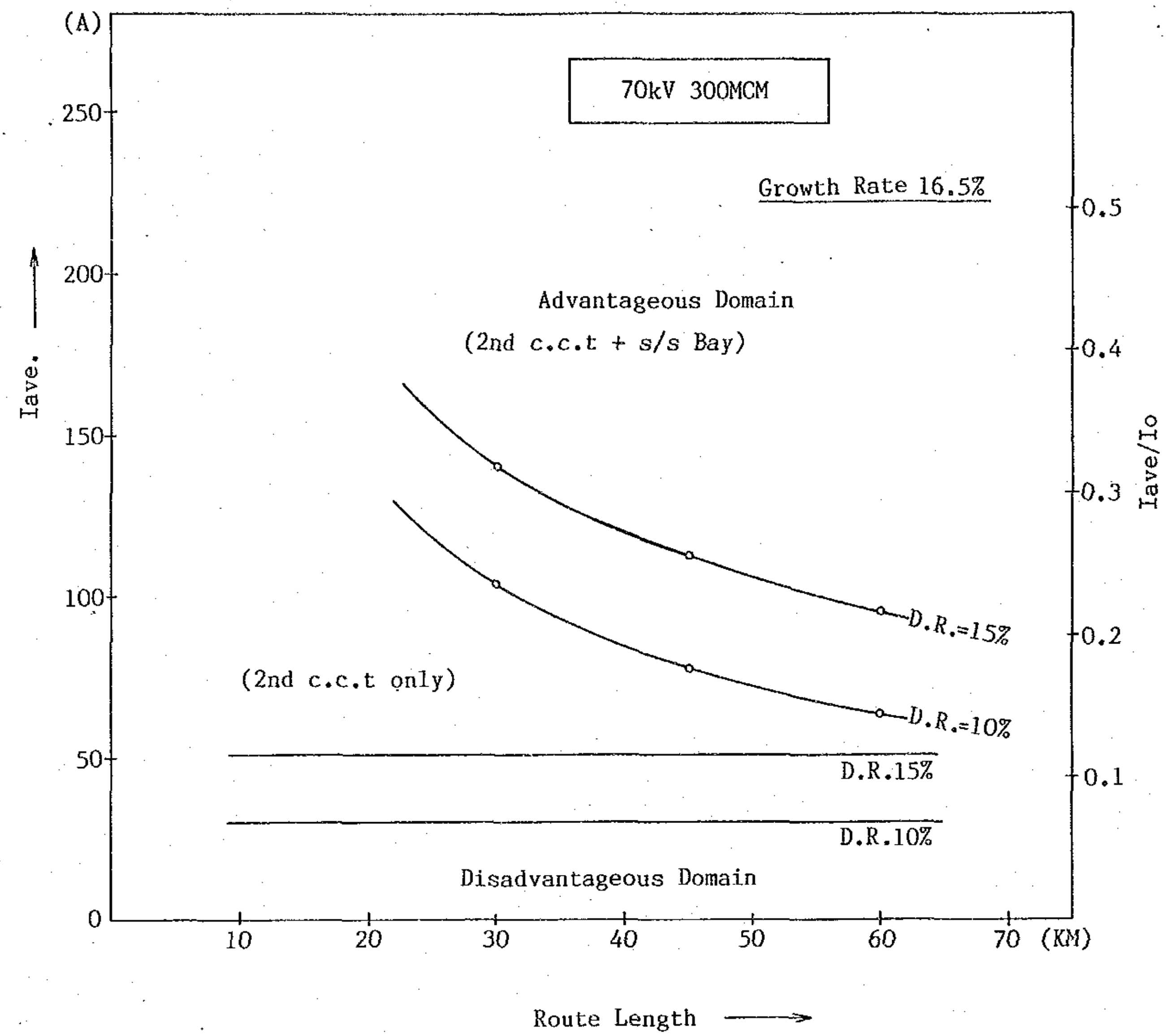


Fig. 5.2−6 East Java I K L Map (1950−1970) And Fault Record (1983/11−1984/6)

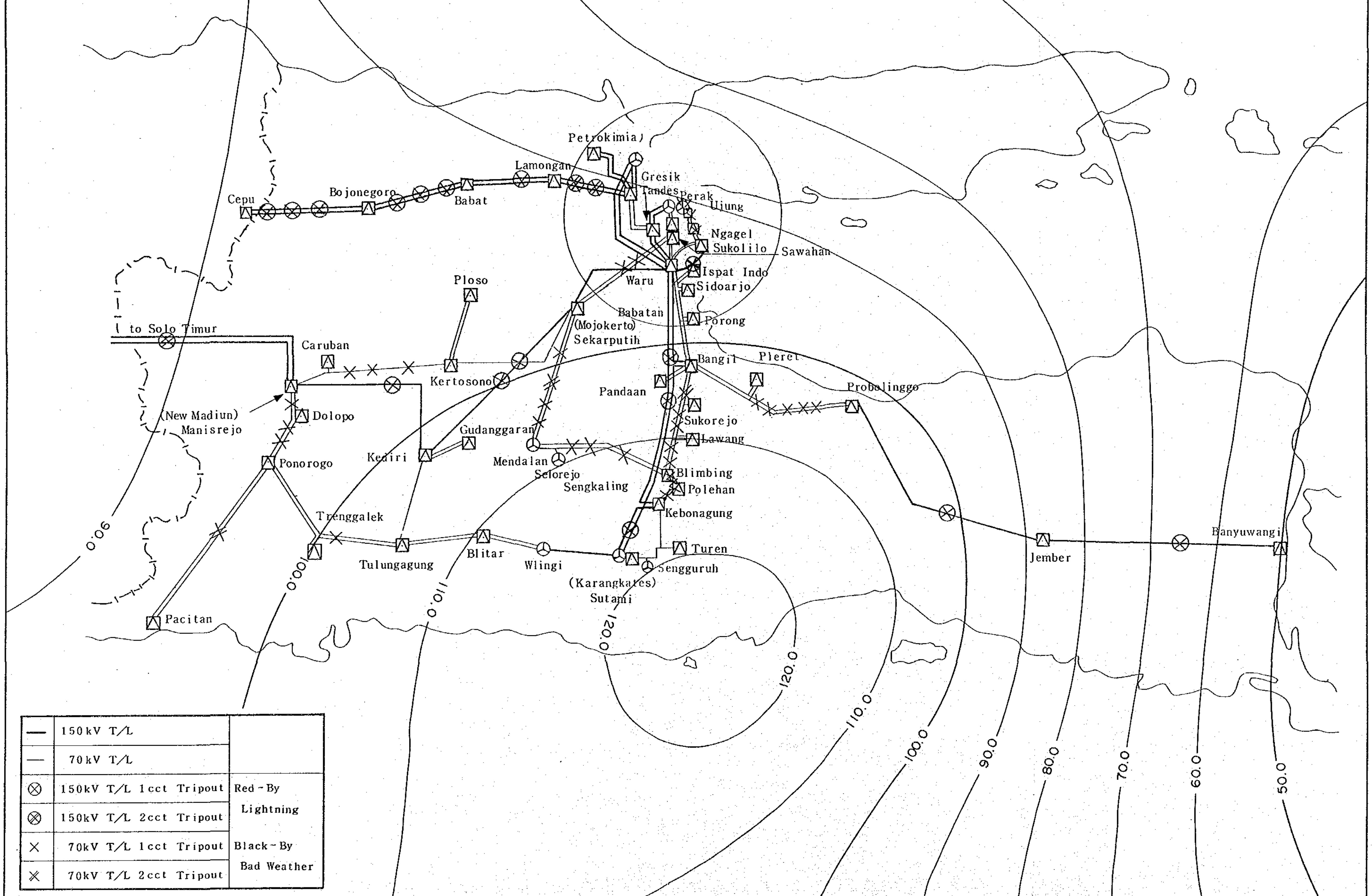


Fig. 5.2-7 Probability of occurrence of Peak Amplitudes of stroke Currents (From AIEE Trans Vol. 69, 1950)

