CHAPTER 6 PC SLEEPER, RAIL WELDING AND BALLAST

CHAPTER 6 PC SLEEPER, RAIL WELDING AND BALLAST

6-1 General

This project proposes to improve track facilities consisting of the following:

- Rails and fastenings
- Sleepers
- Ballast

The quality and form of track materials differ according to the class and conditions of the track where they are to be used.

As previously stated in the Report on the Long Term Modernization Program (Chapter 5), the Improvement Project for the Mandalay line proposes to replace the existing track materials with those conforming to a new criteria, and to install the required quantities of ballast and thereby reinforce the track structure.

The Mandalay line has a total length of 620 km (M 320.5), of which 362 km (M 225) is of double track, and a large quantity of materials will be required for the track improvement.

The track materials are presently manufactured by BRC or by other manufacturers, however, the quantities are small and BRC is currently having difficulties to meet its own needs.

For the project proposed where rails are welded to fabricate long-welded rails and wood sleepers will be replaced with PC sleepers, the length of the sections to be improved or the total length of rail sections to be improved will be assessed.

In the analysis the condition of the existing tracks, such as curved tracks, bridges, level crossings, length and location of station yards, etc. will have a bearing on the length of track improvements, especially for the length and sections to be improved to long-welded rail.

Based on the conditions described, the data presented in Table 6.1.1, the construction period and the materials on hand, etc. will determine the overall length of track improvement work.

In order to procure the track improvement materials, it will be necessary to construct additional plants in addition to the factories presently owned by BRC to manufacture the materials required for the project. The new plan facilities to be constructed will be the base rail welding shop, the site welding in the field, the PC sleeper factories, the crusher plant for ballast at the quarries, all of which will be described further in the following paragraphs.

The track improvement work cannot be implemented if any one of the components of rail, sleeper, ballast cannot be supplied (especially in the case of long-welded rails),and it will be absolutely necessary for BRC to construct the plant facilities and to obtain the technical transfer of the necessary techniques to operate the plants.

Table 6.1.1 List of Quantity for Alternative Plans

Type of Track	Construction Condition			Alternative plan		
	Rail	Sleeper	Ballast	A	B	C
Long-welded rail (KM)	Replacement	PC	New	610	490	410
Jointed rail (KM)	Replacement	PC	Existing	145	265	25
	Replacement	Wood	Existing	-	-	320
Jointed rail (KM)	Replacement	Wood	Existing	45	45	45
Existing rail (KM)	Remains	PC	Existing	177	27	27
Existing rail (KM)	Remains	Wood	Existing	10	160	160
Total (KM)				987	987	987
PC sleepers (1,000 pieces)				1,410	1,180	700
Ballast (1,000 m^3)				630	590	530

Note: Refer to Section 5-2-1, (3), on the concept alternative plans A, B and C.

6-2 PC Sleeper

6-2-1 Amount of PC Sleepers Required

The Track Improvement Project proposes to replace the existing wooden sleepers with PC sleepers, and the amount required to be produced are as follows:

Table 6.2.1 Number of Sleeper Required for the Mandalay Line

Track Section	Number of Sleepers Alternative Plan A	 B	 C
Rangoon - Pegu	215,000	215,000	215,000
Pegu - Toungoo	551,000	445,000	205,000
Toungoo - Pyinmana	280,000	227,000	130,000
Pyinmana - Thazi	178,000	143,000	60,000
Thazi - Mandalay	186,000	150,000	90,000
Total	1,410,000	1,180,000	700,000

6-2-2 Production of PC Sleepers

There are presently two methods of production of PC sleepers:

- Pretension method
- Post-tension method

PC sleepers are produced in accordance with the above two methods, and there seems to be very little difference in the finished product, however, the following differences can be given in the method of production:

- In the pretention method compression is applied to the concrete by the adhesion of the concrete to the prestressed wires, whereas, in the post-tension method the compression does not resort to the adhesion of the concrete to the prestressed bars.
- Steel wires are used for the pretension method, whereas, high-strength alloy steel bars are used in the post-tension method.
- In the pretension method the steel wires are stressed prior to placing of the concrete, whereas, in the post-tension method the

steel bars are stressed after the concrete has been placed and hardened.

As stated in the above there are differences in the materials and the method of production which requires the use of different plant facilities.

A general description of the plant facilities for the two types of PC sleepers is as follows:

(1) Pretension method

1) Method of production

Depending on the method placing concrete, the following methods are presently in use:

Long-Line Method ——┬—— Fixed Bench
　　　　　　　　　　 └—— Transfer Bench

Individual Mould Method

The above methods are described in the following:

2) Long-line method

This is the general method of producing PC sleepers by the pretension method, and the casting moulds are laid longitudinally in a long line with a space of 15 cm to 20 cm between them. The PC wires are placed in tension with the ends fixed. When the ends of the PC wires are secured to abutments fixed on the ground, it is called the Fixed Bench System, and when the PC wires anchors are fixed to the sleeper, as for bridge beams, it is called the Transfer Bench System.

In the Fixed Bench System the abutments can be placed up to distances of 100 m, but for the Transfer Bench System there is a limit to the distance of the abutments.

3) Individual mould method

In the Individual Mould Method the PC wires are prestressed before the concrete is placed in the mould, after which the wires are anchored to the mould. Thus, the mould will not have to be placed lengthwise but can be placed sideways. In the Individual Mould Method the moulds will not have to be placed in a long line, but since the moulds will be stressed they will have to be constructed sturdily to bear the loads and provided with special fittings for securing the PC wires, and are not used in Japan.

4) Selection of the method

The three methods of production described above have their merits and demerits but in consideration of the large quantities required, the period of production, production plant sites, and other factors, the long-line pretension method with the fixed bench system is recommended. A layout of the pretension fixed-bench system production plant is shown in Fig. 6.2.1. The total quantity of sleepers is 1,410,000 pieces for the Mandalay Line, and the number of sleepers required by section is given in Table 6.2.1. The daily production rate per plant is set at 200 pieces. The plant layout is as shown, and the number of moulds required is (35 x 3) x 4 = 420 each.

The reason for this quantity is due to the setting up of one set each in (A Group) and (B Group) for the (35 x 3) x 2 rows, and using the moulds alternately.

It is recommended to construct several PC sleeper plants between Rangoon and Mandalay, and to relocate them with the progress of the work. Thus, the plants should be constructed to be relocatable by using discarded rails for the plant building frames and other similar simple means.

5) Production sequence of PC sleepers

Day 1

A Group

- Cut PC wires and remove moulds.
  (from sleepers cast on the previous day)
- Clean moulds and apply bond breaking agent.
- Set moulds in place.
- String PC wires and apply initial tension.
- Install sleeper hardware.
- Stress PC wires.
  (by moving abutment and stress all PC wires simultaneously)
- Raise mould ends (open end) and assemble mould.

B Group

- Place concrete and cure.

Day 2

B Group

- Same as Day 1 of A Group.

A Group

- Place concrete and cure.

Although the temperature in Burma is high, steam curing is recommended to raise production efficiency, and this will accelerate the reuse of moulds and give better use.

(2) Post-tension method

1) Method of production

The post-tension method can be classified into the following three:

- After-hardening form-removal system
- Semi-spot form-removal system.
- Spot form-removal system.

In the post-tension PC sleepers, high-strength alloy steel bars are used instead of PC wires. The PC bars are prevented from adhering to the concrete and are stressed after the concrete has hardened. The concrete is compressed after the concrete has hardened.

In order to prevent the concrete from adhering to PC bars, prestressing ducts (sticks) are placed in the mould and removed after the concrete has hardened. PC bars are placed in the annular space and stressed, after which the space is grouted with mortar.

In recent methods of production, the surface of PC bars is coated with anti-corrosive polymer agents to prevent the concrete from adhering to PC bars and to place the coated PC bars at an earlier stage, and this method is called the "unbonded" method.

The "unbonded" method has the merit of not having to remove the prestressing duct (stick) during the curing stage prior to inserting PC bars, thereby reducing the production time and rendering PC bars corrosion-proof.

In the post-tension method the various methods are similar in the placing of the concrete and they differ after the placing of the concrete, where it is in the method of tensioning PC bars that the methods differ basically in the three methods.

The after-hardening form-removal system is a method where PC bars are stressed after the concrete has hardened and then the mould form is removed. In the semi-spot form-removal system the mould is removed before the concrete has reached its required strength, and the concrete is cured by other means and the concrete is compressed after it has reached the specified strength.

In contrast to the above two systems, under the spot form-removal system the mould is removed immediately after the concrete has been placed, but all other processes are the same.

2) Selection of the method

Of the above three systems, the after-hardening form-removal system does not use any special method of curing. As a consequence the reuse of moulds is the lowest but this system has the merit that concrete with a higher slump can be used, and the use of heavy concrete vibrators will not be necessary.

The other two methods require special methods of concrete curing, and the spot form-removal system requires the use of low slump concrete and it is necessary to use compactor-vibrators, but the reuse of moulds is the highest.

For this project, it is recommended to use the post-tension method with after-hardening form-removal system.

