PART III

DETAILED DESIGN

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CHAPTER 7

CONTRACT PACKAGING

7.1 CONTRACT PACKAGING

During the Feasibility Study stage, contract packaging was studied and recommended in due consideration of the following:

- Construction period
- Construction cost
- Road length
- Type of work

Construction Period

Considering the disturbance to traffic and inconvenience to local people, construction period should not be too long. Contract packaging was so made that construction period would not exceed three years.

Construction Cost

Construction cost of a package should be within an appropriate range. If too low, reliable contractors may lessen their interest and if too high, construction period becomes very long. Considering past performance of contractors and construction period established as mentioned above, appropriate range of construction cost of a package was established to be 100 to 400 million pesos.

Road Length

Road length of a package should not be too long. Maximum road length of a package was set to be about 50km.

Type of Work

Two types of contract packaging were studied.

Area basis packaging :	Start and end points are determined and all works comprised between the two points are covered in a package, and;
Work basis packaging :	Only similar nature of works are selected and form a package.

The work basis packaging is more advantageous if the works require special technique and equipment. If not, the area basis packaging is more advantageous because of better efficiency, manageability and economy. Since all works comprised in this project can be done only by commonly used equipment and require no special technique, the area basis packaging was recommended to this project.

At the beginning of the detailed design stage, contract packaging recommended by the feasibility study was reviewed and minor changes were made. Intersecting points between the Project Road and other road, bridge ends, etc. were selected as the boundary of contract packages during the feasibility study, however, construction works are rather difficult to separate at these points. Therefore, the nearest Km post was selected as the beginning/end point of contract packages which will be also easier to identify construction limit. New limits of contract packages are shown in Table 7.2-1.

7.2 NAMING OF CONTRACT PACKAGES

Each contract package was named based on Barangay or Municipal town name located nearest to the construction limit of each contract package. Table 7.2-1 shows name and construction limit of each contract package.

TABLE 7.2-1 CONTRACT PACKAGE NAME AND CONSTRUCTION LIMITS

Package No.	Contract Package Name	STATION		Net Length (km)
		Beginning	End	
1	Lipata - Alegria Section	1113+402	1167+013	53.611
2	Alegria - Santiago Section	1167+000	1189+945	22.923
3	Santiago - Cabadbaran Section	1190+000	1209+998	19.998
4	Cabadbaran - Tabon-Tabon Section	1210+025	1237+000	26.975
5	Tabon-Tabon - Sibagat Section	1237+000	1253+938	17.101
6	Sibagat - Bayugan Section	1254+000	1271+033	17.042
7	Bayugan - Awa Section	1271+000	1291+046	20.046
8	Awa - San Francisco Section	1291+000	1306+968	15.968
9	San Francisco - Rosario Section	1307+000	1324+044	17.049
10	Rosario - Bunawan Section	1324+000	1348+940	24.942
11	Bunawan - Kapatungan Section	1349+000	1363+941	14.941
12	Kapatungan - Langkilaan Section	1364+000	1376+805	12.805
13	Langkilaan - Monkayo Section	1376+830	1395+185	18.355
14	Monkayo Bypass	1393+540	1395+989	2.956
15	Monkayo - Nabunturan Section	1396+000	1425+071	29.071
16	Nabunturan - Tagum Section	1425+000	1455+977	30.976
17	Tagum - Carmen Section	1456+000	1468+049	12.000
18	Carmen - Panacan Section	1468+000	1496+966	28.966
19	Davao City Diversion Road	1497+000	1516+000	19.000
TOTAL				404.725

Note: Some contract packages have equations, therefore, net length does not always tally with the length computed as L = (End Sta. - Beginning Sta.)

CHAPTER 8

ROADWAY REHABILITATION/IMPROVEMENT

8.1 DESIGN POLICIES

Detailed design was carried out in line with the following policies:

- To attain cost effectiveness
- To preserve environment
- To improve maintenability of road facilities
- To increase resistability to natural disasters
- To consider movement of uncontrolled river flows
- To provide proper countermeasures against flood
- To properly evaluate restoration/improvement works implemented by local fund

8.2 GEOMETRIC DESIGN STANDARDS

The Project is to improve/rehabilitate the existing PCC paved road, therefore, the geometric design standards are greatly governed by the existing standards. When the Pan-Philippine Highway was originally constructed, the geometric design standards as shown in Table 8.2-1 were adopted.

TABLE 8.2-1 GEOMETRIC DESIGN STANDARDS ORIGINALLY ADOPTED FOR PAN-PHILIPPINE HIGHWAY

	Terrain		
	Flat	Rolling	Mountainous
Design Speed (km/h)	80-100	60-80	40-60
No. of Lanes	2	2	2
Carriageway Width (m)	6.7	6.7	6.7
Shoulder Width (m)	2.5	2.5	1.0
Minimum Radius (m)	220-350	120-220	50-120
Maximum Grade (%)	4-3	5-4	7-6

The existing alignment was constructed more or less in accordance with the said standards. In flat sections, the existing alignment of most sections meets the requirements of the design speed of 80 km/hr.. In rolling sections, the design speed of 60 km/hr. can be more or less satisfied, although there are some exceptional sections of which the design speed has to be reduced to 50 km/hr.. In mountainous sections, the design speed of 50 km/hr. can be more or less attained, although some exceptional sections warrant the design speed of 40 km/hr due to unfavorable terrain conditions.

The following guidelines were reviewed and referenced to establish the design standards:

- Design Guidelines, Criteria and Standards, Bureau of Design, DPWH
- A Policy on Geometric Design of Highways and Streets, 1994, AASHTO

Based on the above guidelines/standards and design standards adopted during the initial construction of the Pan-Philippine Highway as well as the existing and actual conditions of the alignment, the geometric design standards were established as shown in Table 8.2-2.

8.3 PAVEMENT DESIGN

8.3.1 Pavement Rehabilitation Criteria

In accordance with the recommendation of the Feasibility Study, Rehabilitation Requirement Index (RRI) was adopted as an index to express overall condition of pavement.

Pavement rehabilitation criterion to decide whether the pavement should be rehabilitated or not was established based on the recommendation of the Feasibility Study as follows:

Pavement rehabilitation shall be designed for the sections of which RRI is 3.0 or less

RRI of 2.5 or less is the most appropriate timing for implementation of pavement rehabilitation. Above criterion was established in anticipation that present RRI of 3.0 would be decreased to 2.5 by the time of start of construction.

TABLE 8.2-2 GEOMETRIC DESIGN STANDARDS FOR PAN-PHILIPPINE HIGHWAY (MINDANAO SECTION)

Design Element \ Terrain / Design Speed (km/h)	Flat	Flat / Rolling	Rolling / Mountainous	Mountainous
	80	60	50	40
1. Lane Width (m)	3.35	3.35	3.35	3.35
2. Pavement Width (m)	6.70	6.70	6.70	6.70
3. Shoulder Width (m)	2.50	2.50	2.50 - 1.00	2.50 - 0.50
4. Minimum Horizontal Radius (m)	220	120	80	50
5. Maximum Vertical Grade (%)	4.0	5.0	7.0	8.0
6. Absolute Max. Grade (%) and It's Max. Length (m)	-	6% : 500m 7% : 400m	8% : 400m	-
7. Maximum Superelevation (%)	6	6	6	6
8. Maximum Combined Gradient Rate of Vertical Grade and Superelevation (%)	11.5	11.5	11.5	11.5
9. Non-Passing (Stopping) Sight Distance (m)	115	70	60	40
10. Passing Sight Distance	560	420	360	270

The index of RRI is expressed as follows:

$$RRI = 5.12 - 2.1 \log R - 0.087\sqrt{D}$$

or

$$RRI = 8.04 - 6.68 \log R$$

or

$$RRI = 3.58 - 0.104\sqrt{D}$$

$$D = C + 0.63P + 0.18S + 6Dp + 2H$$

where:

R = International Roughness Index (m/km)
D = Pavement Distress Factor
C = Crack ($m/1000\ m^2$)
P = Patching ($m^2/1000m^2$)
S = Scaling ($m^2/1000m^2$)
Dp = Depression ($No./1000m^2$)
H = Pothole ($No./1000m^2$)

An average crack and roughness condition for RRI = 3.0 is as follows:

	Roughness (IRI)	Cracks (m/1000 sq.m)
RRI = 3.0	4.9	59.4

Above shows that pavement rehabilitation shall be planned and designed for sections of which crack length exceeds 59.4 meters per 1000 sq.m..

8.3.2 Pavement Design Criteria

1) Initial Performance Period

An initial performance period is defined as "the performance period of the initially rehabilitated or reconstructed pavement before next rehabilitation is required. Selection of an appropriate initial performance period is quite important". When a longer initial performance period is selected, thicker pavement structure is required resulting in higher initial investment. A shorter initial performance period results in thinner pavement structure and lower initial investment, however, next rehabilitation is required in a shorter period of time. Initial performance period should be determined in due consideration of the following:

- Most economic initial performance period (or rehabilitation strategy) within a life cycle period.
- The minimum initial performance period before next rehabilitation is required.

First subject is achieved by a life cycle cost analysis. Second subject is a matter of DPWH's policy. During the Feasibility Study, a life cycle cost analysis for various type of pavement rehabilitation was undertaken. Also DPWH's policy on the minimum initial performance period was discussed with DPWH officials. The minimum initial performance period for various pavement rehabilitation types and traffic loading classes was recommended as shown in Table 8.3-1. The detailed design of pavement rehabilitation methods under this project was undertaken in accordance with the recommendations of the Feasibility Study.

TABLE 8.3-1 INITIAL PERFORMANCE PERIOD FOR THE PROJECT

Rehabilitation Method	Traffic Loading Class	Most Economical Initial Performance Period (years)	Recommended Initial Performance Period (years)
	A	8.4	
	B	8.6	
AC Reconstruction	C	9.7	10
	D	11.2	
	E	11.2	
	F	11.7	
	A	11	
PCC Reconstruction	B	13.9	12
	C	18.9	
	D	23.1	15
	E	20.9	
	F	22.6	20
	A	4.9	
	B	5.8	
AC Overlay of PCC Pavement	C	7.6	10
	D	9.1	
	E	12.0	
	F	17.0	

2) Design Method

DPWH's Design Guidelines, Criteria and Standards recommends two design methods, i.e. AASHTO method (AASHTO Interim Guide for Design of Pavement Structures, 1972) and TRRL method (Road Note 29, A Guide to the Structural Design Pavement for New Roads, 1970). TRRL method gives thinner concrete slab thickness than AASHTO method. Previous studies such as the JICA-assisted Feasibility Study of the Road Improvement Project on the Pan-Philippine Highway, suggested that a concrete slab thickness determined by TRRL method may result in under-design (or dangerous side design) in the Philippines. In this Project, AASHTO method for pavement design was adopted.

The latest AASHTO method is compiled in the AASHTO Guide For Design of Pavement Structures, 1993, (hereinafter referred to as "1993 AASHTO Guide") which covers design of new pavement as well as design of various rehabilitation methods.

8.3.3 Design Requirements

Design requirements for rigid (PCC) pavement and flexible (AC) pavement are summarized in Table 8.3-2.

a. DESIGN VARIABLE

a.1 Time Constraints (or Dimension of Time)

Initial Performance Period: This is shown in Table 8.3-1.

Analysis Period: This refers to the period of time for which the analysis is to be conducted. An analysis period of 25 years was adopted for a life cycle analysis. For pavement design, an initial performance period was adopted.

a.2 Traffic Loading: The analysis is based on cummulative 18-kip equivalent single axle loads (ESAL) during the analysis period.

Based on the results of the axle load survey undertaken by the Feasibility Study at four stations along the Project Road, following two factors were developed:

Bus Factor : Number of ESAL per bus
Truck Factor : Number of ESAL per truck

Bus and truck factors recommended for the Project are shown in Table 8.3-3, whereas these factors derived from the survey for each survey station are presented in Table 8.3-4.

TABLE 8.3-3 RECOMMENDED BUS AND TRUCK FACTORS

	Survey Station	
	L-1, L-2, L-3 (Section from Lipata Ferry Terminal to Tagum)	L-4 (Section from Tagum to the end of Davao City)
Bus Factor	1.5	0.9
Truck Factor	1.8	2.5

Six traffic loading classes were established as shown in Table 8.3-5 and Figure 8.3-1. Traffic loading class of each section of the Project Road is shown in Figure 8.3-2.

Cumulative ESAL for each loading class is attached in Appendix 8.3-1.

TABLE 8.3-2 DESIGN REQUIREMENTS

Category	Description
a. Design Variable	
a.1 Time Constraints	
o Performance Period	Life of Initial Pavement Structure
o Analysis Period	Planned Stage Construction; 25 years
a.2 Traffic Loading	W_{18} = 18 kip Equivalent Single Axle Load (ESAL) Application Traffic Loading Classes; 6 classes (A to E)
a.3 Reliability	Z_R = 1.645 for 95% Reliability, R) not considered S_o = 0.3~0.4 for Standard Error) not considered
a.4 Environmental Impact	
o Roadbed Swelling	PSI_{sw} = Loss of PSI; not considered
b. Performance Criteria	
b.1 Serviceability	$PSI = P_o - P_t = P_o - PSI_w - PSI_{sw}$ (PSI_{sw} ; not considered)
c. Material Properties for Structural Design	
c.1 Effective Roadbed Soil Resilient Modulus (Flexible)	MR (pci); estimated based on CBR
c.2 Effective Modulus of Subgrade Reaction (Rigid)	K-Value (pci); estimated based on CBR and subbase thickness
c.3 Pavement Layer Materials Characterization	E_{SB} = Modulus of Subbase (13,0000 psi) E_{BS} = Modulus of Base (23,000 psi) E_{AC} = Modulus of Asphalt Concrete (350,000 psi) E_C = Modulus of Elasticity of PCC (3.28×10^6 psi)
c.4 PCC Modulus of Rupture (Rigid) (Flexural Strength)	S'_c = Estimated Mean Value for PCC Modulus of Rupture (psi); 580 psi
c.5 Structural Layer Coefficient (Flexible)	Asphalt Concrete Layer Coefficient ; 0.39 Bitumen Stabilized ; 0.2 Crushed Gravel Base ; 0.105 Subbase ; 0.095
d. Pavement Structural Characteristics	
d.1 Drainage	*Flexible m = Layer Coefficient Modifying Factor; 0.9* Rigid CD = Drainage Coefficient; 1.0
d.2 Load Transfer (Rigid)	
o Jointed Pavement	
o Tied Shoulder or Widened Outside Lane	J = Load Transfer Coefficient; 4
d.3 Loss of Support (Rigid)	LS = Loss of Support 1.0~3.0 for unbounded granular materials 2.0~3.0 for fine granular or natural subgrade materials 0~1.0 for cement Treated Granular Base
e. Reinforcement Variables (Rigid)	
e.1 Slab Length	
e.2 Working Stress	Depending on local conditions, subbase type, course aggregate, etc.
e.3 Friction Factors	

TABLE 8.3-4 BUS AND TRUCK FACTORS BASED ON AXLE LOAD SURVEY

Survey Station	Direction	Bus Factor	Truck Factor											
			Empty Trucks				Loaded Trucks				(Empty + Loaded) Trucks			
			2-Axle Truck	3-Axle Truck	Trailer	All Trucks	2-Axle Truck	3-Axle Truck	Trailer	All Trucks	2-Axle Truck	3-Axle Truck	Trailer	All Trucks
L-1	South B.	1.46	0.05	0.20	0.28	0.09	0.48	5.88	18.22	3.75	0.22	3.22	13.09	1.76
	North B.	1.39	0.03	0.12	0.25	0.08	1.16	4.36	13.81	1.89	0.98	3.09	5.68	1.53
L-2	South B.	1.31	0.11	0.26	0.58	0.18	0.59	4.70	9.49	1.46	0.37	1.57	3.01	0.77
	North B.	1.43	0.05	0.47	0.17	0.13	1.48	7.01	5.83	2.89	0.87	4.34	4.89	1.77
L-3	South B.	1.45	0.08	0.39	0.45	0.18	1.37	4.84	12.05	3.10	0.80	2.79	6.83	1.79
	North B.	1.48	0.03	0.15	0.58	0.11	0.93	5.86	10.76	2.71	0.53	4.20	3.48	1.60
L-4	South B.	0.85	0.10	0.32	0.48	0.23	1.57	4.37	7.58	3.17	1.22	3.44	5.17	2.48
	North B.	0.88	0.12	0.21	0.56	0.19	1.39	3.75	7.70	2.70	1.07	1.89	6.24	1.82

Notes: Bus Factor = Number of 18-kip Equivalent Single Axle Load (ESAL)/Number of Buses
Truck Factor = Number of 18-kip Equivalent Single Axle Load (ESAL)/Number of Trucks
L - 1 : Boundary Between Surigao del Norte and Agusan del Norte
L - 2 : Boundary Between Butuan City and Agusan del Sur
L - 3 : Boundary Between Agusan del Sur and Davao del Norte
L - 4 : Boundary Between Davao del Norte and Davao City

TABLE 8.3-5 TRAFFIC LOADING CLASS

Traffic Loading Class	Truck and Bus Traffic Per day (Both directions)		AADT (Veh/day)	Initial Year 18-kip ESAL (x10^6)
	Truck	Bus		
A	2,810 - 2,840	1,420 - 400	9,400 - 6,700	1.52 - 1.36
B	2,020 - 2,080	1,240 - 610	7,200 - 9,500	1.13 - 1.05
C	1,560	670	4,100	0.69
D	920 - 690	430 - 420	2,700 - 2,200	0.42 - 0.34
E	670 - 490	270 - 210	2,400 - 1,400	0.29 - 0.22
F	400 - 220	160 - 95	1,500 - 960	0.18 - 0.10

Note: Initial year was assumed to be 1998.
Truck and bus traffic and AADT are for 1998.