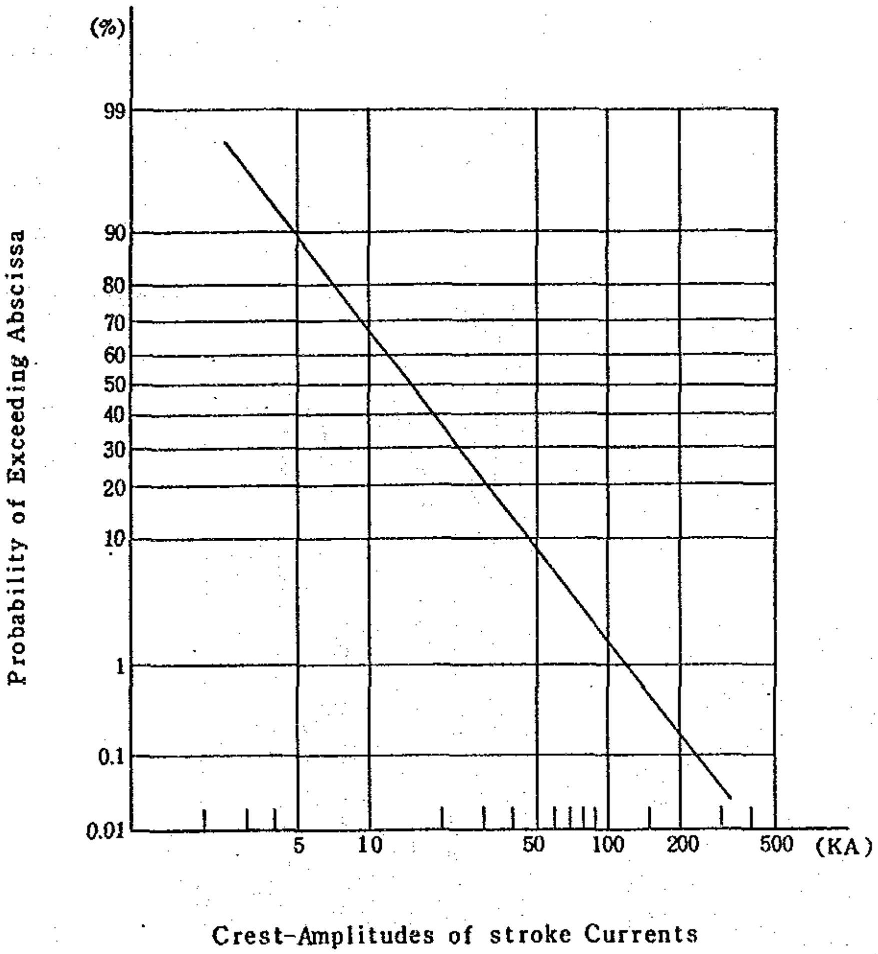


Fig. 5.2-8 Trip out Rate Record and Forecast

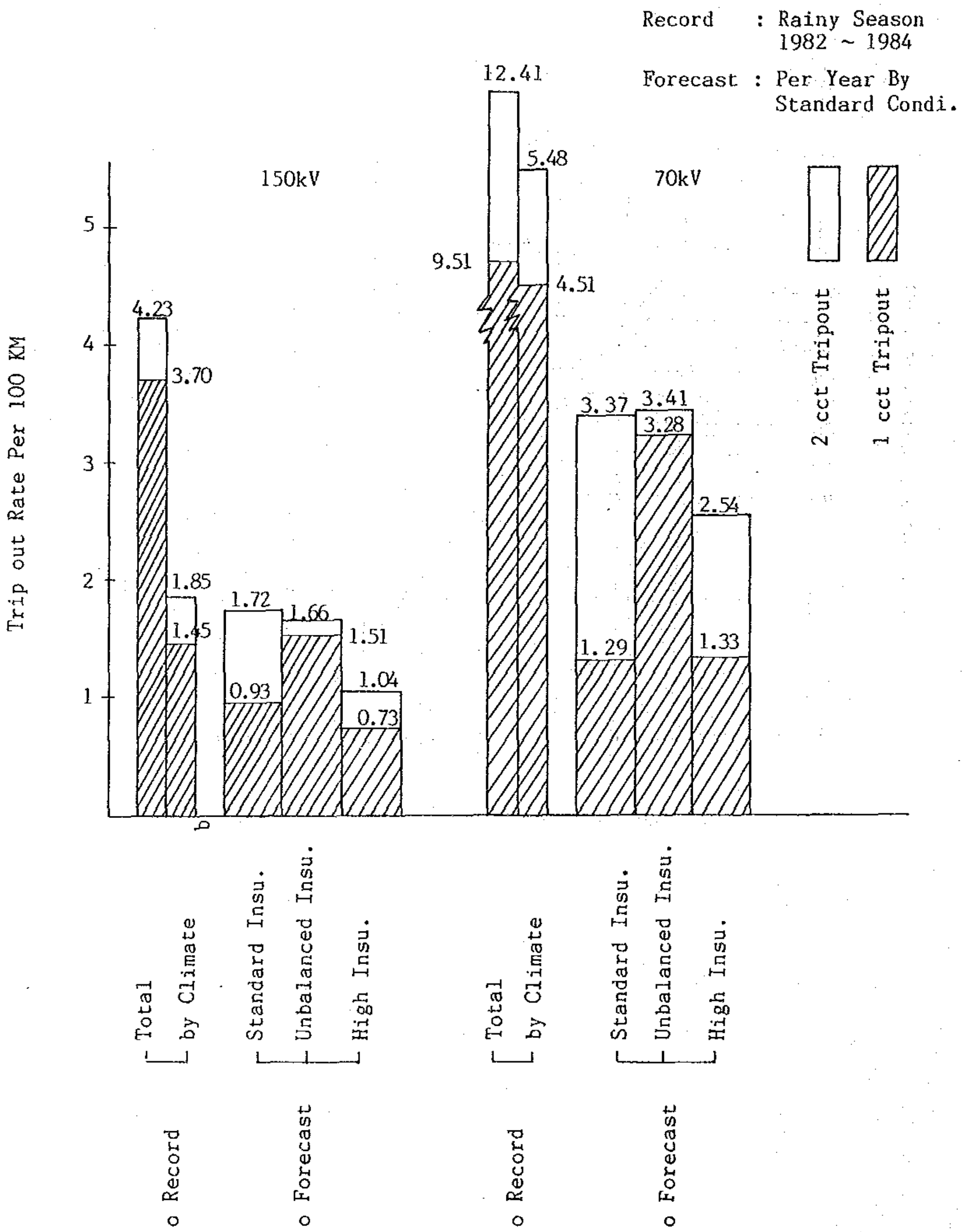


Fig. 5.2-9 Ratio of Another Conductor T/L Tower Weight to 330 mm^2 ACSR T/L one

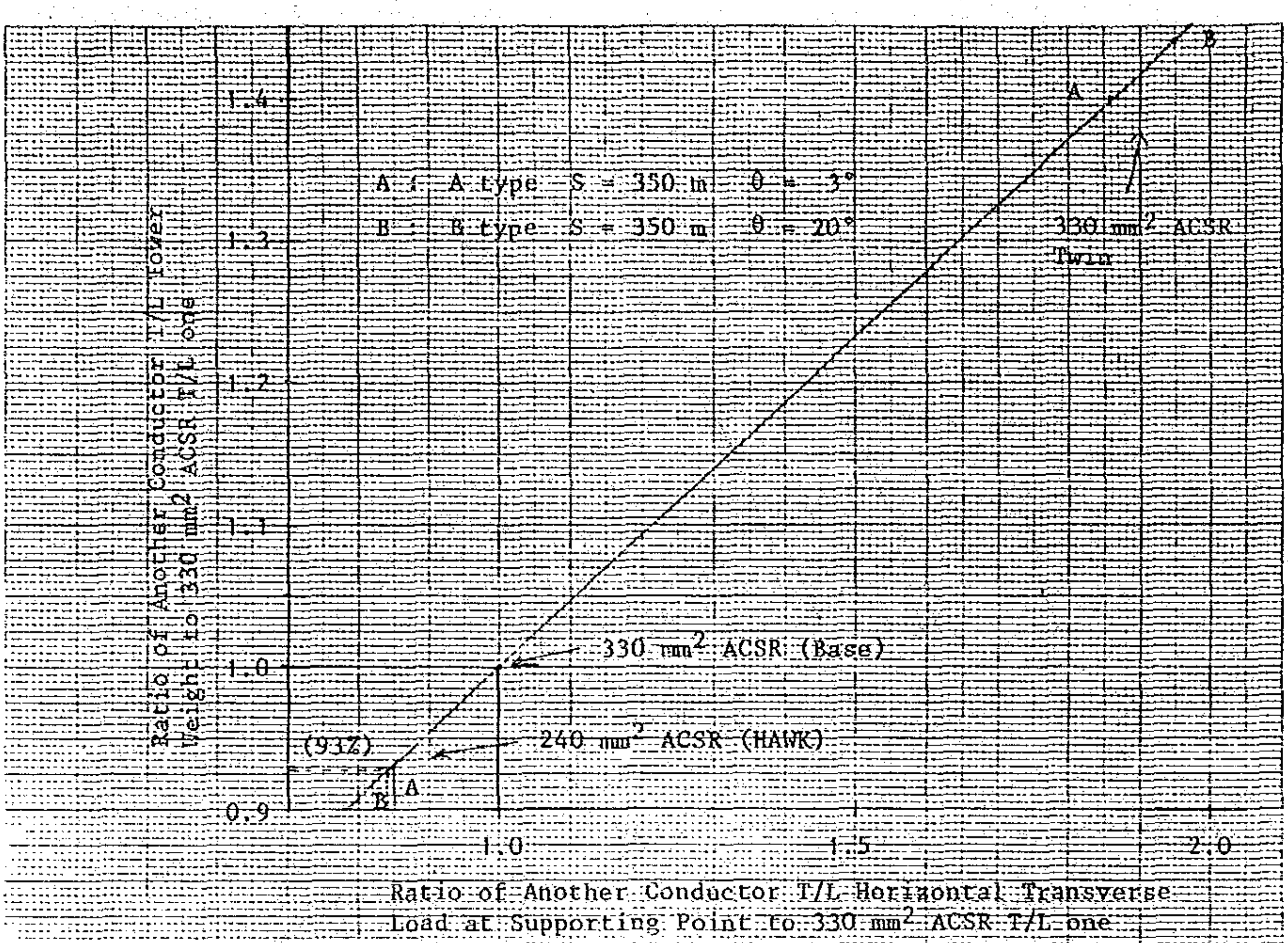
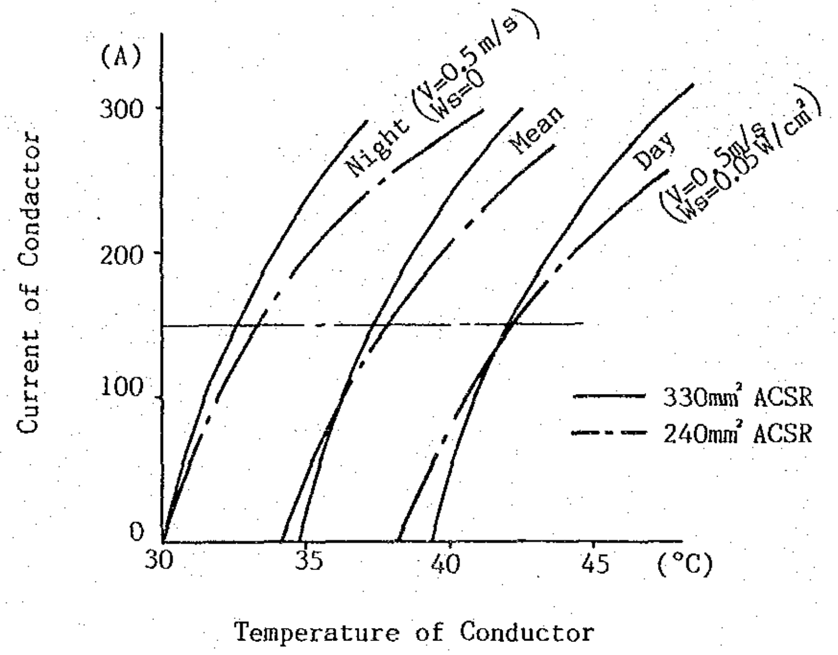


Fig 5.2-10 Current-Temperature Characteristic of Conductor



Condnctor Current is calcurated by next formula

$$Ic=\sqrt{\frac{K\cdot\pi\cdot D\cdot\theta}{\beta R_{dc}\times10^{-5}}}$$

K : Thermal Radiation Coefficient (W/°C.cm^2)

Function of Ws and V

Ws - Quantity of solar radiation (Watt/cm^2),V-Wind Velocity (m/s)

θ : Temperature Rise of Condnctor (°C)

β : Ratio of DC Resistance to AC Resistance

Rdc: DC Resistance (Ω/KM)

D : Overall Diameter (cm)

Estimated Conductor Temperature According to Fig.-2 (Mean) at Condnctor Current 150A (Current-Carring Capacity of 240mm^2 A.C.S.R. x0.25)