Although the reuse of mould is not as high as the other two methods, this method is recommended because the capital investment cost for the plant is the lowest and placement of concrete will be easier than the other two systems and no special technique will be required and moulds can be reused quite easily.

The plant layout for the post-tension method with after-hardening form-removal system is shown in Fig. 6.2.2. The daily production rate is 200 sleepers and is the same as the pretension method.

The number of moulds required for the post-tension method can be the same as that for the daily production rate of PC sleepers, and the reason for this is given in the following:

3) Production sequence of PC sleeper

Whole production process is in a day.

The manufacturing operation splits into two.

a) Work on PC sleeper proper

- Prestress PC bars.
- Grout annular space with mortar.
- Perform last check.
- Move to stock yard.

b) Concrete moulds

- Clean moulds and apply bond-breaking agent.
- Install rail fastening devices and other sleeper hardware.
- Install PC bars.
- Install mould ends (open ends of moulds).
- Secure PC bars in place.
- Perform final check.
- Place concrete.
- Cure, store and stack.

Curing of PC sleepers is the same as that for the pretension method.

6-2-3 PC Sleeper Plant Equipment

For a daily production of 200 PC sleepers the plant facilities required will be as follows for the method of production indicated:

(1) Plant facilities for pretension method of production

Description	Specifications	Unit	Quantity
Plant building facilities	Reduced building framing with discarded rails, zinc coated roofing	m^2	1,660
Concrete mixer	1.5 m^3	ea	1
Concrete sleeper mould	Steel, 4.3 mm thick	ea	420
Pretensioning jack		ea	4
Jack anchoring abutment	Steel	set	4
Overhead traveling crane	4.0 ton capacity	ea	2
Concrete vibrator	Form vibrating	ea	3
Steam boiler	0.75 t/H	set	1

(2) Plant facilities for post-tension method of production

Description	Specifications	Unit	Quantity
Plant building facilities	Reused rail framing, zinc coated roofing	m^2	770
Concrete mixer	1.5 m^3	ea	1
Concrete sleeper mould	Steel 4.3 mm thk	ea	210
Pretensioning jack		ea	4
Overhead traveling crane	1.0 ton capacity	ea	2
Roller conveyor		set	1
Steam boiler	0.75 t/H	set	1

6-2-4 Plant Labour

Based on a daily production of 200 PC sleepers the number of workers required for the plant will be as follows for the method of production described.

(1) Pretension method of manufacture

Description of Work	Classification	Skilled Worker	Labourer
Cut PC wires	Mechanic	4	-
Pretension PC wires	PC cable worker	2	2
	Jack operator	4	2
Clean mould	Labourer	-	6
Apply bond breaking agent	Labourer	-	6
Set mould	Carpenter	3	3
Install PC wires anchor	Steel setter	6	3
Bend reinforcing bar	Steel setter	8	8
Install reinforcing bar	Steel setter	6	3
Set bulkhead	Carpenter	3	3
Move PC sleeper within casting yard	Crane operator	1	8
Grout sleeper end	Plasterer	2	6
Remove mould	Labourer	-	6
Place concrete	Mechanic	2	-
	Concrete worker	12	6
	Equipment operator	2	-
Steam curing	Boilerman	2	-
Total		47	45

(2) Post-tension method of production

Description of Work	Classification	Skilled Worker	Labourer
Move mould within casting yard	Concrete worker	2	-
Remove moulds	Mechanic	1	2
Pretension of PC bars	PC bar worker	4	-
Grout annular space with mortar	Plasterer	4	-
Move sleeper within casting yard	Crane operator	1	4
Clean mould	Labourer	-	3
Apply bond breaking agent	Labourer	-	3
Install PC bars hardware	Steel setter	1	1
Install PC bars	Steel setter	1	1
Set bulkheads	Carpenter	1	2
Fix PC bars	PC bar worker	1	-
Cast concrete	Mechanic	3	-
	Concrete worker	4	2
Transfer mould	Concrete worker	2	-
Steam curing	Boilerman	2	-
Total		27	18

6-2-5 Standards for PC Sleepers

The standards for PC sleepers can be classified as follows:

(1) For curved tracks larger than 600 m in radius and tangent tracks

(2) For curved tracks less than 600 m in radius but larger than 300 m

The above classification is further broken down into two more sub-classifications depending on the production method (pretension, post-tension). Actually there are other classifications depending on the usage, however, out of the four types of sleepers only two will be discussed.

For curved tracks (less than 600 m in radius) the number of sleepers will be increased by 2 or 3 more sleepers, or sleepers designed for curved tracks will be used.

For PC sleepers used in curved tracks, the outer dimensions will be slightly increased and all other dimensions will remain the same.

In consideration of moulds needed for the difference and the added complexity of the work process, it is recommended to use sleepers for tangent tracks (larger than 600 m in radius) and make adjustments in the number of sleepers used.

6-2-6 Selection of Production Method for PC Sleepers

(1) Method of comparison

There are two general methods of PC sleeper production, the pretension method and the post-tension method.

Regardless of the method, there is very little difference in the quality of the final product.

The difference is in the method of applying compression to the concrete. In the pretension method it is applied by PC wires, and in the post-tension method it is by PC bars. The plant facilities will differ depending on the method used.

Selection of the method will depend primarily on the quality of the PC sleeper, and if there is no difference in the quality, then the secondary consideration will be the cost of production, and all things being equal, then thirdly, the constructability will be the factor which will decide the method to be selected.

(2) Comparison of costs

The cost of PC sleepers consists of the following three items:

- Direct Costs: The cost of labourers engaged at the PC sleeper plant, cement, aggregates, reinforcing steel, hardware, equipment used, depreciation of equipment, and costs incurred at the plant

- Indirect Costs: Cost of the plant facilities, maintenance costs, equipment costs, etc.

- Overhead Costs: Management costs of plant and head office costs

The above costs will be divided into foreign and local costs, of which foreign costs will constitute a large portion, and this is shown in Table 6.2.2.

Table 6.2.2 Comparison of Construction Cost (Foreign Currency)

	Pretension			Post-tension		
	Quantity	Unit	Amount (kyat)	Quantity	Unit	Amount (kyat)
Steel Material						
(I Beam Angle, etc.)	243,700	kyat 6 (Factory)	1,462,200	152,950	6 (Factory)	917,700
Equipment (Machine)	4,550,000	6	27,300,000	3,250,000	6	19,500,000
Sub-total			28,762,200			20,417,700
P.C wires	5,780 t	13,000	75,140,000			
P.C Bars				6,350 t	13,000	82,550,000
Sub-total			75,140,000			82,550,000
Total			103,902,200			102,967,700
						-934,500

As shown in the table, the direct costs for materials for the pretension method is less than those for the post-tension method.

On the other hand, the cost of moulds for the pretension method is larger than that for the post-tension method, and on the whole the post-tension method is less costly than the pretension method.

(3) Comparison of ease of production

Each method has its following special features.

a) BRC is producing PC sleepers by pretension method at the Mahlwagon PC Sleeper Plant on a small scale (300 to 400 pieces per week). For this reason, the techniques for the production of PC sleepers and know-how are already available.

This means that for any future increase in quantities, it will be easier to train and secure the required personnel for the pretension method, as compared with the post-tension method.

b) The scale of the post-tension method will be smaller than that for the pretension method. Thus, the plant construction cost, the relocation thereof, and time requirements will be less than those for the pretension method.

(4) The recommended method of production

As described in the above paragraphs, there are some good points in each method, and very little difference in the quality and costs, which makes it difficult to make a decision, but the pretension method is recommended for this project.

The reasons are as follows:

- Steel materials constitute a major part of the PC material cost and they require the use of foreign currency, and it has been requested by BRC to keep these costs to a minimum.

- The techniques and know-how for the pretension method are already available in Burma.

- It has been requested to make use of materials possessed by BRC to construct the plant facilities.

- The PC sleeper plant facilities should be convertible to other uses in order to reduce indirect costs.

6-2-7 Quality Control and Inspection

In the production of PC sleepers the specifications and the methods of inspection must be specified so that quality control can be performed.