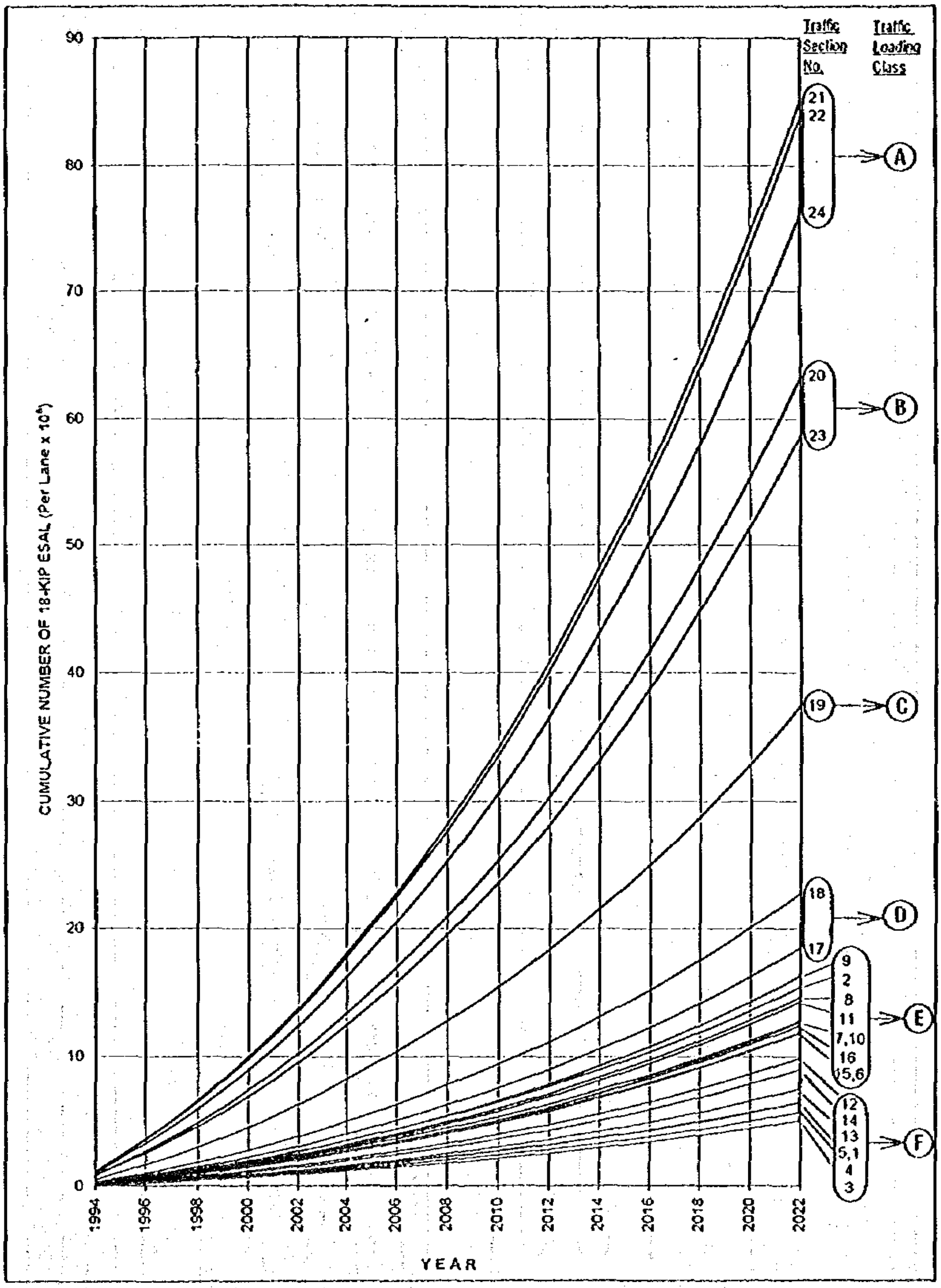


FIGURE 8.3-1 TRAFFIC LOADING CLASS

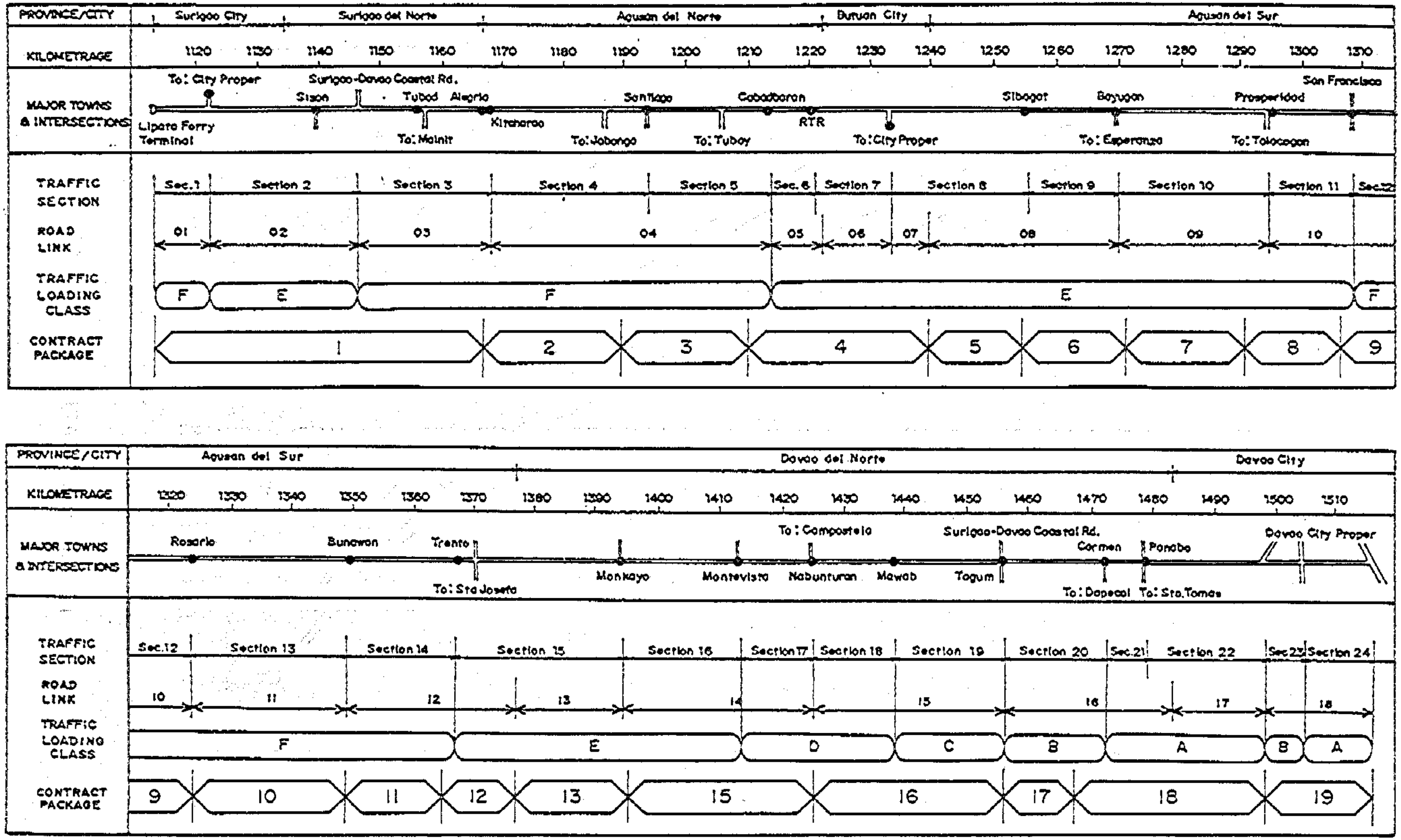


FIGURE 8.3-2 TRAFFIC LOADING CLASS AND CONTRACT PACKAGES

a.3 Reliability: Reliability concept was introduced in 1993 AASHTO Guide to account for chance variation in both traffic prediction and performance prediction. In this Project, reliability was concluded not to be considered after discussion with representative of DPWH.

a.4 Environmental Impacts: Serviceability loss due to roadbed swelling was not considered, because the effects of seasonal temperature and moisture changes on material properties are not known yet.

b. PERFORMANCE CRITERIA

The primary measure of serviceability is the Present Serviceability Index (PSI) which ranges from 0 to 5. The initial serviceability (Po) observed at the AASHTO Road Test were:

Po = 4.5 for rigid pavement
Po = 4.2 for flexible pavement

1993 AASHTO Guide suggests the lowest allowable PSI or the terminal serviceability index (Pt) as follows:

Pt = 2.5 for design of major highway
Pt = 2.0 for design of highway

The terminal serviceability of 2.5 was adopted in this Project, which nearly correspond to RRI of 2.5.

c. MATERIAL PROPERTIES FOR STRUCTURAL DESIGN

c.1 Effective Roadbed Soil Resilient Modulus (MR) for Flexible Pavement: This value was estimated based on CBR as shown in Table 8.3-6.

c.2 Effective Modulus of Subgrade Reaction (k-value) for Rigid Pavement: This value was estimated based on subgrade CBR and subbase thickness as shown in Table 8.3-6.

TABLE 8.3-6 MR AND K-VALUE

Subgrade CBR	MR	K-Value (pci)	
(%)	(psi)	Subbase Thickness 20cm	Subbase Thickness 15cm
2	2,500	180	160
3	4,000	250	220
4	5,000	300	280
6	6,000	350	330
8	7,000	390	370
10	8,000	420	400
15	12,000	580	550
20	15,000	700	680

c.3 Pavement Layer Materials Characteristics: modulus of pavement layer materials were estimated following the suggestion by 1993 AASHTO Guide.

- Modulus of Subbase (CBR = 20) E_{SB} = 13,000 psi
- Modulus of Base (CBR = 45) E_{BS} = 23,000 psi
- Modulus of Asphalt Concrete E_{AC} = 350,000 psi
- Modulus of Portland Cement Concrete E_C = 3.28x10^6 psi

c.4 PCC Modulus of Rupture: in accordance with the DPWH specifications, the modulus of rupture of 580 psi was used in this Study.

c.5 Layer Coefficient for Flexible Pavement: layer coefficient for the following materials was estimated based on 1993 AASHTO Guide suggestion.

Layer Material	Layer Coefficient
Asphalt Concrete Surface Course	0.39
Bitumen Stabilized Base	0.20
Crushed Gravel Base (CBR = 45)	0.105
Subbase (CBR = 20)	0.095

d. PAVEMENT STRUCTURAL CHARACTERISTICS

d.1 Drainage: drainage level defined by 1993 AASHTO Guide is as follows:

Drainage Level

Quality of Drainage	Water Removed Within
Excellent	2 hours
Good	1 day
Fair	1 week
Poor	1 month
Very poor	(water will not drain)

Drainage level is planned to be improved to a level of fair condition, and following values were used:

- Value for modifying structural coefficient of base and subbase materials for flexible pavement; m = 0.9

- Value of drainage coefficient for rigid pavement; Cd = 1.0

d.2 Load Transfer (Rigid Pavement): the load transfer coefficient, J, is a factor used in rigid pavement design to account for the ability of a concrete pavement structure to transfer (distribute) load across discontinuities such as joints. Load transfer coefficient of 4 was used in consideration of effect of plain joint.

d.3 Loss of Support (Rigid Pavement): this is to account for the potential loss of support arising from subbase erosion and/or differential vertical soil movement. In this Study, loss of support of 1 was used.

e. REINFORCEMENT VARIABLES (RIGID PAVEMENT)

As the plain jointed concrete pavement is adopted, reinforcement variables are not required for the design.

8.3.4 Comparative Study of Pavement Rehabilitation Methods

The type of existing pavement along the Project Road is PCC pavement. Rehabilitation methods of PCC pavement are as follows:

- Reconstruction
  - AC Reconstruction (Reconstruction with AC)
  - PCC Reconstruction (Reconstruction with PCC)

- Rehabilitation Methods With Overlay
  - AC overlay of PCC pavement
  - PCC overlay of PCC pavement

- Rehabilitation Methods Other Than Overlay
  - Full Depth Pavement Repair
  - Partial Depth Pavement Repair
  - Joint and Crack Sealing
  - Subsealing of Concrete Pavements
  - Grinding/Milling of Pavements
  - Subdrainage Improvements
  - Pressure Relief
  - Restoration of Joint Load Transfer
  - Surface Treatments

As the study Road requires major rehabilitation, rehabilitation methods other than overlay were not considered in this Project. PCC overlay of PCC pavement has not been experienced in this country, thus was not considered in this Project.

The following three rehabilitation methods which are commonly adopted in this country were compared in this Project.
- AC Reconstruction
- PCC Reconstruction
- AC Overlay of PCC Pavement

COST COMPARISON

Initial construction cost and total discounted cost (analysis period = 25 years) of above three types of rehabilitation method were compared and results of analysis are presented in Figure 8.3-3 and 8.3-4, respectively. From these figures, followings were made clear:

- AC reconstrction is the most expensive rehabilitation method in almost all cases.
- AC overlay is the most economical method in all most all cases
- Cost difference between AC overlay and PCC reconstruction is about 10% for Traffic Loading Classes A, B and C, and about 15 to 25% for Traffic Loading Classes D, E and F.

From the economic viewpoint, AC overlay is advantageous. However, AC overlay should not be applied under the following conditions:

Pavement Conditions Under Which AC Overlay Should not be Applied

- Heavy depression (or localized settlement area) is observed.
- Pumping and/or water bleeding is observed which is suspicious to void under PCC slab.
- Block (or alligator) cracks with depression are observed.
- Slab rocking suspicious to uneven settlement is observed.
- Remarkable differences in elevation between cracked fragments (or cracks with fault) are observed.
- Drainage condition is assessed to be bad.
- Rehabilitation Requirement Index (RRI) is less than 1.5.

When above conditions are observed, the existing PCC pavement should be removed and subbase course and subgrade should be properly treated and strengthened with proper drainage facilities.

Based on above study, selection of pavement rehabilitation method was made under the following principles:

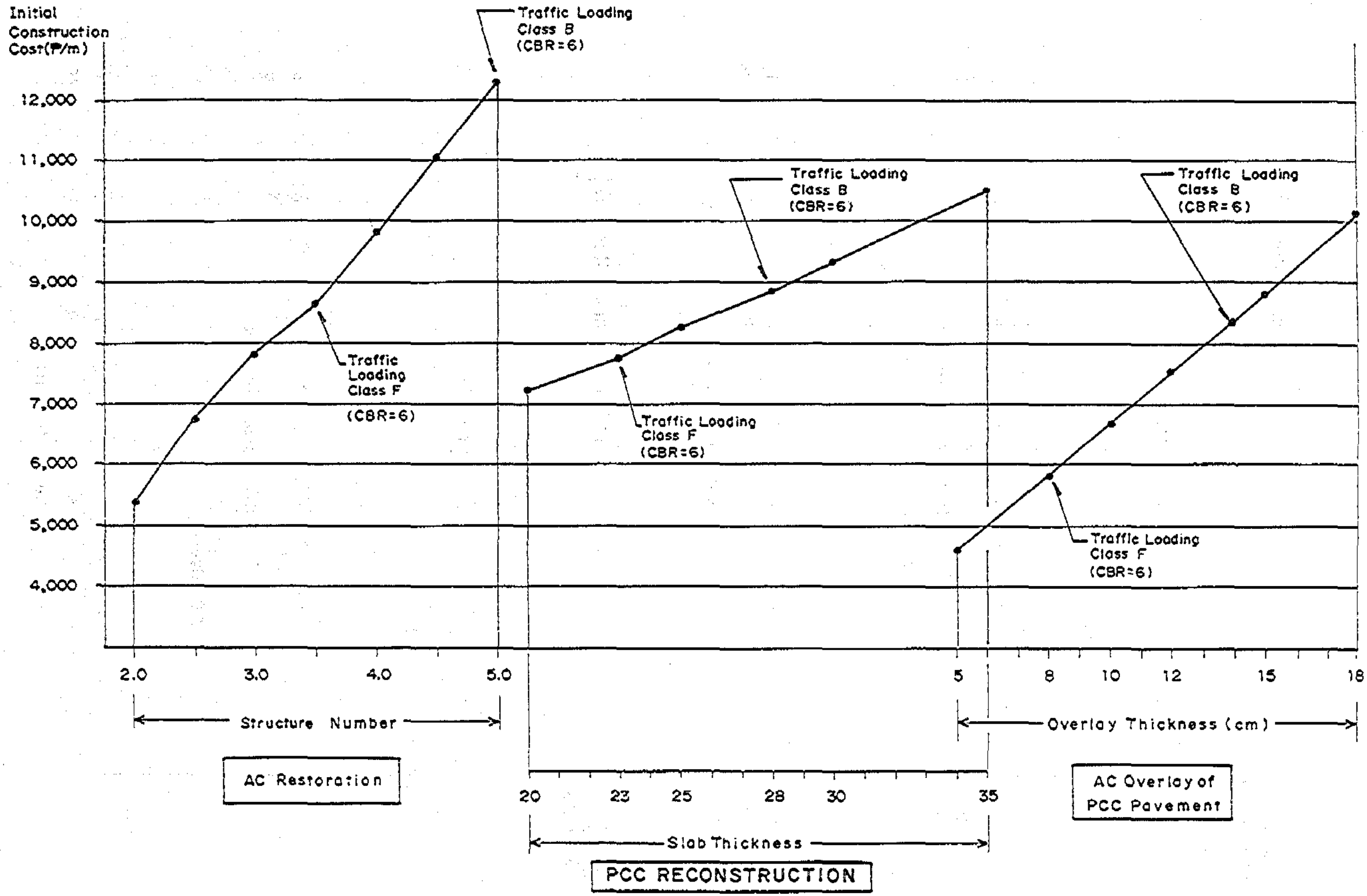
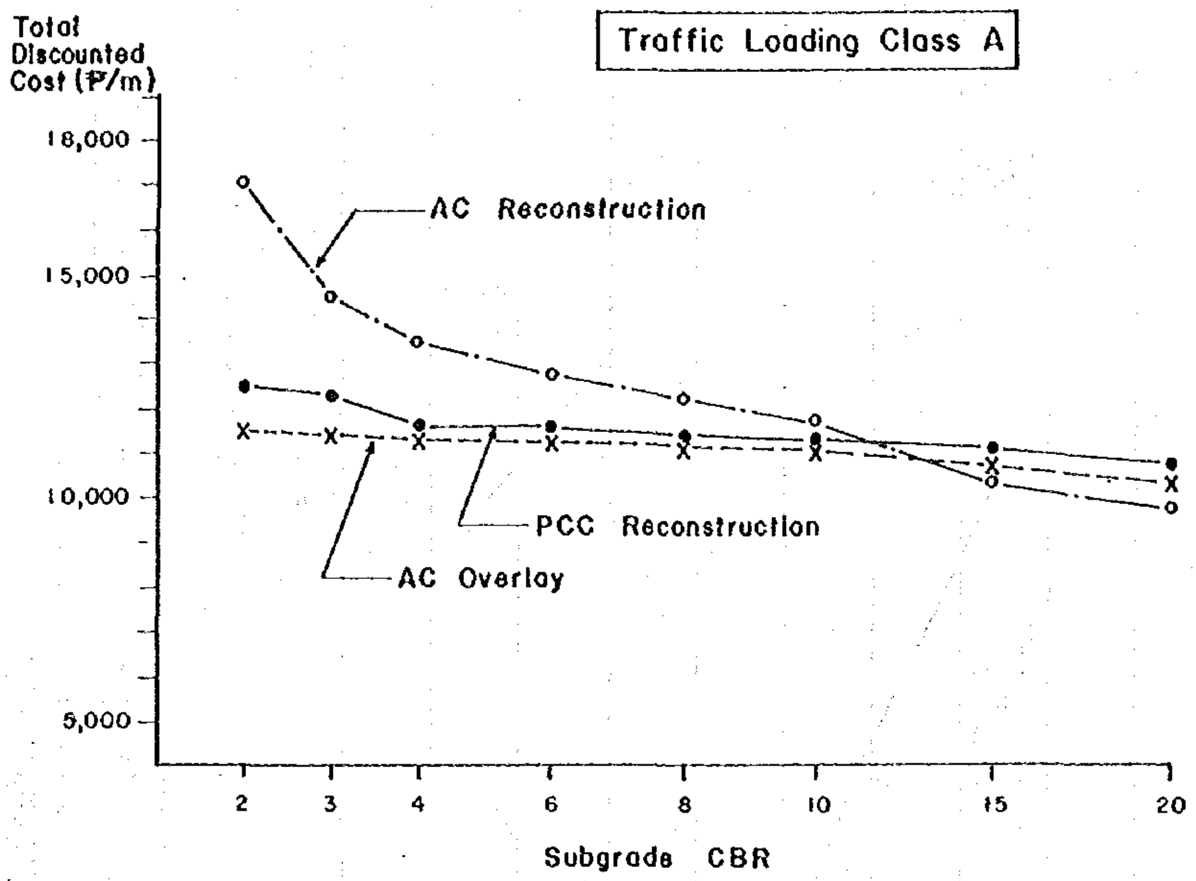


FIGURE 8.3-3 INITIAL CONSTRUCTION COST



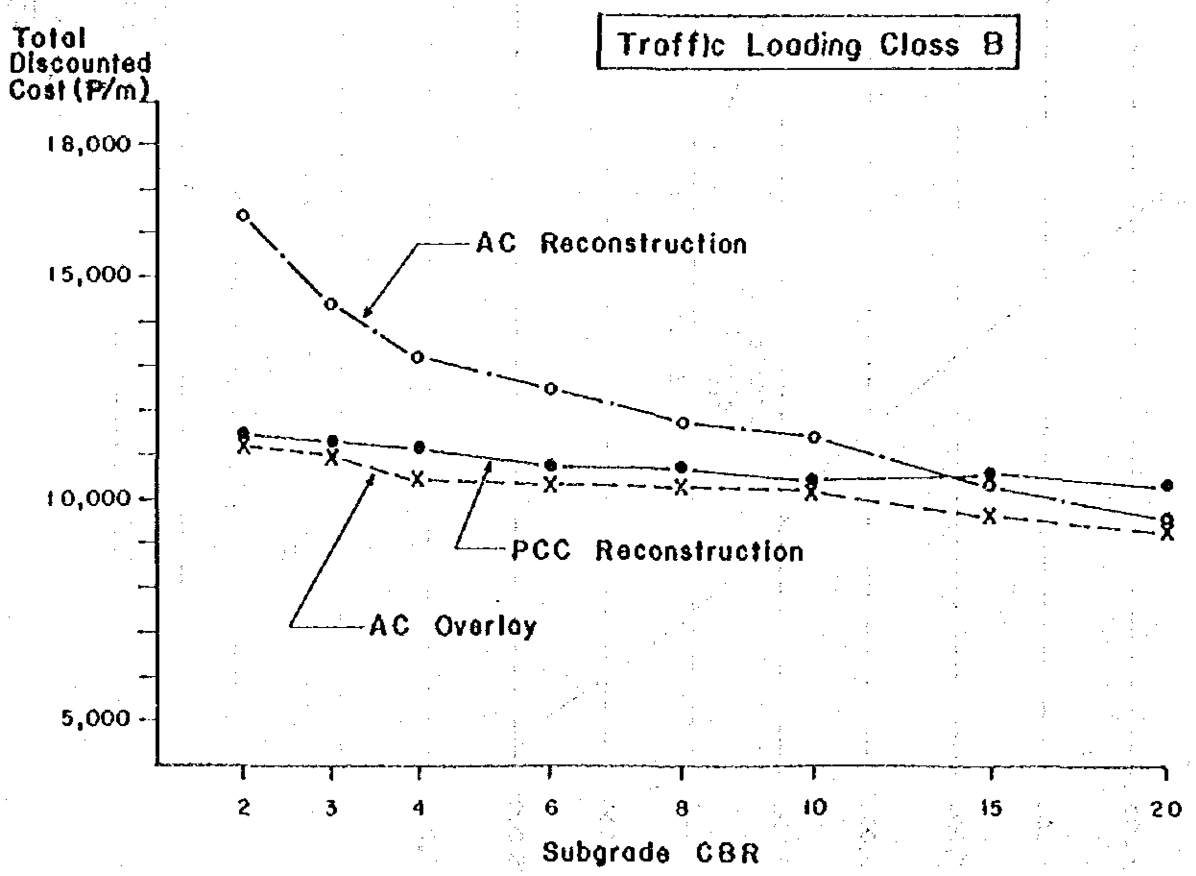
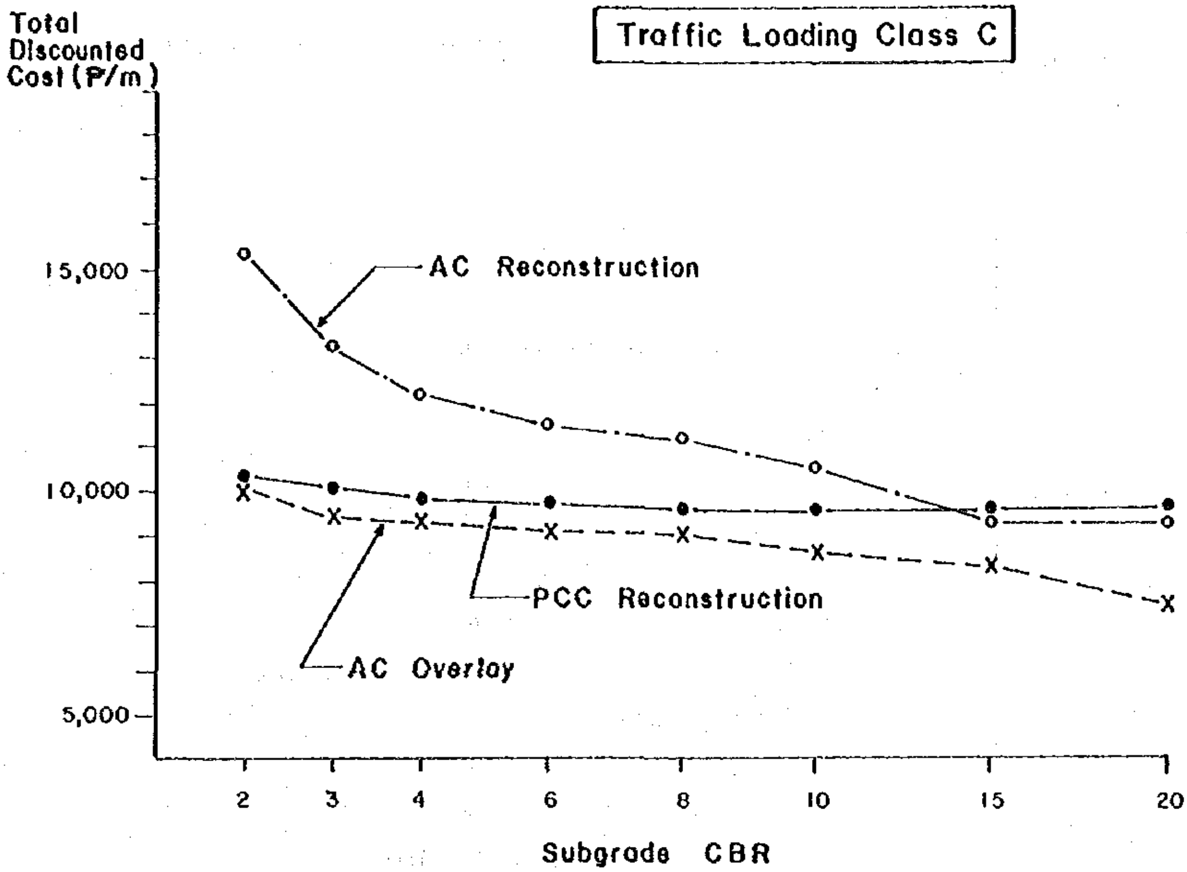