240 mm^2 ACSR mean Temperature → 38°C

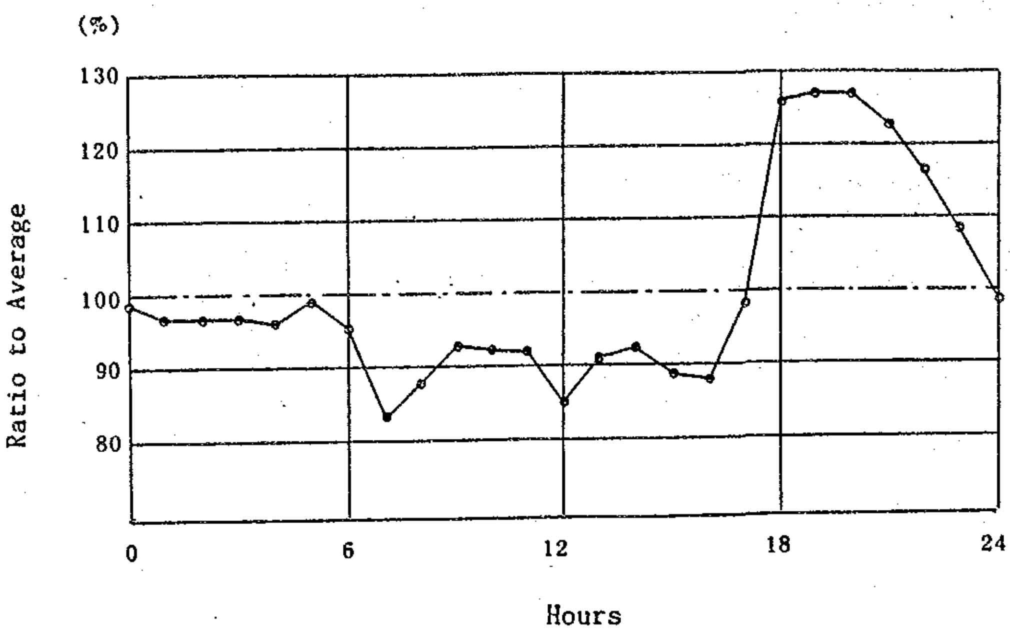
$$R_1 = 0.12235 \times (1 + 0.004 \times 13) \times 1.003 = 0.1290 \quad (\Omega/KM)$$

330 mm^2 ACSR mean Temperature → 37.5°C

$$R_2 = 0.0888 \times (1 + 0.004 \times 17.5) \times 1.005 = 0.0955 \quad (\Omega/KM)$$

$$R_1 - R_2 = 0.0335 \quad (\Omega/KM)$$

Fig 5.2-11 Standard Weekday Load Curve and Table in East Java System



Time	L.C. (% per ave.)	L.C.^{2}	Time	L.C. (% per ave.)	L.C.^{2}
1	97	9,409	13	91	8,281
2	97	"	14	92	8,464
3	97	"	15	89	7,921
4	96	9,216	16	88	7,744
5	99	9,801	17	99	9,801
6	95	9,025	18	126	15,876
7	83	6,889	19	127	16,129
8	88	7,744	20	127	"
9	93	8,649	21	123	15,129
10	92	8,464	22	117	13,689
11	92	"	23	108	11,664
12	85	7,225	24	99	9,801
			Total	2,400	244,332

$$\text{Loss Factor} = \frac{\frac{\Sigma In^2}{24}}{Ip^2} = \frac{\frac{244,332}{24 \times (1.03)^2}}{127^2} = 0.595$$

