CHAPTER 4

AGRICULTURAL DEVELOPMENT BENEFIT

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AGRICULTURAL DEVELOPMENT BENEFIT

4-1 APPROACH

The similar approach as in the Phase 1 Study was employed in the estimation of agricultural development benefits in the Phase 2 Study. Agricultural development benenits are measured by the increment of net value added due to the following major factors:

- increase of farmgate prices
- increase of crop yield
- expansion of cultivated area

In the Phase 2 Study, however, the last item among the above factors was deemed not to be dominant. More precise examination of the existing land use and land capability revealed that very few cultivable land remains unused in the area of influence of the proposed roads. Planted areas in the area of influence were also reduced, comparing with the Phase 1 Study, due to the reduction of the areas of influence mainly by the full consideration of physical constraints to define the area as mentioned in Chapter 2.

Development benefits were estimated by the following formula:

$$DB^t = \sum_i (P(w)_i^t \cdot FP(w)i - PA(w)_i^t \cdot PC(w)_i^t)$$

$$- \sum_i (P(\bar{w})_i^t \cdot FP(\bar{w})i - PA(\bar{w})_i^t \cdot PC(w)_i^t)$$

$$- LPC \cdot (PA(w)^t - PA(\bar{w})^t)$$

where, DBt : Development benefit at year t

P_i^t : Production amount of i crop at year t

FPi : Farmgate price of i crop

PA_i^t : Planted area of i crop at year t

PC_i^t : Production cost of i crop at year t

LPC : Land preparation cost

(w) : with project case

($\bar{w}$) : without project case

Kind of crops considered in the Phase 1 Study was limited to 9 crops such as rice, maize, mungbeans, soybeans, ground nuts, sugarcane, cassava, cotton and tobacco. In addition to them, in the Phase 2 Study, garlic, chilli, vegetables and fruit were taken into account.

While the basic data of planted area, production amount and yeild used for the analysis in the Phase 1 were of 1978/79 crop year, averages of 3-year data during 1977/78 to 1979/80 were applied as the base data for the case of the Phase 2 Study.

4-2 CONDITIONS OF ESTIMATION

1) Planted Area

Land use and land capability in the area of influence of each proposed road were examined precisely checking aerial photographs, LANDSAT photos, and supplementing by field survey information. As the result, a considerable deviation from the Phase 1 Study was found. Especially, unused cultivable lands are quite few remained in the areas of influence of the proposed roads. The estimated future planted areas in each influence area of the proposed road are shown in Appendix 4-1.

2) Crop Yields

Trends of crop yields were carefully reviewed adding newly collected latest data to those obtained in the Phase 1 Study. As a result, revised figures of base year crop yields were obtained. Based on them, future crop yields were newly estimated for both with project case and without project case by Amphoe as shown in Appendix 4-2. Effects of road development to the increase of yields are multiple. Improvement of bargaining power of farmer due to the better accessibility will bring about an incentive for farmers to improve productivity. Social and economic mobility, including easy access for agricultural extension officers, enhanced by the road development will also provide various impacts to contribute indirectly to the improvement of farmers' agricultural practices. More direct effects will be brought about by the availability of less expensive agricultural inputs as a results of improvement of transport conditions.

Viewing the above-mentioned and taking into consideration results of the analysis of relationship between production costs and yields, future targets of crop yields at Amphoe level was forecasted.

3) <u>Farmgate Prices</u>

Latest data of farmgate prices in 1980 were provided by Division of Agricultural Economics of Ministry of Agriculture and Cooperatives.

To obtain prices in 1981 to be used for this study, prices of 1980 were inflated at 17.8% for grains, 28.9% for commercial crops. They are then converted to economic prices in a same manner as in the Phase 1 Study. These prices, to be used as the prices for without project case, are shown in Appendix 4-3. Farmgate prices in the with project case were also reviewed. Field survey information collected in the Phase 2 Study period indicated that the assumption employed in the Phase 1 for the price difference between with and without project is so conservative. In Phase 2 Study, the farmgate prices in the with project case were estimated as also shown in Appendix 4-3.

4) <u>Production Costs and Land Preparation Costs</u>

Latest data of production costs by agro-zone were obtained at Ministry of Agriculture and Cooperatives. Based on this new data, production costs to be used for the estimation of agricultural development benefits were revised as shown in Appendix 4-4. In estimation of future production costs, due consideration was paid to the reasonable consistency with the target crop yields set up.

Corresponding to the higher crop yield in the with project case, it was estimated that the production costs of the with project case would be higher than those of without project case. As the improvement of transport conditions may help farmers to obtain easily less expensive agricultural input such as fertilizer, agro-chemicals and new improved seeds of high yielding varieties, their intensive inputs may consequently bring about raising up of production costs. Improvement of farming practice such as mechanization may also affect the increase of productin costs. The above-mentioned increase of production costs in case of with project will not cause the disbenefits as the higher increase of production value due to the yield increase will be attained. Land preparation costs for new land opening is up-dated to 900 Baht per rai.

4-3 NET VALUE ADDED

Under the revised conditions mentioned in the foregoing section, net added value of agricultural production was calculated in a same manner as in the Phase I Study, for both with and without project cases. Agricultural develolment benefits attributable to the project are deemed to be the increment of net added value in the with project case comparing with the without project case. The calculated benefits are summarized in Table 4-1.

Table 4-1 AGRICULTURAL DEVELOPMENT BENEFITS

(Million Baht/Year)

Study Route No.	Origin	Destination	1987	1993	2001
6	A. Khanu Woralaksa Buri	Rt. 117 (B. Bon Doo)	8.4	9.8	11.5
8	Rt. 115 (B. Thung Maha-chai)	B. Nong Takhian	13.7	21.6	31.8
11	Rt. 1068	Pho Prathap Chang	0.4	0.6	0.9
12	B. Wang Chik	Rt. 117 (B. Pa Daeng)	2.9	4.6	6.8
14	Rt. 11 (B. Nong Khanak)	B. Wang Pong	4.1	5.0	6.3
15	B. Wang Tham	Rt. 1114 (B. Tha Makham)	1.1	1.6	2.2
19	Phrom Phiram	Rt. 11 (B. Nong Makhang)	2.2	3.1	4.2
20	Wat Bot	B. Nakham	2.4	3.0	3.6
23	Rt. 12 (B. Muang Kao Sukhothai)	Rt. 1048 (Si Satchanalai)	7.8	13.5	20.8
25	Thoen	Wang Chien	5.8	7.2	9.1
27	Rt. 106 (B. Mae Thoei)	Thung Hua Chang	1.3	3.7	1.8
29	Rt. 110 (B. Rons Sua Ten)	B. Huai Khom	1.9	2.1	2.4
30	Rt. 1020 (B. Thung Ngiu)	Rt. 1020 (B. Chomphu)	10.1	11.1	12.5
31	Rt. 1016 (B. Kiu Phrao)	Rt. 1174 (B. Kaen Tai)	11.8	13.1	14.8

CHAPTER 5

ROAD USERS BENEFITS

CHAPTER 5

ROAD USERS BENEFITS

5-1 GENERAL

Vehicle operating costs (VOC) used in the Phase 2 Study were updated based on the recent information collected. Furthermore, selection of representative vehicles differed from the Phase 1 Study, revising it after examination of the results of the latest O-D Survey. Method of calculation of VOC employed in this study is basically same as that given in the report, "Standardization of Vehicle Operating Costs for Thailand, 1977" (hereinafter referred to as SVOCT). First, VOC on level tangent paved road at benchmark speed is calculated. Then it is varied due to the travelling speed and road surface condition, and finally it is transformed to the actual costs of each subject road link corresponding to the actual running conditions on the links such as curves, grades and speed chage. The method of conversion from the costs on level tangent roads to the costs on actual road links was quoted from SVOCT, differing form the Phase 1 where Delta - L Method was employed. Road users benefits were measured by savings of VOC, valued in economic prices, in case of with project.

5-2 REPRESENTATIVE VEHICLES

Analysis of the result of the O-D Survey conducted for the Phase 2 Study revealed a set of representative vehicles prevailing in the study area, as explained in Chapter 3. They are classified into motor cycle (M/C), passenger car (P/C), light bus (L/B), medium bus (M/B), heavy bus (H/B), pick-up truck (P/T), 4-wheel truck (4/T), 6-wheel truck (6/T), and 10-wheel truck (10/T). Speaking in comparison with the Phase 1 Study, M/B was newly added and the size of L/T differed from that in the Phase 1 study. P/T, 6/T and 10/T mostly correspond to L/T, M/T and H/T in the Phase 1, respectively.

Basic characteristics of the representative vehicles selected are given in the following table:

Standard Vehicle Types

	M/C	P/C	L/B 1/	M/B	H/B	P/T 1/	4/T	6/T	10/T
Typical Vehicle	Suzuki A100	Toyota Corolla	Toyota Hilux, Isuzu Faster	Toyota Dyna	Hino BX321	Toyota Hilux, Isuzu Faster	Toyota Dyna	Isuzu KS22R	Isuzu JCM490Y
No. of Axle	2	2	2	2	2	2	2	2	3
No. of Tyre	2	4	4	4	6	4	4	6	10
Engine Capacity (CC)	100	1,300	1,600	3,000	6,400	1,600	3,000	3,900	5,800
New Vehicle Price (10^3Baht)	21.3	234	126 ∿130	223	600	121 ∿124.5	216	335	580
Economic 2/ Cost (10^3Baht)	16.7	102.2	104.2 ∿107.3	183.2	491.0	99.8 ∿102.8	175.3	275.9	470.7

Note: 1/ Toyota Hilux represents the petrol engine type vehicle and corresponds to the upper figures in the table, and Isuze Faster represents the diesel engine type vehicle and corresponds to the lower figures.

2/ economic cost of each vehicle was calculated net of tyre and tube costs.

5-3 ROAD USERS COSTS AT BENCHMARK SPEED ON LEVEL TANGENT ROAD

5-3-1 Components of Road Users Costs

Usually, road users costs include mainly vehicle operating costs and occupants time cost. In this study, however, occupants time cost was excluded because of its insignificance in rural areas, although crew cost which depends on time was included in VOC. Thus, road users costs in this study mean VOC composed of the following components:

1) Fuel cost
2) Oil cost
3) Tyre and tube cost
4) Repair and maintenance cost
5) Depreciation and interest cost
6) Overhead cost
7) Crew cost

5-3-2 Benchmark Speed and Lifetime Speed

First, each cost component of VOC is calculated in a standard condition, i.e. at benchmark speed or lifetime speed on level tangent paved road. The fuel cost, oil cost and repair and maintenance cost were calculated at the benchmark speeds, which is 80 km per hour for passenger car and 72 km per hour for the other vehicles. While, tyre and tube cost, depreciation and interest cost, overhead cost and crew cost were calculated at the average lifetime speed which was taken at 56 km per hour.

5-3-3 Basic Data of Cost Components

1) Fuel Cost

In accordance with the revision of representative vehicles which differed from the Phase 1 Study, fuel consumption rate for each vehicle type was reviewed. As data obtained from vehicle manufactures in Japan are of different criteria such as 10-mode fuel consumption and fuel consumption at most economical speed on flat roads, they are not applicable directly.

However, they were useful to check data available in Bangkok and to find out the most reasonable figures of fuel consumption. The figures obtained are given in the following table.

The unit cost of fuel was obtained from interviews to the fuel distributing companies and related organizations.

The selling price of premium gasoline, regular gasoline and diesel were calculated, by averaging the pump prices in 10 points in the Northern Region, at 12.234, 11.734 and 7.719 Baht per liter, respectively.

The taxes included in these prices are 4.0624, 3.8927 and 0.9927 Baht per liter, and subsidies granted to each type of fuel are 0.4051, 0.3355 and 0.3659 Baht per liter, respectively.

Thus, the economic unit costs of fuel calculated are 9.5767, 8.1778 and 7.0922 Baht per liter, respectively for premium, regular gasoline and diesel.

The fuel cost by vehicle type, together with relevant data, is shown below:

Fuel Cost

	M/C	P/C	L/B	M/B	H/B	P/T	4/T	6/T	10/T
Fuel type 1/	Regular	Premium (80%) Regular (20%)	Premium (60%) Regular (25%) Diesel (15%)	Diesel	Diesel	Premium (60%) Regular (25%) Diesel (15%)	Diesel	Diesel	Diesel
Fuel consumption (km/liter)	30.0	13.5	11.0	9.5	5.3	11.0	9.5	6.6	4.0
Fuel cost (Baht/liter)	0.273	0.629	0.750	0.747	1.338	0.750	0.747	1.075	1.773

Note: 1/ Component of fuel was estimated from O-D survey.

2) Oil Cost

Though a wide variety of oils are used in Thailand, the commonly used oils can be classified into two groups, namely standard type as SHELL X-100 or ESSO EXTRA and high-class type as SHELL SUPER PLUS or ESSO UNIFLO. An average price of them is 35.56 Baht per liter in Bangkok. Viewing that oil prices in Northern Region is around 2 Baht higher than that in Bangkok, figure of 37.56 Baht per liter was used in this study as the selling price of oils.

The custom duty and business tax of oils were estimated at 2.439 and 1.956 Baht per liter, respectively. Hence the economic cost of oils is estimated at 33.165 Baht per liter.

The oil cost by vehicle type, together with the consumption ratio is shown below:

Oil Cost

	M/C	P/C	L/B	M/B	H/B	P/T	4/T	6/T	10/T
Consumption (Km/liter)	750	1,000	920	770	450	920	770	450	450
Oil cost (Baht/liter)	0.044	0.033	0.036	0.043	0.074	0.036	0.043	0.074	0.074

3) Tyre and Tube Cost

The data on unit price of new tyre and its discount structure were obtained from interviews to the major tyre manufacturing companies and local distributors. Tyres are sold at about 20% discounted prices for motorcylce and about 30% discounted prices for other vehicles against the list prices, and tubes are sold at about 25% discounted prices for all vehicles. The selling price of retread tyre is 35-45% of that of new tyre. The tax components included in selling price are 7.7% for the business tax and 2.0% for the import duty on materials.