The items to be specified are as follows:

- Specifications for the concrete
- Production requirements
- Design requirements
- Types of inspection to be performed

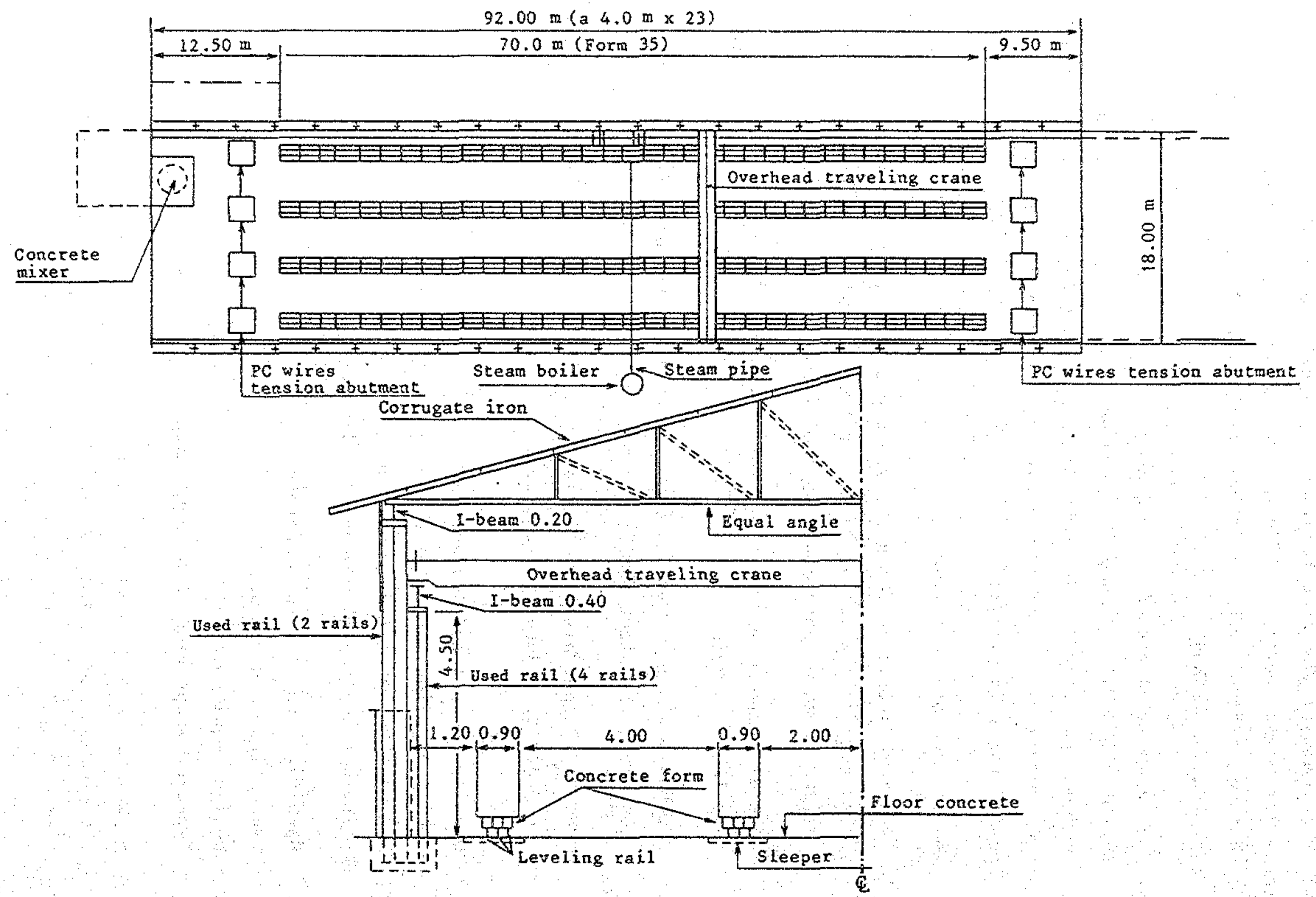


Fig. 6.2.1 Typical PC Sleeper Factory (Pretention) Layout

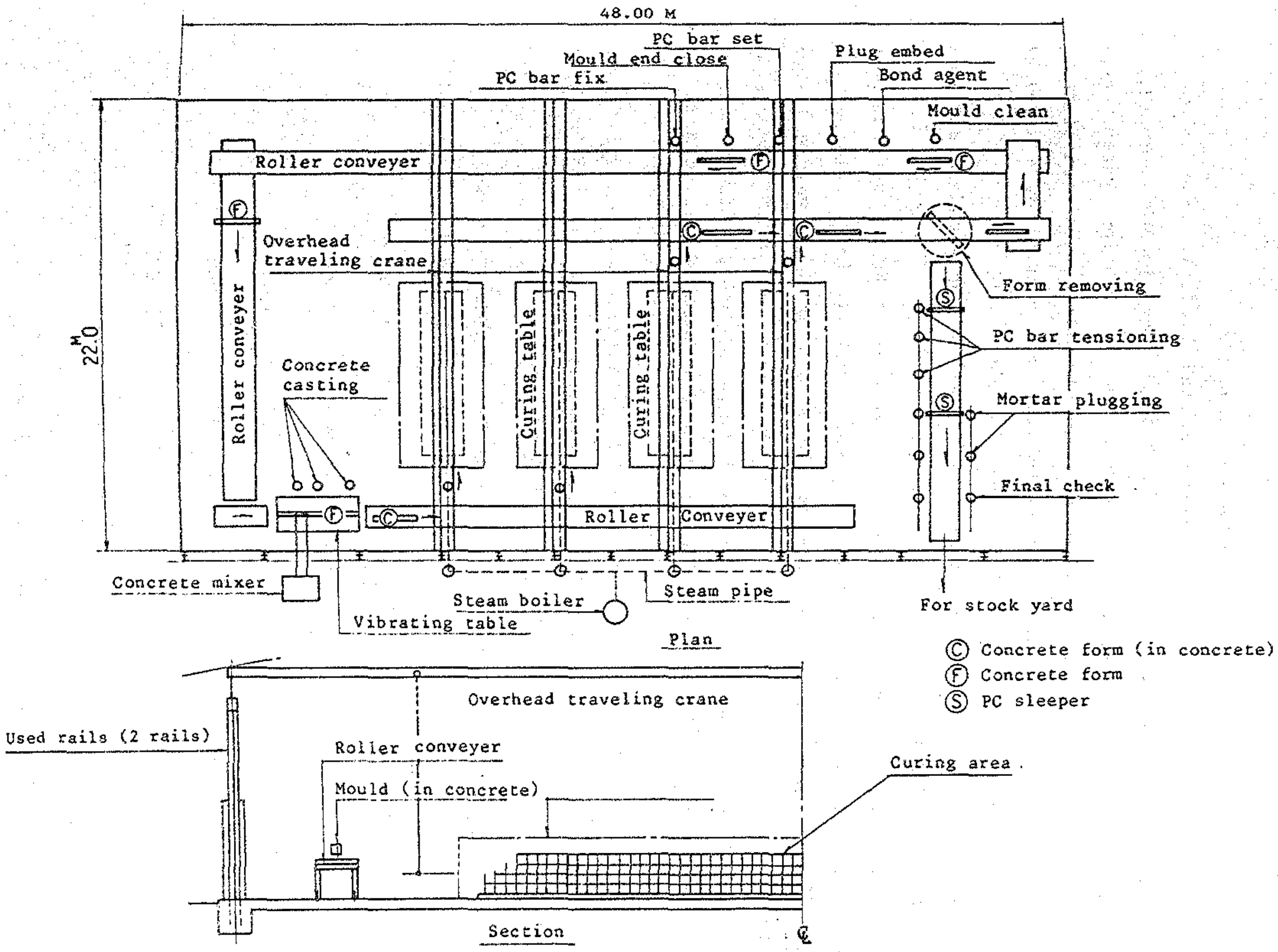


Fig. 6.2.2 Typical PC Concrete Sleeper Factory (Post-tension) Layout

6-3 Rail Welding

6-3-1 Welding Method and Amount of Welding Required

The length of a long-welded rail for the Mandalay Line is to be 1,600 m (1 mile), and excluding rails for bridges (more than 25 m long), curved tracks (radius less than 600 m), and at station yards where long-welded rails cannot be installed due to structural constraints, approximately 610 km of long-welded rails will be required for a total of 987 km (equivalent length for single line) for all sections.

Long-welded rails will be fabricated by welding the standard BRC rail (11.887 m = 39 ft) to form a single length of rail. The rails will be welded by gas pressure welding. Since it will be difficult to transport rails of 1,600 m length, it is recommended to weld (primary welding) the rails into shorter welded sections and to weld (secondary welding) them into 1,600 m length in the field. In this case the largest number of welds will be the initial weld performed at the workshop. The number of primary welds required to fabricate a long rail of 1,600 m will be as follows:

Section	Number of Welds		
	Alternative plan		
	A	B	C
Rangoon - Pegu	19,000	19,000	19,000
Pegu - Toungoo	45,000	44,000	22,000
Toungoo - Pyinmana	24,000	23,000	14,000
Pyinmana - Thazi	15,000	14,000	6,000
Thazi - Mandalay	16,000	15,000	10,000
Total	119,000	115,000	71,000

6-3-2 Workshop Welding (Primary Welding)

(1) General description of workshop facilities

The welding operation at the workshop consists of collecting the required number of standard rails and welding them into 200 m long.

The equipment to be provided in the workshop is as shown in Fig. 6.3.1.

The principal workshop equipment is as follows:

Description of Equipment	Specifications	Quantity
Rail welding machine	Gas pressure welding machine, TGP 119	1 set
Engine generator	8.0 KVA	1 set
Engine generator	5.0 KVA	3 sets
Winch	5 KW	1 ea
Gantry crane		15 ea
High roller		42 ea
Low roller		40 ea

The above equipment is based on welding 17 pieces of standard rails to fabricate long-welded rails of approximately 200 m length, and if the length of the 200 m changes, the equipment requirements will have to be modified accordingly.