1.03 : Weekday Factor

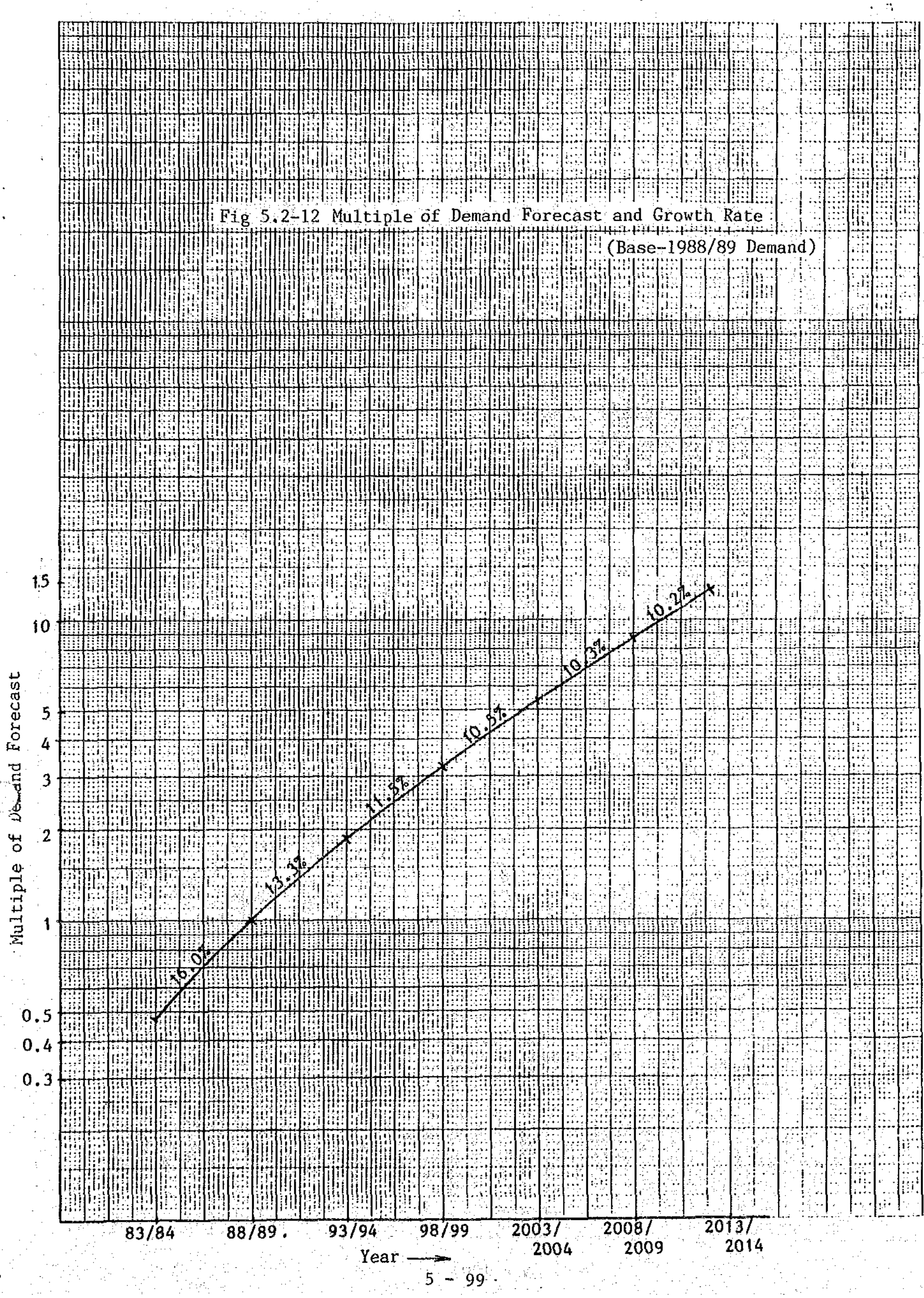
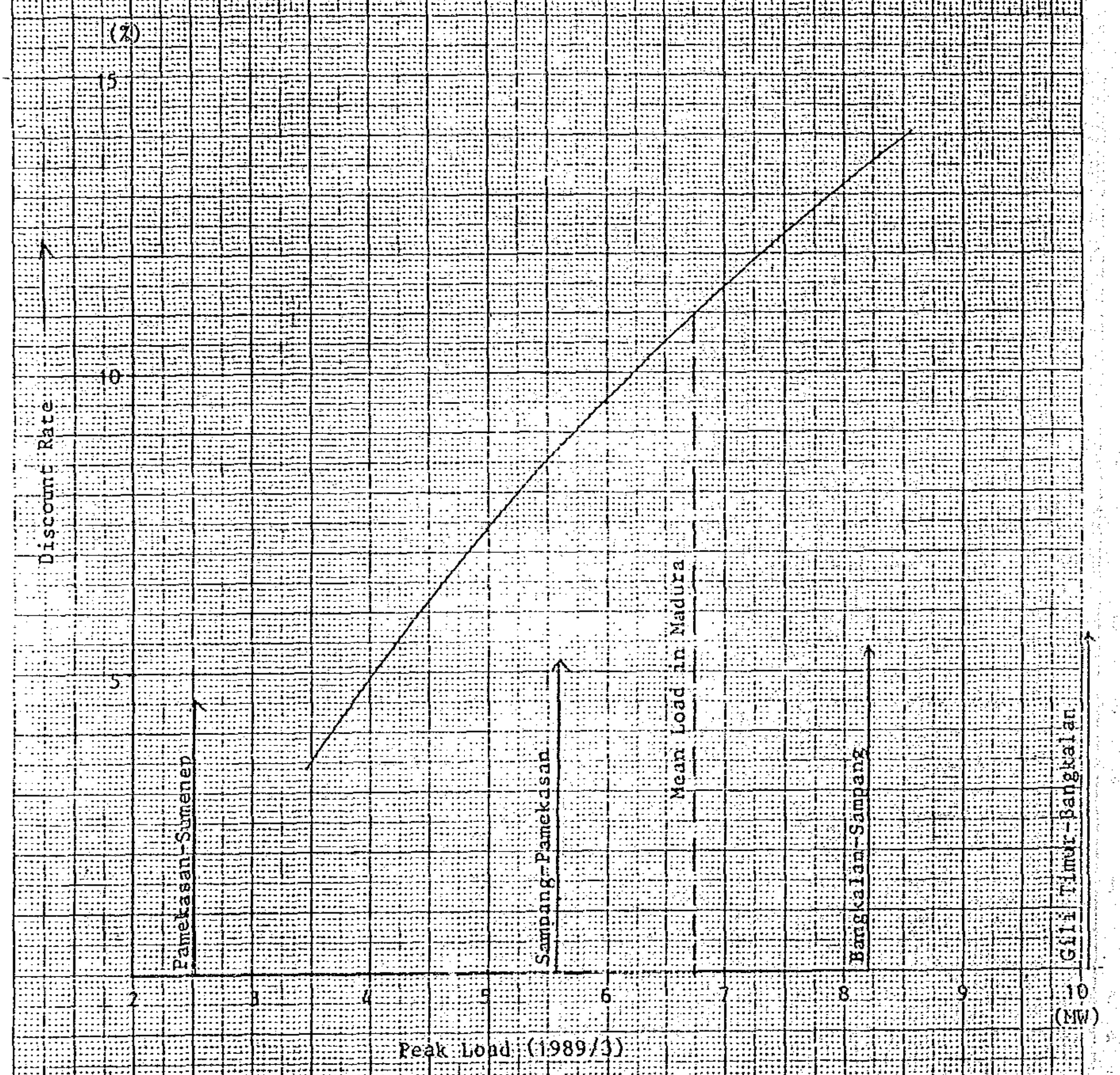


Fig 5.2-12 Multiple of Demand Forecast and Growth Rate
(Base-1988/89 Demand)
Multiple of Demand Forecast
15
10
5
4
3
2
1
0.5
0.4
0.3
16.0%
13.3%
11.5%
10.5%
10.3%
10.2%
83/84
88/89
93/94
98/99
2003/2004
2008/2009
2013/2014
Year

Fig 5.2-13 Discount Rate Characteristic



Base -
Fig 5.2-14 Multiple of Demand Forecast (1983/84 Demand)