The tyre and tube cost by vehicle type, together with the relevant data is shown below:

Tyre and Tube Cost

	M/C	P/C	L/B	M/B	H/B	P/T	4/T	6/T	10/T
Tyre Size	2.75x18 4 ply	165SR13 -	6.00x14 6 ply	7.00x15 8 ply	9.00x20 14 ply	6.00x14 6 ply	7.50x15 10 ply	7.50x16 12 ply	9.00x20 14 ply
Selling Price of New T&T (Baht)	172	770	918	1,314	3,573	918	1,622	1,875	3,573
New tyre and tube cost less tax(Baht)	155	695	829	1,187	3,226	829	1,465	1,693	3,226
Average life of new tyre (10^3 km)	30	45	35	40	50	35	40	45	50
Selling price of retread tyre(Baht)	-	-	380	580	1,600	380	580	620	1,600
Retread tyre cost less tax (Baht)	-	-	343	524	1,445	343	524	560	1,445
Average life of retread tyre (10^3 km)	-	-	28	32	40	28	32	36	40
Nos. of retread	-	-	0.5	0.5	1.0	0.5	0.5	1.0	1.0
Tyre and tube cost (Baht/Km)	0.010	0.062	0.082	0.104	0.311	0.082	0.123	0.167	0.519

4) Repair and Maintenance Cost

The figures for hours of labor used in this study are basically same as given in SVOCT, with minor adjustment. The percentages of parts costs were reviewed and adjusted referring to the Jan De Weille's "Quantification of Road User Savings".

The labor wage rate was taken as the same figure of minimum wage rate for Northern Region, i.e. 51 Baht per hour.

The calculated repair and maintenance costs are given belows:

Repair and Maintenance Cost

	M/C	P/C	L/B	M/B	H/B	P/T	4/T	6/T	10/T
Labor Cost (hour/1,000 km)	1.30	1.65	1.90	1.90	9.40	1.65	1.90	7.64	9.40
Parts Cost (% of economic cost of vehicle/1,000km)	0.10	0.11	0.21	0.21	0.12	0.12	0.21	0.21	0.07
Repair and Maintenance Cost(Baht/Km)	0.083	0.197	0.317	0.482	1.069	0.205	0.465	0.969	0.809

5) Depreciation and Interest Cost

Depreciation and interest cost of respective vehicle was calculated using the following equation:

$$D = (P - L)\,CRF + L \cdot i$$

Where, D = Depreciation and interest cost
P = Economic value of vehicle
L = Salvage value of vehicle
CRF = Capital recovery factor
i = Annual rate of interest, 12 percent

The salvage value and annual milage differed from those of the Phase 1 Study revising based on latest survey information and discussion with DOH.

The depreciation and interest cost by vehicle type is shown below:

Depreciation and Interest Cost

	M/C	P/C	L/B	M/B	H/B	P/T	4/T	6/T	10/T
Economic Value of Vehicle (10^3 Baht)	16.7	102.2	104.7	183.2	491.0	100.3	175.3	275.9	470.7
Salvage Value of Vehicle (10^3 Baht)	-	20.0	10.0	10.0	50.0	15.0	10.0	45.0	50.0
Service Life (Years)	6	10	7	7	9	10	8	10	10
CRF	0.2432	0.1770	0.2191	0.2191	0.1877	0.1770	0.2013	0.1770	0.1770
Annual Travel (10^3 Km)	10	20	40	40	70	25	35	40	50
Depreciation and Interest COST (Baht/Km)	0.406	0.847	0.549	0.979	1.268	0.676	0.985	1.157	1.609

6) Overhead Cost

The overhead cost was counted for commercial vehicles: medium bus, heavy bus, 6-wheel truck and 10-wheel truck. It was estimated that overhead costs at average lifetime speed of 56 km per hour were 7% of economic cost of vehicle for heavy bus, 4% for 10-wheel truck and 2.5% for medium bus and 6-wheel truck.

The overhead cost by vehicle type is shown below:

Overhead Cost

	M/B	H/B	6/T	10/T
Overhead Cost (10^3 Baht/Year)	4.6	34.4	6.9	18.8
Annual Travel (10^3 Km)	40	70	40	50
Overhead Cost (Baht/Km)	0.115	0.491	0.173	0.376

7) Crew Costs

Crew costs were estimated basing on the actual wages to be paid to crews of buses and trucks. As light buses and 4 wheel trucks are usually owner operated, their crew costs were counted at half of wages for employed drivers.

Wage rates were carefully reviewed referring to the latest information obtained from ETO and other agencies and some modification was made.

The crew costs by vehicle type are shown below:

Crew Costs

	L/B	M/B	H/B	4/T	6/T	10/T
Number of Crew:						
- Driver	1	1	1	1	1	1
- Asst. Driver	-	-	-	-	-	1
- Conductor	-	1	2	-	-	-
- Labor	-	-	-	-	-	1
Crew costs at lifetime speed (Baht/Km)	0.600	1.440	1.303	0.686	1.020	1.680

5-3-4 VOC at Benchmark Speed

Thus calculated vehicle operating costs at benchmark speed on level tangent road, asphalt concrete paved and good conditioned, are summarized in the following table:

Vehicle Operating Costs
(at Benchmark Speed on Level Tangent Paved Road)

(Baht/km)

Vehicle Type	Bench-Mark Speed (Km/hr)	Fuel Cost	Oil Cost	Tyre & Tube Cost 1/	Repair & Main-tenance Cost	Depre-ciation & Interest Cost 1/	Over-head Cost 1/	Crew Cost 1/	Total
M/C	72	0.273	0.044	0.013	0.083	0.406	-	-	0.819
P/C	80	0.629	0.033	0.093	0.197	0.847	-	-	1.799
L/B	72	0.750	0.036	0.107	0.317	0.443	-	0.465	2.118
M/B	72	0.747	0.043	0.135	0.482	0.816	0.089	1.116	3.428
H/B	72	1.338	0.074	0.404	1.069	1.057	0.381	1.010	5.333
P/T	72	0.750	0.036	0.107	0.205	0.545	-	-	1.643
4/T	72	0.747	0.043	0.160	0.465	0.794	-	0.532	2.741
6/T	72	1.075	0.074	0.217	0.969	0.964	0.134	0.791	4.224
10/T	72	1.773	0.074	0.674	0.809	1.341	0.291	1.302	6.264

Note : 1/ converted from the costs at lifetime speed of 56 Km/hr to the costs at benchmark speed.

5-4 ROAD USERS COSTS ON ACTUAL ROADS

5-4-1 Factors Affecting VOC

The actual VOCs on each road link concerned are to be estimated transforming the basic costs calculated in 5-3 into the actual costs corresponding to the actual conditions of each road link. Major factors affecting VOC may include: travelling speed, road surface type, grades, curves, speed change caused by traffic restriction.

As the basic costs estimated in 5-3 are those at benchmark speed on level tangent paved road, it is required first to obtain VOCs on each road class by surface type at travelling speed on level tangent road. Then, they are to be varied into actual VOC with additional costs caused by grades, curves and speed change.

5-4-2 VOC on Level Tangent Road at Initial Speed

The VOCs at banchmark speed on level tangent paved road were converted to VOCs at initial speeds on level tangent road of three road classes, i.e. paved, laterite and earth.

Judging from the field observation in the project area, travelling speeds on level tangent roads, or initial speeds in other words, were determined as follows:

Initial Speed by Road Class
(on Level Tangent Road)

Vehicle Type	Initial Speed (Km/hr)		
	Paved road	Laterite Road	Earth road
M/C	64	48	32
P/C	80	56	32
L/B	72	48	32
M/B	72	48	32
H/B	72	48	32
P/T	72	48	32
4/T	72	48	32
6/T	64	48	32
10/T	64	48	32

The conversion indices for variation due to speed and road surface were quoted from the T.P. O'Sullivan's "Road User Cost in Thailand; Technical Report No. 36" (hereinafter referred to as RUCT) and also referred to SVOCT.

For fuel cost, oil cost, tire cost and repair and maintenance cost, the conversion factors in RUCT were employed, and for depreciation and interest cost, overhead cost and crew cost, those in SVOCT were employed.

The fuel cost curve is U shaped, rising at high and low speeds. The lowest point is appeared at in between 45 and 55 km per hour of speed.

The oil cost are not changed by speed, but varied by surface type; 50% increase for cars and 75% increase for other vehicles on earth road, compared with paved road.

Tire wear is a function of speed and of road surfaces. The tire and tube cost is higher in the higher vehicle speed, and also the higher costs appear on the worse road surface. Conversion indices of tire and tube costs are assumed to be the same for all vehicles.

The repair and maintenance cost curve is U shaped, rising at high and at low speeds, in similar fashion to fuel consumption. The lowest point is at speed of 48 km per hour.

The depreciation and interest cost of cars is not different by speeds, but that of other vehicles is higher at lower speeds, and it also increases depending on the badness of the road surface.

As the overhead cost and the crew cost involve a conception of time cost, they are higher at lower speeds.

Thus converted VOCs on level tangent road by three road classes are summarized in Appendix 5-1 and VOCs by different speed were also tabulated in Appendix 5-2 and illustrated in Appendix 5-3.

5-4-3 Additional Costs due to Road Geometrics

Additonal costs caused by curves, grades and speed change cycle were calculated applying the coefficients given in SVOCT, as quoted in Appendix 5-3. In this study, it is assumed that speed change cycle is occurred by three causes; i.e. timber bridge, village and cross road.

5-4-4 Road Users Costs on Each Link

Based on the calculated VOC on level tangent road of three classes and given coefficient for variation due to road geometrics, actual VOCs are estimated for each road link to be concerned with each proposed route.

5-5 ROAD USERS BENEFITS

The road users benefits were defined as the savings of VOC due to the project. The savings were obtained from the difference of total VOCs in the related road network in case of with project and those of without project case. They were calculated by vehicle type and by traffic type and then summed up.

Thus calculated road users benefits of each proposed road are given in Table 5-1. Deviation from the figures in the Phase 1 Study is mainly caused by change of projected ADT, up-dated VOC data and difference of method of cost transforming.

Table 5-1 ROAD USERS COST SAVINGS

(Million Baht/Year)

Study Route No.	Origin	Destination	1987	1993	2001
6 (6-4)	A. Khanu Woralaksa Buri	Rt. 117 (B. Don Doo)	31.4	46.0	79.0
8	Rt. 115 (B. Thung Maha-chai)	B. Nong Takhian	13.4	20.3	35.8
11	Rt. 1068	Pho Prathap Chang	0.7	1.1	1.7
12	B. Wang Chik	Rt. 117 (B. Pa Daeng)	6.1	9.5	15.0
14	Rt. 11 (B Nong Khanak)	B. Wang Pong	2.4	3.4	5.0
15	B. Wang Tham	Rt. 1114 (B. Tha Makham)	2.4	3.8	6.0
19	Phrom Phiram	Rt. 11 (B. Nong Makhang)	2.2	3.2	5.1
20	Wat Bot	B. Nakham	2.0	2.9	4.6
23 (23-2)	Rt. 12 (B. Mung Kao Sukhothai)	(Si Satchanalai)	13.5	18.8	28.7
25	Thoen	Wang Chin	16.7	26.6	48.6
27	Rt. 106	Thung Hua Chang	0.6	0.7	1.1
29	Rt. 110	B. Huai Khom	1.8	2.9	5.1
30	Rt. 1020 (B. Thung Ngiu)	Rt. 1020 (B. Chomphu)	12.8	17.4	26.5
31	Rt. 1016 (B. Kiu Phrao)	Rt. 1174 (B. Kaen Tai)	18.0	28.6	51.9

CHAPTER 6

ENGINEERING

CHAPTER 6

ENGINEERING

6-1 FIELD SURVEY

The inventory surveys were conducted for all the existing roads concerned with the proposed routes in order to collect data necessary for the road design. Additionally, the topographic surveys were carried out for the rolling and mountainous sections, to grasp the diversified geographical features, Soil samplings and tests were also made mainly to obtain data for pavement design.

6-1-1 Inventory Survey

Length of the existing roads on which the inventory survey was performed totaled at 482 km, including alternative routes. The major items, the methods and the purposes of the inventory survey are as follows:

Item	Method	Purpose
Distance	Distance measure instrument	To determine the length of the subject road
Alignment	Hand level and prismatic compass	To determine poor alignment sections to be improved
Cross section	Tape measurement at intervals of 500 m	To judge the necessity of raising up and widening
Road surface	Observation	To estimate traveling speed
Flood condition	Observation and hearing	To determine the sections to be raised up and additional drainage structures
Drainage structure	Tape measurement and observation	To determine the drainage structures to be improved
Bridge	Tape measurement and observation	To determine the bridges to be improved
Right of way	Tape measurement	To estimate required width of right of way

The outline of the condition of the existing roads revealed by the inventory survey are as follows. Their details are shown in Volume 2 by each study road.