FIGURE 8.3-4 (1) TOTAL DISCOUNTED COST



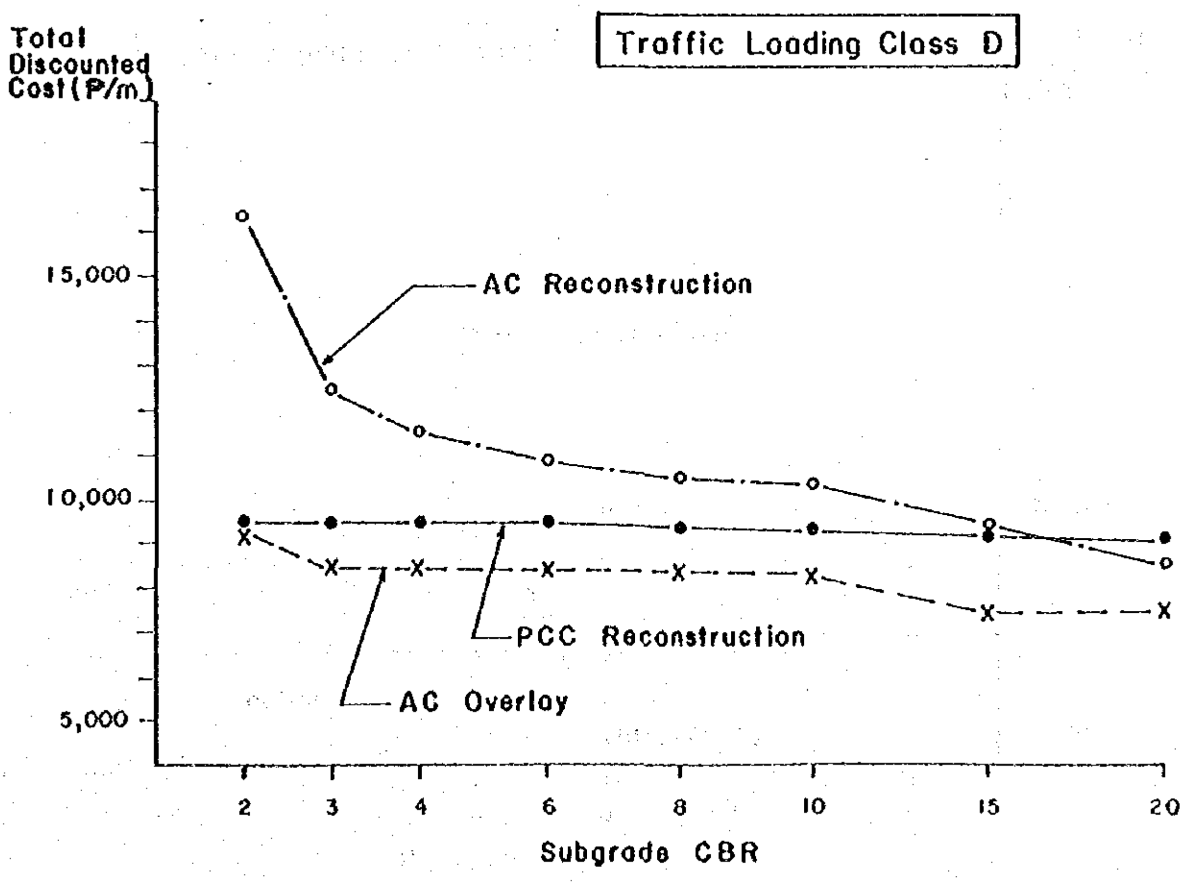
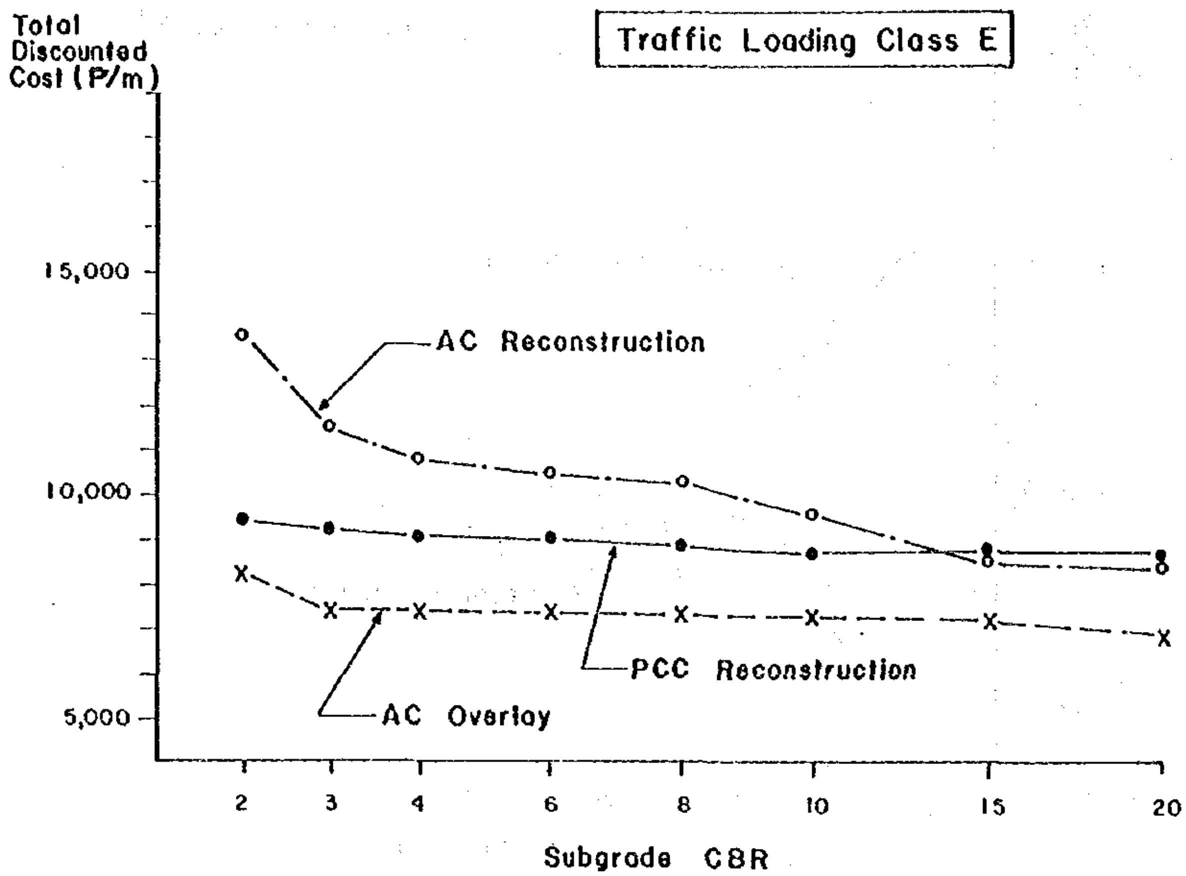


FIGURE 8.3-4 (2) TOTAL DISCOUNTED COST



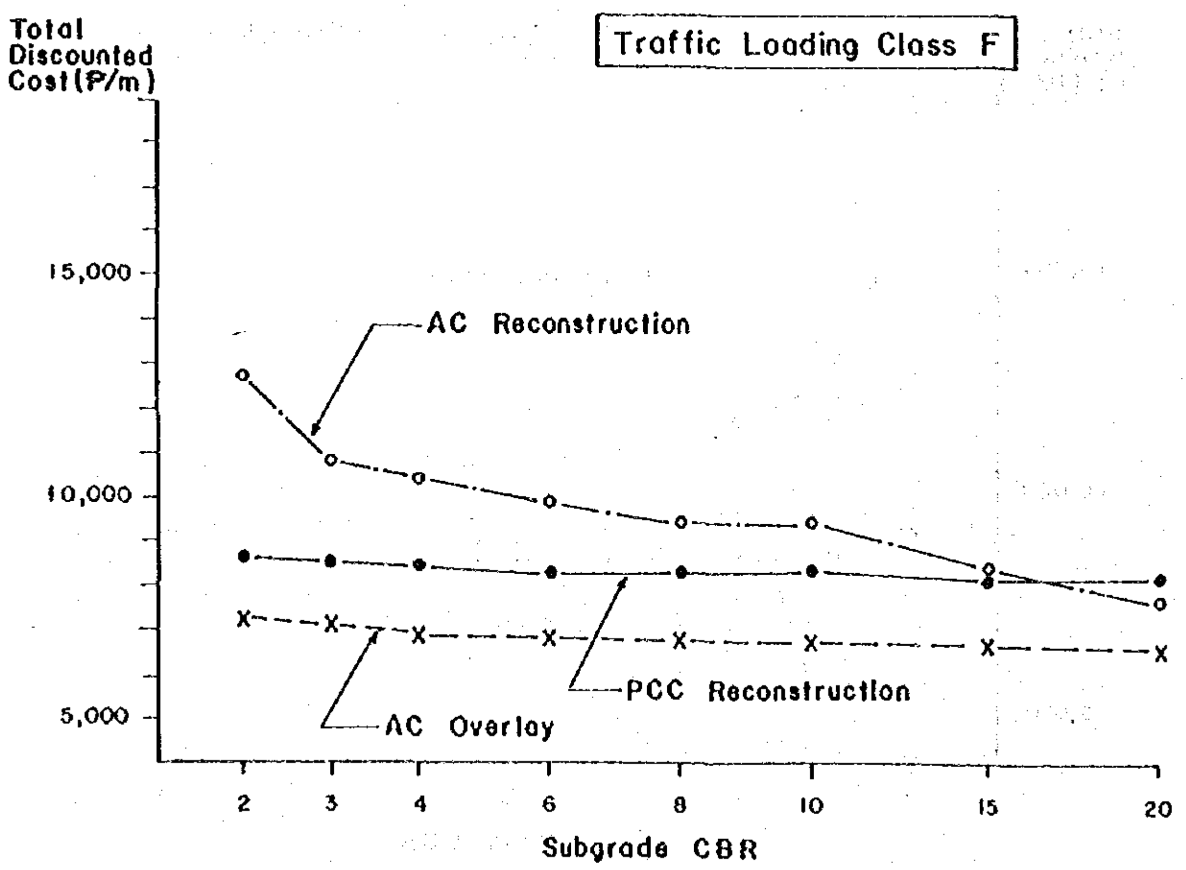


FIGURE 8.3-4 (3) TOTAL DISCOUNTED COST

Selection of Pavement Rehabilitation Method

- AC overlay should be considered whenever applicable.
- Where AC overlay is not applicable, PCC reconstruction should be considered.
- AC reconstruction should be considered only for the special cases such as for soft ground sections.

8.3.5 Standard Pavement Thickness Design

In anticipation of various conditions, pavement thickness design was carried out.

<u>PCC Reconstruction and AC Reconstruction</u>

For various subgrade conditions, pavement thickness design was carried out for each traffic loading class. The results of design are summarized in Table 8.3-7 for PCC reconstruction and Table 8.3-8 for AC reconstruction.

<u>AC Overlay of PCC Pavement</u>

Overlay thickness design was undertaken for the following cases:

- Existing Concrete Slab Thickness: 20cm, 23cm

- Existing Concrete Slab Strength:

Compressive Strength of Concrete	= 3,000 psi
Modulus of Portland Cement Concrete	= $3,03 \times 10^6$ psi
Modulus of Rupture	= 460 psi

- Subbase: Thickness = 20cm, CBR = 15

- Pavement Condition:

Very bad	: Effective Slab Thickness	= 0.85 D
Bad	: Effective Slab Thickness	= 0.90 D
Fair	: Effective Slab Thickness	= 0.95 D

(D = Slab thickness)

- Subgrade Condition: CBR = 2, 3, 4, 6, 8

- Initial Performance Period = 10 years

Results of thickness design are presented in Tables 8.3-9, 10 and 11.

TABLE 8.3-7 REQUIRED PCC SLAB THICKNESS: PCC RECONSTRUCTION

Slab Thickness (cm)

Traffic Loading Class	Initial Year ESAL (x10^6)	Subgrade CBR								Initial Performance Period
		2	3	4	6	8	10	15	20	
A	1.52 ~ 1.36	28.0 (10)	28.0 (10)	28.0 (11)	28.0 (11)	28.0	28.0	28.0	28.0	12 years
B	1.13 ~ 1.05	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	
C	0.69	28.0	28.0	28.0	28.0	28.0	28.0	25.0	25.0	15 years
D	0.42 ~ 0.34	28.0	25.0	25.0	25.0	25.0	25.0	25.0	23.0	
E	0.29 ~ 0.22	28.0	25.0	25.0	25.0	25.0	25.0	25.0	23.0	20 years
F	0.18 ~ 0.10	25.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	

Note:
1) Provision of filter layer is required for CBR less than 3.
2) Improvement method for weak subgrade should be applied for CBR 2 or less.
3) ( ) shows initial performance period which is less than recommended initial performance period.
4) Subbase thickness: 20 cm

TABLE 8.3-8 REQUIRED STRUCTURAL NUMBER: AC RECONSTRUCTION

Required Structural Number (SN)

Traffic Loading Class	Initial Year ESAL (x10^6)	Subgrade CBR								Initial Performance Period
		2	3	4	6	8	10	15	20	
A	1.52 ~ 1.36	5.5	5.5	5.0	5.0	4.5	4.5	4.0	3.5	10 years
B	1.13 ~ 1.05	5.5	5.5	5.0	5.0	4.5	4.0	3.5	3.5	
C	0.69	5.5	5.0	4.5	4.5	4.0	4.0	3.5	3.0	
D	0.42 ~ 0.34	5.5	5.0	4.5	4.0	4.0	3.5	3.0	3.0	
E	0.29 ~ 0.22	5.0	4.5	4.0	4.0	3.5	3.5	3.0	3.0	
F	0.18 ~ 0.10	5.0	4.0	4.0	3.5	3.5	3.0	3.0	2.5	

Note:
1) Provision of filter layer is required for CBR less than 3.
2) Improvement method for weak subgrade should be applied for CBR 2 or less.

TABLE 8.3-9 REQUIRED AC OVERLAY THICKNESS PAVEMENT CONDITION: VERY BAD

Overlay Thickness

Existing Slab Thickness	Traffic Loading Class	Subgrade CBR					Initial Performance Period
		2	3	4	6	8	
20cm	A	26.3	25.6	25.2	24.9	24.6	10 years
	B	24.2	23.5	23.1	22.7	22.4	
	C	20.9	20.2	19.8	19.4	19.1	
	D	17.7	17.0	16.5	16.1	15.8	
	E	15.5	14.7	14.2	13.8	13.4	
	F	12.3	11.5	10.9	10.4	10.0	
23cm	A	22.6	21.9	21.5	21.2	20.9	10 years
	B	20.5	19.8	19.4	19.0	18.8	
	C	17.1	16.4	16.0	15.6	15.3	
	D	13.8	13.0	12.5	12.0	11.7	
	E	11.4	10.6	10.0	9.5	9.1	
	F	7.9	6.9	6.3	5.7	5.3	

Note: Above Table shows computation results.
Application of overlay thickness must be carefully done.
Appllicable overlay thickness will be as follows:

Minimum : 8cm
Maximum : 16cm

TABLE 8.3-10 REQUIRED AC OVERLAY THICKNESS
PAVEMENT CONDITION: BAD

Overlay Thickness

Existing Slab Thickness	Traffic Loading Class	Subgrade CBR					Initial Performance Period
		2	3	4	6	8	
20cm	A	24.8	24.2	23.8	23.4	23.0	10 years
	B	22.7	22.0	21.6	21.2	21.0	
	C	19.4	18.7	18.3	17.9	17.6	
	D	16.2	15.4	14.9	14.5	14.2	
	E	13.9	13.1	12.6	12.1	11.8	
	F	10.6	9.7	9.1	8.6	8.2	
23cm	A	21.0	20.3	19.9	19.5	19.2	10 years
	B	18.9	18.2	17.7	17.3	17.1	
	C	15.4	14.7	14.2	13.8	13.5	
	D	12.0	11.1	10.6	10.1	9.8	
	E	9.5	8.6	8.0	7.5	7.1	
	F	5.7	4.7	4.1	3.5	3.0	

Note: Above Table shows computation results.
Application of overlay thickness must be carefully done.
Applicable overlay thickness will be as follows:

Minimum : 8cm
Maximum : 16cm

TABLE 8.3-11 REQUIRED AC OVERLAY THICKNESS
PAVEMENT CONDITION: FAIR

Overlay Thickness

Existing Slab Thickness	Traffic Loading Class	Subgrade CBR					Initial Performance Period
		2	3	4	6	8	
20cm	A	23.4	22.7	22.3	22.0	21.7	10 years
	B	21.3	20.6	20.2	19.8	19.6	
	C	18.0	17.3	16.8	16.4	16.1	
	D	14.7	13.9	13.4	12.9	12.6	
	E	12.3	11.5	11.0	10.5	10.1	
	F	8.9	8.0	7.4	6.8	6.4	
23cm	A	19.3	18.6	18.2	17.9	17.6	10 years
	B	17.2	16.5	16.0	15.6	15.3	
	C	13.6	12.9	12.4	12.0	11.6	
	D	10.0	9.1	8.6	8.1	7.7	
	E	7.4	6.5	5.9	5.3	4.9	
	F	3.5	2.4	1.7	1.1	0.6	

Note: Above Table shows computation results.
Application of overlay thickness must be carefully done.
Applicable overlay thickness will be as follows:

Minimum : 8cm
Maximum : 16cm

8.3.6 Pavement Design of Each Package

1) Basis for Selection of Pavement Rehabilitation Method

The following field survey results were plotted on one sheet (Refer to Appendix 8.3-1) in order to properly select the type of pavement rehabilitation method:

Indices	Data Source
• Crack Ratio ($m/1,000m^2$)	Pavement Distress Survey
• Number of slabs with depression (no.)	Pavement Distress Survey
• PCC Slab thickness (cm)	Pavement Carriageway and Test Pitting
• Compressive Strength of Concrete (kg/cm^2)	Pavement Coring Survey
• Subbase material (or sand and gravel layer under PCC slab) thickness (cm)	Test Pitting and Auger Boring
• CBR of subbase (or sand and gravel layer under PCC slab)	Test Pitting
• CBR of subgrade (or soil layer under sand and gravel)	Test Pitting

Following are basis of judgement for pavement rehabilitation need and selection of rehabilitation method:

Crack Ratio

59.4 $m/1000m^2$: RRI = 3.0 (Rehabilitation to be planned)

110.1 $m/1000m^2$: RRI = 2.5 (Rehabilitation already required)

No. of Slabs with Depression

When this value is high, AC overlay should not be adopted, unless properly treated.

PCC Slab Thickness

Standard thickness was 23 cm.

Compressive Strength of Concrete

DPWH specification requires 3,500 psi (245 kg/cm^2).