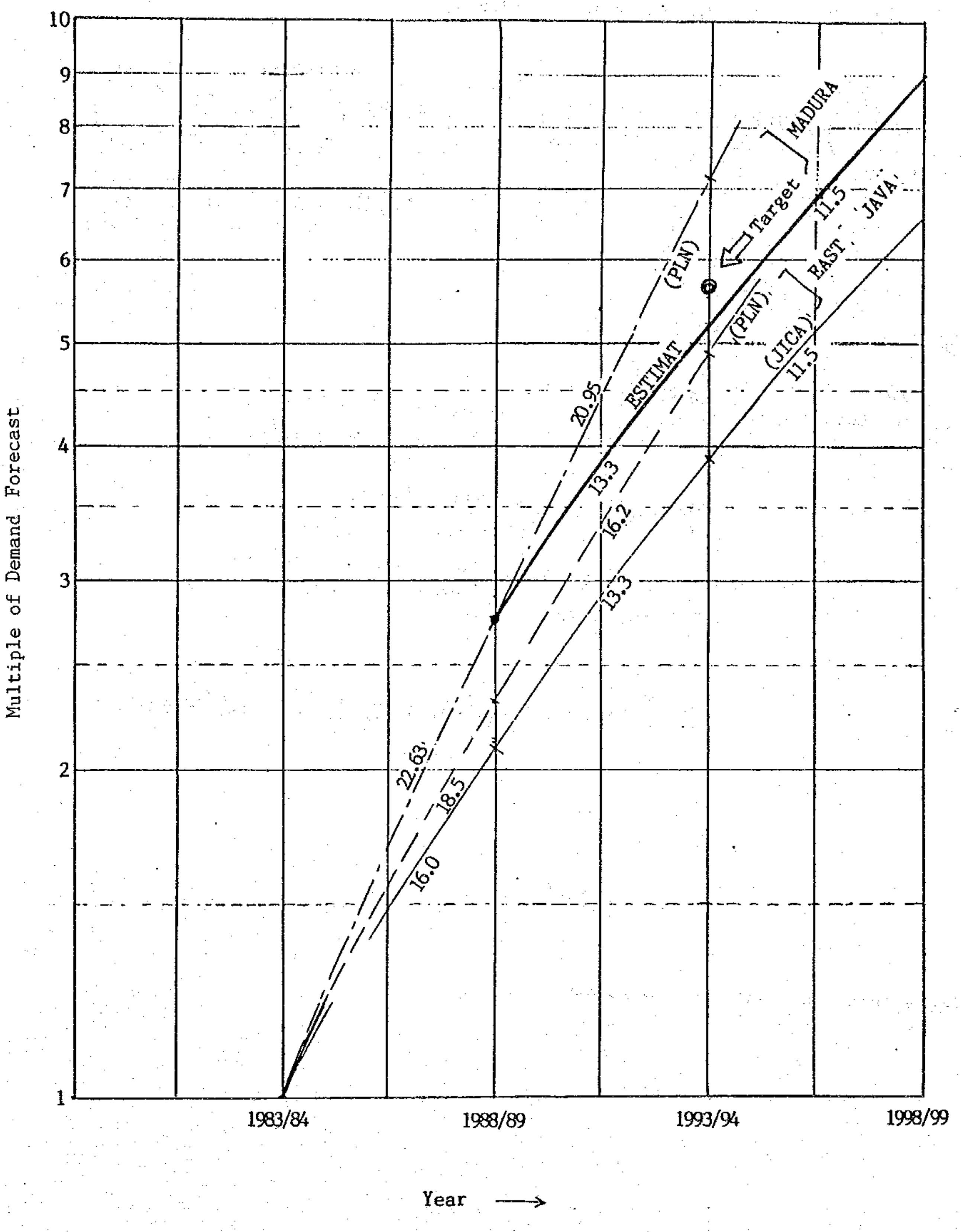
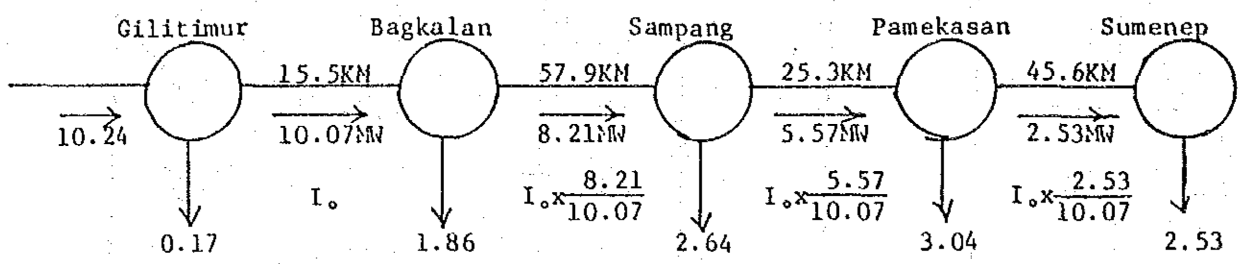


Fig. 5.2-15 Power Flow in Madura (MW) 1989/3



Mean T/L Loss per KM $= \frac{3R\Sigma In^2 \ell n}{\Sigma \ell n}$

In: Current of Each T/L

$I_\circ$: Current from Gilitimur to Bangkalan

ℓn: Route Length

Wn: Load of Earch T/L

$W_\circ$: Load from Gilitimur to Bangkalan

$$= \frac{3RI_\circ^2}{\Sigma \ell n}\Sigma\left(\frac{In}{I_\circ}\right)^2 \ell n$$

$$= \frac{3RI_\circ^2}{\Sigma \ell n}\Sigma\left(\frac{Wn}{W_\circ}\right)^2 \ell n$$

$$= \frac{3RI_\circ^2}{144.3}[1x15.5+\left(\frac{8.21}{10.07}\right)^2 x57.9+\left(\frac{5.57}{10.07}\right)^2 x25.3+\left(\frac{2.53}{10.07}\right)x45.6]$$

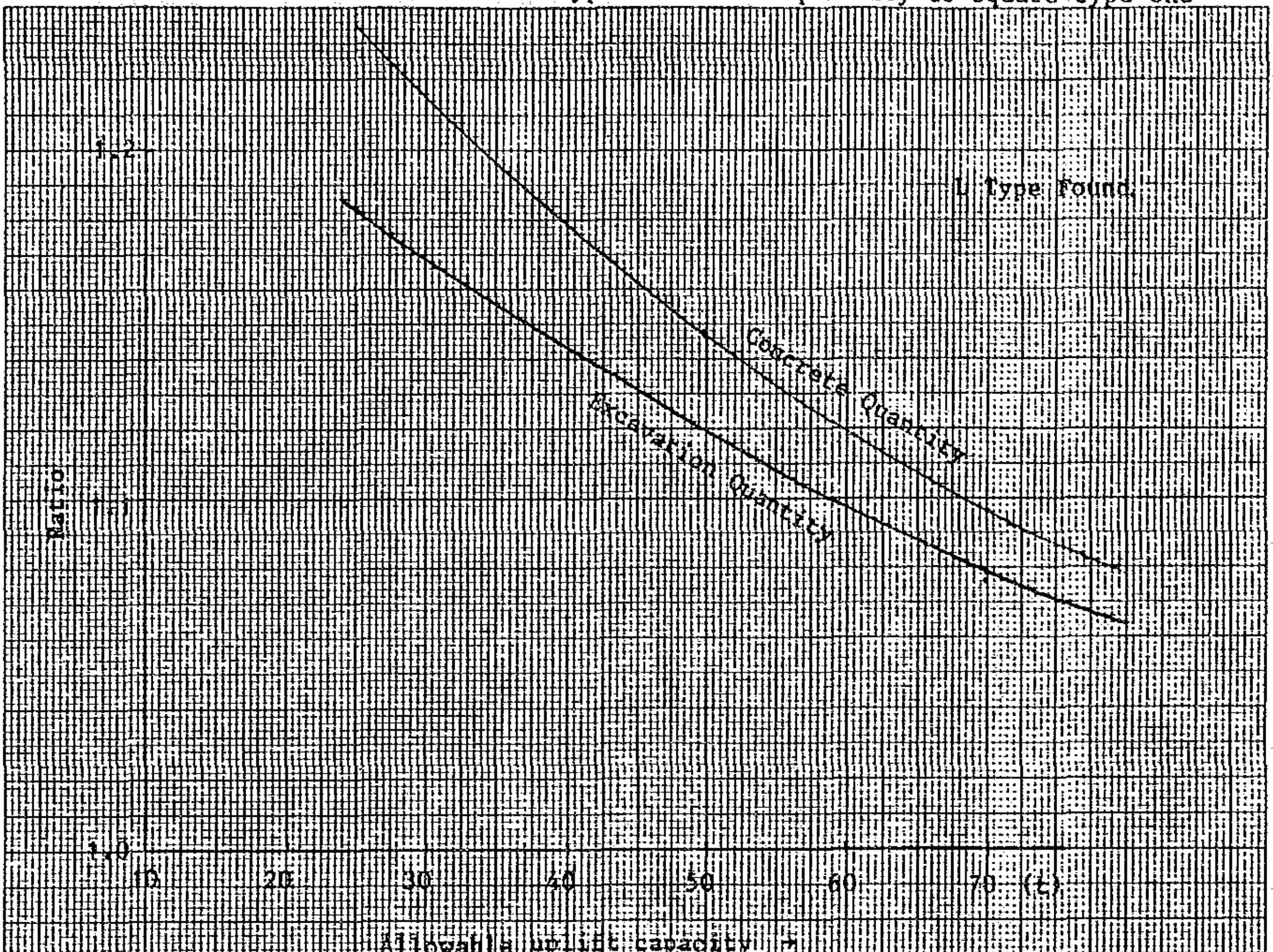
$$= 3RI_\circ^2 x0.448$$

$$= 3R(I_\circ x0.669)^2$$

Equivalent T/L Load = 10.07x0.669

= 6.74 (MW)