Outline of the Conditions of the Existing Roads

Route No.	Lengtn (Km)	Terrain	Road Condition Align-ment	Width (m)	Surface	Number of bridges	Overflows length (km)
No.6 (6-4)1/	46.0	Flat	Fair/Bad	3.0~10.0	Laterite Earth	C-1	12.0
No.8	53.5	Falt	Fair/Bad	2.5~8.4	Laterite Earth	C-2 T-15	11.3
No.11	6.8	Flat	Fair	8.0	Laterite	-	6.8
No.12	13.0	Flat	Fair	3.0~9.0	Earth	T-5	6.1
No.14	21.0	Flat/ Rolling	Fair/Bad	3.5~8.0	Laterite Earth	T-2	-
No.15	8.3	Flat	Fair	3.5~4.7	Laterite	-	-
No.19	14.4	Flat	Fair	3.5~9.0	Laterite Earth	T-1	6.5
No.20	15.7	Flat	Fair/Bad	4.0~8.0	Laterite Earth	T-2	0.1
No.23 (23-2)1/	51.9	Flat	Fair/Bad	5.0~9.0	Laterite Earth	T-1	7.3
NO.25	54.0	Rolling/ Mountainous	Fair/Bad	3.4~9.3	Laterite	T-35	1.9
No.27	16.6	Rolling/ Mountainous	Fair/Bad	4.8~7.7	Laterite	T-7	0.2
No.29	13.2	Flat/ Rolling	Fair	3.5~10.0	Laterite	T-3	-
No.30	47.8	Flat	Fair	4.5~6.0	Laterite	T-11 C-1	12.4
No.31	55.0	Flat/Rolling /Mountainous	Fair/Bad	4.0~8.0	Laterite	T-19 C-1	4.4

1/ Selected alternative

6-1-2 Reconnaissance for New Road Sections

For new road sections, careful reconnaissances were carried out to determine the new alignment.

Prior to the reconnaissance, desk studies for routing were carried out based on the 1/50,000 scale topographic maps and the 1/15,000 scale aerial photos obtained from the Royal Thai Survey Department.

The principal check points in the reconnaissance were : i) deep cut, ii) high embankment, iii) soil characteristics, iv) required drainage structures, v) river conditions and bridge locations, vi) necessities of access roads, and vii) difficulties of acquisition of right-of-ways.
The reconnaissances were carried out for about 51 km in total length.

6-1-3 Topographic Survey

Topographic surveys were carried out mainly for the existing and new road sections in rolling and mountainous areas. Although Study Route No.19 passes through a flat area, a profile survey was performed especially to confirm the length of overflow section.

For partial or whole sections in Study Route No.8, No.11, No.14, No.23, No.29 and No.31, topographic surveys have been done by DOH, PWD, and other agencies. The results were fully utilized for this studt.

Length of sections on which the topographic survey was conducted was 96.0 km in total as shown in the below table.

Length of Topographic Survey

Route No.	Length (km)		
	Existing Road Section	New Road Section	Total
No.11	-	0.2	0.2
No.15	-	0.5	0.5
No.19	-	14.6	14.6
No.23	-	8.1	8.1
No.25	54.3	1.7	56.0
No.27	16.6	-	16.6
Total	70.9	25.1	96.0

Horizontal and vertical alignments were measured by using transit and level, respectively, and cross sections were surveyed at intervals of 100 m in principle and also at crest and sag portions in addition to them.

River cross section survey was performed only at one site where a long bridge crossing over the Li River was planned on Study Route No.27. Fo the other rivers, the surveys were carried out in the inventory or topographic survey for the existing roads.

6-1-4 Soil Test

Physical and mechanical tests were carried out for 61 soil samples in total as shown below.

Number of Soil Tests

Route No.	Objectives			
	Subgrade Soil	Laterite	Crushed Stone	Total
No.6	5	-	1	6
No.8	5	-	2	7
No.11	2	-	-	2
No.12	2	-	-	2
No.14	6	3	-	9
No.15	2	1	-	3
No.19	4	1	-	5
No.20	3	1	-	4
No.23	-	-	-	-
No.25	6	3	1	10
No.27	3	-	1	4
No.29	3	1	-	4
No.30	-	-	1	1
No.31	2	1	1	4
Total	43	11	7	61

Prior to the performance of the sampling existing test data pertaining to the proposed roads were collected.

In Study Routes No.23, No.30 and No.31, the soil tests for subgrade and subbase soils have already done by DOH, for the whole or some section of them. All the collected existing data were used for this study and soil samplings in these sections were omitted.

The main items of soil tests are as follows.

- Natural moisture content test
- Consistency test
- Particle size distribution test
- Specific gravity test
- Compaction test
- CBR test

Samplings were made by the study team and tests were carried out by the Material and Research Division of DOH.

The outline of characteristics of subgrade soils is summarized below and the details of soil test results are shown in Volume 2 by each study route.

Soil Characteristics of Subgrade Soil

Route No.	Description	PI	CBR %
No. 6	Silty clay-Clayey Silt	9.7 ∿ 11.0	2.2 ∿ 3.5
No. 8	Clayey silt	4.1 ∿ 18.7	3.0 ∿ 8.9
No.11	---- do ----	9.4 ∿ 15.2	1.15∿ 2.0
No.12	Silty sand	NP ∿ 22.4	6.0 ∿ 6.7
No.14	Clayey silt	8.1 ∿ 20.9	1.8 ∿ 13.3
No.15	---- do ----	10.6	2.3
No.19	Silty clay-Clay	NP ∿ 17.3	1.6 ∿ 17.0
No.20	Clayey silt	NP ∿ 37.4	2.1 ∿ 10.6
No.23	---- do ----	35.4∿ 53.8	1.8 ∿ 2.8
No.25	Silty clay-Clay	6.2 ∿ 13.8	1.3 ∿ 15.0
No.27	Sand-Silty soil	NP ∿ 66	3.9 ∿ 30.0
No.29	Silty clay	NP	4.1 ∿ 13.2
No.30	Clayey silt	11.4 ∿ 24.5	3.1 ∿ 6.4
No.31	Clay-Sand	10.1 ∿ 22.0	4.2 ∿ 7.0

As shown in the above table, subgrade soils are mostly classified as clay or silt and have 2.0 to 5.0 of CBR value, except for some study routes.

6-2 DESIGN STANDARD

According to the highway classification of DOH, provincial highways are defined as the roads which are of secondary importance for national development but essential to efficient provincial administration, linking Amphoe and other important centers or areas to provincial capitals. Based on this definition all the proposed roads in this study are categorized as provincial highways.

DOH has the minimum design standards for provincial highway under the name of F standard. The F standard is subdivided into seven road classes from F0 to F6 according to the projected ADT in Table 6-1.

Projected average ADT of each study route at 7th year and 15th year after opening range from 90 to 1435 as shwon in Table 3-7 of Chapter 3. F4 standard was applied for most of the study routes based on the forecasted ADT. The estimated ADT at 15th year of Study Route No.6 and No.12 are in excess of 1000. Although F3 standard should be adopted to these routes F4 standard was also applied from the economical viewpoint. On the other hand, ADT at 7the year of Study Route No.11 and No.19 were forecasted to be less than 300. F4 standard was applied to them, although F5 standard should be applied according to the ADT. The reason is that the existing roads, at present, satisfy mostly the F4 standard. ADT at 7th year of Study Route No.20 and No.27 are estimated at 246 and 80 respectively, and F5 and F6 standards was applied to each road corresponding to each ADT.

Design standards applied to each study route are summarized below.

Application of Design Standard

Standard	Route No.	ADT	
		7th Year	15th Year
F4	6, 8, 11, 12, 14, 15, 19, 23, 25, 29, 30, 31	242 - 887	380 - 1435
F5	20	213	361
F6	27	90	136

6-3 PRELIMINARY DESIGN

6-3-1 Geometric Design

1) Design Speed

The design speed employed in the engineering study is as follows:

Design Speed

Terrain Condition	Design Speed (km/h)	
	F4	F5 and F6
Flat or Moderately Rolling	80(60 - 80)	60
Rolling or Hilly	60(45 - 60)	45
Mountainous	45(30 - 45)	30

Figures in parentheses in the above table show the range of design speed specified in DOH's standard. The higher design speeds were employed for this engineering study. Besides them, 40 km/h was applied to the design speed on the sections passing through densely populated areas.

2) Geometric Design Criteria

The geometric design criteria corresponding to design speed were determined referring to AASHTO's recommendation as follows:

Geometric Design Criteria

Description	Design Speed (km/h)				
	80	60	45	40	30
Min. Radius Curvature (m)	210	120	65	50	30
Min. Stopping Sight Distance(m)	115	75	55	45	40
Gradient(%)					
Desirable	4	8	6.5	7	8
Maximum	8	10	12	12	12

3) Alignment

In principle, the alignments of the proposed route were designed so as to follow the existing alignments of the existing roads concerned, as much as possible.

Thus, the improvement of alignment was considered only for poor existing alignments, which do not satisfy of the geometric design criteria. In the sections that pass through densely populated areas, even if there are sharp horizontal curves which do not fulfil the geometric design criteria, no improvement was designed when removing number of houses is necessitated.

By-passes were planned in sections passing through villages in which it is difficult to obtain more than 20 m wide right of ways. Beside by-passes, a new access road to National Highway Route 117 was planned for Study Route No.6.

New roads including the by-passes and an access road were designed for about 51 km in total length as shwon below.

Length of New Road

Route No.	Length (km)	Remark
No. 6 (6-4) 1/	16.3	excluding alternative routes
No.15	0.5	
No.19	1.5	
No.23 (23-2) 1/	30.4	excluding alternative routes
No.25	1.9	
No.30	0.25	
Total	50.85	

1/ Selected alternative

4) Typical Cross Section

The typical cross sections of F4, F5 and F6 standards are shown in Fig. 6-1 dividing into embankment and cut sections.

In the typical cross section provided in the DOH's standard, the dimensions of the width of roadbed, carriageway and shoulder are shown. They were applied with no change for this study. The DOH's typical cross section specifies the cross slope of carriageway from 1.5 % to 3.0 % for F4 class road. In this study, 3% was used as the cross slope.

The components which are not shown in DOH's typical cross section, such as the embankment and cut slopes, the minimum depth of the side borrow ditch and the width of berms between the toe of embankment slope and side borrow ditch were determined through the study of the typical sections of recent DOH's highway projects. Their specificatios are as follows:

- The gradient of embankment slope is 2:1

- The gradient of cut slope is 1.5:1 in principle, but variable according to the cut depths and soil conditions.

- In embankment section, 2 m wide berms were provided between the toe of embankment slopes and the side borrow ditches.

- The minimum sizes of the side borrow ditch specified are 80 cm in depth and 100 cm in bottom width.

- The minimum gradient of the side slope of the side borrow ditch is 1.5:1.

6-3-2 Earthwork Design

Required minimum heights of embankment were determined mainly in consideration of the influence of surface water on the road structures. The minimum height of embankment employed in this study are shown below.

Minimum Embankment Height

Description	Minimum Height (m)
Upland	1.0
Low land	
Field of Upland Crops	1.0
Paddy	1.5
Approach of Bridge in Flat Area	2.0
Flood Section	0.7 (above flood level)

The side borrow method is the most common and economical method for embankment construction in Thailand. This method was, therefore applied to almost whole sections of the proposed roads and construction costs were estimated under this method. However, in some sections of submerged areas such as Study Route No.11 and No.19, it was found through the soil test results that the road side soils are unsuitable for the materials of embankment because their CBR values are very low, less than 2.0. In such section, the borrow pit method which carries the embankment materials from the borrow pits set at distant places was applied.

Cutting was designed to improve poor existing vertical alignments of the existing roads mainly in mountainous areas. Such cuttings were ne necessary in a few short sections of Study Route No.20, No.23, No.25, No.27 and No.31. The deepest cutting is about 5.0 m in the mountainous section of Study Route No.31. Others are mostly less than 3.0 m. All these cuttings were judged to consist of common soils based on observations during the inventory survey.

6-3-3 Pavement Design

1) General

For F4 class road, single bituminus surface treatment (SBST) with crushed stone base and soil aggregate subbase was applied. For F5 and F6 class road, soil aggreagate surfacing with selected material layer was employed in general, but SBST was designed in the sections passing through densely populated areas and 1.0 km long approach section to the existing paved roads.

In Thailand, following two design methods are mainly used for flexible pavement:

a) DOH Method : Technical Note No.12/2520 of the Material and Research Division of DOH. This method is mainly based on the Asphalt Institute Ms-1 "Thickness Design, Full Depth Asphalt Pavement Structures for Highways and Streets".

b) Road Note 31 Method : Overseas Unit Transport and Road Research Laboratory United Kingdom Road Note 31 "A guide to the Structural Design Of Bitumen-Surface Roads in Tropical and Sub-Tropical Countries".

Prior to pavement design a concise comparision of the above two design methods was carried out. The summary of the results of comparative study is described below.

i) In Road Note Method, the thickness of the base is fixed at 150 mm or 200 mm and only thickness of the subbase can be determined through the design procedures. On the other hand, in DOH method, the thicknesses of both base and subbase can be determined arbitrarily. Thus DOH Method can freely choose pavement materials considering utilization of local resources.

ii) The design chart in Road Note 31 Method is given for double bituminous surface treatement (DBST). Where SBST is designed, the thickness of base plus subbase estimated by Road Note 31 Method is usually thinner than that in DOH Method. Therefore DOH Method is thought to be suitable for the conservative design of SBST pavement.

iii) On the overlay at the stage construction, Road Note 31 Method recommends fixed thickness of overlay 50 mm of asphalt concrete or DBST with 75 mm of crushed stone base. In DOH Method, the thickness of overlay can be calculated.

Viewing the characteristics mentioned above, DOH Method was applied for the design of SBST pavement in this study.

The design period of pavement was set at 7th year and overlay was planned at the beginning of 8th year, after opening in this study. The advantages of the stage construction are as follows:

i) Through locating and repairing, to be done in the second stage, of weak spots that may develop during the first stage, pavement performance can be improved more effectively.

ii) Through the survey of the actual traffic on the road during the first stage, more accurate analysis of traffic can be done to enable the necessary corrections of original pavement design.

However, the overlay by asphalt concrete is not always economical because the cost of asphalt concrete is rather high and there are cases that thicker layer than that of theoretically estimated is required actually due to difficulties of construction. The overlay by SBST with crushed stone base was, therefore employed in this study.