Subbase Thickness and CBR

Standard thickness was 20cm and CBR of 25% required.

Subgrade

CBR of less than 3 is considered soft subgrade.

2) Type of Pavement Rehabilitation Method

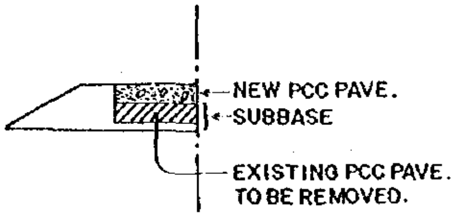
Following pavement rehabilitation methods were considered:

Abbreviation	Procedure	Schematic Diagram

Reconstruction with PCC Pavement or Replacement of PCC slabs

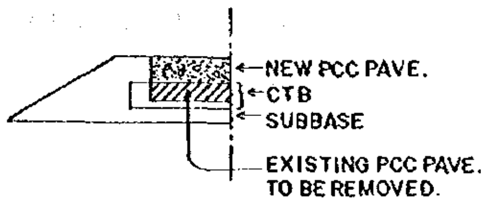
PCC TYPE-1

- Remove Existing PCC Pave.
- Construct New PCC Pave. with Subbase



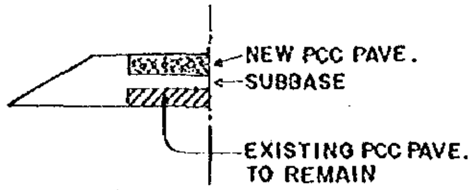
PCC TYPE-2

- Remove Existing PCC Pave.
- Construct New PCC Pave. with Cement Treated Base (CTB)



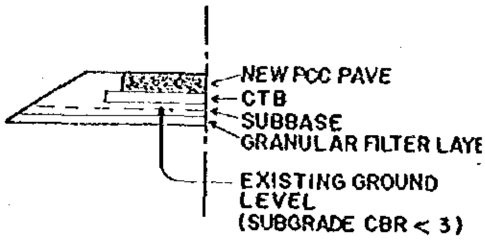
PCC TYPE-3

- Remain Existing PCC Pave.
- Construct New PCC Pave. with Subbase on Existing PCC Pave.



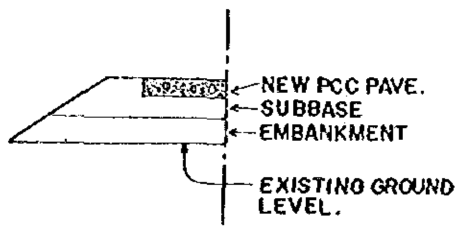
PCC TYPE-4

- New PCC Pave. on Weak Subgrade (CBR < 3%) with granular Filter Layer and CTB



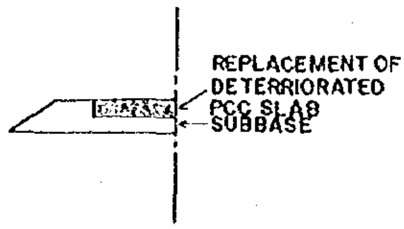
PCC TYPE-5

- Construct New PCC Pave. along New Alignment and/or sections of which road elevation is changed



PCC TYPE-6

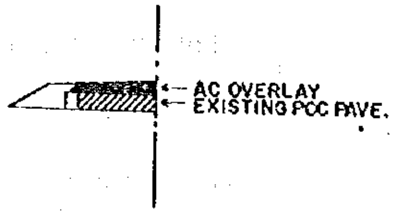
- Replace only Deteriorated PCC Slabs



AC Overlay on PCC Pavement

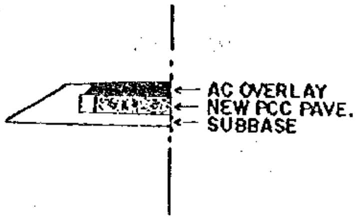
ACO TYPE-1

- Replace severely deteriorated PCC slab
- Seal cracks/joints
- Provide AC Overlay on existng PCC Pave.



ACO TYPE-2

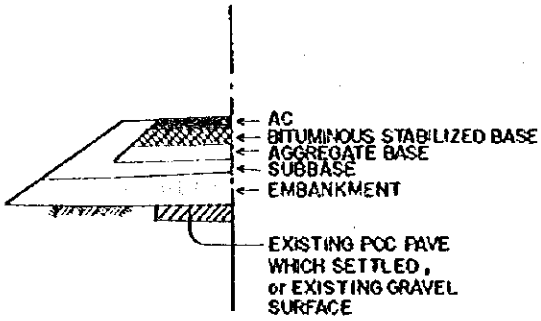
- AC overlay on New PCC Pave. (Applicable for new alignment or road elevation to be changed in the section between ACO TYPE-1)



Asphalt Concrete Pavement

AC TYPE-1

- Construction of New AC Pavement (Applicable for gravel section, new alignment section and uneven surface section, all of which are soft ground section)



3) Selected Pavement Rehabilitation Method

Appendix 8.3-2 shows present conditions of existing pavement.

PACKAGE 1

RRI of most sections is more than 3.0. Major rehabilitation is not required yet. Recommended is to replace only deteriorated PCC slabs (PCC Type-6).

For the flood sections, road elevation was proposed to be raised where new PCC pavement (PCC Type-5) is required.

PACKAGE 2

RRI of majority of sections reached to 3.0. Number of PCC slabs with depression or cracks with faulting is minimal, therefore, AC overlay on the existing PCC pavement (ACO Type 1) was selected.

Road elevation is proposed to be raised for the flood sections. Each flood section is short in length, thus ACO Type-2 was selected.

PACKAGE 3

RRI of most sections is more than 3.0. Major rehabilitation is not required yet. Recommended is to replace only deteriorated PCC slabs (PCC Type-6).

For the flood sections, road elevation was proposed to be raised where new PCC pavement (PCC Type-5) is required.

PACKAGE 4

RRI of most sections is more than 3.0. Major rehabilitation is not required yet. Recommended is to replace only deteriorated PCC slabs (PCC Type-6).

For the flood sections, road elevation was proposed to be raised where new PCC pavement (PCC Type-5) is required.

PACKAGE 5

The section of this package can be divided into two subsections as follows:

Subsection 5-1: From beginning of the package to Afga Bridge (Km 1237 + 000 - Km 1246 + 400)

Subsection 5-2: From Afga Bridge to End of the package (Km 1246 + 400 - Km 1254 + 000)

Subsection 5-1:

Majority of this subsection has RRI of less than 3.0, therefore, pavement of whole subsection should be rehabilitated.

Although there are some short sections where depressions are concentrated, AC overlay was judged to be applicable (ACO Type-1). PCC slabs with depressions and numerous cracks were planned to be replaced with new PCC prior to AC overlay.

Existing PCC slabs at Km 1241 and Km 1246 has substandard concrete strength. Slab thickness varies from 20cm to 26cm. Subbase material layer thickness is more or less satisfactory, except three locations at Km 1242+250, Km 1243+750, and Km 1244+750 where thickness is thin ranging from 14cm to 17cm. CBR of subbase material layer is mostly sub-standard. At two locations, subgrade soil has CBR value of less than 3%.

Considering the above conditions, AC overlay thickness was calculated to be 8cm.

Subsection 5-2:

Pavement condition of this subsection has been deteriorated with severe cracks, thus whole subsection requires rehabilitation.

Crack ratio is high and many slabs with depressions exist. Concrete strength of PCC slab is mostly substandard with thinner slab thickness than required. Most subbase materials have low CBR value, ranging from 9 to 30%.

Considering the above conditions, PCC Type-1 was selected. Pavement structure was designed as shown in Figure 8.3-5.

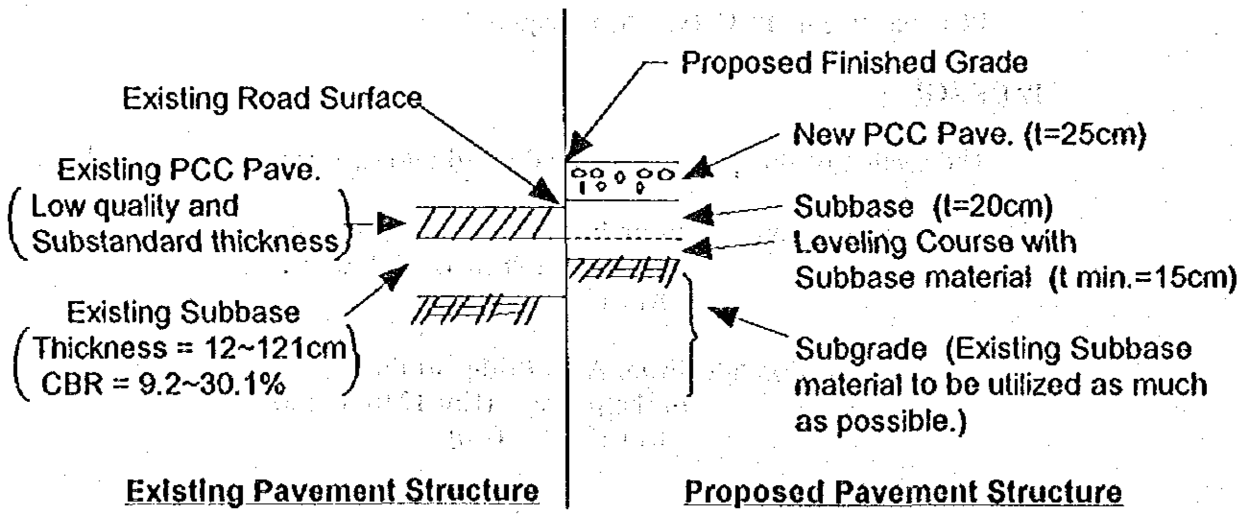


FIGURE 8.3-5 PROPOSED PAVEMENT STRUCTURE: PACKAGE 6

PACKAGE 6

Proposed pavement rehabilitation methods were as follows:

Subsection 1	(Km 1254+000 - Km 1254+300)	: PCC Type-1
Subsection 2	(Km 1254+300 - Km 1257+300)	: ACO Type-1
Subsection 3	(Km 1257+300 - Km 1259+600)	: PCC Type-1
Subsection 4	(Km 1259+600 - Km 1265+600)	: ACO Type-1
Subsection 5	(Km 1265+600 - Km 1271+000)	: PCC Type-1

Subsections 2 and 4 suffers a lot of cracks, however, slabs with depression and cracks with faulting are not significant, thus AC overlay was recommended.

In Subsections 1, 3 and 5, there are many slabs with depression and cracks with faulting together with severe longitudinal cracks and scaling. PCC slab concrete is extremely low quality. Thus, PCC pavement reconstruction (Type-1) was proposed.

PACKAGE 7

Pavement condition in this package is the worst along the Study Road.

The compressive strength of existing PCC slab is mostly very weak. 12 cored concrete samples out of 16 showed very low value ranging from 92 kg/cm^2 to 217 kg/cm^2. Slab thickness is mostly insufficient.

In some sections, PCC slab was constructed directly on subgrade and no subbase materials were provided. Most subbase materials where provided are also weak. Also, boulders were used, therefore, filler materials are easily eroded.

Another critical problem of this package is existence of weak subgrade for almost entire stretch.

Proposed pavement structure is as follows:

- Subgrade replacement as required
- Subbase course
- Cement treated base course (CTB)
- New PCC pavement

Another important works to be done are to provide underdrain as well as surface water drainage and shoulder pavement which prevents surface water to infiltrate into pavement.

PACKAGE 8

All stretch of this package suffers very poor condition of pavement. A lot of depressions, cracks with faulting and continuous longitudinal cracks exist. Reconstruction with PCC pavement was selected for the rehabilitation method.

In view of types of pavement deterioration, subgrade replacement (30 to 100cm) with borrow material was proposed for the full stretch of the package.

PACKAGE 9

Pavement condition varies drastically frm very bad to fair in this package. In accordance with condition, pavement rehabilitation method was proposed as follows:

Km 1307+000 - Km 1310+200	: PCC TYPE-1
Km 1310+200 - Km 1316+800	: ACO TYPE-1
Km 1316+800 - Km 1320+260	: PCC TYPE-6
Km 1320+260 - Km 1324+000	: ACO TYPE-1 or AC Type-1

AC Type-1 was applied to gravel section and deep settlement area due to consolidation of soft clay layers.

PACKAGE 10

This package suffers uneven road surface due to consolidation settlement of soft clay layers for the first 10 km. There is a short gravel section near Km. 1343. AC Type-1 was recommended for uneven road surface sections and a gravel section.

Except for the above section, ACO Type-1 and PCC Type-1 were recommended as follows:

Km 1324+000 - Km 1338+000	: ACO Type-1
Km 1338+000 - Km 1349+000	: PCC Type-1

PACKAGE 11

There are two flood sections where road elevation was proposed to be raised. For these two sections, ACO Type-2 (new PCC pavement plus AC overlay) was adopted, as the adjacent sections were proposed to be ACO Type-1.

PACKAGE 12

Due to high ratio of PCC slabs with depression, cracks with faulting and serious longitudinal cracks, reconstruction with PCC pavement (PCC Type-1) was recommended for the entire stretch of this package.

PACKAGE 13

Pavement condition was very bad, especially for the first 10 km. section. However, DPWH District Office undertook extensive PCC slab replacement for the last two years. Thus, pavement condition was moderately improved compared with the time of the pavement distress survey under this project. In due consideration of this improvement, AC overlay was proposed. Overlay thickness was computed on the basis of existing PCC pavement condition of "very bad".

AC overlay with thinner thickness than the first 10 km section was adopted for the rest of the section.

PACKAGE 14

This package passes through new alignment. Proposed type of pavement is PCC.

PACKAGE 15

Pavement condition varies from fair to bad. For fair condition sections, replacement of deteriorated PCC slabs (PCC Type-6) was recommended. For bad condition sections, AC overlay (ACO Type-1) was adopted. There are two bridge sections of which approach elevation was raised, and PCC pavement was adopted for approaches of two bridges.

PACKAGE 16

For the first 25 km section, RRI reached to RRI of 3.0 or less and PCC slabs with depression or cracks with faulting are not significant, AC overlay (ACO Type-1) was adopted.

The rest of the section is in fair condition, therefore, replacement of deteriorated PCC slab (PCC Type-6) was recommended.

PACKAGE 17

Existing pavement condition is generally fair and RRI shows more than 3 for the most of the section. Replacement of deteriorated PCC slabs (PCC Type-6) was selected as the rehabilitation method.

There are two new alignment sections at Liboganon Bridge and New Gov. Miranda Bridge where PCC pavement (PCC Type-5) was adopted.

PACKAGE 18

In the section between Km 1477+800 and Km 1482+800, RRI reached to less than 2.5. Reconstruction with PCC pavement (PCC Type-1) was adopted.

There are 6 short sections of which road elevation is to be adjusted due to uneven road surface and new bridge approaches. PCC Type-5 was used for these sections.

Pavement condition of the rest of the sections is generally fair, therefore, replacement of deteriorated PCC slabs (PCC Type-6) was selected.

PACKAGE 19

RRI of most sections is more than 3.0, therefore, PCC Type-6 was selected for the rehabilitation method.

Selected rehabilitation methods are summarized in Table 8.3-12.

TABLE 8.3-12 SUMMARY OF SELECTED PAVEMENT REHABILITATION METHOD (1/2)

Package	Section	Section Length (km)	Rehabilitation Method	Remarks
1	1113+400 - 1124+760	11.36	PCC Type-6 (t=23 cm)	
	1124+760 - 1125+240	0.48	PCC Type-5 (t=23 cm)	Flood Section
	1125+240 - 1160+580	35.34	PCC Type-6 (t=23 cm)	
	1160+580 - 1161+980	1.40	PCC Type-5 (t=23 cm)	Flood Section
	1161+980 - 1163+520	1.54	PCC Type-6 (t=23 cm)	
	1163+520 - 1164+400	0.88	PCC Type-5 (t=23 cm)	Flood Section
	1164+400 - 1164+800	0.40	PCC Type-6 (t=23 cm)	
	1164+800 - 1165+220	0.42	PCC Type-5 (t=23 cm)	Flood Section
	1165+220 - 1167+000	1.78	PCC Type-6 (t=23 cm)	
2	1167+000 - 1184+020	17.02	ACO Type-1 (t=8 cm)	
	1184+020 - 1184+380	0.36	ACO Type-2 (t=8 cm)	Flood Section
	1184+380 - 1187+560	3.18	ACO Type-1 (t=8 cm)	
	1187+560 - 1188+220	0.66	ACO Type-2 (t=8 cm)	Flood Section
	1188+220 - 1190+000	1.78	ACO Type-1 (t=8 cm)	
3	1190+000 - 1199+840	9.84	PCC Type-6 (t=23 cm)	
	1199+840 - 1200+340	0.50	PCC Type-5 (t=23 cm)	Flood Section
	1200+340 - 1200+940	0.60	PCC Type-6 (t=23 cm)	
	1200+940 - 1201+340	0.40	PCC Type-5 (t=23 cm)	Flood Section
	1201+340 - 1202+960	1.62	PCC Type-6 (t=23 cm)	
	1202+960 - 1203+380	0.42	PCC Type-5 (t=23 cm)	Flood Section
	1203+380 - 1210+000	6.62	PCC Type-6 (t=23 cm)	
4	1210+000 - 1219+670	9.67	PCC Type-6 (t=23 cm)	
	1219+670 - 1220+200	0.53	PCC Type-5 (t=23 cm)	Flood Section
	1220+200 - 1237+000	16.80	PCC Type-6 (t=23 cm)	
5	1237+000 - 1246+400	9.40	ACO Type-1 (t=8 cm)	
	1246+400 - 1254+000	7.60	PCC Type-1 (t=25 cm)	
6	1254+000 - 1254+300	0.30	PCC Type-1 (t=25 cm)	
	1254+300 - 1257+300	3.00	ACO Type-1 (t=8 cm)	
	1257+300 - 1259+600	2.30	PCC Type-1 (t=25 cm)	
	1259+600 - 1265+600	6.00	ACO Type-1 (t=8 cm)	
	1265+600 - 1271+000	5.40	PCC Type-1 (t=25 cm)	
7	1271+000 - 1291+000	20.00	PCC Type-2 (t=25 cm)	Some sections with subgrade replacement (t = 40~100cm)
8	1291+000 - 1307+000	16.00	PCC Type-1 (t=25 cm)	All section with subgrade replacement (t=30~100cm)
9	1307+000 - 1310+200	3.20	PCC Type-1 (t=25 cm)	
	1310+200 - 1316+800	6.60	ACO Type-1 (t=8 cm)	
	1316+800 - 1320+260	3.46	PCC Type-6 (t=23 cm)	
	1320+260 - 1324+000	3.74	ACO Type-1 (t=8 cm) and AC Type-1 (t=10 cm)	AC for uneven road surface sections, gravel section and two bridge approaches
10	1324+000 - 1338+000	14.00	ACO Type-1 (t=8 cm) and AC Type-1 (t=10 cm)	AC for uneven road surface sections, and one bridge approaches
	1338+000 - 1342+840	4.48	PCC Type-1 (t=25 cm)	
	1342+840 - 1343+060	0.22	AC Type-1 (t=10 cm)	Gravel Section
	1343+060 - 1349+000	5.94	PCC Type-1 (t=25 cm)	

TABLE 8.3-12 SUMMARY OF SELECTED PAVEMENT REHABILITATION METHOD (2/2)

Package	Section	Section Length (km)	Rehabilitation Method	Remarks
11	1349+000 - 1355+140	6.14	ACO Type-1 (t=8 cm)	
	1355+140 - 1357+620	2.48	ACO Type-2 (t=10 cm)	Flood Section
	1357+620 - 1360+100	2.48	ACO Type-1 (t=8 cm)	
	1360+100 - 1361+220	1.12	ACO Type-2 (t=10 cm)	Flood Section
	1361+220 - 1364+000	2.78	ACO Type-1 (t=8 cm)	
12	1364+000 - 1376+830	12.83	PCC Type-1 (t=25 cm)	
13	1376+830 - 1387+000	10.17	ACO Type-1 (t=10 cm)	
	1387+000 - 1393+320	6.32	ACO Type-1 (t=8 cm)	
	1393+320 - 1394+120	0.80	ACO Type-2 (t=8 cm)	Flood Section
	1394+120 - 1395+185	1.07	ACO Type-1 (t=8 cm)	
14	1393+540 - 1396+145	2.61	PCC Type-5 (t=23 cm)	New Alignment
	1395+636 - 1396+000	0.36	PCC Type-6 (t=23 cm)	
15	1396+000 - 1404+000	8.00	PCC Type-6 (t=23 cm) and PCC Type-5 (t=25 cm)	Type-5 for two bridge approaches of which elevation raised.
	1404+000 - 1409+000	5.00	ACO Type-1 (t=8 cm)	
	1409+000 - 1412+000	3.00	PCC Type-6 (t=23 cm)	
	1412+000 - 1425+000	13.00	ACO Type-1 (t=10 cm)	
16	1425+000 - 1433+140	8.14	ACO Type-1 (t=10 cm)	
	1433+140 - 1433+880	0.74	AC Type-1 (t=10 cm) and ACO Type-1 (t=10 cm)	Scattered uneven road surface
	1433+880 - 1437+000	3.12	ACO Type-1 (t=10 cm)	
	1437+000 - 1446+220	9.22	ACO Type-1 (t=12 cm)	
	1446+220 - 1446+520	0.30	ACO Type-2 (t=12 cm)	New Alignment
	1446+520 - 1450+200	3.68	ACO Type-1 (t=12 cm)	
	1450+200 - 1456+000	5.80	PCC Type-6 (t=23 cm)	
17	1456+000 - 1465+150	9.15	PCC Type-6 (t=23 cm)	
	1465+150 - 1465+540	0.39	PCC Type-5 (t=28 cm)	New Alignment
	1465+540 - 1466+220	0.68	PCC Type-6 (t=23 cm)	
	1466+220 - 1467+980	1.76	PCC Type-5 (t=28 cm)	New Alignment
	1467+980 - 1468+000	0.02	PCC Type-6 (t=23 cm)	
18	1468+000 - 1477+800	9.80	PCC Type-6 (t=23 cm) and PCC Type-5 (t=28 cm)	Type-5 for uneven road surface section
	1477+800 - 1482+800	5.00	PCC Type-1 (t=28 cm)	
	1482+800 - 1497+000	14.20	PCC Type-6 (t=23 cm) and PCC Type-5 (t=28 cm)	Type-5 for 2 bridge approaches
19	1497+000 - 1516+000	19.00	PCC Type-6 (t=23 cm)	

8.4 SHOULDER DESIGN

8.4.1 Rehabilitation/Improvement Criteria

In due consideration of functions of shoulders, rehabilitation/improvement criteria were established as follows:

i) Earth shoulders shall be improved with better quality of material.
ii) Shoulders with distress such as drop-off, heave or scour shall be rehabilitated.
iii) Shoulders along sections whose vertical gradient is 5% or more shall be paved in order to prevent scouring.
iv) Shoulders in a dense residential area shall be paved to provide spaces for pedestrians and/or pedicabs/tricycles.