(2) Personnel requirements at workshop

The personnel requirements for rail welding at the workshop are as follows for a standard organization:

Classification	Number	Description of Work
Chief	1	Supervises all rail welding operations.
Trackman	6 (3)	Performs rail work.
Mechanic	10 (2)	Cut rails and performs finishing work on rails.
Welder	7	Performs rail welding.
Inspector	3	Inspects finished work and final inspection.

The above personnel is based on obtaining skilled workers from BRC, and the figures given in parenthesis indicate the unskilled workers required to assist in the work.

The engineers to be dispatched from BRC to the welding workshop will be from 1 to 3 engineers.

(3) Establishment of welding workshop base

The long rails welded at the Welding Workshop Base will be transported to the site of laying by work trains. The work train will consist of a heavy-duty locomotive and trolley cars, and the speed of the moving train is limited to 15 km/h (10 mph).

The distance between the welding workshop base and rerailing sites is assumed to be 30 km to 40 km taking into account the transport, unloading and deadheading.

The equipment at the welding workshop base will all be relocatable and the conditions of installation will be governed by the the size of the base site and the general topography.

The length of BRC intermediate stations are longer than 500 m, and it will be possible to install the welding equipment at most of the stations.

As stated in the above, it will be possible for one welding base to cover a sector of 30 km to 40 km, and when the welding operation of the long rails has been completed, it is recommended to move the welding base to the next area for reasons of economy and to maintain the work schedule.

6-3-3 At-Site Welding

(1) General description of welding plant facilities

The at-site welding consists of welding the 200 m long rails at the site of work into the specified length of 1,600 m.

Since the welding at the site of work requires welding every 200 m, the welding equipment will have to be mobile. The moving of the welding machine can be performed on manually operated trolleys using the existing tracks.

The principal equipment required for the at-site welding will be as follows:

Description of Equipment	Specifications	Quantity
Rail welding machine	Gas pressure welding machine, TGP 119	1 set
Engine generator	8.0 KVA, with diesel engine	1 set
Engine generator	5.0 KVA, with diesel engine,	2 sets
Trolley	With crane	1 ea
Trolley	Semi type	3 ea
Low roller		70 ea

(2) Personnel requirements

The following personnel will be required for the at-site welding and this will form a standard crew:

Classification	Number	Description of Work
Chief	1	Supervises all work.
Trackman	15 (3)	Performs rail work.
Mechanic	7 (2)	Performs finishing work on rails.
Welder	5	Performs rail welding.
Inspector	2	Inspects finished work.

The figures given in the parentheses indicate unskilled workers assigned as helpers.

BRC engineers to be dispatched will be 1 to 2 engineers.

6-3-4 Quality Control

The welded rails are to be inspected for the quality of work, and inspected for the following:

- Appearance
- Non-destructive inspection
- Magnetic particle inspection
- Ultrasonic inspection

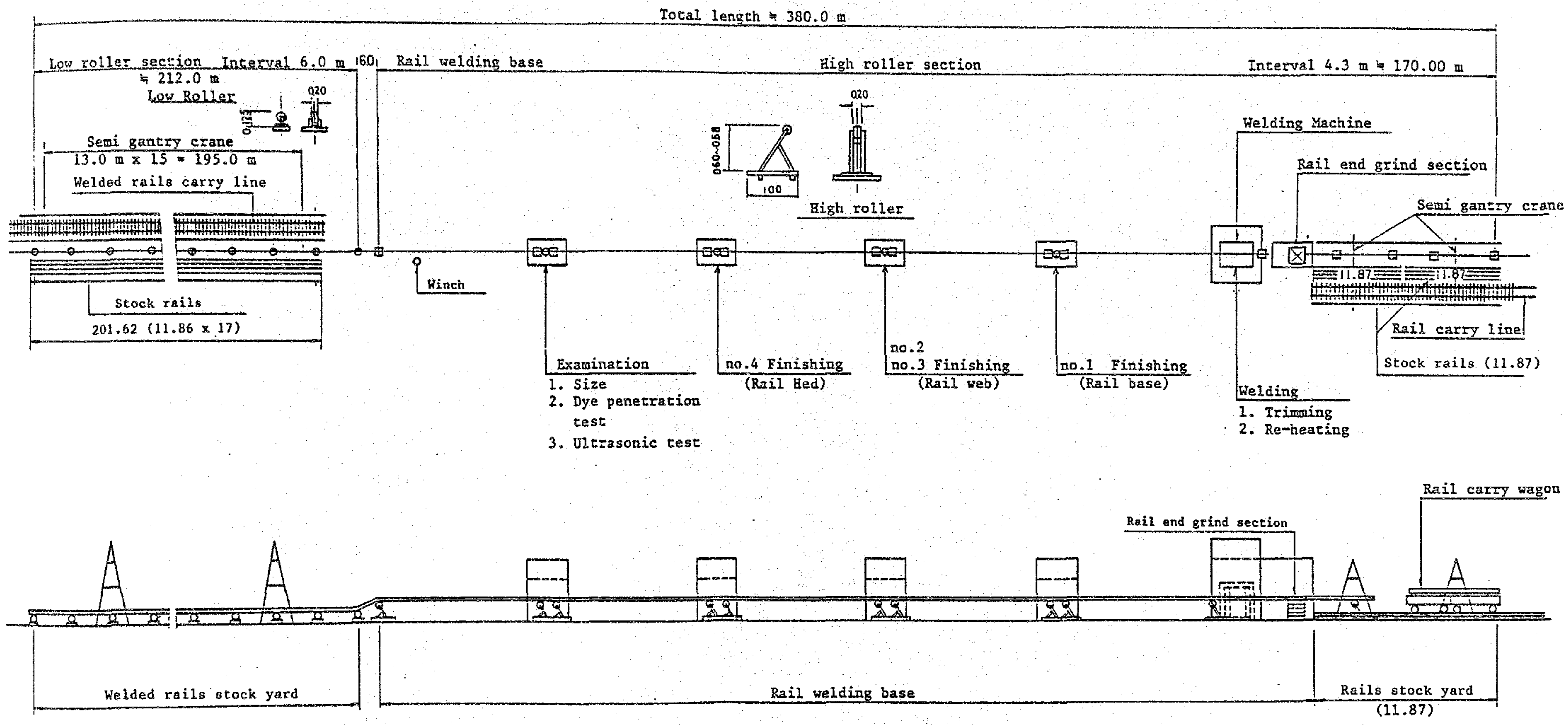


Fig. 6.3.1 Typical Rail Welding Workshop

6-4 Production of Ballast and Distribution

6-4-1 Amount of Additional Ballast Required

The ballast required to reinforce the track for the Mandalay Line (equivalent single line length of 987.0 km) is approximately 985,000 m^3, and deducting 355,000 m^3 for the quantities already used to the present time, there is still a shortage of approximately 630,000 m^3. The additional ballast required for the work in connection with the improvement is 630,000 m^3. (Alternative Plan A)

The breakdown of these quantities by railway section is as follows:

	Amount of Ballast (m^3)		
	Alternative Plan		
Section	A	B	C
Rangoon - Pegu	100,000	100,000	100,000
Pegu - Toungoo	246,000	230,000	201,000
Toungoo - Pyinmana	128,000	119,000	106,000
Pyinmana - Thazi	79,000	71,000	60,000
Thazi - Mandalay	77,000	70,000	63,000
Total	630,000	590,000	530,000
	(22,240,000 ft^3)	(20,830,000 ft^3)	(18,710,000 ft^3)

6-4-2 Present Status of Ballast Supply

The supplementary ballast used on the Mandalay Line is produced at the Tonbo Quarry on the Lashio Line, Belin Quarry on the Mandalay Line, and the quarries along the Martaban Line.

Since the ballast produced at the quarries on the Martaban Line will be used for the new work on the Rangoon Airport (1987 - 1990), the ballast for the railway work will have to rely on the Belin and Tonbo Quarries.

The method for producing ballast at the Belin and Tonbo Quarries is by manual labour with an average daily production rate of 30 m^3 to 40 m^3.

BRC is hauling ballast in ballast wagons (DF 1600 locomotive and 20 wagons), and it requires 5 days for a ballast train to make a round trip from the quarry to the work sites, and on a yearly basis the amount of 12,000 m3 to 13,000 m3 is transported on the Mandalay Line.

This amount is totally unsatisfactory for the proposed new project and it will be necessary to modernize the quarry facilities and to improve the method of hauling in order to meet the large quantities of ballast required.

6-4-3 New Ballast Production Facilities for the Quarries

As described hereinbefore, if the Rangoon - Toungoo section is assumed as the 1st phase of the project to be implemented, the ballast will be supplied from the Belin and Tonbo Quarries. If the construction period is assumed as 6 years, the major portion of the ballast should be produced in 4.5 years. The rate of production of ballast for the Rangoon - Toungoo section will be approximately 325 m^3/day.