2) Number of Heavy Trucks (NHT)

From ADT by vehicle type by study route shown in Volume 2, average ADT of heavy trucks, medium trucks and heavy busses were obtained first.

As all the proposed roads consist of two traffic lange, number of heavy trucks (NHT) on design lane are extimated as follow:

NHT = Average ADT x 50%

3) Average Gross Weight of Heavy Trucks (AGW)

Based on the O/D survey results, average gross weight of heavy trucks was estimated as follows:

Average Gross Weight of Heavy Trucks (AGW)

Type of Vehicle	Gross Weight (kg)		Empty Rate(%)	Average Gross Weight (kg)
Heavy Truck	Laden	21,000	60	
	Empty	7,000	40	15,400
Medium Truck	Laden	8,400	55	
	Empty	3,400	45	6,150
Heavy Bus*	Laden	12,300	100	12,300

* 40 persons x 60^{kg} + Vehicle weight 9,900 ^{kg}

The average gross weight of heavy trucks on the design lane was calculated multiplying the above average gross weight by component ratio of NHT by vehicle type and then totalling them.

4) Design Traffic Number

Assuming that single axle load limit is 8,200 kg, initial traffic number (ITN) is estimated based on traffic analysis chart (Fig. 6-2) using AGW and NHT previously estimated.

Using annual growth rate of ADT, ITN adnustment factor was calculated by the following formula:

$$\text{Factor} = \frac{(1 + r)^n - 1}{20\, r}$$

Where r = annual growth rate of ADT

n = Design period

Design traffic number (DTN) for the design periods of 7 and 15 years were obtained by multiplying ITN by the ITN adjustment factor.

5) Design CBR

If the number of CBR tests is not large, say less than 10, the standard deviation can be estimated by the following equation:

$$Se = \frac{R}{d}$$

Where; Se : estimated standard deviation

R : range of values, i.e, the difference between the greatest value and the smallest value.

d : factor (see the below table)

Factor for Estimating Standard Deviation

Number of Value n	Factor (d)
2	1.1284
3	1.6926
4	2.0588
5	2.3259
6	2.5344
7	2.7044
8	2.8472
9	2.9700
10	3.0775

The Material and Research Devision of DOH uses the CBR value of about the 30th percentile as the design CBR. Using the standard deviation calculated by the above equation, the 30th percentile CBR value, i.e, the design CBR, was estimated corresponding to number of CBR tests through the following equation:

$$\text{Design CBR} = CBRm - 0.524\ Se$$

Where, CBRm : mean value of tested CBR value
0.524 : factor for estimating 30th percentile value
Se : standard deviation corresponding to number of CBR tests

When the selected material layer is planned, taking the effect of the selected material layer into account, average CBR value of subgrade at the point was calculated by the following equaltion:

$$CBRs = \left(\frac{h_1 CBR_1^{1/3} + h_2 CBR_2^{1/3}}{100} \right)^3$$

where : CBRs = CBR value of subgrade layer included selected material layer (%)
CBR_1 = CBR of slected material (%)
CBR_2 = CBR of subgrade soil (%)
h_1 = thickness of selected material layer (cm)
h_2 = thickness of subgrade soil (cm) $h_2 = 100 - h_1$

6) Pavement Thickness

Applying the calculated design traffic number (DTN) and design CBR to the thickness design chart (Fig. 6.3), required thickness of full-depth asphalt concrete layer was obtained.

The Asphalt Institute recommends the use of a substitution ratio (S_r) for making conversion from asphalt concrete layer to untreated granular base and subbase. Specifically it is recommended that;

- High quality granular material (crushed stone)...Sr = 2.0

- Low quality granular material (good quality laterite)..Sr = 2.7

Assuming that the substitution ratio of SBST surface is 0, required thickness of base and subbase was calculated as the following example:

- Estimated thickness of full-depth asphalt concrete layer : 230 mm

- Where 150 mm thick crushed stone base is designed, converted asphalt concrete layer is 75 mm because the substitution ratio of crushed stone is 2.0

- Required thickness of subbase is calculated as follows:

  230 mm - 75 mm = 155 mm
  155 mm x 2.7 (Substitution ratio of good quality laterite)
  = 420 mm

The overlay thickness of asphalt concrete is obtained by deducting the estimated thickness of 7 years design period from that of 15 years design period. The overlay thickness by asphalt concrete thus estimated was converted to the thickness of crushing stone base using substition ratio.

The designed pavement structures of SBST by each study route are shown in the table below .

Designed Pavement Structure

Route No.	Road Class	Sturctures of 7 years Design Period (mm)			Selected Material	Overlay Thickness (mm)	
		Surface	Base	Subbase		Surface	Base
6 *1	F4	SBST	150	390	-	SBST	60
		AC=50	150	330	-	AC = 40	-
8	F4	SBST	150	260	-	SBST	40
11	F4	SBST	150	270	-	SBST	60
12	F4	SBST	150	170	-	SBST	60
14	F4	SBST	150	190	-	SBST	50
15	F4	SBST	150	350	-	SBST	60
19	F4	SBST	150	190	-	SBST	40
20 *2	F5	SBST	150	300	-	SBST	70
		SBST	100	140	-	SBST	50
23	F4	SBST	150	380	-	SBST	70
25	F4	SBST	150	180	200	SBST	60
27	F6	SBST	150	150	-	SBST	50
29	F4	SBST	150	150	200	SBST	50
30	F4	SBST	150	260	-	SBST	40
31 *2	F4	SBST	150	250	-	SBST	50
		SBST	150	190	-	SBST	40

* In F5 and F6 class road, SBST pavement was planned only in the sections passing through village areas and the approach sections to existing pvaed road.

*1 In Route No.6, asphalt concrete pavement was designed in some sections considering heavy traffic for suger cane transportation.

*2 In Route No.20 and Route 31, since there were extreme differences for ADT and CBR by section, two kinds of pavement thickness were designed.

The design of soil aggregate surfacing for F5 and F6 class roads was made with the following thickness, in accordance with the DOH Standard for typical pavement structure.

Soil aggregate surface	CBR ≥ 20	150 mm
Selected material	CBR ≥ 6	200 mm

Typical pavement structure for F4, F5 and F6 are shown in Fig. 6-4.

6-3-4 Drainage Design

Perfection of drainage facilities is an indispensable factor for maintaining the road in all-weather condition. The existing roads of the proposed route have very poor drainage facilities in number and in capacity. Substantial improvement of drainage facilities was required for all the proposed roads.

1) Pipe Culvert

Pipe culverts of 100 cm diameter in minimum was applied for this study considering easy maintenance. The standard drawing of pipe culvert is shown in Fig. 6-5.

In flat areas the locations of pipe culverts were determined through the inventory survey, with the following standard interval:

Standard Interval of Pipe Culvert in Flat Area

Description	Standard Interval (m)
Paddy area flood Section	200
Others	500

In rolling and mountainous areas, pipe culverts were set at the selected, sag points based on the results of topographic surveys.

For the improvement sections, where the existing pipe culverts are in good condition, only extension of pipes of short diameter were planned. In other words,existing pipe culverts of less than 80 cm diameter,even if they are in good condition, are wholly replaced by 100 cm diameter pipe culverts.

2) Box Culvert

A size of 2.4 m x 2.4 m concrete box culvert with head wall and aprons was applied to this study as a standard type. In case that bigger flow capacity was required, the double cell culvert paired with the said size of culverts was used. The standard drawing of box culvert is shown in Fig. 6-6

Required locations and types of culverts were determined by comparing discharge with flow capacity, calculated by procedures described below.

3) Discharge Calculation

The discharge of respective catchment areas was calculated separating into the following two cases.

Where the catchment area is less than 50 km^2, the following Rational Formula was use:

$$Q = 0.278.C.I.A$$

where, Q = design discharge (m^3/sec)
C = run-off coefficient
I = intensity of rainfall (mm/hr)
A = catchment area (km^2)

Intensity of rainfall was determined based on rainfall intensity - duration curve for a frequency of 20 years, prepared by DOH. There are only two observatory stations, Phitsanulok and Phrae stations, which provide the said curve in the study area. They were applied to the study routes dividing into two groups as follows:

Application of Rainfall Intensity - Duration Curve

Observatory Station	Route No.
Phitsanulok	No.6, No.8, No.11, No.12, No.14, No.15, No.19, No.20, No.23
Phrae	No.25, No.27, No.29, No.30, No.31

Run-off coefficient was determined by the graph used by DOH, which is corresponding to the rainfall intensity and the topographic features in the catchment area. Run-off coefficients by topography against the rainfall intensities of 50 to 150 mm per hour are shown below.

Run-Off Coefficient (Intensity 50 mm/hr - 150 mm/hr)

Topography	Run-off Coefficient
- Steep, barren, impervious surface	0.7 - 0.9
- Steep forest and steep grass meadow	0.4 - 0.7
- Forest lands of moderate to steep slopes	0.2 - 0.4
- Flat pervious surface	0.1 - 0.2

Catchment areas were measred based on 1/50,000 scale of topographic maps.

Where the catchment area is more than 50 km^2, the following Snyder's Equations were applied to obtain the design discharge:

$$Q = 0.001\ qp\ (\alpha \cdot i - \phi)\ tr \cdot A$$

where, Q : design discharge (m^3/sec)

qp : peak discharge (l/sec/km^2)

α : reduction point rainfall intensity for large catchment area

i : rainfall intensity (mm/hr)

ϕ : infiltration capacity (mm/hr)

tr : critical duration of rainfall (hour)

A : catchment area (km^2)

In the above equation, the peak discharche (qp) is expressed by the following formaula:

$$qp = \frac{kp}{tr}$$

where, kp : peak discharge coefficient

The critical duration of rainfall (tr) is expressed by the following equation:

$$tr = \frac{1.5}{5.5} \times L^{0.6} \times L_1^{0.3}$$

where, L : length of stream from source to structure site (km)

L_1 = Lc/L ; Lc is the length of stream from the point nearest the center of gravity of the catchment area to the structure site (km)

In the Snyder Equation, α is given by the curves developed by the U.S. Weather Bureau and kp and ϕ may be taken from Ven Te Chow's "Hand book of Applied Hydrology"

4) Capacity Calculation

The flow capacity of box culvert and bridge was calculated by the following Manning's Formula:

$$Q = AV$$

$$V = \frac{1}{n} R^{2/3} I^{1/2}$$

where, Q : Flow capacity (m3/sec)

A A : Cross sectional area of drainage structure (m^2)

V : Mean velocity (m/sec)

n : Nanning's roughness coefficient; 0.02 for box culverts and 0.05 for waterway at bridge sites

R : Hydraulic radius (m)

I : Slope of the drainage facility

The results of the hydrological analysis mentioned above are shown by each study route in Volume 2.

6-3-5 Bridge Design

1) General

Number and length of the proposed bridges, replacement of the existings timber bridges and new construction, are shown below, by each study routes.

Number and Length of Proposed Bridge

Route No.	Replacement		New Construction		Total	
	Number	Length(m)	Number	Length(m)	Number	Length(km)
No.6(6-4)	1	10.0	2	29.0	4	39.0
No. 8	11	230.0	2	36.0	13	266.0
No.11	-	-	-	-	-	-
No.12	5	107.0	-	-	5	107.0
No.14	2	29.0	-	-	2	29.0
No.15	-	-	-	-	-	-
No.19	1	40.0	-	-	1	40.0
No.20	2	36.0	1	20.0	3	56.0
No.23(23-2)	1	45.0	8	167.0	9	212.0
No.25	22	397.0	6	143.0	28	540.0
No.27	3	91.0	-	-	3	91.0
No.29	3	54.0	-	-	3	54.0
No.30	11	202.0	-	-	11	202.0
No.31	17	280.0	21	292.0	38	572.0

Most of the existing bridges are timber bridges with widths range from 2.5 to 6.0 m. Some of then are remained broken in their conditions. All these existing timber bridges have no bearing capacity to design loading of HS-20 and thus were planned to be replaced by permanent concrete bridges or concrete box culverts.

New bridges were planned mostly for the new road sections based on the results of the field reconnaissance. In the improvement sections they were also planned at the selected sites where bridges are required.

2) Bridge Length

The length of bridges was determined through the hydrological analysis of discharge and flow capacity as described in 6-3-4.

3) Super-Structure

A majority of super-structure of the DOH's Standard design is made of reinforced concrete or pre-stressed concrete sturcture. Major types of super-sturcture and relative span length applicable are as follows:

Major Types of Super-Structure

Types of Super-Structure	Applicable Span length (m)	Remarks
Reinforced Concrete Slab (RC-Slab)	5 - 10	Thickness of Slab 32 - 53 cm
Precast Pre-stressed Concrete Beam(PC-Beam)	5 - 10	Height of Beam 16 - 35 cm
Pre-stressed Concrete Box-Girder (PC-Box Girder)	up to 21	Rectangle-shaped 1.0 x 0.7 m
Pre-stressed Concrete Girder (PC-Girder)	20 and more	I - shaped

Both RC-Slab and PC-Beam bridge are suitable for short span bridge which no salient differences in construction cost per unit length. On the other hand, PC-Box Girder and PC-Girder are appropriate for long span bridge. The following two types of concrete bridge were applied in this study.

RC-Slab bridge for short span bridge
PC-Girder bridge for long span bridge

In principle, the long span bridge was planned over the deep rivers where the construction of sub-structures was supposed rather difficult. While, short span bridge was planned at the places where the rivers are relatively shallow.

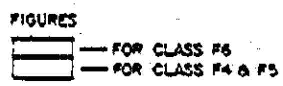
Among the proposed roads, only one bridge, about 65 m in length, crossing over the Li river on Study Route No.27 was designed as a long span bridge and all other bridges as a short span bridge.