In a section where only shoulder rehabilitation/improvement works under criteria i) and ii) are required, but other rehabilitation works such as pavement rehabilitation and/or drainage improvement are not needed, shoulder rehabilitation/improvement works are proposed to be undertaken by maintenance works and not to be included in this project.

8.4.2 Shoulder Design

PCC pavement shoulder was selected for sections of which roadway pavement rehabilitation is PCC reconstruction. Thickness of PCC pavement shoulder in the urban section from Tagum to the end of the Study Road in Davao City was selected to be 23cm in view of frequent utilization of heavy vehicles. For other sections, 18cm PCC pavement shoulder was selected.

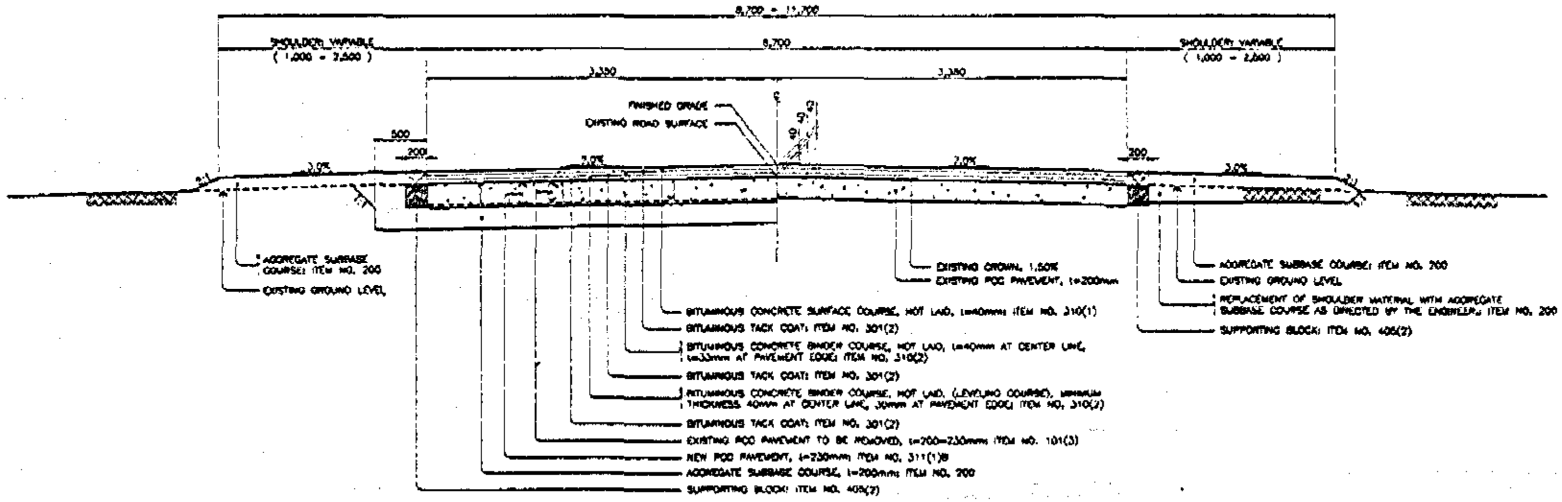
AC pavement shoulder of 5cm was selected for sections of which roadway pavement rehabilitation is AC overlay or AC reconstruction.

Gravel shoulder was adopted for the sections where paving of shoulder is not required.

8.5 TYPICAL ROADWAY CROSS-SECTION

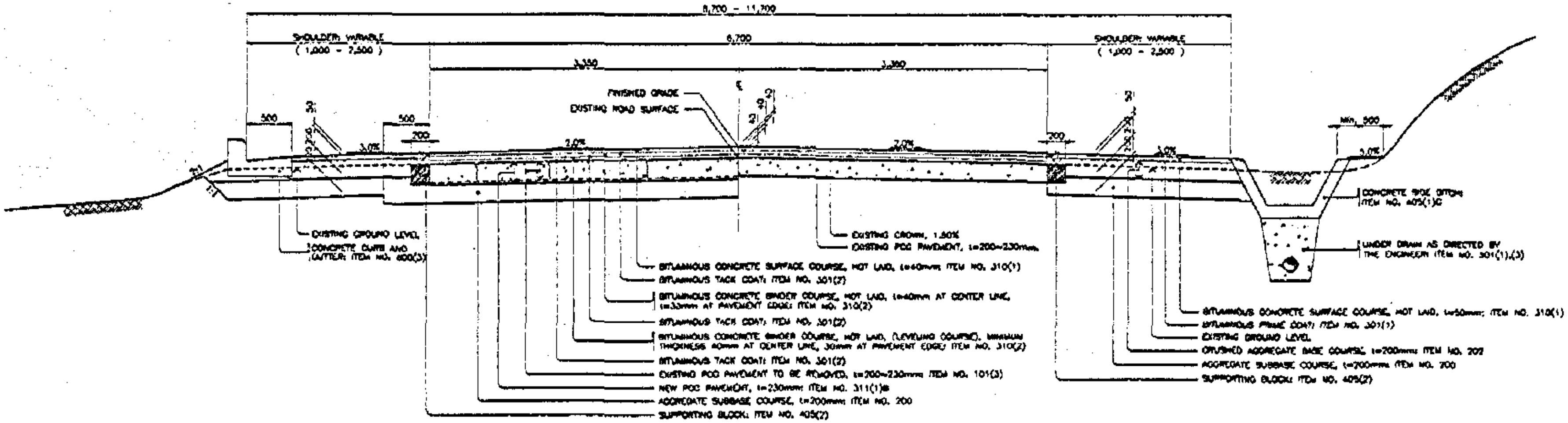
Based on the geometric design standards, pavement design, shoulder design, roadway surface drainage and actual conditions of topography and soils conditions, typical roadway cross-sections were established, which are shown in the following figures:

Figure 8.5-1	ACO TYPE-1
Figure 8.5-2	ACO TYPE-2
Figure 8.5-3	PCC TYPE-1
Figure 8.5-4	PCC TYPE-2
Figure 8.5-5	PCC TYPE-5
Figure 8.5-6	PCC TYPE-6
Figure 8.5-7	AC TYPE-1



ACO TYPE-I (t=8cm) : WITH REPLACEMENT OF DETERIORATED PCC SLABS

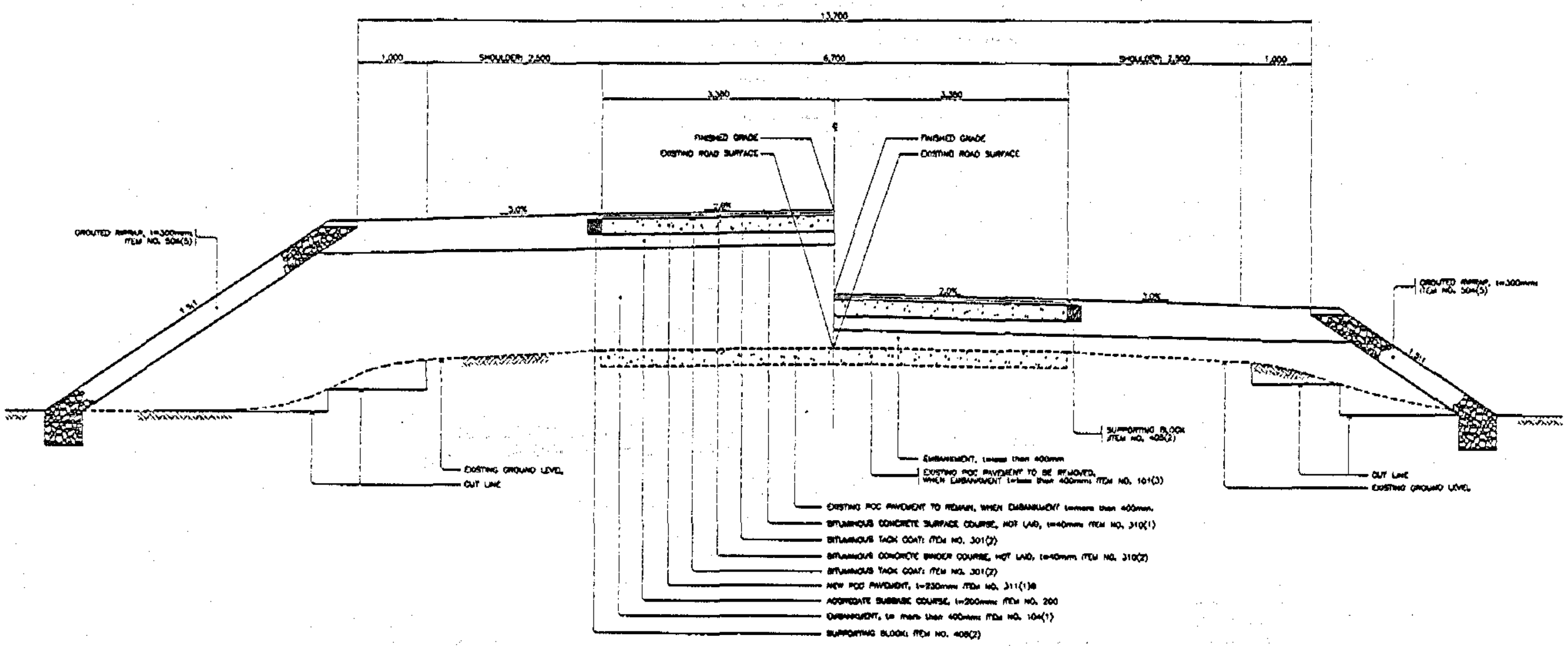
ACO TYPE-I (t=8cm) : ON EXISTING PCC SLABS



ACO TYPE-I (t=8cm) : WITH REPLACEMENT OF DETERIORATED PCC SLABS AND AC PAVED SHOULDER

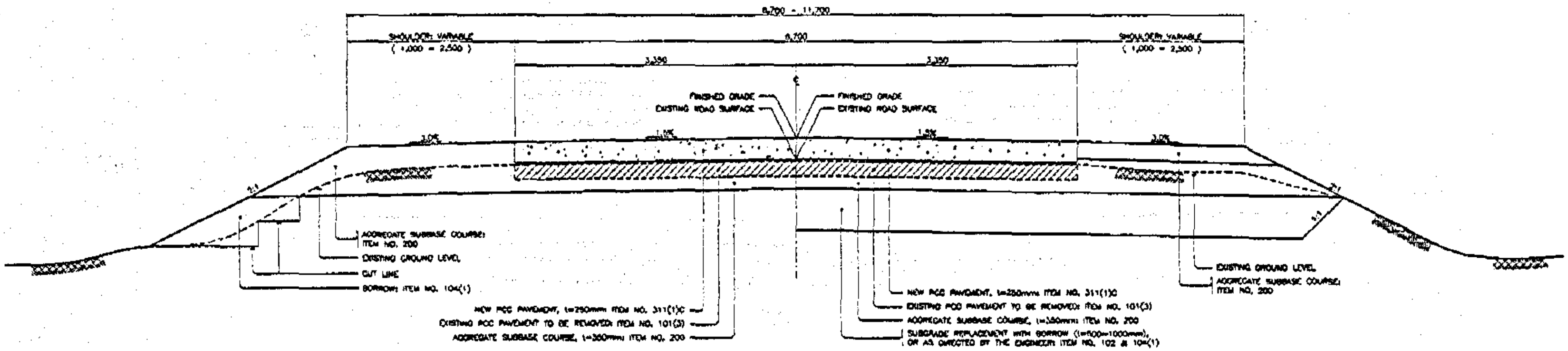
ACO TYPE-I (t=8cm) : WITH AC PAVED SHOULDER

FIGURE 8.5-1 TYPICAL ROADWAY CROSS-SECTION: AC OVERLAY TYPE-1



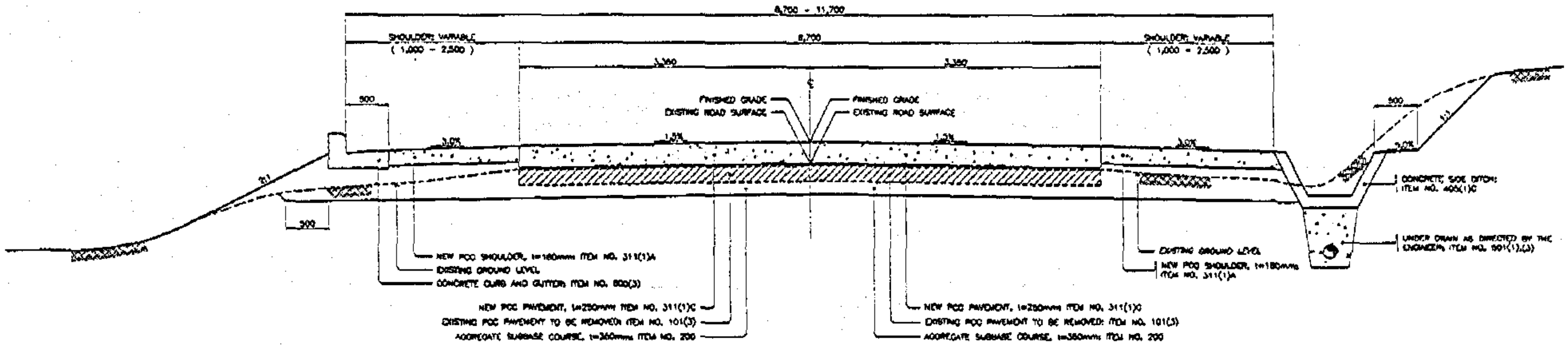
ACO TYPE-2 : FLOOD SECTION (ROAD ELEVATION TO BE RAISED)

FIGURE 8.5-2 TYPICAL ROADWAY CROSS-SECTION: AC OVERLAY TYPE-2



PCC TYPE–1 : NORMAL SECTION

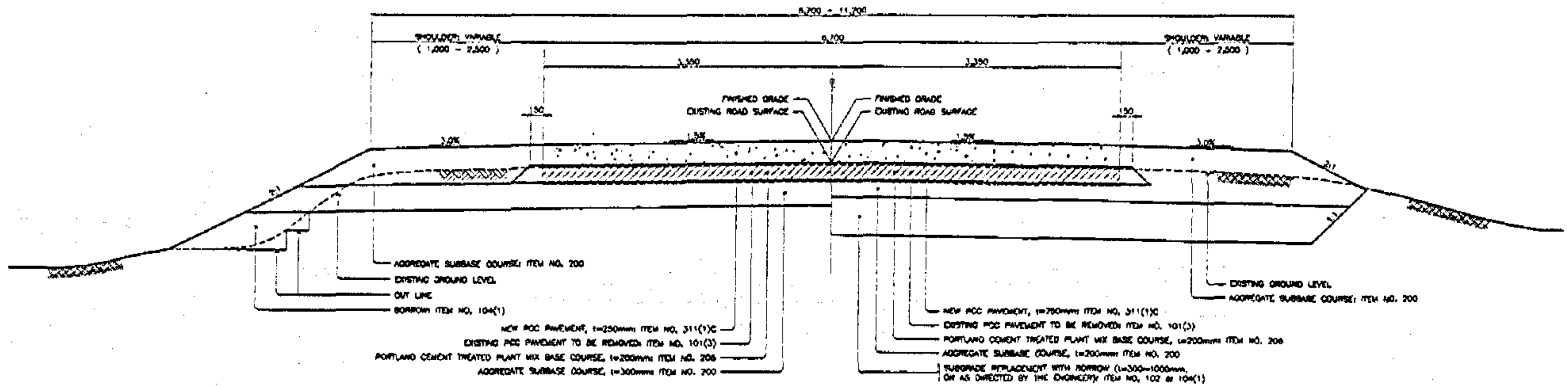
PCC TYPE–1 : GRAVEL SECTION AND SUBGRADE REPLACEMENT SECTION



PCC TYPE–1 : WITH PCC SHOULDER

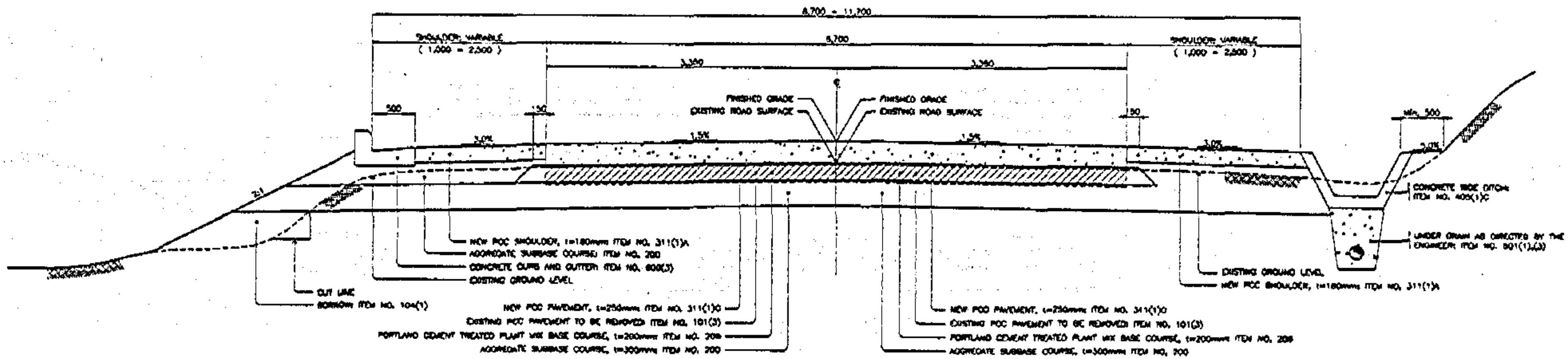
PCC TYPE–1 : WITH PCC SHOULDER

FIGURE 8.5-3 TYPICAL ROADWAY CROSS-SECTION: PCC RECONSTRUCTION TYPE-1



PCC TYPE-2 : NORMAL SECTION

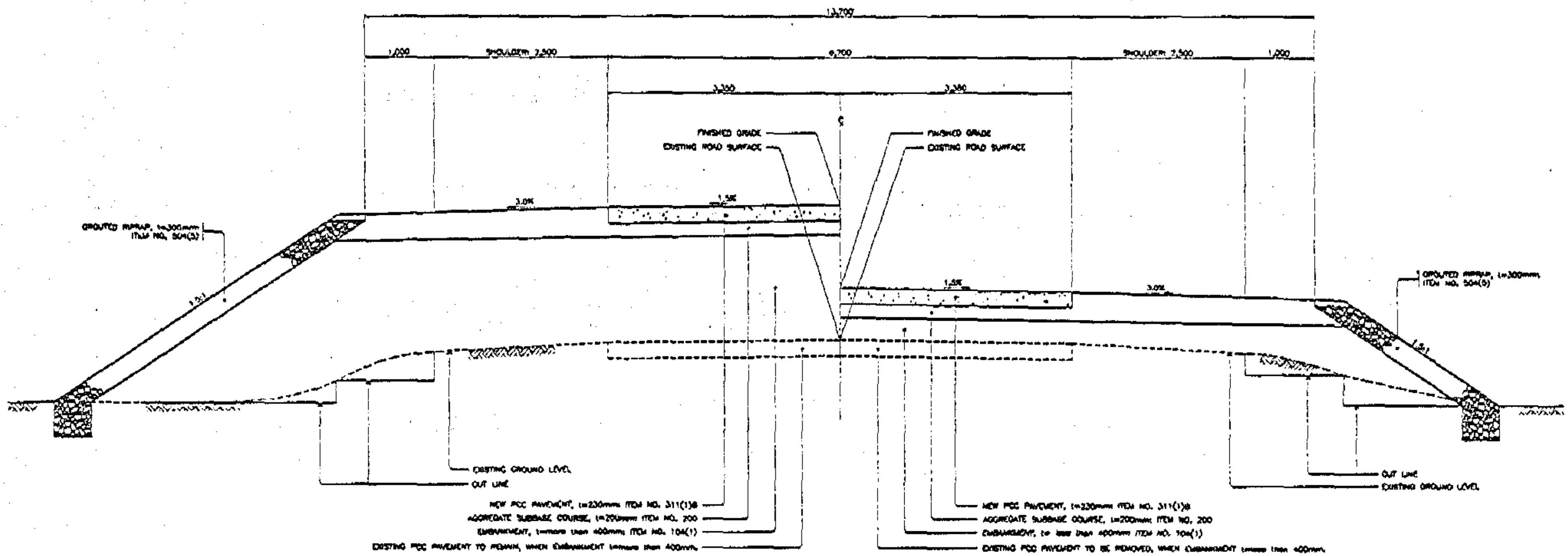
PCC TYPE-2 : GRAVEL SECTION AND SUBGRADE REPLACEMENT SECTION



PCC TYPE-2 : WITH PCC SHOULDER (EMBANKMENT SECTION)