(1) General description of the facilities required

The rubble stone required to produce 160 m^3/day of ballast is approximately 300 m^3, and if the crusher capacity is assumed at 0.6 of the rubble stone, then the crusher will be required to produce

$$160\ m^3 \div 0.6 \fallingdotseq 266\ m^3.$$

The capacity of the crusher should be approximately 300 m^3/day.

The equipment to be provided in the quarry is as shown in Fig. 6.4.1.

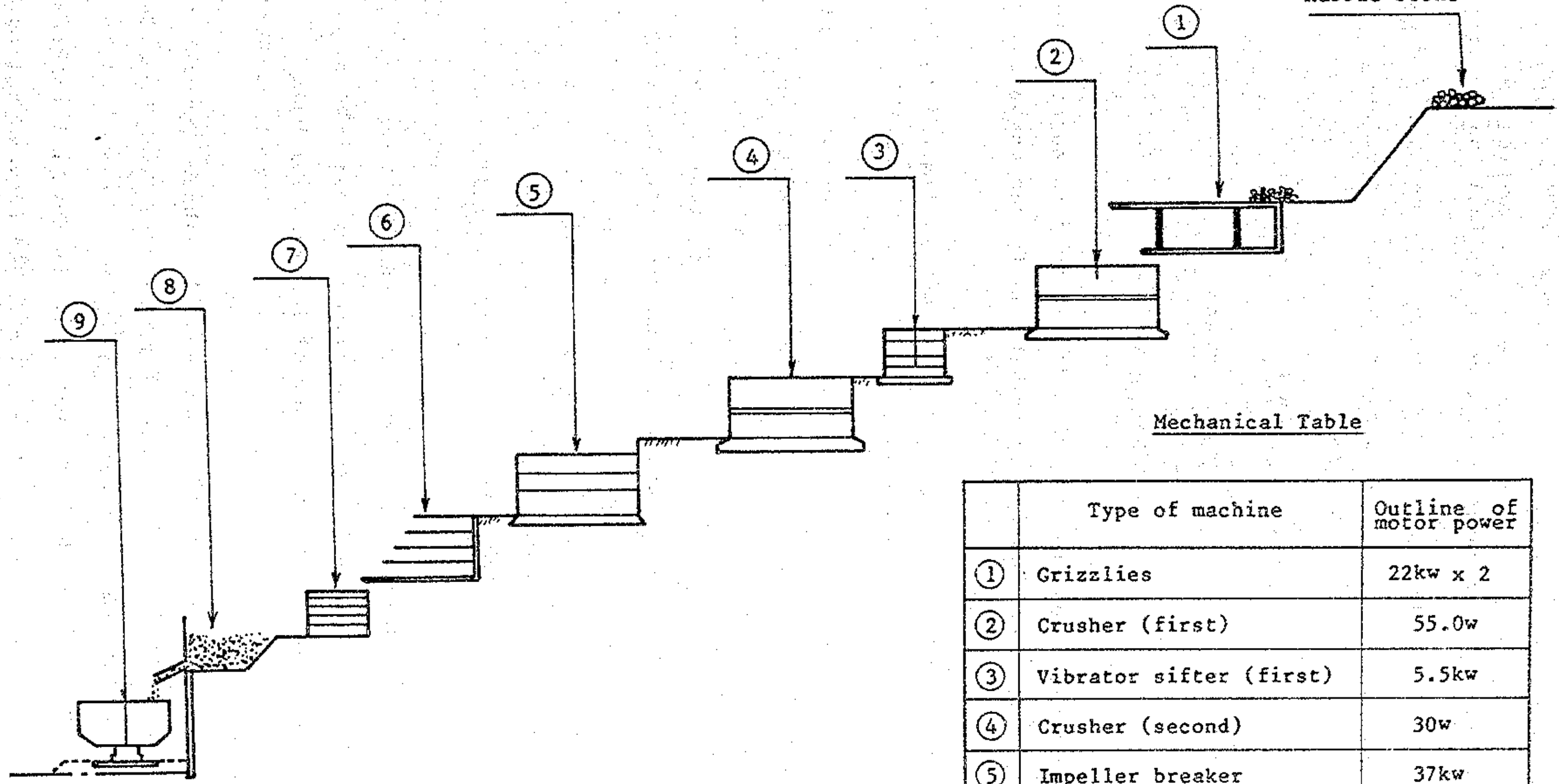
1) Equipment requirements

- air compressor	1 set
- rock drill	5 - 7 ea
- bulldozer	1 ea
- power shovel	1 ea
- dump truck	5 ea

2) Crushing equipment

- grizzlies (secondary fragmentation)
- primary crusher
- secondary crusher
- vibration screens

The actual equipment to be installed will depend on the amount of quarry rock produced.



Mechanical Table

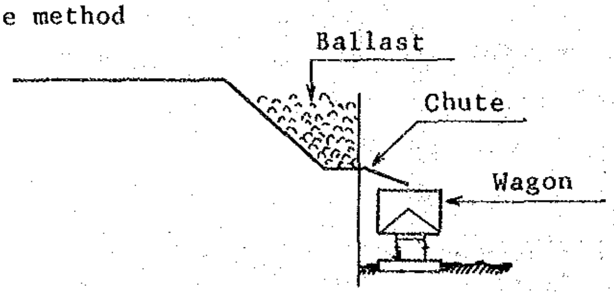
	Type of machine	Outline of motor power
①	Grizzlies	22kw x 2
②	Crusher (first)	55.0w
③	Vibrator sifter (first)	5.5kw
④	Crusher (second)	30w
⑤	Impeller breaker	37kw
⑥	Vibrator sifter (second)	7.5kw
⑦	Vibrator sifter (third)	3.7kw x 2
⑧	Ballast store	
⑨	Ballast wagon	

Fig. 6.4.1 Outline of Ballast Quarry Mechanical System

(2) Ballast loading equipment

There are three methods proposed for loading ballast on to the ballast wagons as follows:

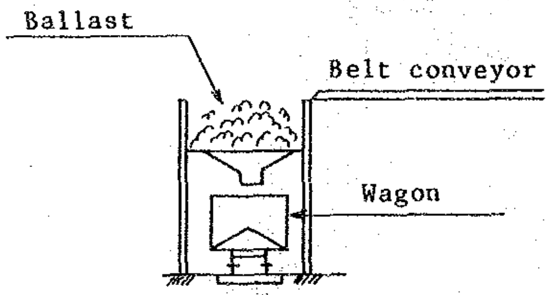
1) Ballast chute method



This method consists of constructing a ballast stockpile adjacent to the ballast loading siding and loading by gravity on to the wagon using a chute as shown on the drawing.

This is an effective method of loading ballast but is limited in its use by the general configuration of the site.

2) Ballast storage bin method



The use of wagon loading bin is effective but is more costly compared with other methods. Also, it is necessary to move the wagon under the bin hopper depending on the number of loading bins used.

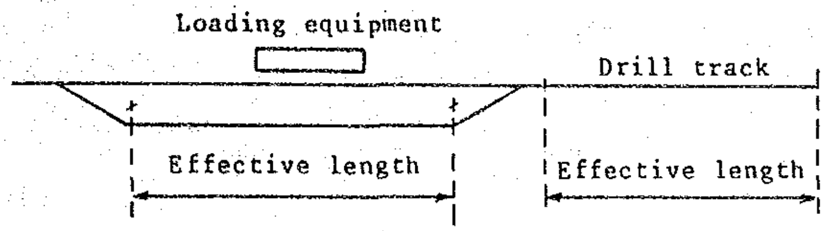
3) Manual loading method

This method is performed entirely by manual labour or by a combination of manual labour and belt conveyors. It is very low in efficiency but requires the least outlay of capital.

From the above, the chute method of loading is recommended for the Belin Quarry, but for the Tonbo Quarry it is recommended to load ballast manually, or by the use of other system.

(3) Ballast loading siding

The loading of the ballast will have to be performed at sidings where ballast wagons have been deadheaded. It will be necessary to shunt the wagons into the sidings by switches, and the minimum track siding lengths will have to be provided as shown in the following drawing.



Effective length = (Wagon length x Wagon number) + Locomotive length + 20 m (Overrun)

6-4-4 Ballast Train Operation Schedule

(1) Between quarry and construction site

The ballast required for the Rangoon - Toungoo section will be supplied from the Belin and Tonbo Quarries which are closer to Mandalay.

These quarries are located 585 km and 624 km respectively from Rangoon and are quite long distance away from the work sites. Since it will be difficult to maintain a regular supply of ballast, it will be necessary to operate ballast trains between the quarries and the construction work sites.

The ballast train will be used to transport the ballast from the quarry to the construction sites and will consist of 30 ballast wagons. It will be necessary for BRC to include the operation of this train in their regular train operation diagram.

The operation of the ballast train will be further described in the various plans:

1) Alternative Plan A

The ballast required for the Rangoon - Toungoo section is approximately 346,000 m^3, and in order to haul this ballast in 4.5 years, will be 325 m^3/day.

The train consist of the ballast train will be:

Locomotive (DF 1200) + 30 x wagons (10 m^3).