4) Sub-Structure

Careful observation on the conditions of sub-soil and data collection on the foundation types of existing and on-going bridges in the study area were carried out. From the results of the above works, it was found that the pile foundation with 10 to 12 m long concrete piles are commonly used and are suitable for sub-soil conditions in the study area. The pile foundation with 12 m concrete piles was, therefore, applied to the design of all proposed bridges.

All planned bridges have 7.0 m wide carriageway and 1.0 m sidewalks on both sides. The standard drawing and the drawing of long span bridge are shown in Fig. 6-7 and 6-8.

Figure 6-1 TYPICAL CROSS SECTION - 1
(EXISTING ROAD SECTION)



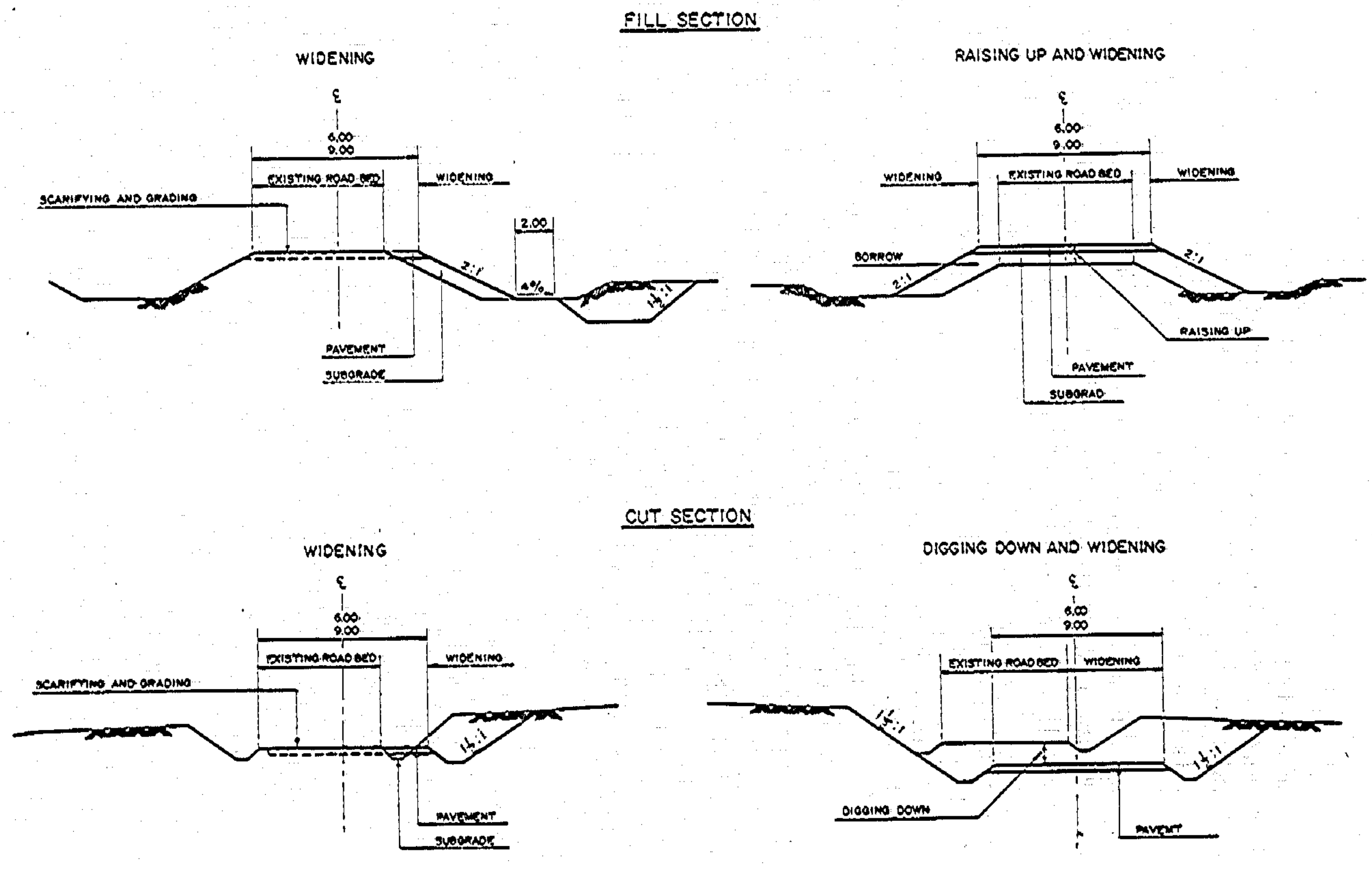


Figure 6-1 TYPICAL CROSS SECTION-2
(NEW ROAD SECTION)