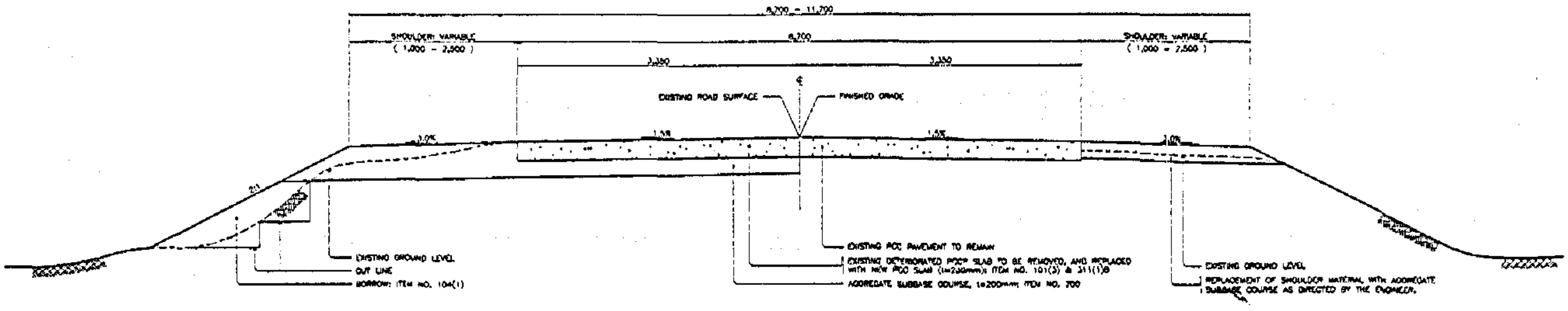
PCC TYPE-2 : WITH PCC SHOULDER (CUT SECTION)

FIGURE 8.5-4 TYPICAL ROADWAY CROSS-SECTION: PCC RECONSTRUCTION TYPE-2



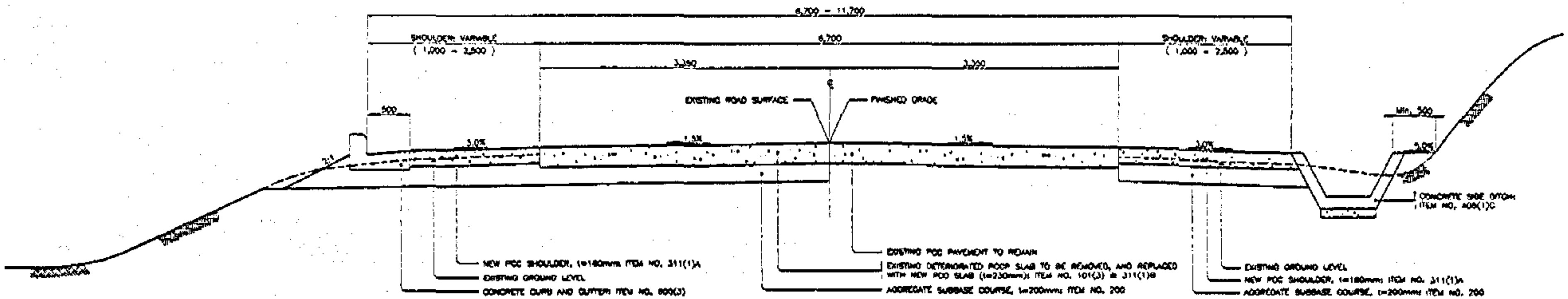
PCC TYPE–5 : FLOOD SECTION (ROAD ELEVATION TO BE RAISED)

FIGURE 8.5-5 TYPICAL ROADWAY CROSS-SECTION: PCC RECONSTRUCTION TYPE-5



PCC TYPE–6 : REPLACEMENT OF PCC SLABS

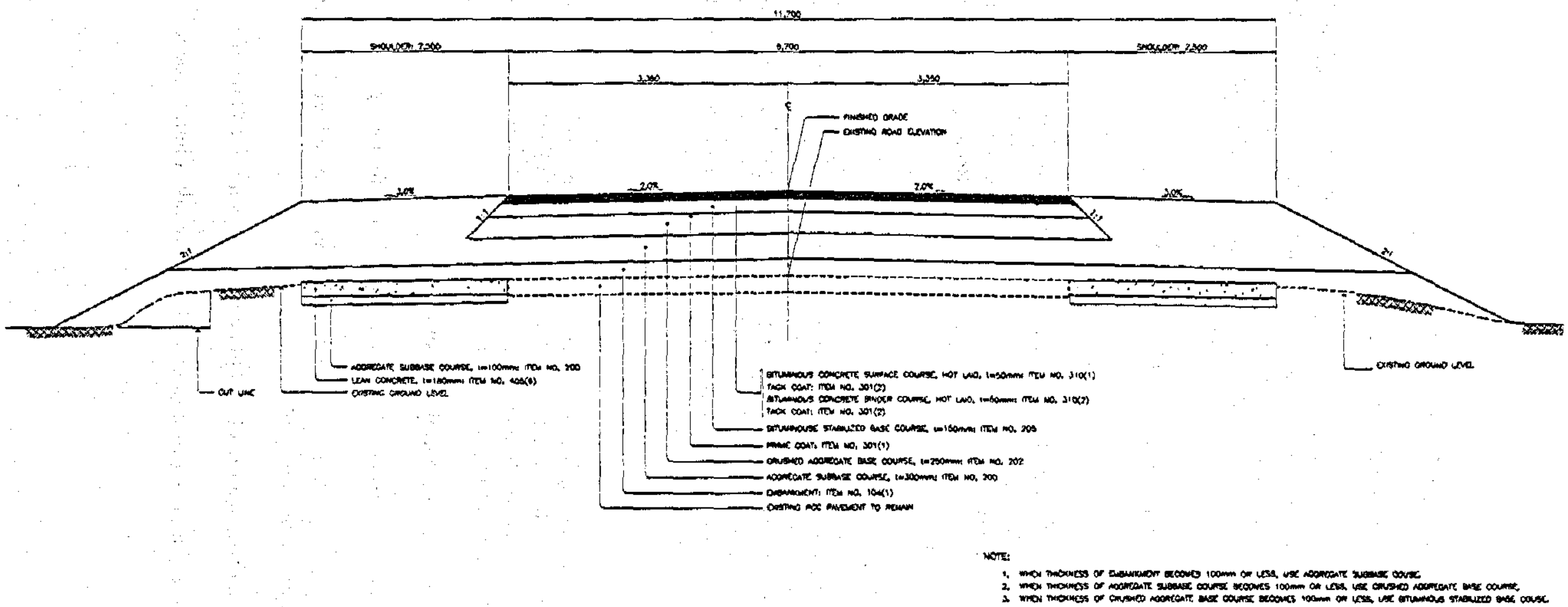
REPLACEMENT OF SHOULDER MATERIAL



PCC TYPE–6 : REPLACEMENT OF PCC SLABS
WITH PCC SHOULDER

PCC PAVED SHOULDER

FIGURE 8.5-6 TYPICAL ROADWAY CROSS-SECTION: PCC SLAB REPLACEMENT TYPE-6



AC TYPE-1 : SOFT GROUND SECTION

FIGURE 8.5 TYPICAL ROADWAY CROSS-SECTION: AC RECONSTRUCTION TYPE-1

8.6 MONKAYO BYPASS ALIGNMENT STUDY

8.6.1 Condition of Monkayo Town Area

Monkayo Bypass is not an ordinary bypass which usually aims relief of traffic problems in urban areas, but is planned as a countermeasure against floods. *Monkayo town in Davao del Sur oftenly suffers flood problem during heavy rains* due to overflow water of Agusan River. In December 1994, most areas of Monkayo town were submerged to a depth of 1 to 2 meters.

Figure 8.6-1 shows present condition of Monkayo Town area.

<u>Flood Area</u>

Hydrological analysis (discussed in Chapter 6) concluded that water level of Agusan River goes up to the elevation of 51.0 meter for a return period of 50 years. As shown in Figure 8.6-1, only the areas hatched remain above water and the rest of the areas are submerged including Kalaw Bridge, Pan-Philippine Highway and Monkayo town proper.

<u>Monkayo Resettlement Project</u>

The Municipal Government of Monkayo has developed a plan to relocate people who are affected by floods and squatters along the national highways. The project is called as the Monkayo Resettlement Project. The Municipal Government has already acquired the land for the project as shown in Figure 8.6-1, and requested National Housing Authority (NHA). Site development was scheduled to start June 1996.

<u>Related Road</u>

In addition to Pan-Philippine Highway, there is a barangay road which runs west side of Agusan River. It is a narrow (4 to 6 meters) gravel road constructed almost at the foot of steep mountan slopes. It will be submerged for a short section at a small valley during heavy rain.

8.6.2 Alternative Alignments for Monkayo Bypass

Selection of alignments was made in consideration of the following:

- New alignment should pass through high lands of which elevation is more than 51m as much as possible.
- The existing barangay road should be utilized as much as possible.
- Monkayo Resettlement Project should be fully taken into account.

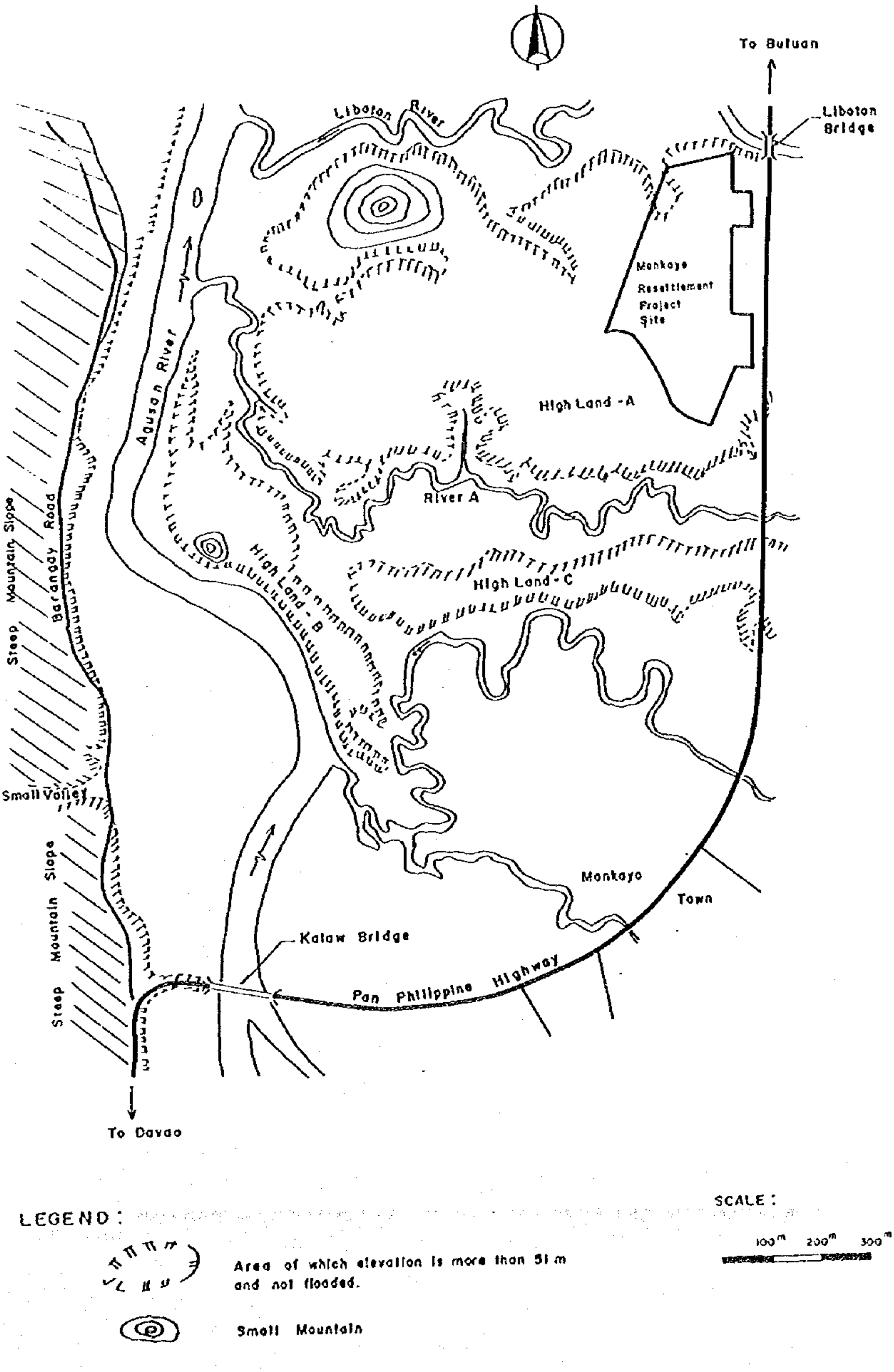


FIGURE 8.6-1 PRESENT CONDITION OF MONKAYO TOWN AREA

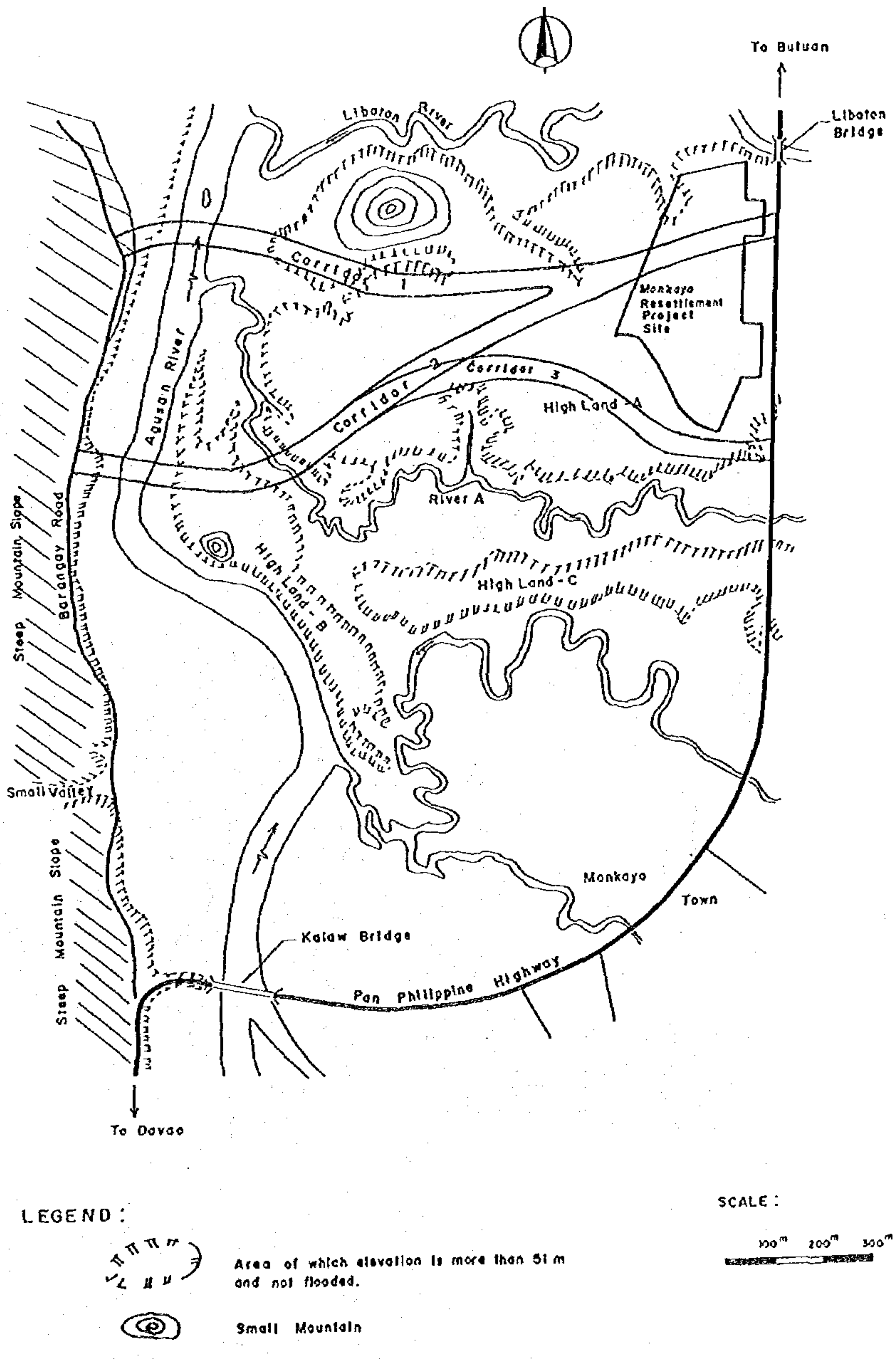


FIGURE 8.6-2 POSSIBLE CORRIDORS FOR BYPASS ALIGNMENT

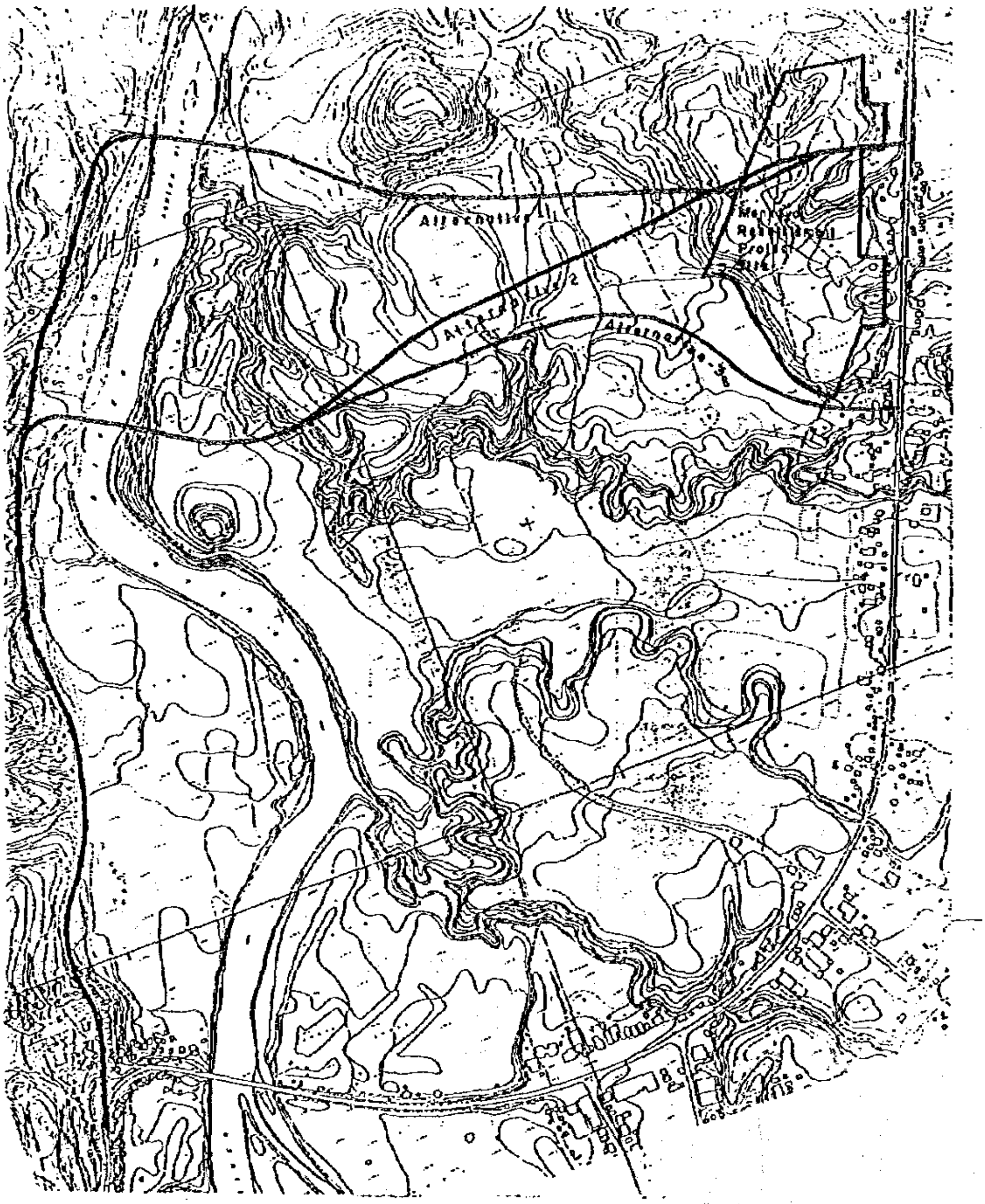


FIGURE 8.6-3 ALTERNATIVE ALIGNMENTS FOR MONKAYO BYPASS

8.7 EMBANKMENT SLOPE STABILITY AND CONSOLIDATION SETTLEMENT AT SOFT GROUND AREAS

There are some soft ground areas spotted along the project road. There are two types of work at these aras as follows:

- Construction of new bridge approaches where the bridge centerline was shifted.
- Correction of road elevation where the existing road was settled.