2) Alternative Plan B

The ballast required for the Rangoon - Toungoo section will be 330,000 m^3, and to transport this amount of ballast in 4.5 years, will be 290 m^3/day, and this is about the same as for Plan A.

3) Alternative Plan C

The total ballast requirement will be 301,000 m^3, and in this Plan it will require 260 m^3/day to complete in 4.5 years.

If the number of ballast wagon is the same as for Plan A or Plan B, there will be some slack time in the train schedule and the locomotive can be used for other duties during the off hours.

The ballast trains will require the following:

Description	Specifications	Quantity
Locomotive	DF 1,200 or equivalent	2 ea
Ballast wagon	10 - 15 m^3/car	60 ea

(2) Quarry - ballast depot - construction site

1) Reasons for establishing ballast depot

In this project the quantity of ballast required is large, but the quantity per metre of track length is small since the length of the railway line is great.

Simply stated, the ballast requirements for the Rangoon - Pegu section is 100,000 m^3 for track length of 150 km, and so the ballast to distance ratio is 0.6 m^3/m. The total ballast transported by a ballast train of 320 m^3 will be spread over 533 m.

The ballast used for track raising will be performed in several stages and so the distribution of ballast will be small for each hauling operation.

For this reason the ballast will be hauled directly from the quarries to the construction sites, and in addition, there will be some ballast placed in stockpiling depots from where the ballast will be hauled to the construction sites in small quantities.

This will allow for the ballast to be placed in the stockpile depots at sidings so the unloading of the ballast will not affect train operation on the main line, and the distance from the stockpile depot to the construction sites will be much shorter and will have the merit of facilitating observance of the construction schedule.

On the other hand, it will have the drawback of having to use several modes of transportation for the short haul of ballast, and additional equipment will have to be procured for the short distance hauling.

Apart from the above, it will be necessary to provide facilities to stockpile ballast as a safeguard against unforeseen accidents and changes in the train schedule on the main line.

For the reasons stated above, it is proposed to establish ballast stockpile depots for this project as follows:

Section	Distance (km)	Number of Stockpile Depots
Rangoon - Pegu	75	2
Pegu - Toungoo	192	5
Toungoo - Pyinmana	95	3
Pyinmana - Thazi	130	2
Thazi - Mandalay	128	2

For the Pyinmana - Mandalay section which is near the quarry, it will be possible to make adjustments in the ballast train at the quarry.

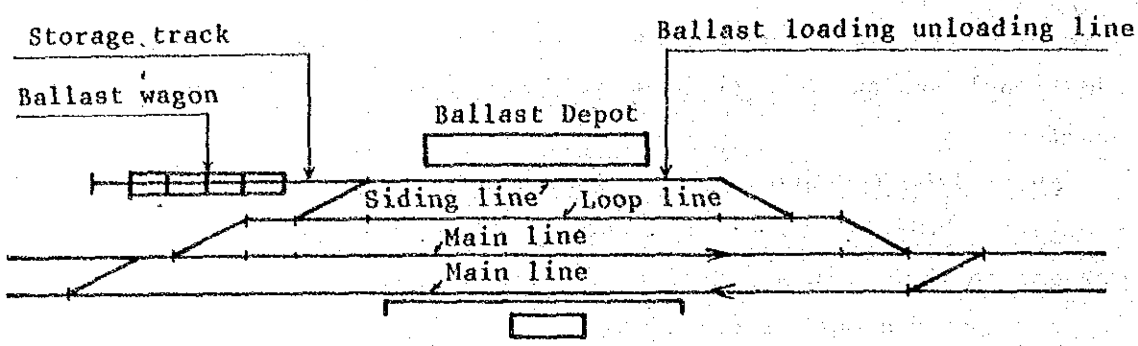
The number of ballast stockpile depots can be varied as necessary according to the progress of construction. Thus, the number of depots will change as time goes on.

2) The facilities to be provided at the stockpile depot

Since ballast will be transported from the stockpile depot to the construction sites by ballast trains and there will be ample time to load the wagons, the loading of the wagons can be performed by manual labour easily available locally.

For this reason it will not be necessary to procure special loading equipment. Depending on the locality, when the necessary labour forces cannot be obtained, it may be necessary to procure small shovel loaders of 0.3 m^3 capacity.

The stockpile depots will be established at intermediate stations between main stations, and a standard layout of a stockpile depot is given as follows:



3) The short-haul construction ballast train

The transport of ballast from the stockpile depot to the construction sites will be performed by work trains with consist as follows:

Description	Specifications	Quantity
Track motor car	Diesel engine driven, 185 PS	1 ea
Ballast wagon	8.0 - 10.0 m^3/car	10 ea

There should be one train assigned to each depot, but the locomotive should be used on a flexible basis between the various depots, and it is recommended to provide at least 3 ballast trains in the section between Rangoon - Toungoo.

6-4-5 Equipment Required to Transport Ballast

(1) From Quarry to Construction Site and from Quarry to Stockpile Depot:

Description	Specifications	Quantity
Locomotive	DF 1200	2 ea
Ballast wagon	8.0 - 10.0 m^3/car	60 ea

(2) From Stockpile to Construction Sites:

Description	Specifications	Quantity
Track motor car	185 PS	3 ea
Ballast wagon	8.0 - 10.0 m^3/car	30 ea

CHAPTER 7 MAINTENANCE MANAGEMENT AND TRAINING PLAN

CHAPTER 7 MAINTENANCE MANAGEMENT AND TRAINING PLAN

7-1 Maintenance Management

7-1-1 Track

In order to keep the track in good condition and at a certain level, it is important to establish an effective maintenance system, for which the method of track inspection and maintenance work has to be improved.

It is critical, therefore, to grasp the track irregularities and deterioration of track materials by track inspection, based on which the track repair and material replacement plans are to be made.

(1) Track inspection

Track inspection to be carried out is as follows:

- Patrol inspection
- Track irregularity inspection
- Track material inspection

On the method of track inspection, refer to the Appendix 7.1 (1).

(2) Track maintenance standard values

The track repair and material replacement are carried out based on the maintenance standard values. On the standard values for track repair and material replacement, refer to the Appendix 7.1 (2).

(3) Maintenance standard for long-welded rail

In the maintenance of long-welded rail, exceptional care should be taken in the following points:

- Prevention of buckling
- Prevention of excessive expansion and contraction as well as creeping
- Prevention of partial wear

1) Track repair

(a) The points where the partial irregularity is liable to occur (especially near the bridge) have to be carefully repaired.

(b) The points where the train greatly vibrates have to be checked for the cause and promptly repaired.

(c) For the curve section with long-welded rail, the curve adjustment has to be made before the high temperature season starts.

2) Ballast repair

(a) The width of ballast shoulders should be more than the standard value.

(b) The exposure of sleeper sides is to be prevented.

(c) The upper layer of ballast is to be sufficiently tamped.

(d) The lateral resistance of ballast should be 400 kg/m or more.

If the ballast resistance is insufficient, the extra banking on the ballast shoulders is effective.

3) Restriction in repair work

When the rail temperature exceeds the standard set temperature, the ballast tamping for the track raising of more than 10 mm and the re-alignment had better be avoided. If the rail temperature has surged during the work to more than the standard set temperature, the upper layer of ballast should be immediately tamped.

4) Installation and monitoring of standard pegs

Near the centre and movable section of long-welded rail, standard pegs are installed to monitor the creeping of rail and the degree of rail expansion or contraction periodically.

5) Maintenance record

When the long-welded rail are laid, their maintenance record is made for recording the necessary information.

(4) Maintenance system and workers

As to the maintenance system between Rangoon and Mandalay, there are at present, ten Permanent Way Inspector Depots. Besides, the Mechanized Track Maintenance Gangs are located in Rangoon, Pyinmana and Mandalay.

In future, despite the higher speed of train and increased transport volume expected, the introduction of long-welded rail and the adoption of PC sleepers will reduce the volume of total maintenance work. Accordingly, on the premise of the anticipated change of transport conditions, the existing organization and maintenance workers will be able to cover the future maintenance work.

The equipment used in the improvement works may be applicable to the maintenance works after the completion of improvement works. In the near future, it is desirable to study the introduction of heavy duty multiple tie tampers in Mechanized Track Maintenance Gangs.

7-1-2 Telecommunication and Signalling

(1) Maintenance method

Most of the equipment to be newly provided are electronic ones. On the base of an "corrective maintenance method," any equipment, when out of order, will immediately be inspected and repaired through the indication shown on the device provided or the information from the organizations concerned. The non-electronic equipment will be periodically maintained at the pre-set maintenance intervals, based on the so-called "preventive maintenance method."

Table 7.1.1 shows the maintenance method of main equipment.

Table 7.1.1 Maintenance Methods of Main Equipment

	Main equipment	Method		Remarks
		Preventive maint.	Corrective maint.	
Tele-communication	Time division exchange		o	Trouble to be recorded by operating console
	Crossbar exchange: system		o	Trouble to be recorded by trouble recorder
	relay	o		
	Control equipment		o	
	UHF radio: supervision	o		
	system		o	
	Train radio: condition check	o		
	system		o	
Signalling	Electronic interlocking device		o	
	Electronic token block equipment		o	
	Electric lock device	o		
	Engine generator	o		

Source: Study Team

(2) Maintenance organization

A large amount of maintenance service for the equipment is conducted at major stations, and a small amount at wayside stations. Therefore, the inspector offices for maintenance should be set up at major stations and inspectors from the offices may perform maintenance at regular interval and also whenever required to repair the equipment out of order at wayside stations.