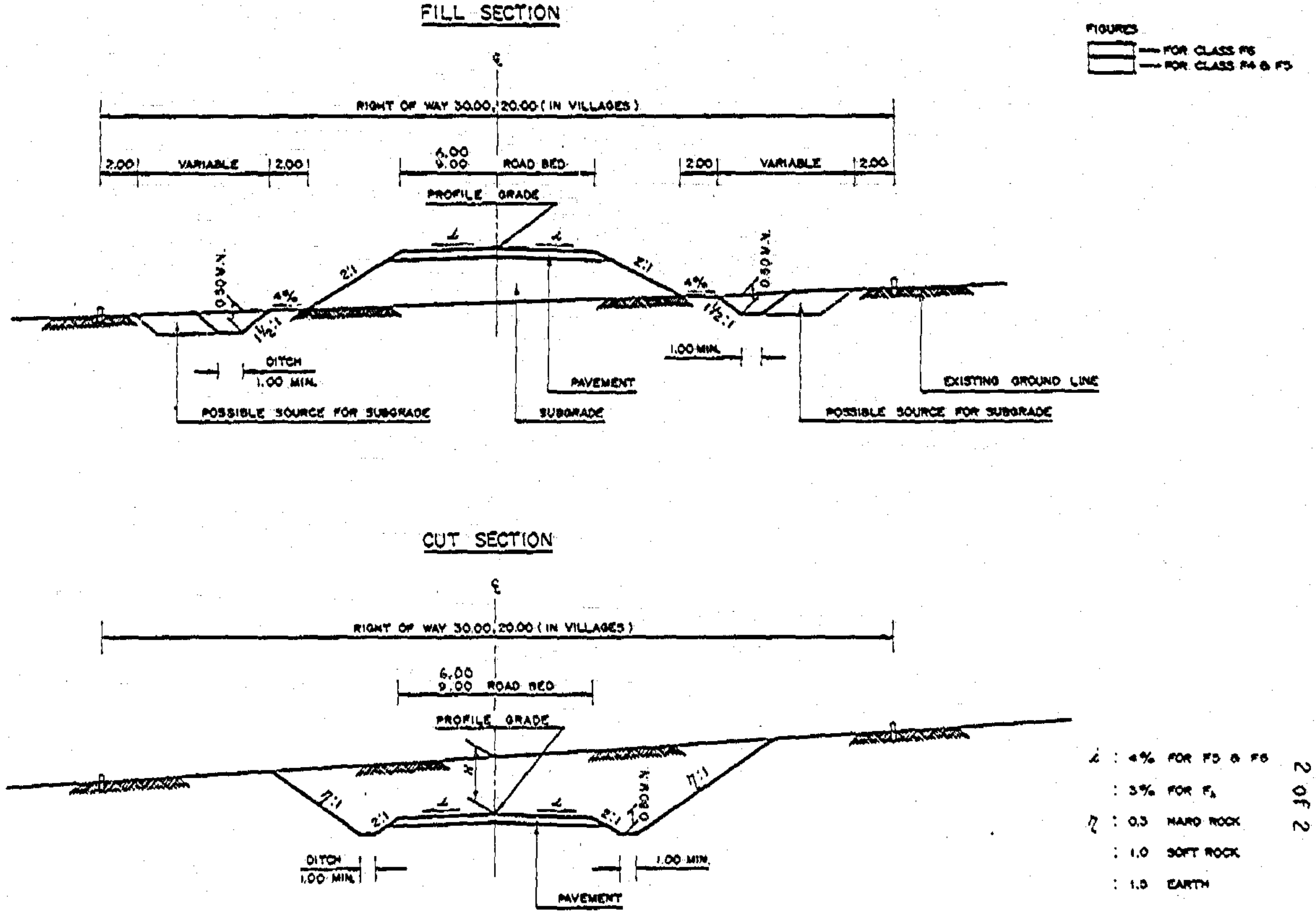


Figure 6-2 TRAFFIC ANALYSIS CHART

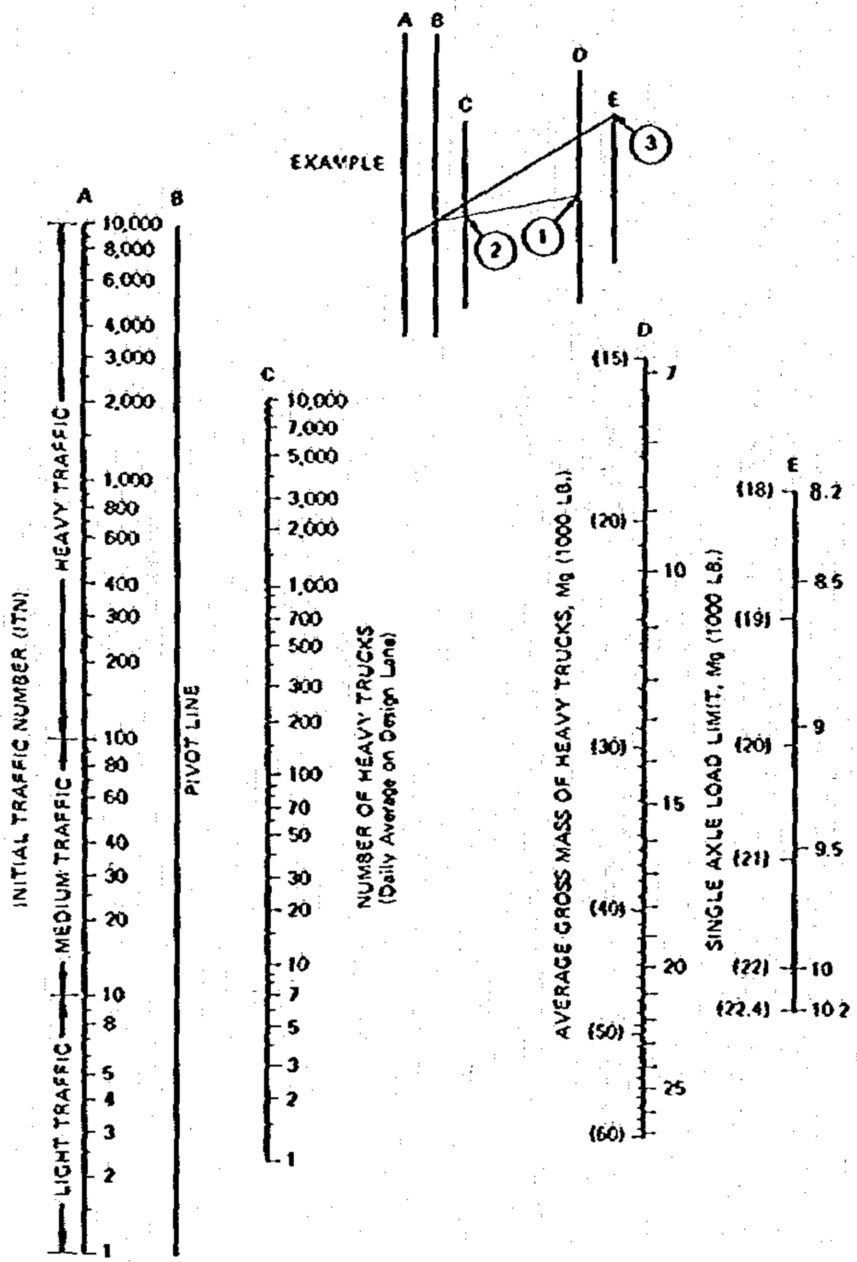


Figure 6-3 THICKNESS DESIGN CHART

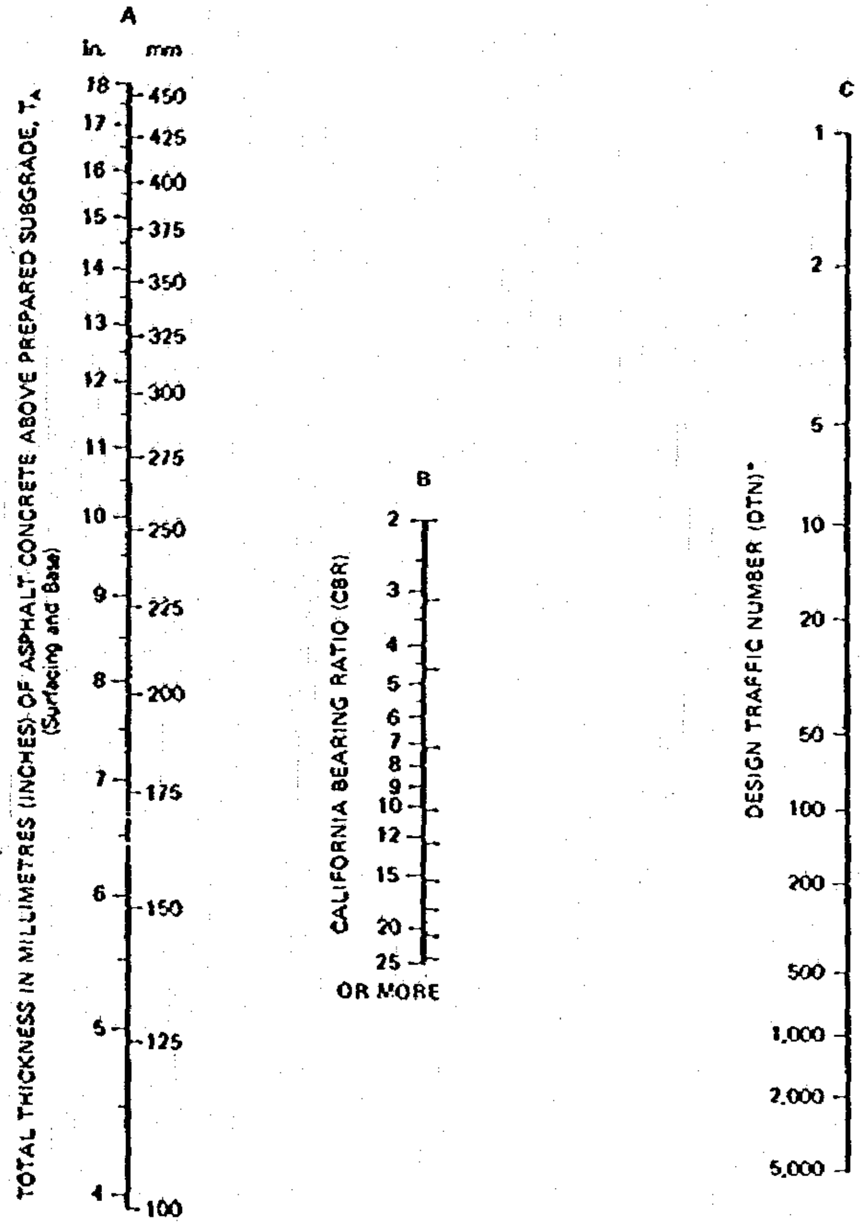
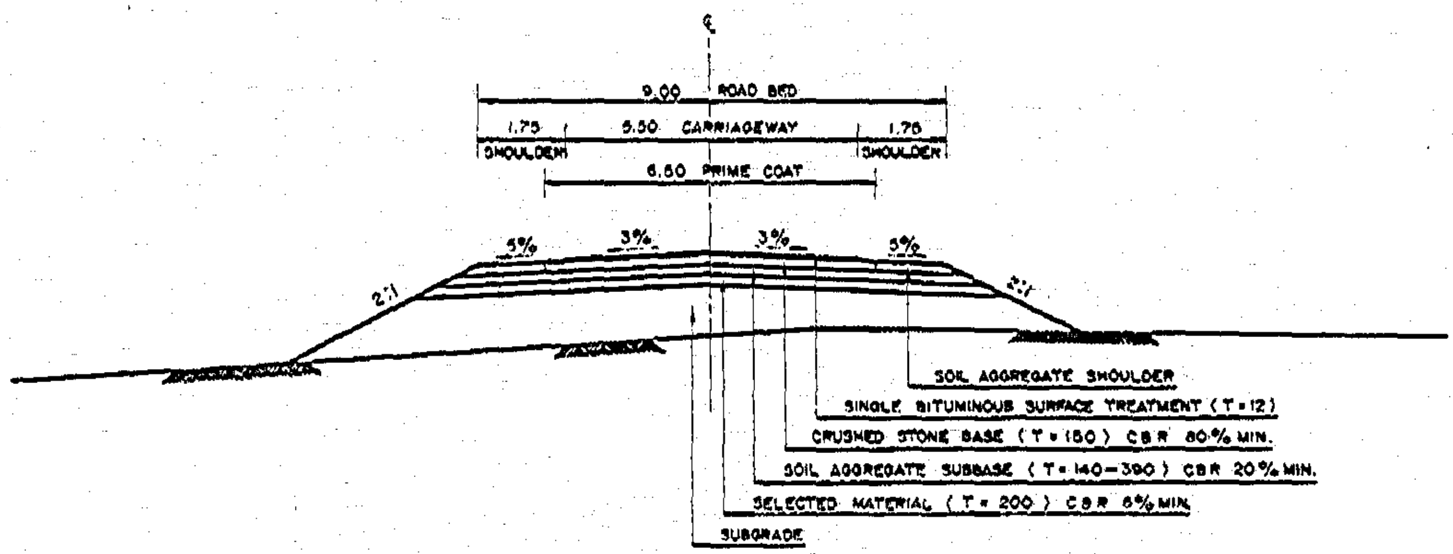


Figure 6-4 TYPICAL PAVEMENT STRUCTURE

SINGLE BITUMINOUS SURFACE TREATMENT (SBST) ROAD (CLASS F4)



SOIL AGGREGATE SURFACED ROAD (CLASS F5 & F6)

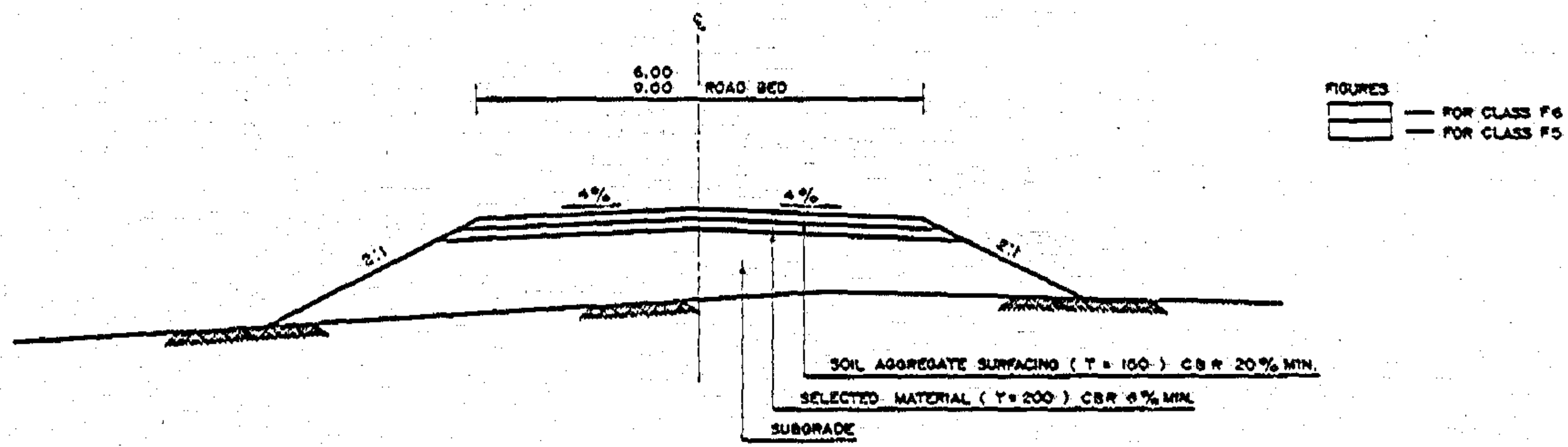


Figure 6-5 TYPICAL DESIGN -1 (PIPE CULVERT)

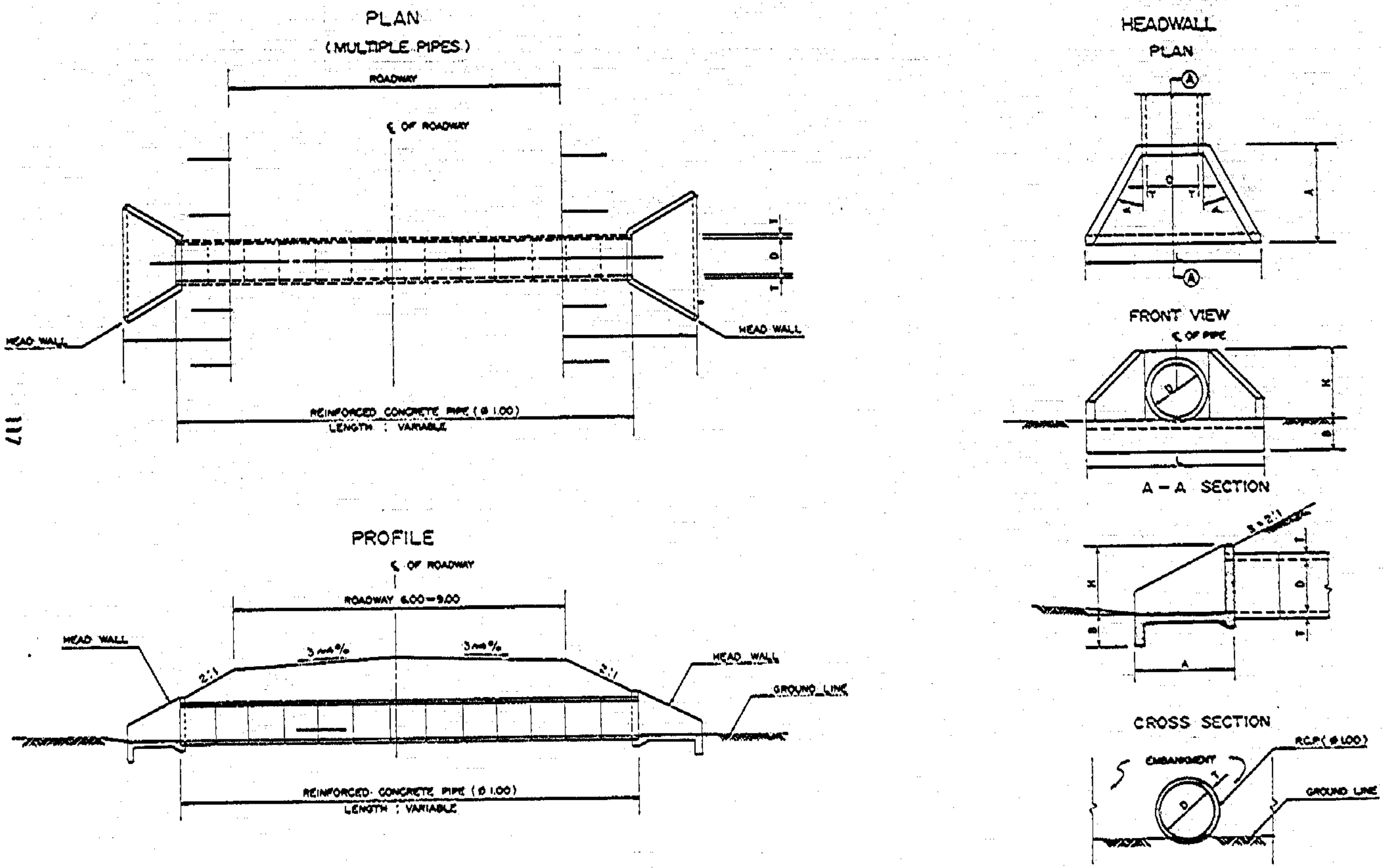


Figure 6-5

Figure 6-6

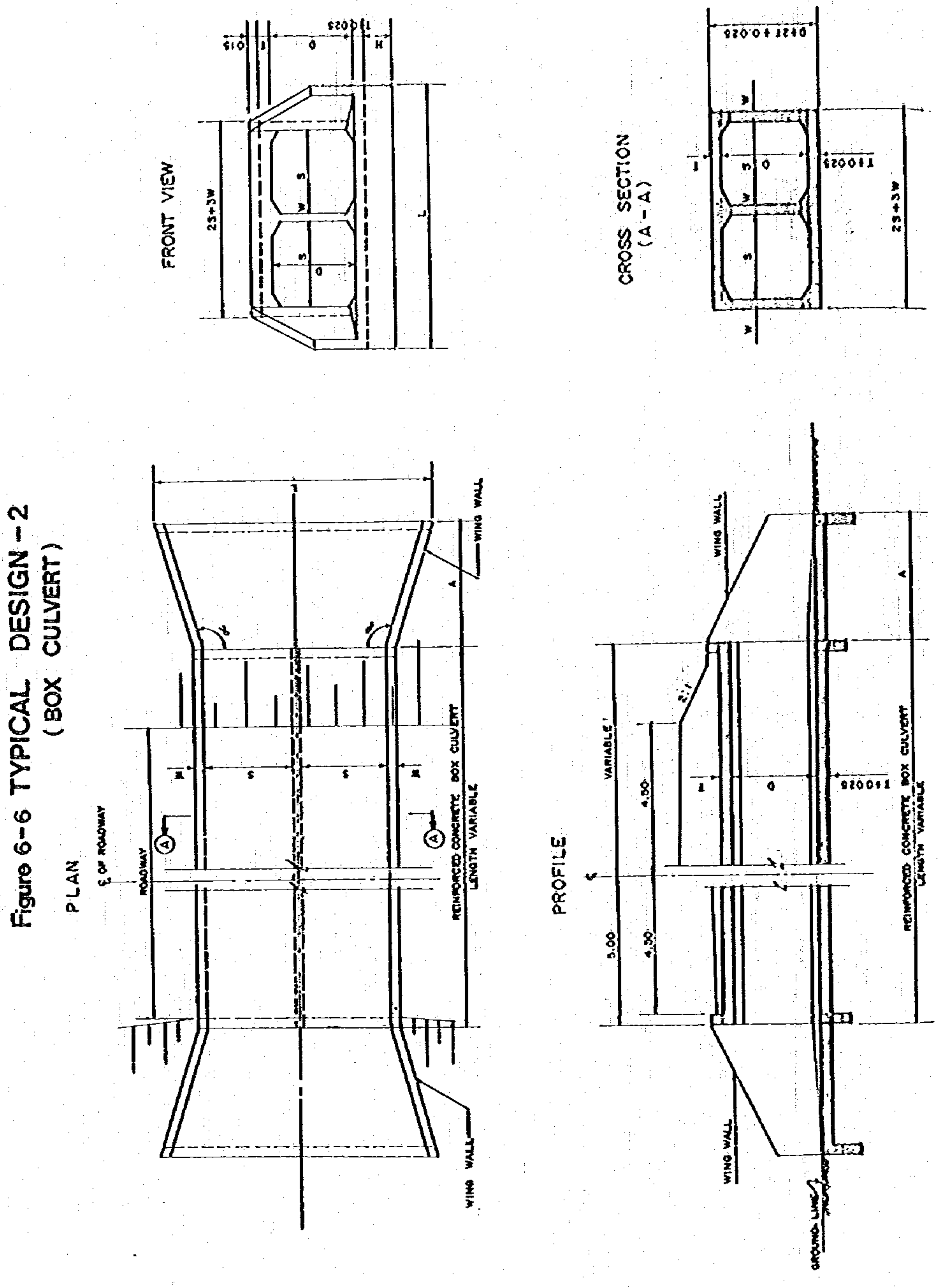


Figure 6-6 TYPICAL DESIGN - 2
(BOX CULVERT)
PLAN
PROFILE
FRONT VIEW
CROSS SECTION
(A - A)
WING WALL
WING WALL
REINFORCED CONCRETE BOX CULVERT
LENGTH VARIABLE
ROADWAY
VARIABLE
2S+3W
GROUND LINE