For the first type of work, embankment slope stability and consolidation settlement were examined for the proposed height of embankment.

- Lacogangan Bridge approach (Package 9)
- Tagbayagan Bridge approach (Package 9)
- Wasian Bridge approach (Package 10)
- Liboganon Bridge approach (Package 17)
- New Gov. Miranda approach (Package 17)
- Liboganon River East Dike (Package 17)

For the second type of work, consolidation settlement was estimated for the addtional load of countermeasures at the following stations:

- Km. 1303 + 900 (Package 8)
- Km. 1322 + 800 (Package 9)
- Km. 1346 + 100 (Package 10)
- Km. 1357 + 300 (Package 11)

8.7.1 Bridge Approach Embankment Slope Stability and Consolidation Settlement

The results of analysis are summarized in Table 8.7-1. The details of analysis are presented in Appendix 8.7-1.

The counterweight embankment was required at approaches of Liboganon Bridge and Tagbayagan Bridge and Liboganon River East Dike. Slope grade of 2.5:1 was required at approaches of Liboganon Bridge and New Gov. Miranda Bridge. Typical cross sections are shown in Figure 8.7-1.

8.7.2 Consolidation Settlement at the Sections Where Road Elevation was Corrected

At soft ground sections, the road was constructed with low embankment ranging from 1.5 to 2.0 meters in height. Uneven settlements exist in such sections with the settlement depth of 0.3 to 1.2 meters. Major cause of uneven settlement is considered to be traffic loads. Due to low embankment, traffic loads reach to soft soil layers, resulting in uneven settlement.

TABLE 8.7-1 BRIDGE APPROACH EMBANKMENT SLOPE STABILITY AND CONSOLIDATION SETTLEMENT

	Lagcogangan Bridge	Tagbayagan Bridge	Wasian Bridge	Liboganon Bridge	New Gov. Miranda Bridge	Liboganon River East Dike
Embankment Height: H(m)	3.3	4.0	2.5	6.0	6.0	4.8
Slope Stability						
1) Satty Factor for Slope Grade at						
2.0 : 1	0.92	0.71	1.23	-	-	-
2.5 : 1	0.97	0.71	-	1.20	1.20	-
3.0 : 1	0.97	0.73	-	-	-	-
2) Satty Factor with Counterweight Embankment	L = 10m H = 1.45m FS = 1.21	L = 10m H = 2m FS = 1.29	-	-	-	L = 4m H = 2m FS = 1.21
3) Embankment Height which satisfy Satty Factor of 1.2 with the slope grade of 2.0:1	N.A.	N.A.	N.A.	H = 5.0m	H = 5.0m	H = 4.0m
Consolidation Settlement						
1) Total Settlement (cm)	62.1	117.1	-	(Similar to New Gov. Gov. Miranda Bridge)	85.0	86.7
2) Remaining Settlement at the end of construction (cm)	17.9 (After 500 days)	4.9 (After 500 days)	-		13.5 (After 600 days)	13.1 (After 600 days)

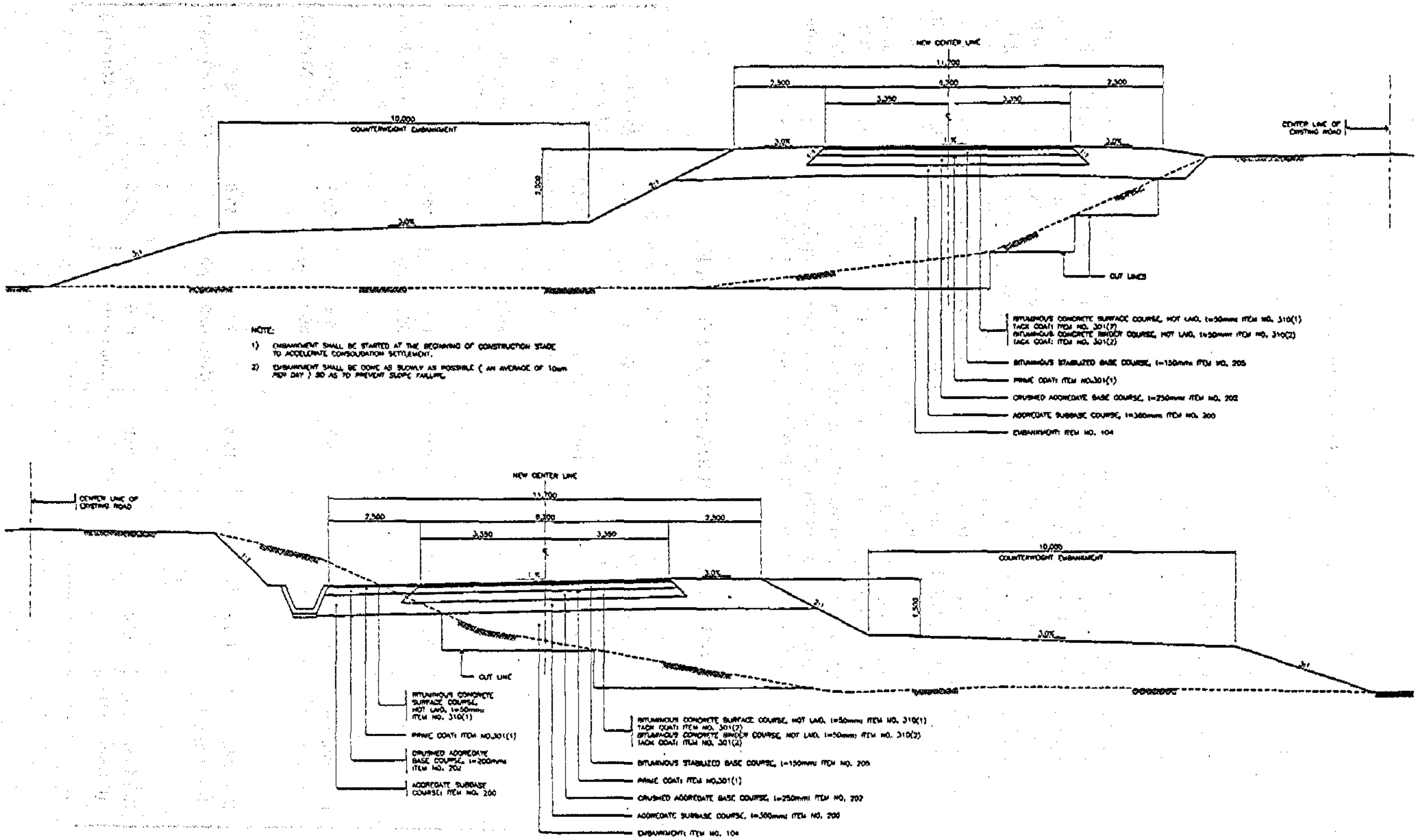


FIGURE 8.7-1 TYPICAL CROSS-SECTIONS AT BRIDGE APPROACHES

There are many kinds of methods for soft ground improvement as follows:

- Soil replacement method
- Soil stabilization method
- Sandwich method
- Surcharge method
- Sand compaction pile method
- Others

As this project is a rehabilitation of existing road and traffic flow must be maintained even during construction, therefore, applicable method is limited. It is recommended that a sandwich method be adopted for this project. This method is suitable for a road section with heavy traffic where deep excavation is not feasible and heavy equipment cannot be introduced, although further settlement cannot be avoided. The existing PCC pavement is remained and lean concrete slab is provided at shoulders. Both existing PCC pavement and shoulder slabs function to distribute traffic load to wider area, thus lessen traffic load subjected to soft soil layers. On the existing PCC pavement and shoulder slabs, embankment and AC pavement is constructed to the original road elevation. Typical cross section is shown in Figure 8.5-7. Embankment and AC pavement on the existing PCC pavement and shoulder slabs act as additional load to the soft layers. Consolidation settlement due to additional load was estimated at four locations and summarized in Table 8.7-2 and details of analysis is presented in Appendix 8.7-1.

TABLE 8.7-2 ESTIMATED CONSOLIDATION SETTLEMENT

Location	Height of Elevation Correction (m)	Traffic Load (ton/m2)	Settlement (cm)			
			Dead Weight		Dead Weight + Traffic Load	
			Total Settlement	Remaining Settlement After Completion of Construction	Total Settlement	Remaining Settlement After Completion of Construction
Km 1303 + 900 (Package 8)	0.88	2.50	8.0	1.6 (After 560 days)	18.6	4.1 (After 560 days)
Km 1322 + 800 (Package 9)	0.98	2.20	25.5	15.4 (After 500 days)	50.1	30.0 (After 500 days)
Km 1346 + 100 (Package 10)	0.72	2.80	19.4	2.5 (After 680 days)	45.9	6.4 (After 680 days)
Km 1357 + 300 (Package 11)	0.90	2.50	19.9	13.5 (After 440 days)	38.9	26.4 (After 440 days)

CHAPTER 9

ROADWAY DRAINAGE IMPROVEMENT

Rainfall data, rainfall intensity, hydrological analysis methods, peak discharge for catchment areas, hydraulic analysis for major bridges and flood sections, etc. were discussed in Chapter 6. In this Chapter, design of culverts (RCPC/RCBC) and side ditches are discussed.

9.1 DESIGN OF CULVERTS (RCPC/RCBC)

9.1.1 Design Criteria

Return period for calculation of design discharge was established as follows:

Type of Culvert	Return Period
Pipe Culvert (RCPC)	10 years
Box Culvert (RCBC)	25 years

9.1.2 Design of Culverts

There are 1,328 pipe culverts and 200 box culverts along the Study Road. Catchment area for respective culvert was delineated based on 1/50,000 maps which are the only available data usable for this purpose. However, it was impossible to determine catchment area for each culvert in many cases because 1/50,000 maps do not reflect small changes in topography. Thus, there are many cases that two or more culverts are located in one catchment area deliniated on 1/50,000 maps. In one catchment area, two types of culverts, i.e. RCPC and RCBC are located in many cases. Thus, design discharge for one catchment area was calculated for 10 and 25 years return periods.

Capacity of RCPC/RCBC was checked in accordance with procedure shown in Figure 9.1-1. When capacity of existing RCPC and/or RCBC is insufficient, following were studied:

- Install additional RCPC or RCBC
- Replace with larger size of RCPC or RCBC
- Combination of above

Which culvert should be replaced or where an additional culvert should be installed was studied and determined based on the following information:

- Opinion or suggestion of District Engineering Office who are familiar with water flow condition at culverts during heavy rain.
- Information from nearby residents.
- 1/1,000 topographical maps prepared under this project, although area coverages of said maps are not always sufficient.