Two groups should be established at Rangoon, Pegu, Pyuntaza, Toungoo, Pyinmana, Thazi and Mandalay - one mainly for the maintenance of wire telecommunication and signalling equipment to be newly provided, and the other for the maintenance of radio equipment, including the existing equipment.

A training course should be set up under the Divisional Engineer at Rangoon with necessary training instruments provided for men to learn without much difficulty how to operate or maintain the equipment to be newly installed.

Fig. 7.1.1 shows the Maintenance Organization.

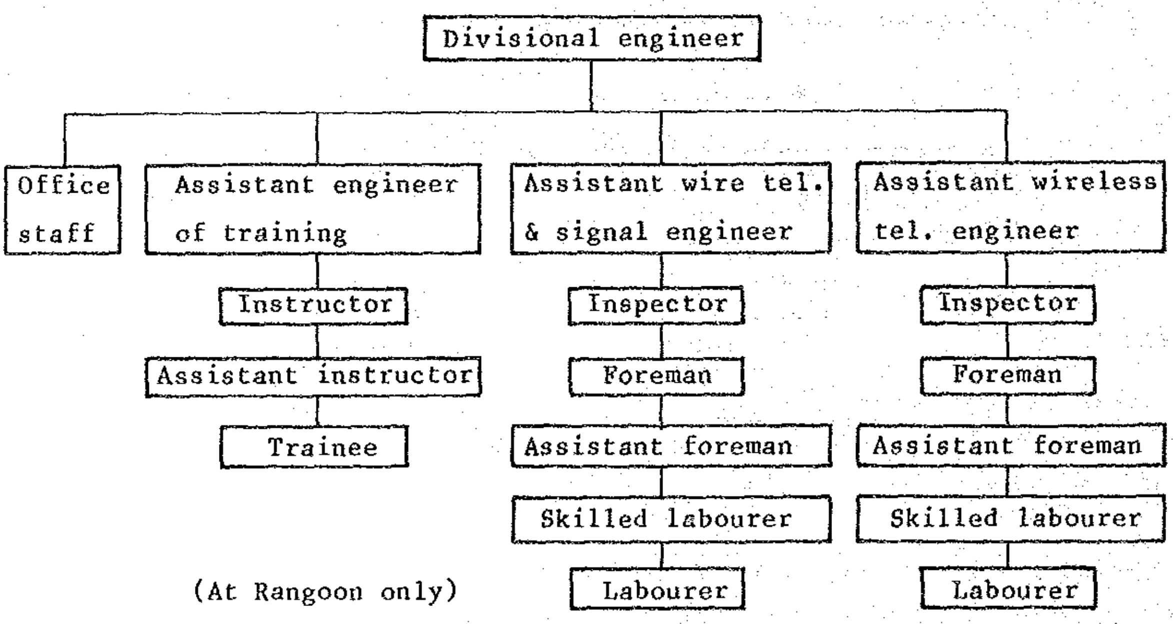


Fig. 7.1.1 Maintenance Organization

(3) Mobile force

Main emphasis is placed on the repair whenever a trouble occurs with any equipment as well as the regular interval maintenance under the present maintenance system. Repair and maintenance are performed by going to the site by train, which takes much time. It is necessary to immediately repair the equipment to be newly provided when out of order. To curtail down-time, mobile force should be provided at main inspector offices and a workshop as shown in Table 7.1.2.

Table 7.1.2 Mobile Force

Place	RGC	GRC	Total
Rangoon	1	1	2
Pegu	1	1	2
Pyuntaza	1	1	2
Toungoo	1	1	2
Pyinmana	1	1	2
Thazi	1	1	2
Mandalay	1	1	2
Workshop		2	2
Total	7	9	16

RGC: Rail Gang Car

GRC: Gang Rail Car

Source: Study Team

(4) Measuring equipment

It is suggested that the inspector office or main equipment rooms at each major station be provided with measuring apparatuses necessary for regular interval maintenance and trouble shooting of the equipment. Table 7.1.3 shows main measuring apparatuses and its functions.

Table 7.1.3 Main Measuring Apparatuses and Their Functions

Apparatuses	Function
Synchro-scope	Measure waveforms, levels, frequencies, timing.
Level meter	Measure voltage output.
Frequency meter	Measure accurate frequencies, levels.
Analyzer	Analyze frequencies, levels.
Tester	Check each unit functions as specified.
Standard oscillator	Measure the characteristics of frequencies.

(5) Rules and regulations

It is necessary that rules and regulations governing the operation and maintenance of the new equipment be revised or provided, as shown in Table 7.1.4.

Table 7.1.4 Rules and Regulations to be Revised or Provided

	Name (provisional)	Revised	Provided	Provision
Tele-communication	Regulations on telecommunication quality		o	Provide for the loss, level, connection and quality of telecommunication line.
	Regulations on telecommunication system configuration		o	Provide for the call numbers of telephone exchanges and automatic telephone number digits.
Signalling	General rules	o		Revise the signal indication method from wayside signal to cab signal (if plan A is adopted). Revise the block handling procedure at station.
	Regulations on train signalling information	o		Revise the signal indication method from wayside signal to cab signal, owing to changes in station facilities and signal indication method (if plan A is adopted).

(Cont'd)

	Name (provisional)	Revised	Provided	Provision
Signalling	Rules on signalling equipment installation		o	Provide the method of installing signalling equipment and the installation procedure not to interfere with train operation.
Signalling and tele-communication	Rules on signal and tele-communication trouble report		o	Provide the standard procedure of reporting signal and telecommunication troubles to the headquarters.

(6) Spare parts

It is considered that electronic equipment parts will not be produced in Burma under the present circumstances for some time. Therefore, it is necessary to stock 20 percent spare parts enough for maintenance at the commissioning stage.

7-2 Training Plan

The success of this project, during construction and in service, depends upon the education and training of employees. First of all, basic education should be aimed at enhancing the morale of employees for securing safety and punctuality, the major advantages of railway transport.

As for train operation handling based on new signalling system, education and training are essential for personnel related to train control system, locomotive crews, stationmasters and staffs concerned with train operation and track, telecommunication and signalling maintenance workers engaged in their respective activities. For this reason, education should be extended to many officials concerned before the project is completed. Before starting education and training, new provision and revision of the various rules and regulations should be drafted with the introduction of new systems and facilities.

7-2-1 Track Improvement Works and Maintenance

(1) Training abroad

The training of engineers or technicians should be performed for three to five trainnees for approximately three months in abroad, who will in turn be designated as instructors and will train other BRC personnel.

(2) Domestic training

For smooth implementation of track improvement works and track maintenance, technical training should be provided for maintenance staff and field supervisors under a systematic course.

1) Content of training	a) Basic techniques b) Track improvement works c) Track inspection and maintenance d) Work safety
2) Period of training	About two months

7-2-2 Telecommunication and Signalling

(1) Training abroad

Inspector class staff or those in instructor positions including operators of equipment should be trained at railway installations and manufacturing plants abroad, on the essential technology, installation and maintenance method of electronic equipment.

- Number of trainees: About 20
- Training period: About three months

They will draft instruction manuals under the guidance of experts and will be assigned as instructors to train other BRC personnel.

(2) Domestic training

Employees in installation and maintenance should be trained systematically in the classroom and the model section on the job, under the instructors who received training abroad.

1) Content of training

a) Basic techniques (theoretical and practical)

b) Telecommunication

- UHF radio equipment
- Train radio equipment (if plan A is adopted)
- Telephone exchange
- Connection of cables

c) Signalling

- Electronic token block equipment
- Electronic and/or relay interlocking device
- Level crossing equipment
- Train operation display unit

2) Period of training About three months

(3) Model section and similators as training aids

1) Model section (if plan A is adopted)

An electronic interlocking device is installed at Thingangyun, a model station, for training, and also electronic token block equipment installed at the stations adjacent to Thingangyun after the completion of transmission line.

An on-board unit with cab signals is installed on RGC for training of engine crews and maintainers.

2) Simulators

Simulators for electronic equipment as shown in Table 7.2.1 will be made available for the trainees at the Divisional Engineer's office at Rangoon.

Table 7.2.1 Training Simulators

Simulator
Electronic token block equipment
Electronic interlocking device*
Telephone exchange
UHF radio equipment
Train radio equipment*

* if plan A is adopted.

Source: Study Team

7-2-3 Rail Welding and PC Sleeper Manufacture

(1) Rail welding

The training on welding techniques by gas-pressure method will be performed as follows:

1) Content of training
   - Handling of rails
   - Cutting of rails and drilling of fish holes
   - Stringing of rails and storage
   - Finishing of cut ends of rails
   - Rail alignment
   - Operation of rail welding machine
   - Grinding of welded rail joints
   - Heat treatment and straightening of rails

2) Period of training

About two months

The training of engineers or technicians will be performed for two to three trainees for approximately three months in abroad, who will in turn be designated as instructors and will train other BRC staff.