Figure 6-7 TYPICAL DESIGN-3 (BRIDGE)

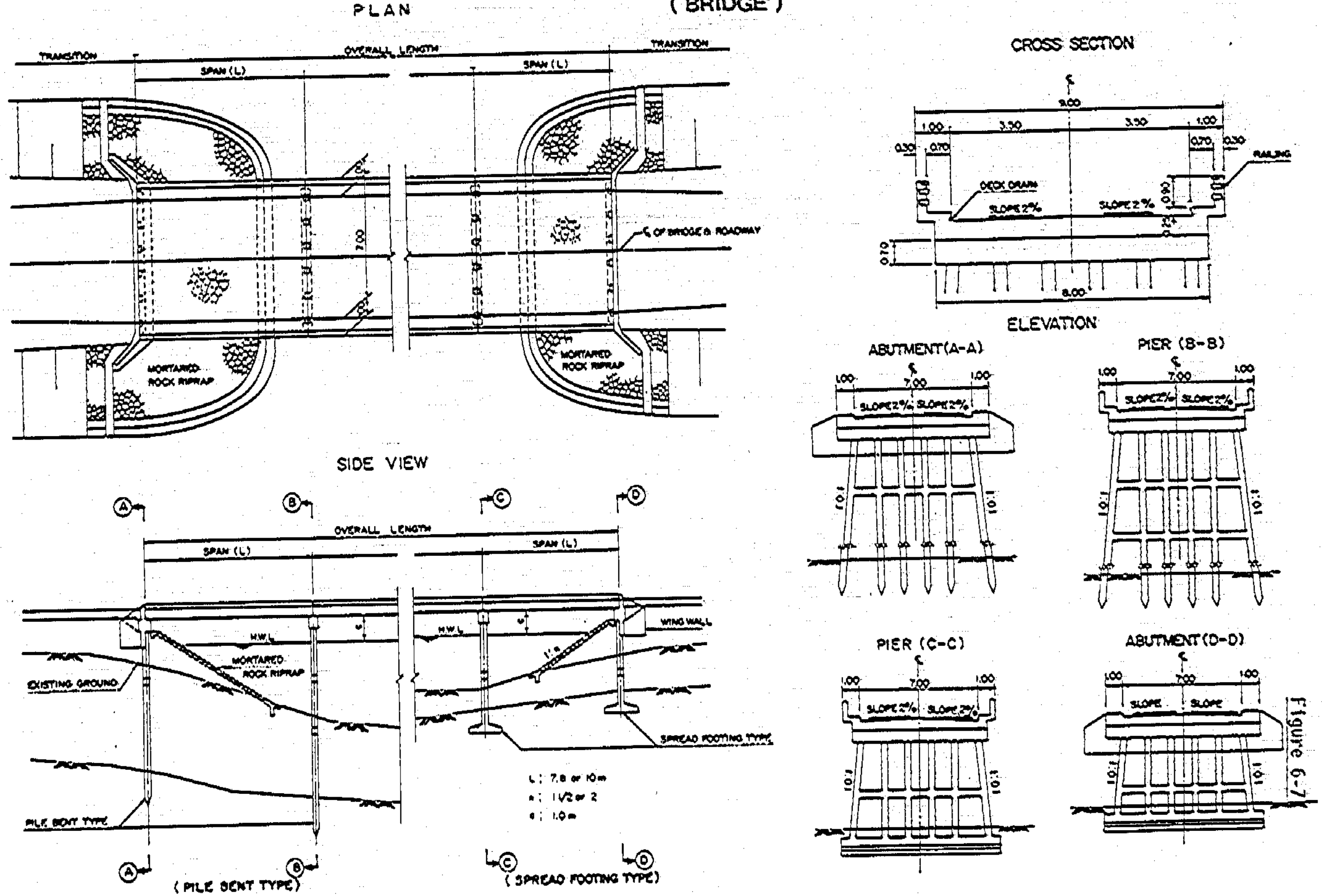


Figure 6-7

Figure 6-8

Figure 6-8 LONG SPAN BRIDGE AT LI RIVER
(STUDY ROUTE NO. 27)

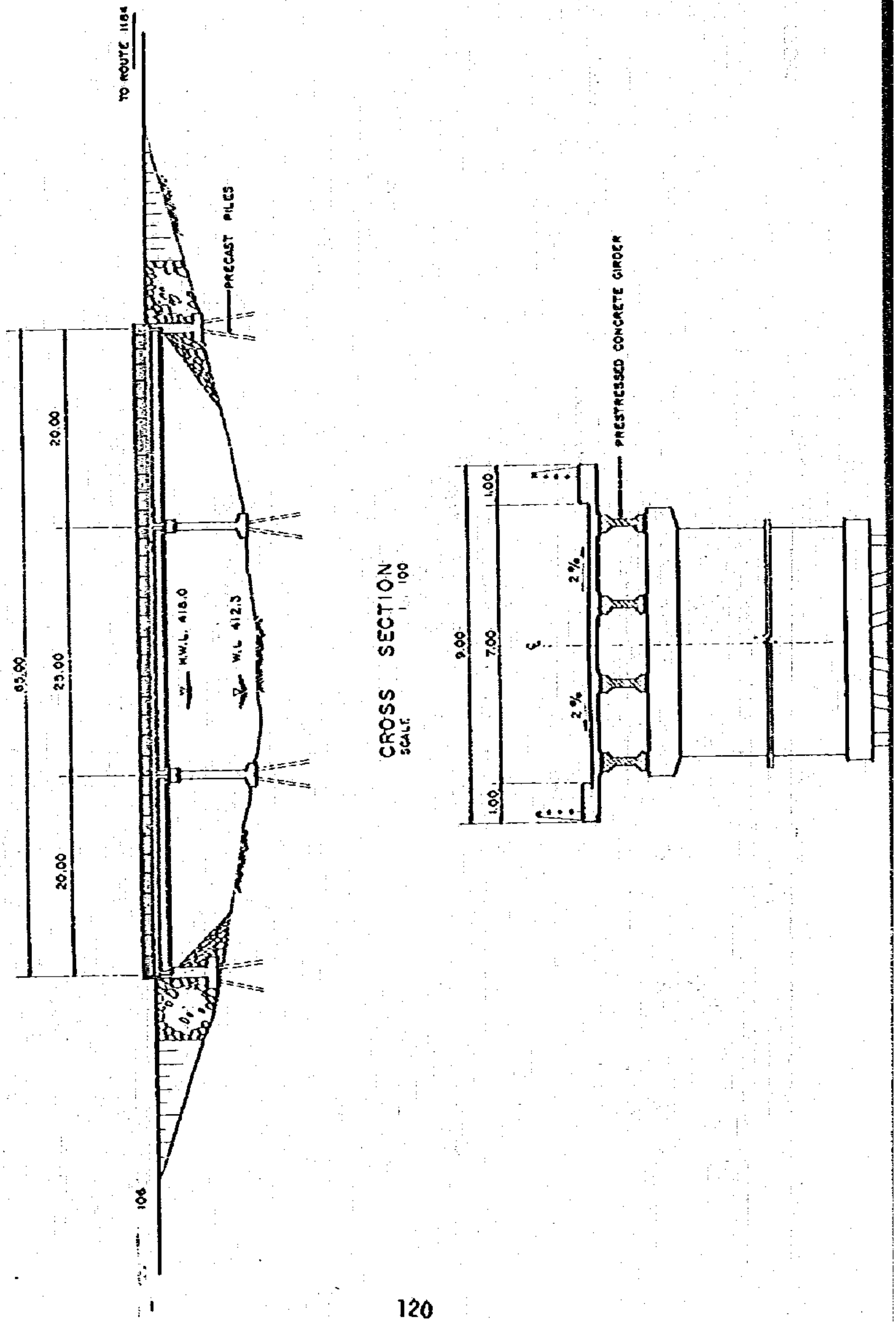


Table 6-1 MINIMUM DESIGNSTANDARDS FOR PROVINCIAL ROADS

1. Access control: When designated under the Highway Law.
2. Highway crossing: Grade separation only after proven viable by economic feasibility calculations.
3. Railroad crossing: Grade separation only after proven viable by economic feasibility calculations.
4. Bridge width (1): 8 m. for F_1 & F_2, 7 m. for F_3 to F_6
5. Vertical clearance = 4.50 m
6. Design bridge loading = HS 20
7. Pavement design shall be based on the accumulated number of equivalent axle load predicted during the first 7-year after construction.
8. Follow AASHO recommendation for any design details not separately specified.

Class		F_D	F_1	F_2	F_3	F_4	F_5	F_6
Average Daily Traffic	(5)	Above 8,000	4,000-8,000	2,000-4,000	1,000-2,000	300-1,000	← Below 300 →	
Design Speed k.p.h.	(2)							
Flat and moderately rolling				← 70 - 90 →		60-80		← 60 →
Rolling and hilly				← 55 - 70 →		45-60		← 45 →
Mountainous				← 40 - 55 →		30-45		← 30 →
Maximum Gradient %	(3)							
Flat and moderately rolling				← 6 →		8		← 12 →
Rolling and hilly				← 8 →		10		← 12 →
Mountainous				← 10 →		10		← 12 →
Suggested Surface Type			← High →	← Intermediate →		← Low →	← Soil Aggregate →	
Width of Carriageway m.		Divided 2 @7.00	7.00	6.50	6.00	5.50	9.00	6.00
Width of Shoulder m.		2.50	2.50	2.25	2.00	1.75	Travelled way	Travelled way
Right of Way m.	(4)			← 40 - 60 →				← 20 - 40 →

Explanatory Notes

(1) Any F_D, F_1 or F_2 road that planned to be raised to National Highway system in the future, bridges less than 15 m. long shall be to the full roadbed width.

(2) Design speed may be relaxed in exceptional circumstances on account of right of way difficulties or mountainous terrain.

(3) Refer to the AASHO Policy on Geometric Design of Rural Highways to relate desirable grade lengths, climbing lanes, etc.

(4) May be reduced in urban or semi-urban conditions at the discretion of the Department provided that a suitable cross section including service roads, where necessary, is obtainable.

(5) Class F_D roads are required on the basis of a 7-year ADT projection or be justified by economic feasibility calculations. Class F_1 to F_3 roads are required on the basis of a 15-year ADT projection. Class F_4 roads have a projected ADT more than 300 in 7 years and less than 1,000 in 15 years. Class F_5 roads have a projected ADT less than 300 in 7 years and more than 300 in 15 years. Class F_6 roads have a projected ADT less than 300 in 15 years.

CHAPTER 7

CONSTRUCTION AND MAINTENANCE COSTS

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CONSTRUCTION AND MAINTENANCE COSTS

7-1 CONSTRUCTION WORK QUANTITIES

Construction work quantities on major work items were calculated on the basis of the engineering studies performed in the preceding sections. The major construction work comprises the following 16 items:

a) Clearing and grubbing
b) Roadway excavation - classified earth
c) Roadway excavation - classified soft rock
d) Embankment - side borrow method
e) Embankment - borrow pit material
f) Embankment - selected material
g) Subbase - soil aggregate
h) Base - crushed rock
i) Shoulder - soil aggregate
j) Asphaltic prime coat
k) Single bituminous surface treatment
l) Asphaltic concrete
m) R.C. pipe culvert
n) R.C. box culvert
o) R.C. bridge - short span
p) P.C. bridge - long span

The area of land acquisition attributable to the widening of existing road and new road construction was also calculated. The area was classified into developed land and less developed land, on the basis of data obtained during field surveys.

The cost of land acquisition for DOH roads was not considered as it has been the usual practice for DOH rural roads. Width of right-of-way for roads which belong to the agencies other than DOH was considered to be 30 meters except for road in villages where it was considered to be 20 meters.

The calculated work quantities and land area by Study Route are presented in the respective section of route description in Volume 2.

7-2 CONSTRUCTION UNIT RATE

The unit rates as of 1981 for major construction work items were studied. In the analysis of the unit rates, due consideration was paid to the hauling charge of construction materials from the source to the construction site. Materials such as bitumen, cement and reinforcing steel bars were considered to be transported to the project site from Bangkok.

The selected material for embankment and laterite for subbase course and shoulder were considered to be procured within the reasonable distance from construction site according to the results of soil and material tests.

The rock quarries available for such work items as SBST, base, asphaltic concrete and structures are limited in numbers around the proposed roads. Their locations are indicated in the respective sections of Volume 2. The shortest routes for hauling of rock materials were examined referring to the existing road network around the proposed road.

Calculated unit rates were compared with those in bids for highway projects located in the similar geographical areas.

The unit rates for the major work items are shown in Table 7-1.

7-3 CONSTRUCTION COST

Construction costs of major work items were calculated by applying the unit rates to the estimated work quantities. The cost of miscellaneous works such as slope protections, concrete ditches, guard rails, traffic signs and marking etc. were estimated at 7 percent of total cost of major work items referring to the similar type of highway projects.