Fig 5.2-16 Rate of circular type foundation quantity to square type one



JIS A4 180×250㎜ SEKIREI NO. 401 C

Fig. 5.2-17 Circular type foundation in Japan

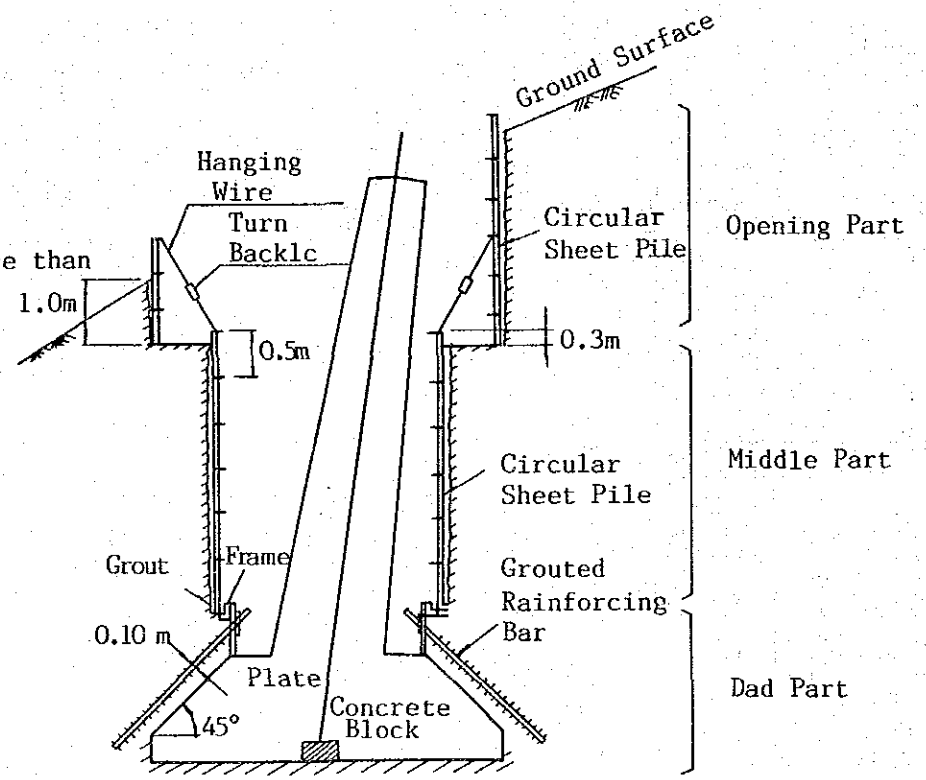


Fig. 5.2-18 MICRO PILE

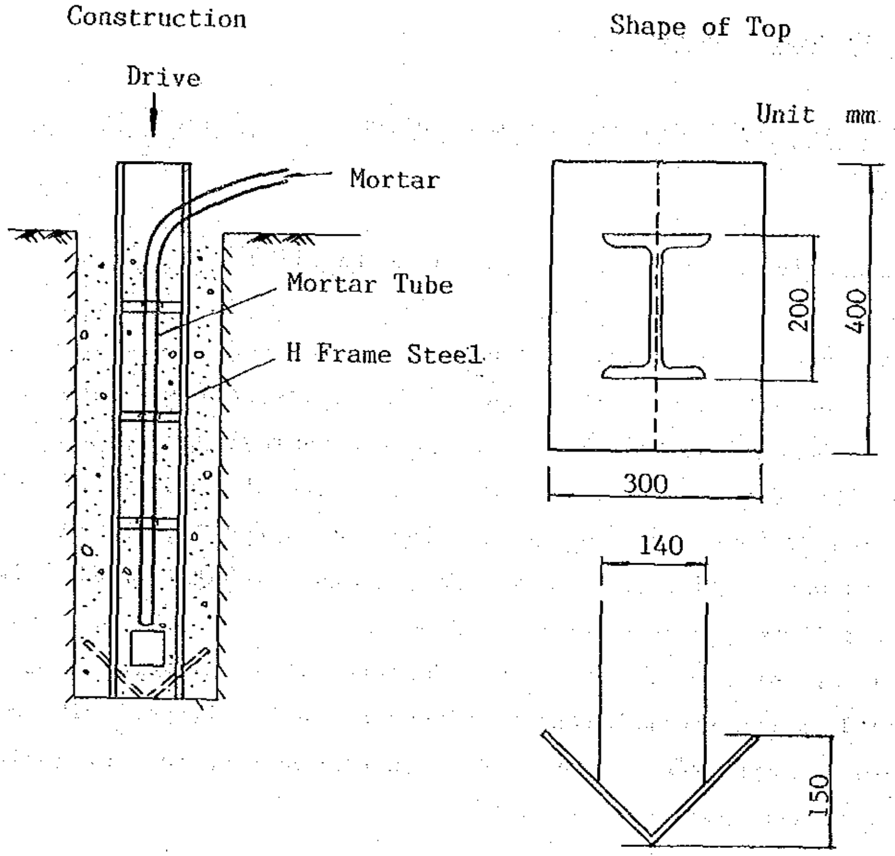
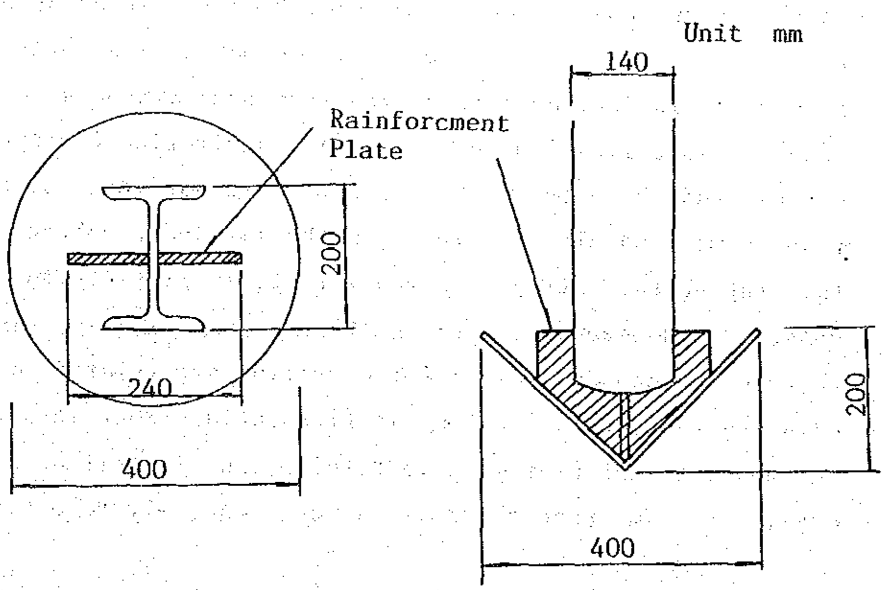


Fig. 5.2-19 Modified Shape of Top



5.3. Study of Substation Facilities

5.3.1. Study of Design Criteria and Recommendation for Standardization of Facilities

(1) Comparative Study of main substation facilities

Bid Documents of Belgium loan, France loan and acceleration project could be got by the first field investigation. Based on these Documents, Comparision between technical particular of specifications in these proposal and those of Surabaya Distribution Project was made and studied. As a result, the differences were hardly seen in general, because substation facilities are designed to be manufactured on the basis of international standard of I.E.C. and so on. However little difference is found in the specifications of substation facilities. The main point of difference is listed up in comparative form of Table 5.3-1. and summarized as below:

Regarding the power transformer, increase of capacity is tried by use of forced air cooling, forced air circulation and so on in the transformer. But in any use, the efficiency of power transformer made in Japan is best. In purchasing power transformer, it is desirable to do the loss evaluation in accordance with the specifications of Surabaya Distribution Project, concretely and properly on the basis of forecast load curve of transformer and electric fee. In the impedance voltage and the step voltage of voltage regulation, small difference is observed. However, it will be difficult to take off the difference because conditions for operation are related to the existing facilities. Automatic fire extinguisher is attached to the power transformer made in Belgium, but it will be a special case. It seems that there is no need generally to attach

the automatic fire extinguisher at present. However, in the future it might be necessary to consider the attachment of automatic fire extinguisher at the main substations, namely nitrogen system fire extinguisher indoors and water system outdoors.
Circuit breaker, as shown in Table 5.3-1., is used gas circuit breaker and small oil volume circuit breaker. Taking into account the international trend in the future, the gas circuit breaker having a long interval in the maintenance will become used as circuit breaker for not only 150kV and 70kV but also 20kV. However, it is also desirable to adopt vacum type circuit breaker for only 20kV because of easiness in the maintenance.
Air or motor system is used as the power operation system of isolator. This type of isolator has the same operation system as circuit breaker installed at the same substation and therefore it is reasonable for operation. Regarding the isolator for 150kV in case of emergency in operation, it is desirable to operate switching from control panel by electric remote control system without going to the site.
It is also desirable for the line isolator to use the isolator with earthing switch for line use which is mechanical interlocked with the line isolator, but the isolators made in France and Korea were not made an entry. Regarding the voltage transformer for 150kV and 70kV class, capacitor voltage transformer (PD) is used in this voltage class because of high reliability and economy, and regarding that for 20kV class, winding type voltage transformer is used in place of capacitor voltage transformer, because of highpriced PD.