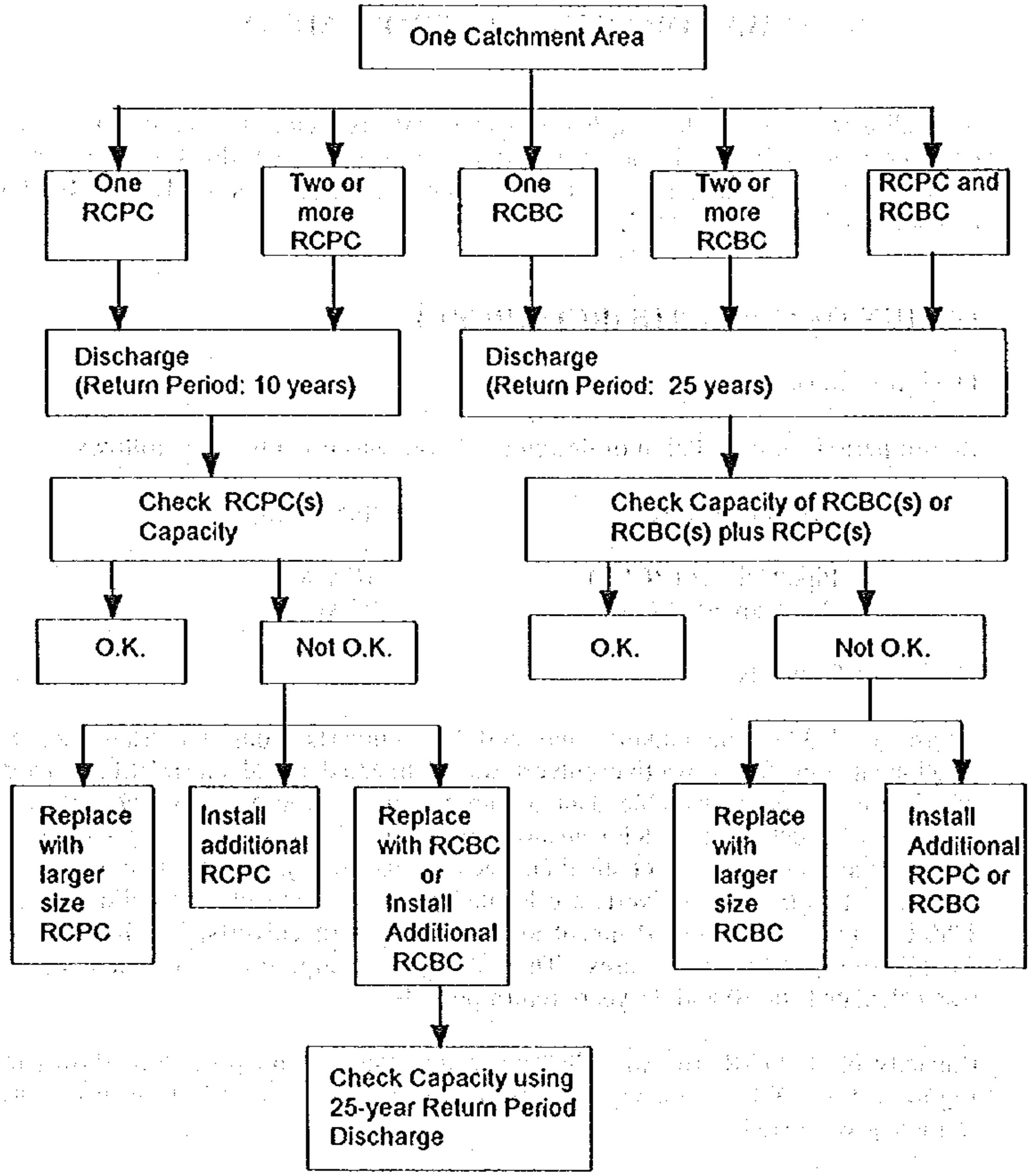


FIGURE 9.1-1 PROCEDURE OF RCPC/RCBC CAPACITY ANALYSIS

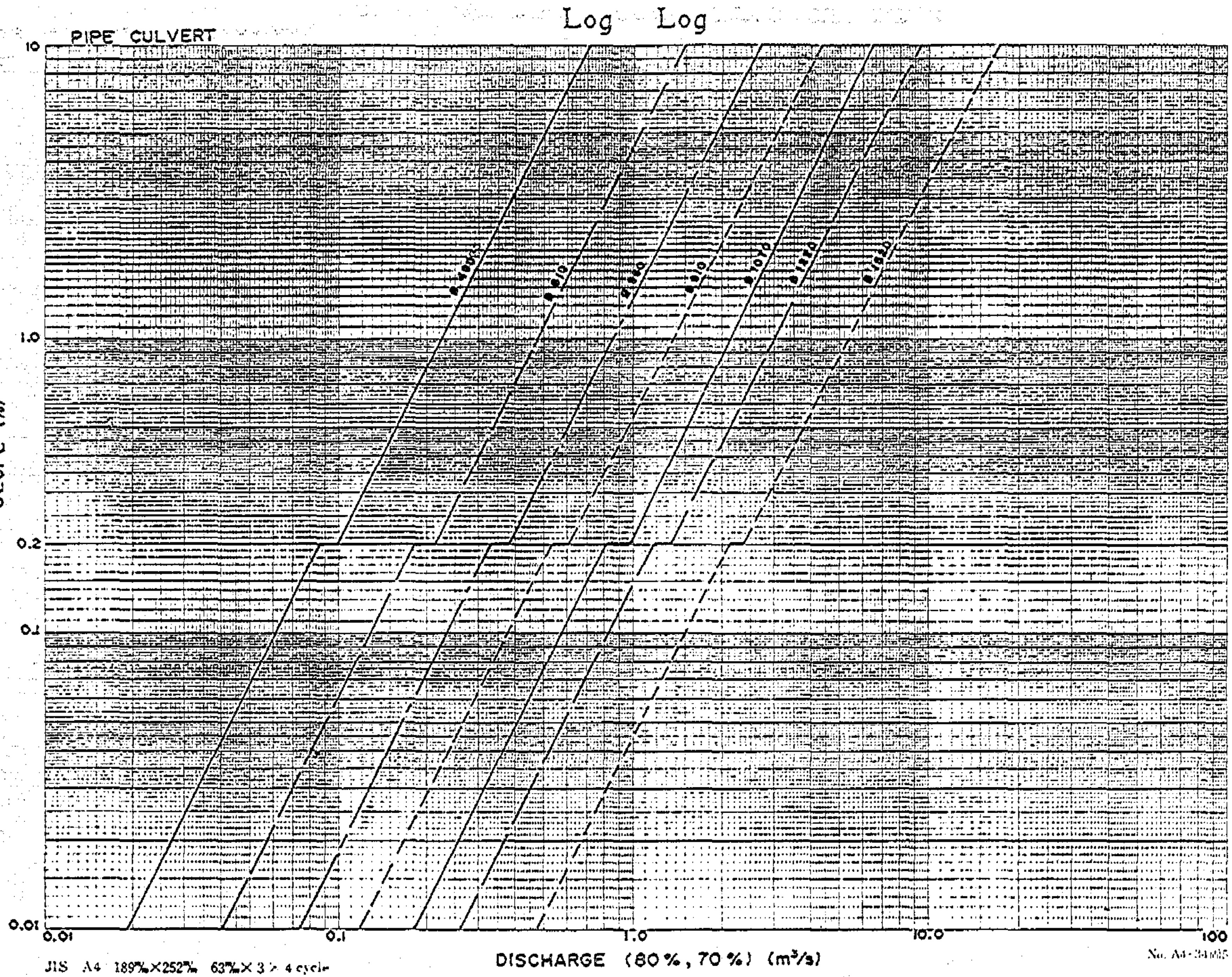


FIGURE 9.1-2(1) DISCHARGE CAPACITY OF CULVERT: PIPE

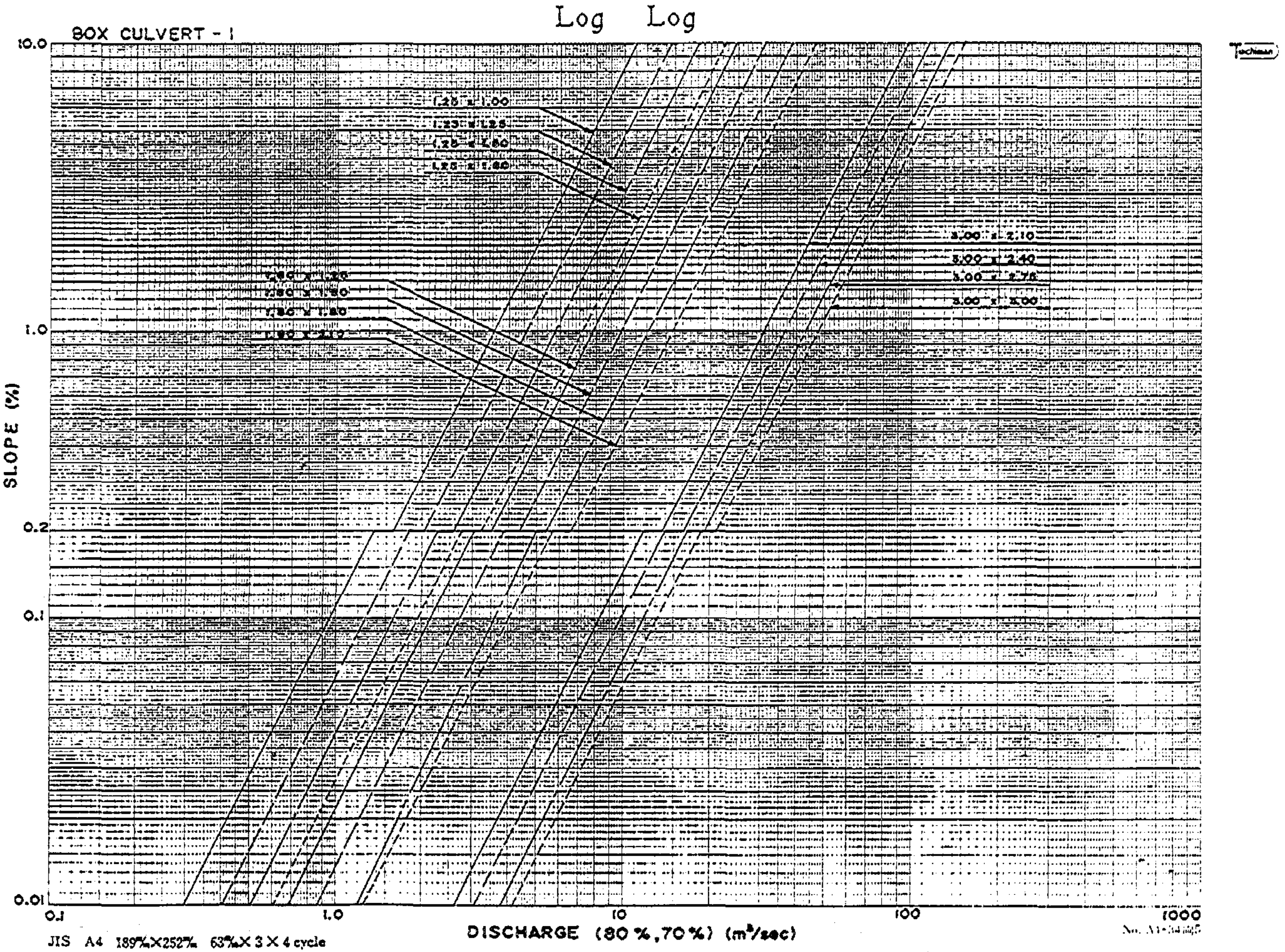


FIGURE 9.1-2(2) DISCHARGE CAPACITY OF CULVERT: BOX

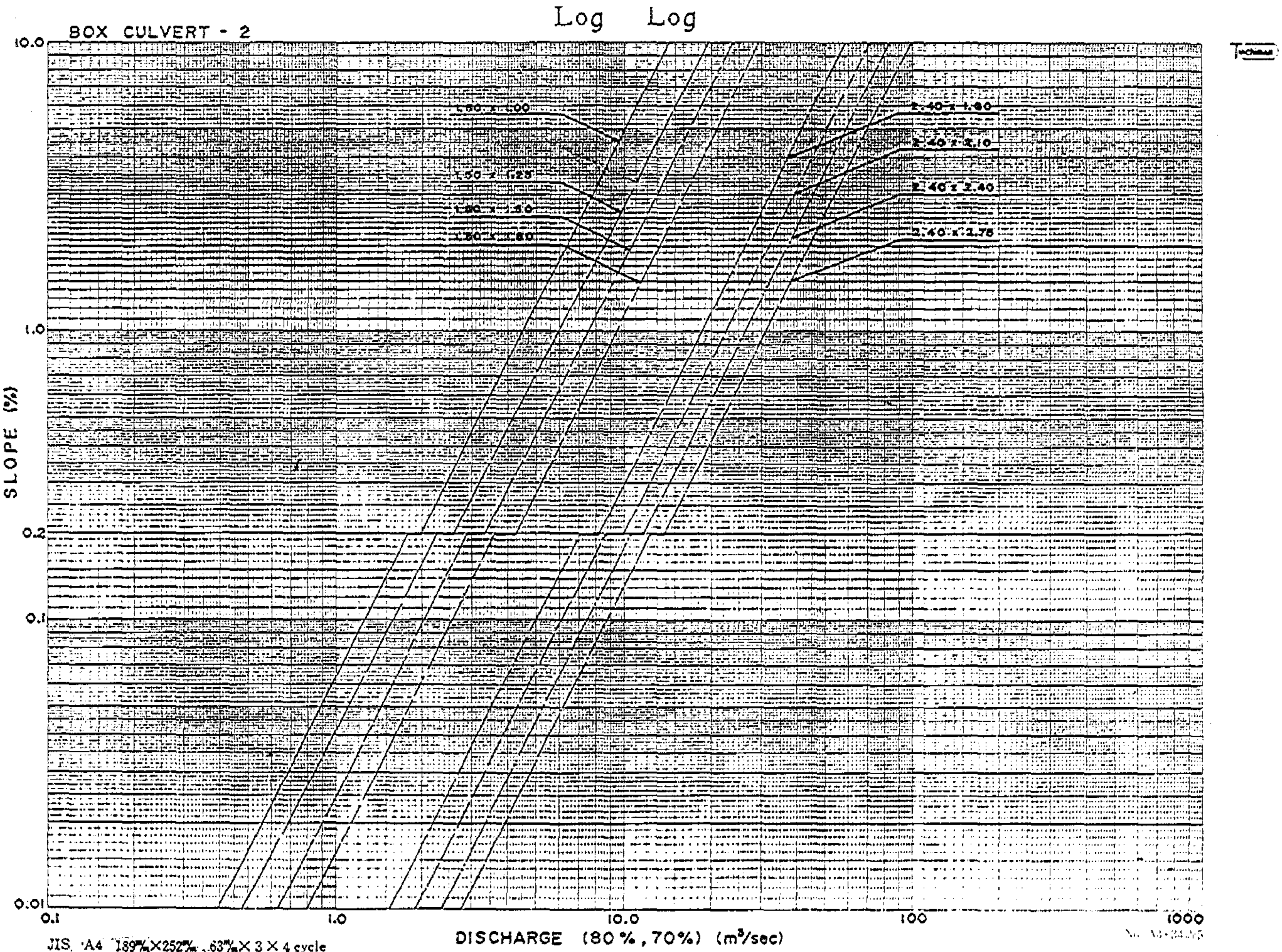


FIGURE 9.1-2(3) DISCHARGE CAPACITY OF CULVERT: BOX

For easier comparison of discharge with culvert capacity, diagrams showing relation among culvert size, culvert gradient and discharge capacity were prepared as shown in Figure 9.1-2.

In addition to capacity problems, most of existing culverts have defects at inlets and outlets. In many cases, no catch basins nor headwalls were provided, causing failure or scouring of nearby roadway slopes. Under this project, design of inlet and outlet facilities as well as slope protections was carefully undertaken to avoid recurrent failures of nearby roadway slopes.

9.1.3 Summary of Proposed Works

Results of culvert capacity analysis are presented in Appendix 9.1-1. Proposed works for culverts were summarized in Table 9.1-1 for the whole Study Road and Table 9.1-2 for each Package.

TABLE 9.1-1 SUMMARY OF PROPOSED WORKS FOR CULVERTS

	No. of Existing Culverts	Proposed Works			To Be Deleted	No Work Required	New/Additional Culverts
		Total Replacement	Improvement/Rehabilitation	Slope Protection/ Scour Protection Only			
RCPC	1,328	420	644	9	27	228	89
RCBC	200	1	36	28	-	135	23
Total	1,528	421	680	37	27	363	112

Of a total of 1,528 culverts, 1,138 culverts (or 74% of culverts) were required replacement, improvement, or slope/scour protection. Number of culverts which do not require any work was 363 (or 24%). Twenty seven culverts were recommended to be deleted or condemned, as they are no longer functioning. Additionally required culverts were 112.

TABLE 9.1-2 SUMMARY OF CULVERT IMPROVEMENT/REHABILITATION BY PACKAGE

PK NO.	NO. OF EXISTING CULVERTS		NUMBER OF CULVERTS FOR:									
			TOTAL REPLACEMENT			IMPROVEMENT, REHABILITATION (OF CULVERT)		CONSTRUCTION OF SLOPE & SCOUR PROTECTION (NO REVISION AT CULVERT)		NEW/ADDITIONAL CULVERTS		DELETED/ CONDEMNED CULVERTS
	RCPC	RCBC	RCPC TO BIGGER PIPE	RCPC TO RCBC	RCBC TO RCBC	RCPC	RCBC	RCPC	RCBC	RCPC	RCBC	
1	207	28	54	25	-	68	5	4	1	1	3	-
2	88	8	14	13	-	35	1	3	2	3	-	-
3	64	2	11	10	-	21	2	2	-	5	5	7
4	85	11	-	1	-	35	3	-	-	-	-	5
5	67	6	16	5	-	45	1	-	3	8	1	1
6	47	8	14	6	-	20	1	-	1	1	4	5
7	52	8	12	2	-	27	1	-	6	2	-	-
8	58	6	11	2	-	37	-	-	1	3	-	-
9	48	20	23	8	-	15	10	-	2	8	3	-
10	86	27	43	7	1	31	2	-	4	5	1	-
11	51	13	14	2	-	30	-	-	3	1	3	-
12	45	7	6	1	-	32	1	-	-	-	-	1
13	56	17	6	3	-	44	1	-	2	6	-	-
14	-	-	-	-	-	-	-	-	-	9	2	-
15	97	21	46	5	-	34	8	-	3	11	1	4
16	96	1	40	2	-	46	-	-	-	17	-	1
17	25	6	-	-	-	24	-	-	-	-	-	-
18	105	7	5	6	-	73	-	-	-	5	-	3
19	51	4	7	-	-	27	-	-	-	4	-	-
TOTAL	1,328	200	322	98	1	644	36	9	28	89	23	27

9.2 SIDE DITCHES/UNDER DRAIN

9.2.1 Design Criteria

Side ditches were designed for the return period of 5 years.

Maximum longitudinal slope of 4% was basically used, except for sections where steeper slope is required. Minimum longitudinal slope of 0.50% in rural areas and 0.35% in urban areas was adopted.

Under drain was planned at the sections where spring water is always observed. These sections were identified during the field survey.

9.2.2 Design of Side Ditch

Catchment area was determined based on 1/1,000 topographic maps prepared under this project.

Diagrams showing relations among size of side ditch, longitudinal slope and discharge capacity were prepared for various types of side ditches as shown in Figure 9.2-1.

All side ditches were proposed to be concrete side ditches for easier maintenance.

All side ditches were extended to the existing/proposed culverts or existing waterways to avoid scouring problem at the outlets.

9.2.3 Summary of Proposed Works

Summary of proposed works for side ditches is presented in Table 9.2-1.

TABLE 9.2-1 SUMMARY OF SCOPE OF WORK FOR SIDE DITCHES AND UNDER DRAIN

Package	Side Ditch (m)	Under Drain (m)
1	9,367	696
2	14,814	360
3	1,167	-
4	-	-
5	19,395	3,979
6	3,794	556
7	14,829	3,263
8	12,184	4,177
9	6,660	870
10	8,078	1,035
11	1,877	-
12	5,940	-
13	11,967	650
14	2,318	1,771
15	9,688	708
16	15,754	-
17	-	-
18	6,839	-
19	15,769	-
Total	160,440	18,065

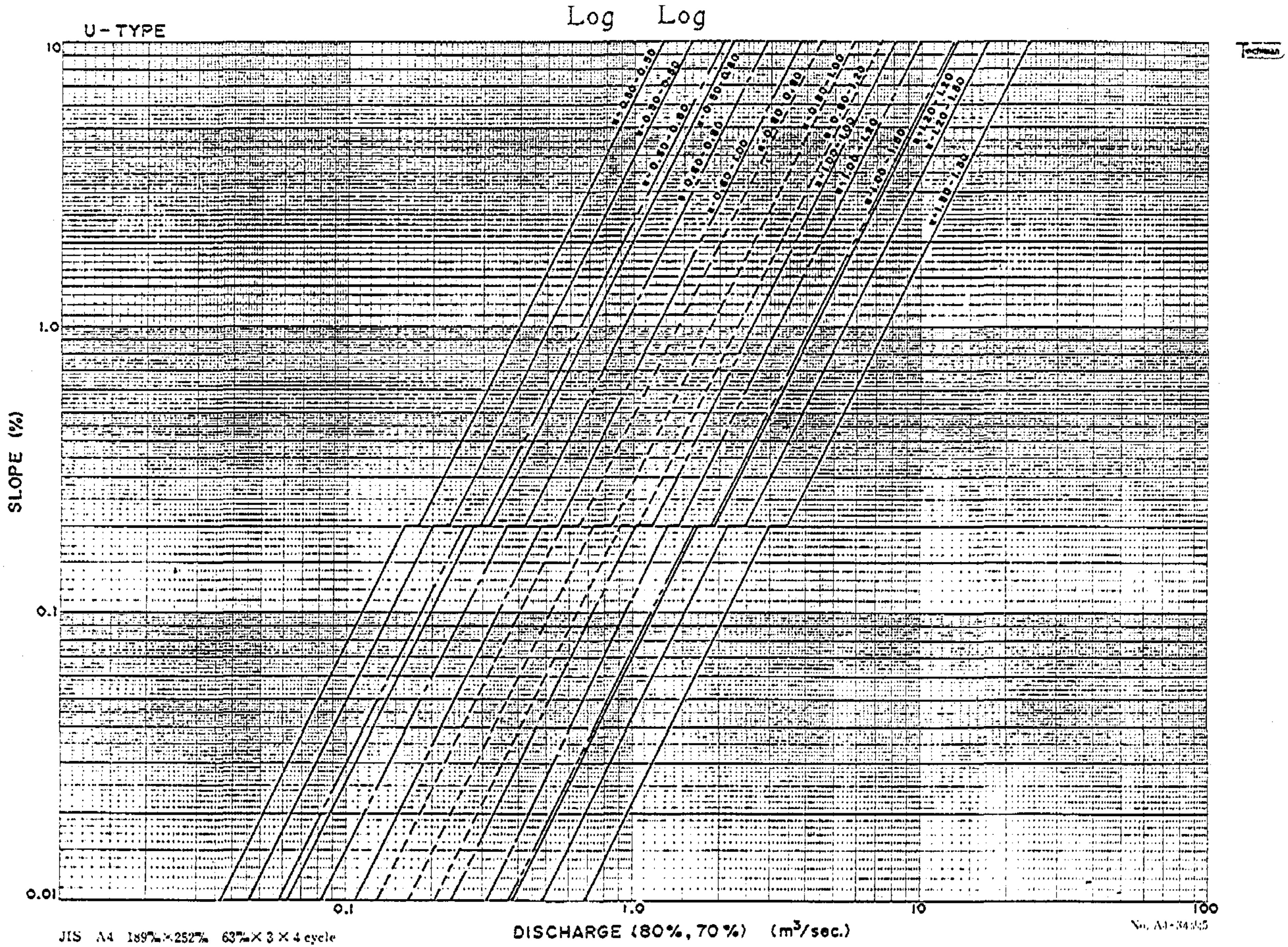


FIGURE 9.2-1(1) DISCHARGE CAPACITY OF SIDE DITCH

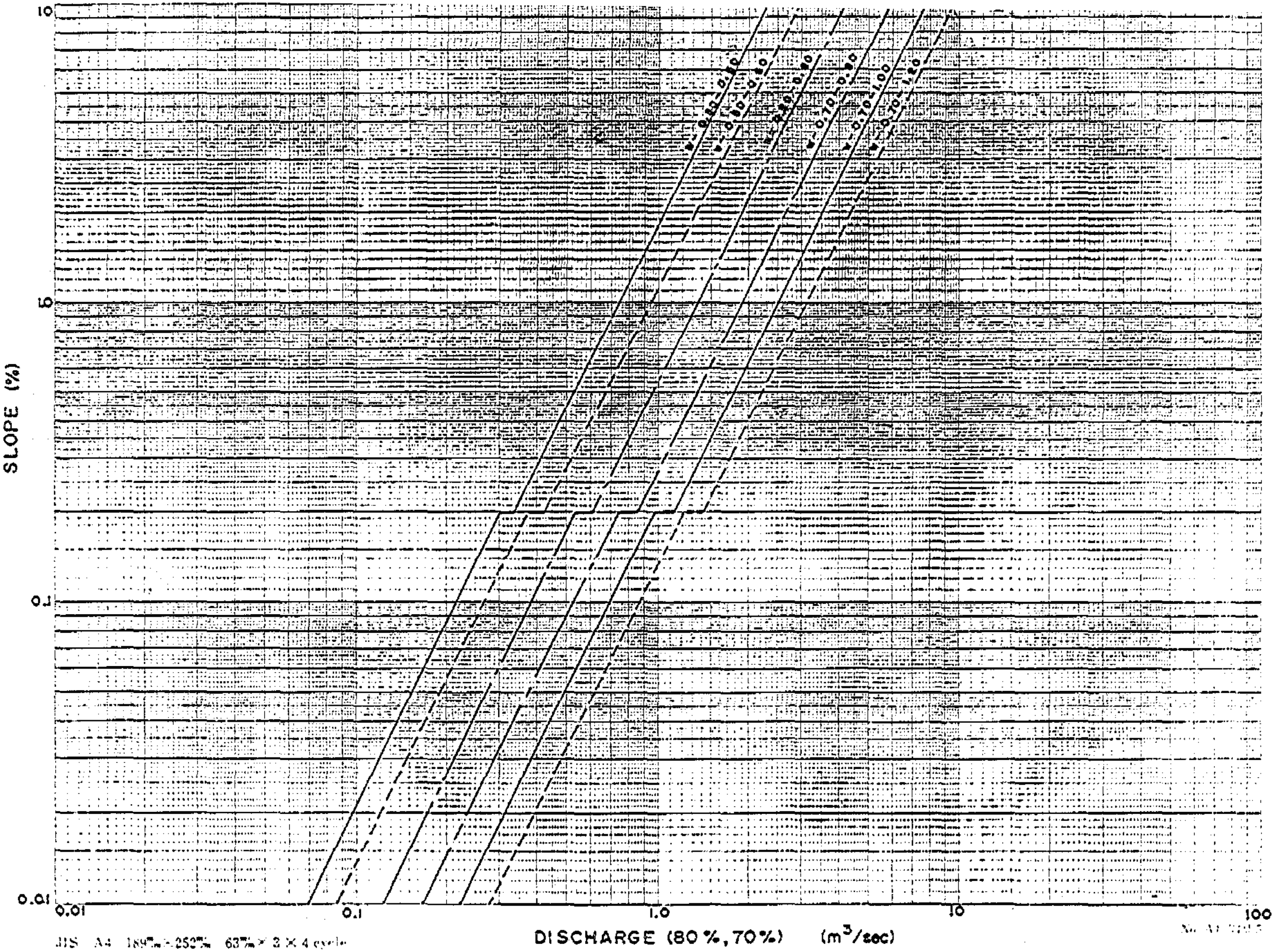


FIGURE 9.2-1(2) DISCHARGE CAPACITY OF SIDE DITCH

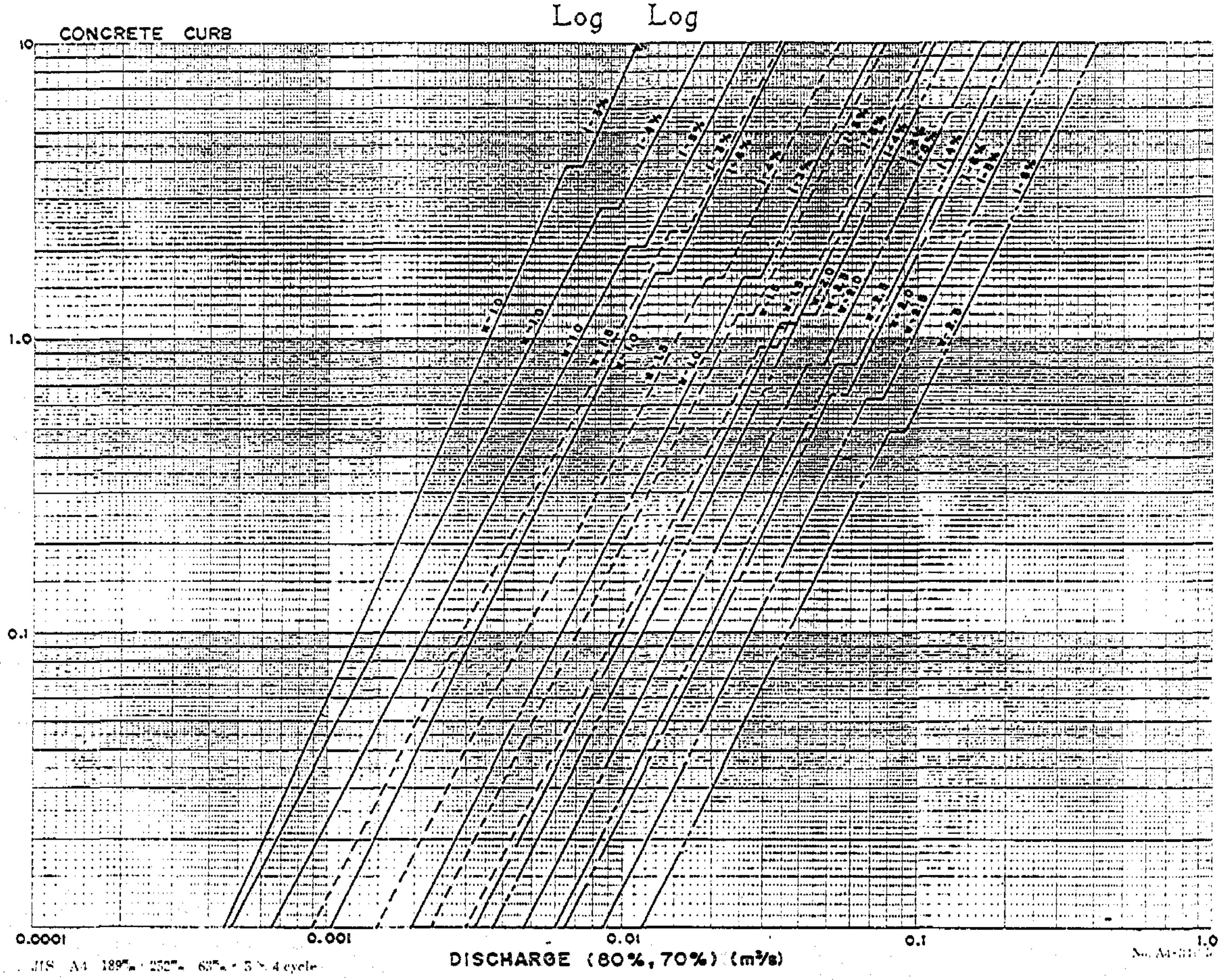


FIGURE 9.2-1(3) DISCHARGE CAPACITY OF SIDE DITCH