Added to these direct costs were physical contingencies (15%), design and construction supervision (10%) and land acquisition cost to obtain a total road cost.

The construction cost together with the land acquisition cost are given in Table 7-2 by Study Route.

Economic construction cost to be used in the economic evaluation was calculated by deducting the tax component of each work item from the financial construction cost. The percentages of tax component included in the unit rate are shown in Table 7-1. They were determined referring to the previous studies on the similar type of construction in Thailand, under the assumption that the construction would be performed by local contractors. Economic construction costs are shown in sections of respective route description in Volume 2.

7-4 MAINTENANCE COST

The annual routine maintenance costs for earth, laterite, SBST and asphaltic concrete road were estimated. In agreement with the practice generally accepted, the formulae derived comprise fixed cost and traffic dependent cost. Though little information was available of the correlation between road maintenance cost and traffic volume by surface type, the following formulae were elaborated from the analysis of the DOH maintenance budget and equipment revolving fund for 1982, together with reference to maintenance studies.1/

Annual Routine Maintenance Cost

Surface Type	Annual Maintenance Cost* (Baht/km)
Earth	12,000 + 75·V**
Laterite	21,000 + 26·V
SBST	27,000 + 11·V
Asphaltic Concrete	30,000 + 4·V

Note: * : Economic Cost
** : V means AADT (Annual Average Daily Traffic)

The road maintenance benefits are considered to be the difference of maintenance costs in the networks related to each proposed road between with and without project construction.

1/ "Study of Highway Maintenance and Equipment Needs" KAMPSAX, March, 1976.

7-5 CONSTRUCTION SCHEDULE AND COST DISBURSEMENT

To estimate the yearly disbursement of construction cost, construction schedule was worked out for each study route. Construction period was estimated from work items and their respective work quantities and also from length of project road. Rainy period of about five-months was also taken into account, considering the work efficiency in that period.

Each project road was classified into either of the construction period of two-years or three-years depending on the project scale. Typical construction schedules for two-years project and three-years project are presented in Figure 7-1.

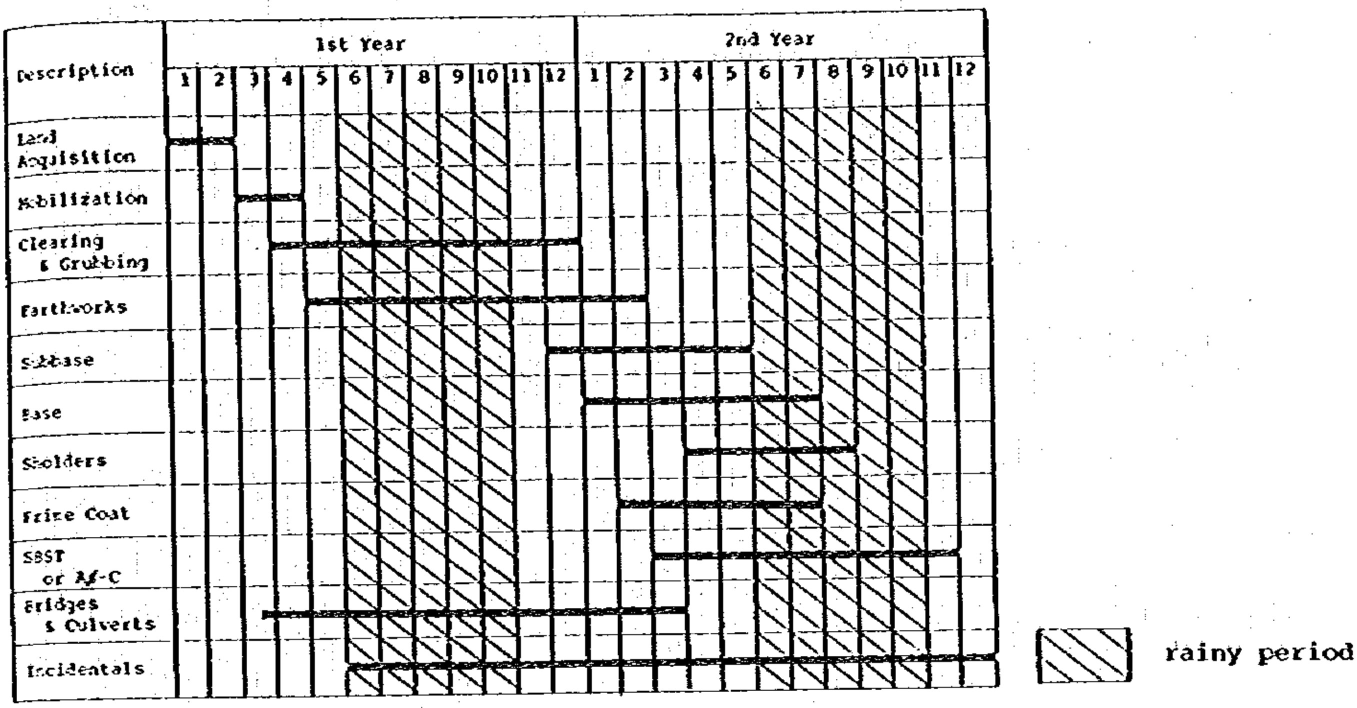
Yearly disbursement of construction cost was calculated on the basis of the construction schedule as set out above.

In the estimation of yearly disbursement of financial cost, annual price escalation rates were assumed as 15% (1981 - 83) and 10% (1983 - 87) for domestic component, and 7.5% (1981 - 83) and 6.5% (1983 - 87) for foreign component.

In Table 7-3, summary of yearly cost disbursement is given dividing it into local and foreign currency component, on condition that foreign portion shares 48% of the total cost before escalation.

Figure 7-1 TYPICAL CONSTRUCTION SCHEDULE

(2-Year Type)



(3-Year Type)

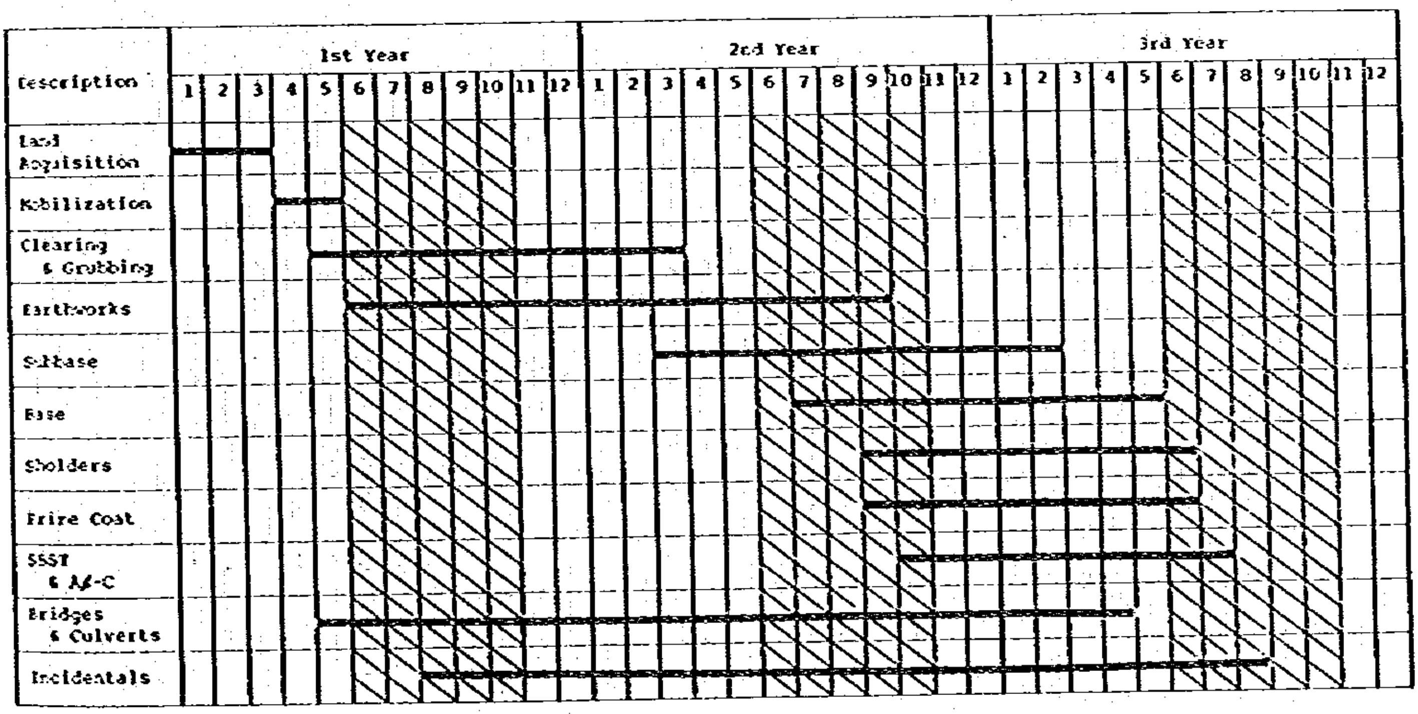


Table 7-1 UNIT RATES FOR MAJOR WORK ITEMS

Description	Unit of Quan-tity	Financial Unit Rate (Baht)	Tax Compo-nent (%)	Remarks
Clearing & Grubbing	ha	17,000	9	
Roadway Excavation - Classified Earth	m^3	36	10	
Roadway Excavation - Classified Soft Rock	m^3	80	10	
Embankment - Side Borrow Method	m^3	45	9	
Embankment - Borrow Pit Material	m^3	60	9	
Embankment - Selected Material	m^3	80	11	
Subbase - Soil Aggregate	m^3	106	11	
Base - Crushed Rock	m^3	309-416	8	
Shoulder - Soil Aggregate	m^3	170	11	
Asphaltic Prime Coat	m^2	10.8 - 11.3	8	
Single Bituminous Surface Treatment	m^2	27.6-28.6	10	t = 12 mm
Asphaltic Concrete	m^2	97	10	t = 50 mm
R.C. Pipe Culvert	m	2,400-2,700	8	ø 100, with Headwalls
R.C. Box Culvert	m	18,000-18,700	10	1·(2.4x2.4) with Aprons
R.C. Bridge - Short Span	m	39,500-41,400	11	Slab Bridge Span 5- 10 m
P.C. Bridge - Long Span	m	70,200	11	P.C. Girder, span 20 - 30 m
Land Acquisition - Highly Developed Land	ha	50,000		
Land Acquisition - Less Developed Land	ha	15,000		

Table 7-2 SUMMARY OF CONSTRUCTION COST

(10^3 Baht)

Study Route Number	Road Class	Length (km)	Financial Cost 1/	Economic Cost
6-4	F4	46.0	110,306	100,384
8	F4	53.5	128,674	116,850
11	F4	6.8	14,350	13,095
12	F4	13,0	42,275	38,430
14	F4	21.0	38,280	34,815
15	F4	8.3	17,634	16,040
19	F4	14.4	33,351	30,460
20	F5	15.7	21,857	19,719
23- 2	F4	51.9	153,377	139,509
25	F4	54.0	139,607	126,010
27	F6	16.6	21,742	19,520
29	F4	13.2	22,570	20,450
30	F4	47.8	110,063	99,757
31	F4	55.0	131,294	118,541
TOTAL		417.2	985,380	893,580

Note: 1/ excluding price contingency

Table 7-3 SUMMARY OF YEARLY COST DISBURSEMENT 1/

(Million Baht)

Study Route No.	1984 L/C 2/	1984 F/C 3/	1985 L/C	1985 F/C	1986 L/C	1986 F/C	Total L/C	Total F/C	Total Total
6 (6-4)	15.2	12.2	41.7	32.6	27.5	20.8	84.4 (3.68)	65.6 (2.85)	150.0 (6.53)
8	17.7	14.3	48.7	38.0	32.1	24.2	98.5 (4.29)	76.5 (3.34)	175.0 (7.63)
11	-	-	3.2	2.6	8.3	6.4	11.5 (0.51)	9.0 (0.39)	20.5 (0.90)
12	-	-	9.6	7.5	24.6	18.6	34.2 (1.49)	26.1 (1.14)	60.3 (2.63)
14	-	-	8.7	6.8	22.3	16.9	31.0 (1.35)	23.7 (1.03)	54.7 (2.38)
15	-	-	4.1	3.1	10.3	7.7	14.4 (0.63)	10.8 (0.47)	25.2 (1.10)
19	-	-	7.6	5.9	19.4	14.7	27.0 (1.18)	20.6 (0.90)	47.6 (2.08)
20	-	-	5.0	3.8	12.8	9.7	17.8 (0.78)	13.5 (0.58)	31.3 (1.36)
23 (23-2)	21.2	17.0	58.0	45.3	38.3	29.0	117.5 (5.12)	91.3 (3.98)	208.8 (9.10)
25	19.2	15.5	52.8	41.2	34.9	26.4	106.9 (4.66)	83.1 (3.62)	190.0 (8.28)
27	-	-	4.9	3.8	12.6	9.6	17.5 (0.76)	13.4 (0.58)	30.9 (1.34)
29	-	-	5.1	4.1	13.1	10.0	18.2 (0.79)	14.1 (0.61)	32.3 (1.40)
30	15.1	12.2	41.6	32.5	27.5	20.8	84.2 (3.67)	65.5 (2.85)	149.7 (6.52)
31	18.1	14.6	49.6	38.8	32.8	24.8	100.5 (4.38)	78.2 (3.41)	178.7 (7.79)
Total	106.5	85.8	340.6	266.0	316.5	239.6	763.6 (33.29)	591.4 (25.75)	1355.0 (59.04)

Note: 1/ including price contingency
2/ Local Currency
3/ Foreign Currency
( ) Million US$ Equivalent (1 US$ = 22.63 Baht)