In the existing substations, different types of equipment from various countries are found in the same substation premises disorderly. However, it is desirable that at lease the relay facilities have the same system with enough functions, and if possible, with the same manufacturers for the purpose of maintaining and improving the reliability of system and substation.

(2) Standardization of facilities

Comparative study on the design criteria of facilities in various countries was not made in this Feasibility study. But in the basic point, it seems that other consultants have also applied the standard used by *NEWJFC* through East Java Projects from first stage to third stage. As described in the previous Sections, even in case of using same skelton at the substation, differences are found at the detailed points of the facilities, such as construction size, operation system, maintaneous method and so on. These differences lead a difference even in foundation design and layout of facilities, and therefore make it difficult to standardize them. Hoever, it is seemingly necessary to make the application standards of the apparatus taking into account the well-understanding of the present condition of facilities as well as the study of various procurement methods of facilities in the future, that is, procurement from other countries and promotion of local production.

As one of the promoting projects in the future, especially attention will be paid to the following point. Most important is to make a matching between the existing facilities and newly installed facilities, in case of expansion project of substations in which various types of facilities from other countries are equipped in the premises of the same substation. And also the important is to make the manufacturers of the facilities to study the conditions of the existing facilities and to supply their products with a good matching to the designing of the facilities, for the effective progress of construction and the consistency of maintenance and operation of the facilities after completion of the construction.

5.3.2. The Substation Scale, and Another Inspection and Study

As a result of inspection and study judging from space requirement for substation extension totally from technical, economical and long-term points of view, the following conclusion was gotten.

(1) Substation capacity and transformer unit capacity

The capacity, in general, of substations and transformers, the larger it will be, the more economical the installation cost which is particular to each expansion pattern will be in proportion to the number of installation, and as unit price of unit capacity in transformers will be moderate, it will be economical in many cases.

On the other hand, an increase in scale, or a decrease in numbers of facilities will create a trend to raise the distribution cost of the secondary side, and to lower the supply reliability at accidents of transformers and transmission lines, and will also increase the capacity of required facilities as a whole and add up to a pre-investment burden.

An adequate investment standard should be establisbed by taking into overall consideration these contradictory trends, but there exist many factors which influence on conclusions such as;

(i) Minimum necessary cost by substation (1) ... Land, building, etc.

(ii) Minimum necessary cost by substation (2) ... Transmission line lead-in bay, etc.

(iii) Minimum necessary cost by transformer ... Transformer bay, etc.

(iv) Characteristics in unit of kVA by capacity of transformer

(v) Increase rate in demand

(vi) Discount rate in future cost

(vii) Relation between the number of substations and the distribution cost

(viii) Relation between the number of substations and the transmission cost

(ix) Upper limit in scale of substations by number of possible lead-in circuits of distribution lines

(x) Desirable number of transformers at each substation

It is difficult for (vii) and (viii) to be quantified, but it is considered offset with (ii). (*Note)

(ix) This will be problematical in the city, where it is impossible to realize one over 300 MVA of final capacity.

(x) It is desirable to transform as preferably as possible the substations with one transformer into those with two transformers to finalize them with over three transformers, but from an economic point of view, it is preferable for connection transformer to be with 2 3 banks and for distribution transformer with 3 banks.

(*Note) The curtailment of distribution cost by construction of one distribution substation is deemed to be offset by the total of transmission line lead-in cost and construction cost of bay for receiving lines.

With regard to the scale of distribution substation and unit capacity of transformer, economic efficiency will be evaluated in comparison for various new expansion patterns in the reflection of each suppositive model for rural districts, local cities and big cities under the following preconditions;

. Initial load

	Rural districts	:	2.0 MW
	Local cities	:	20.0 MW
	Big cities	:	About 200 MW (193.7 MW)

. Growth ratio of load

	Rural districts	:	12.5% p.a.
	Local cities	:	10.0% p.a.
	Big cities	:	Will follow the under-mentioned regressive logistic curve corresponding to the estimated load for Surabaya.

TL = 4717.369/(1+ExP(14.06444 - .1299239 *(84+NY)))

. Discount rate : 15% p.a.

. Required capacity growth: Load growth/0.8
(All the new facilities will be installed separately from existing ones by putting aside the existing facilities as deposits).

. Installation cost in proportion to the numbers of substations and transformers

Per substation 600×10^3 \$ (Building)
1000×10^3 \$ (Bay for 150 kV incommer 2 circuits)

Per transformer 410×10^3 \$ (Bay for 150 kV transformer)

Unit price of transformer

10 MVA	: 100×10^3\$
20 MVA	: 170×10^3\$
30 MVA	: 220×10^3\$
50 MVA	: 300×10^3\$
100 MVA	: 470×10^3\$

(a) Rural Districts

On the service area of 2.0 MW, the accumulated present worth of the above installation costs are shown in Fig. 5.3-1(1) by following the under-mentioned three expansion patterns to load growth for each substation;

(i) 10 MVA + 10 MVA + 10 MVA
(ii) 20 MVA + 20 MVA + 20 MVA
(iii) 30 MVA + 30 MVA

The Figure indicates that the following expansion programs will be the best, such as;

- At the beginning, a substation of 10 MVA x 1 to be newly-established.
- At 14th year, one of 20 MVA x 1 to be added.
- At 19th year, one of 30 MVA x 1 to be added.
- At 28th year, a substation of 20 MVA x 1 to be newly-established.
- At 30th year, one of 30 MVA x 1 to be added.

(b) Local Cities

In the local cities of 20.0 MW load, the values calculated in the same way are shown in Fig. 5.3-1(2) by following the under-mentioned four expansion patterns to load growth;

(i) 20 MVA + 20 MVA + 20 MVA
(ii) 30 MVA + 30 MVA + 30 MVA
(iii) 50 MVA + 50 MVA + 50 MVA
(iv) 100 MVA + 100 MVA + 100 MVA

The Figure indicates the following suitable expansion programs, such as;

- At the beginning, a substation of 20 MVA x 1 to be newly-established.
- At 7th year, one of 50 MVA x 1 to be added.
- At 14th year, one of 100 MVA x 1 to be added.
- At 22nd year, one of 100 MVA (or diverted ones of 50 MVA x 2) x 1 to be newly-established.
- At 26th year, one of 100 MVA x 1 to be added.
- At 29th year, one of 100 MVA x 1 to be added.

(c) Big Cities

On Surabaya area with the initial load of about 200 MW (193.7 MW), by extrapolating the suppositive load growth over 30 years with logistic curves, the values calculated in the same way are shown in Fig. 5.3-1(3) by following seven expansion patterns to load growth;

(i)	50 MVA x 1 + 100 MVA x 2	(250 MVA x 16 S/S)
(ii)	50 MVA x 2 + 50 MVA x 1	(150 MVA x 26 S/S)
(iii)	50 MVA x 2 + 50 MVA x 2	(200 MVA x 19 S/S)
(iv)	50 MVA x 2 + 100 MVA x 1	(200 MVA x 19 S/S)
(v)	50 MVA x 3 + 100 MVA x 1	(250 MVA x 16 S/S)
(vi)	100 MVA x 2 + 100 MVA x 1	(300 MVA x 13 S/S)
(vii)	50 MVA x 2 + 100 MVA x 2	(300 MVA x 13 S/S)

Among these patterns, take (iv) pattern for example, it means the constructions as the first stage of substations of 50 MVA x 2 for 30 years to number the 19th, and then thereafter expansion one by one of 100 MVA.

The Figure clearly states (vi) pattern is the first most economical, that means an expansion only by 100 MVA, but there will be some problems in supply counter-measures at the time of transformer accidents, and economic efficiency will be reduced considerably in case of lowering the utilization factor.

And (v) and (vii) patterns seem to be the second most economical, but as the final capacity should be maintained at 300 MVA per substation, it is controversial to install four transformers provided the 100 MVA x 3 be the final.

It can be extracted from the above that (iv) pattern is recommendable from both points of view - economical and overall vision in 30 years, and thereafter the capacity can be expanded by replacing those of 50 MVA with those of 100 MVA.

Therefore, in this master plan, (iv) pattern or the second 100 MVA pattern will be applied.

(d) Conclusion

. Transformer Unit Capacity

150 kV/20 kV Transformer	100 MVA, 50 MVA, 30 MVA, 20 MVA, 10 MVA
70 kV/20 kV Transformer	50 MVA, 30 MVA, 20 MVA, 10 MVA.

. Number of banks of Transformers per substation

Connecting transformer	2 ~ 3 banks
Transformer for distribution	3 banks

(2) Considerable items on execution of work

(a) Gradual execution of work

Substation scale is decided by whole power system judging from characteristics of load, demand density, expanding percentage of demand totally, but this is decided by long-term consideration. Accordingly, when the substation was newly constructed, transformer of smaller capacity than that in final scale had better be installed and transformer of second bank had better be installed at early time.

The reason is to make countermeasure at power failure and to be more economic than to make reliability of system increase by reinforcement of distribution facilities. At a later period, it is desirable to install the transformer of big capacity at second or third bank.

(b) System in Surabaya City

It needs to study especially regarding high load density district from long-term point of view and save a space for increase of substation. Then, regarding big scale substation it needs to consider for construction substation of final capacity (100 MVA x 3 bank) and prepare points where 20 ~ 25 circuits of 20 kV Feeder can be distributed with the distribution line for 20 kV.

(3) Power Circuit Configuration

(a) Bus configuration system

Bus configuration system is decided by a scale of substation and importance. However, concretely speaking, the said system shall be decided economically and reasonably judging from the operation of system, the inspection of facilities, the disposal at power failure, the work for substation expansion, flexibility operation in bus maintaneous and so on totally.

The bus system which is installed in East Java on the basis of the above way of idea is as follows, and following systems are recommended to be installed as the standard.

(i) 150 kV/70 kV Bus

The bus of the standard shall be double bus, and bus-tie breaker shall be installed. At early time, the work of single bus may be used.

(ii) 20 kV Bus

Single bus with auxiliary bus shall be decided as the standard. Auxiliary bus is used for the purpose of the inspection after stopping the breaker without stoppage of the current of the distribution line for 20 kV.

(b) The substation at the center of big city

It must be considered to construct the substation which will be constructed in densely populated area as indoor type and underground type (, constructed under buildings and parks ,) because of Space restrictions, surrounding environment and so on. In this case, the substation of unit system is recommended. This substation requires incoming cable only, and this does not require transmission line connection to another substation. And this substation is operated for unit by each transformer bank, and the connection is as Fig. 5.3-2. This system has following characteristics.

(i) Space area and structure area decrease very much.

(ii) Incoming circuit breaker and primary circuit breaker of transformer are omitted.

(iii) One transmission line and one transformer form a unit.

(iv) Faults at substation and transmission line are protected by circuit breaker at sending end substation. In this case, trip signal be transferred from incoming substation to sending end substation.

(v) This is the most suitable system, because it can avoid simultaneous power failure of the transformer banks in case of faults at transformer, incoming cable, bus and so on.

(vi) This is the suitable system judging from maintenance too, because the number of breakers is a few.

(4) Gas Insulated Switchgear (GIS)

Recent constructions of substation require the following demands more and more:

. Counter-measures for the social conditions such as difficult land acquisition, effective use of land and environmental harmonization.
. Improvement of reliability on facilities of substation.
. Labor saving of maintenance and inspection and security.

New technology developed in order to meet these demands is called "Gas Insulated Switchgear (GIS)" with excellent di-electric characteristics using sulphur hexafluoride (SF6) gas in place of atmospheric air as the main dielectric.

GIS is furnished inside the grounded metal cubicle with such facilities except transformers as circuit breakers, isolators, lightening arresters, current and voltage transformers, etc., sealed with SF6 gas of 3 ~ 6 kg/cm^2 inside, and therefore the hot part will not expose at all. The mechanism above-mentioned is characterized by the following;

. Possible reduction .... By the system of Atmospheric Air as the main dielectric, a long insulating distance is required between phases and between phases and ground and as the system voltage rises, the occupying space of switching station will suffer a rapid increase enough to require a vast space.

On the other side, by GIS, an insulating distance can be reduced to less than one tenth (1/10) of the former between hot part and ground (grounded metal cubicle) with excellent dielectric characteristics of SF6 gas and by raising the pressure inside the sealed cubicle up to 3 ~ 6 kg/cm^2, and as the distance between phases can be reduced, therefore the whole measurement of facilities can be reduced.

. Environmental harmanization .... In case of outdoor installation of GIS, the installation can be out of sight from a distance by flat disposition and by fencing with trees and walls, and moreover can be made in the basement and on the rooftop, and the construction can be carried out without bringing out any problem on environmental harmonization.

. Excellent reliability .... By the system of Atmospheric Air as the main dielectric, many accidents have occurred by open-air effects such as salt contamination, dust, etc. and by external elements such as birds-and-beasts contamination, etc., but on the other side, the GIS system can hardly be influenced by external elements because of the electric conduction and the insulation parts being held inside the grounded metal cubicle.

The above leads to a higher reliability on the facilities of substation.

. Labor-saving .... The maintenance work can considerably be limited except some replacements of wear-and-tear articles by constant operation, for the deterioration and the damage brought about by external surroundings can be ignored.

. Security .... In inspections, etc., there will not be any concern about electric shocks, and can be safely carried out, for the hot part is not exposed.

(5) 70 kV Neutral Grounding Scheme System

70 kV neutral grounding scheme system was Petersen coil until the reinforcement of system had been planned in earnest in East Java.

Each 70 kV system is usually separated/paralleled based on the operation condition, so difficulty of compensation of the variable zero phase admittance by Petersen coil capacity will not be expected completely, and from the view point of operation, construction of each divided 70 kV system is required deepest consideration for matching between Petersen coil capacity and zero phase admittance by each system individually. This condition will become a large limitation for operation. On the above said reasons, effectiveness of Petersen coil is not so much expected. Since then, the groundin scheme system was re-examined with expansion of 70 kV system, and the resistance (200 Ω) grounded neutral system has been adopted in order.

(a) Basic rule

Our understanding is:-

Basically 70 kV neutral resistor shall be installed in case of Fig.A, and is case of B there is no need of installation of NGR, (Condition):

Basically in the places where large back power supplied from 150 kV side or large plant, 70 kV transformer neutral shall be connected to ground through N.G.R.

(b) Actual 70 kV system

As existing 70 kV system is shown on the Fig.5.3-4, NGRs are installed in 8 S/Ss as follows.

N. MADIUN
N. KEDIRI
MOJOKERTO
GRESIK
WARU
PERAK
S. MALANG
BANGIL

And in the SDP, in TANDES S/S, NGR will be installed. So the problem is for WLINGI S/S and PROBOLINGGO S/Ss. WLINGI's case, 70 kV neutral shall be better to install NGR as soon as possible.

TANDES's case, if TANDES 70 kV bus is connected with GRESIK/New Perak/MOJOKERTO Bus through 70 kV T/L, it is no problem for relay activities without 70 kV NGR.

PROBOLINGGO's case, until now, the situation of PROBOLINGGO's case is same as Fig. B, but PLN has ACE Project in which PROBOLINGGO's 150 kV bus will be connected with BANGIL 150 kV Bus through 150 kV T/L, on the same time 70 kV NGR must be installed in PROBOLINGGO's 70 kV neutral.

(c) Conclusion

Considering 70 kV system in East Java, the following conclusion was gotten.

(i) In WLINGI, 70 kV neutral shall be grounded through NGR, as soon as possible.

(ii) In PROBOLINGGO, on the same time of connection by the 150 kV T/L between PROBOLINGGO and BANGIL, 70 kV NGR shall be installed.

(6) The investigation of coordination of insulation

In the first field investigation, the bid document and etc. of Belgium Loan, France Loan and Acceleration Project can be gotten. Technical particular of these proposals and specification of Surabaya Distribution Project are much the same. These substation facilities are made on the basis of I.E.C. and other international standard.

Accordingly, these facilities are same in the basical point, and problems were not observed in the point of coordination of insulation.