(2) PC sleeper manufacture

For the manufacture of PC sleepers under the pretension method for this project, BRC is currently maufacturing the PC sleepers by the pretension method and so BRC already has acquired the technique and the know-how.

The quantity of PC sleepers presently being manufactured is on a small scale, however, the proposed project will require several plans to be operated simultaneously and BRC will not be able to meet the demand to staff all these plant operations. It will be necessary to provide the necessary engineers and technicians with the latest techniques.

The training programme will generally cover the followings:

1) Content of training
   - Production control
   - Placing of concrete and testing of sleepers
   - Pre-tensioning of PC wires
   - Other related work

2) Period of training

About two months

The training of engineers or technicians will be performed for three to five trainees for approximately three months in abroad, who will in turn be designated as instructors and will train other BRC staff.

CHAPTER 8 ESTIMATED PROJECT COST

CHAPTER 8 ESTIMATED PROJECT COST

8-1 General

Based on the facility improvement plan of the project, described in Chapter 5, the improvement costs were estimated and converted to economic cost for the economic evaluation. Similarly, costs of maintenance were estimated.

The estimation was conducted in accordance with the following criteria:

1) The estimates are made on the assumption that all improvement works except for telecommunication will be constructed by BRC.

2) The unit costs were computed under the economic conditions prevailing in August 1986. The exchange rates are set up as follows: 7.1 Ks/US$, 2.16 ¥/Ks.

3) The cost was estimated for all alternatives and was classified into foreign currency (indicated in Kyat) and local currency (indicated in Kyat) portions.

Foreign currency and local currency components of each unit price were computed based on the following classification of basic cost elements.

The foreign currency component consists of the costs of:

- Imported equipment, materials and supplies
- Domestic materials of which the country is a net importer
- Wages of expatriate personnel
- Overhead and fee of foreign firms.

The local currency component includes the costs of:

- Domestic materials and supplies of which the country is a net exporter
- Wages of local personnel
- Overhead and fee of local firms
- Taxes.

4) The unit cost of each improvement work item is obtained by accumulating the labour cost, equipment cost, material cost, etc. for the item, and the result is checked against the recent actual figures for construction work in Burma.

5) The engineering cost for the project preparation and technical training programme was estimated and the breakdowns are as follows:

Track	: Training	(2 years)	F/C 6.10 x 10^6 Kyats
			L/C -
Telecom. & Signalling			
	: Preparation	(2 years)	F/C 38.38 x 10^6 Kyats
	: Supervision	(4 years)	L/C 0.65 x 10^6 Kyats
	: Training	(2 years)	

6) Contingency allowance was made of 10 percent of the improvement cost.

8-2 Unit Cost by Improvement Work Items

The unit cost by improvement work items is calculated from the material cost, labour cost, equipment cost, and etc., analyzing the data on the project cost of recent similar kinds of projects and taking into consideration the local conditions in Burma.

The material, labour and the resulting unit costs by items are as listed in Tables 8.2.1, 8.2.2, and 8.2.3.

Detailed unit price analysis was carried out for the selected work items to maintain the required accuracy of the cost estimates as well as to determine the components of foreign currency, local currency and tax.

Imported materials are considered to be the following duty and taxes.

1) Customs duty

Customs duty is levied on imported goods, with the assessable value (100.5 percent of CIF value) multiplied by the following rates of customs duty.

Rates of Major Commodities

(Unit: %)

Item	Rate
Electric facilities	20
Rolling stock	10
Track materials	10
Signalling facilities	15
Telecommunication facilities	15
Inspection and repair equipment	15

Source: Customs Tariff

2) Commodities and services tax (C & S Tax)

C & S tax is levied on imported goods at 30 percent of their assessable values.

Table 8.2.1 Unit Prices of Typical Materials (in 1986)

Material	Unit	Price	
Rail B.S 75R (Ordinary rail)	Kyats/ton	4,650.00	(CIF)1/
Fish plate (incl. Bolt)	Kyats/set	193.00	(CIF)
Spike (Screw)	Kyats/each	5.00	(CIF)
(Dog)	Kyats/each	3.50	
Pandrol (for one sleeper)	Kyats/set	109.50	(CIF)
Point & Crossing 1 in 12 BS 75R	Kyats/set	143,325.00	(CIF)
Wood sleeper (Hard Wood)	Kyats/each	32.00	
Concrete sleeper (PC)	Kyats/each	146.71	
Fish plate for BS 75R	Kyats/pair	3,440.00	(CIF)
Signal lamp 80V/40W	Kyats/each	22.00	(CIF)
Dry cells AD 1.4V/250 AH	Kyats/each	74.00	(CIF)
Dry cells AD 1.4V/85 AH	Kyats/each	21.00	(CIF)
Ni-Cad Battery 12V/450 AH	Kyats/each	1,165.00	(CIF)
Cement	Kyats/ton	560.00	
Sand	Kyats/100ft^3	100.00	
Aggregate (2" - 4")	Kyats/100ft^3	46.00	
Aggregate (1/2" - 3/4")	Kyats/100ft^3	78.00	
Crushed stone (Ballast)	Kyats/100ft^3	97.00	
Reinforcing bar	Kyats/ton	5,140.00	
PC wire	Kyats/ton	6,630.00	
Gasoline	Kyats/gallon	3.50	
H.S.D	Kyats/gallon	3.05	
Engine oil	Kyats/gallon	20.20	

1/ including local taxes

Table 8.2.2 Average Labour Costs (in 1986)

Category of Labours	Wage per Month* (Kyats/m)	Basic Salary + Allowance
Track work		
Leader of group	195	(125 + 70)
Patrol men	195	(125 + 70)
Common workers	180	(110 + 70)
Drivers of motor cars	195	(125 + 70)
Drivers of motor cars (with crane)	290	(220 + 70)
Drivers of Trucks	195	(125 + 70)
Electric work		
Leader of group	400	(330 + 70)
Skilled workers (Electric)	290	(220 + 70)
Mechanics	290	(220 + 70)
Welding workers	220	(150 + 70)
Common workers	180	(110 + 70)

* including allowance

Working conditions

Working hours : 8 hr/day, 5 day/week

(Office worker : 6.5 hr/day)

Rate of overtime :

(Weekday) : $150\% \times \frac{\text{Present monthly salary} \times 12}{52 \times 44}$

(Holiday) : $200\% \times \frac{\text{Present monthly salary} \times 12}{52 \times 44}$

3) Income tax

Personal income tax is generally levied on that income which is more than 10,000 Kyats in a year. In this project, personal income tax for expatriate staff was not considered in the project cost.

Table 8.2.3 Unit Costs by Improvement Work Items

(Million Kyats)

Work Item		Unit	F/C	L/C	Tax	Total
Track Work						
Alternative	A	Kyat/km 1/	0.381	0.133	0.162	0.676
	B	Kyat/km	0.348	0.119	0.147	0.614
	C	Kyat/km	0.275	0.087	0.116	0.478
Telecommunicaton Work		Kyat/km 2/	0.365	0.014	0.165	0.544
Signalling Work						
Alternative	A	Kyat/km 2/	0.279	0.004	0.120	0.403
	B	Kyat/km	0.318	0.005	0.137	0.460

Note: 1/: Total Length = 987 km
2/: Total Length = 620 km

8-3 Construction Cost

The construction cost estimated for the plan has been based on the quantities calculated in the facility improvement planning and on the unit costs for each improvement work item.

The whole programme was divided into two phases to meet the stage construction programme, which is as described in Chapter 4 "TRANSPORT AND ROLLING STOCK PLAN".

The summary of the calculation for each stage is presented in Tables 8.3.1 thru 8.3.6. The comparatives of the alternative cases are shown in Table 8.3.7.

8-4 Maintenance Cost

Maintenance has been defined as "the preserving and keeping of each type of facility as nearly as possible in its original condition as constructed or as subsequently improved, and the operation of facilities and services to provide satisfactory and safe transportation."

Although the maintenance costs and the operation costs for the improvement facilities should be considered separately, the estimates include both costs. However the operation costs in this project are very small compared to the maintenance costs.

The results of the calculations for each item are summarized as shown below.

Maintenance Costs

(Million Kyats per year)

Work Item		F/C	L/C	Tax	Total
Track Work					
	A	0.893	5.027	0.381	6.301
	B	0.879	5.793	0.375	7.047
	C	0.852	8.065	0.362	9.279
Without		4.042	8.677	1.705	14.424
Telecommunicaton					
With		0.912	0.041	0.412	1.365
Without		-	0.330	-	0.330
Signalling					
	A	1.210	0.018	0.521	1.749
	B	1.380	0.021	0.594	1.995
Without		-	0.620	-	0.620

8-5 Investment Cost of Plants

The quantities required of sleepers, weldings and ballast for the track improvement plans are described in the Chapter 5 "FACILITY IMPROVEMENT PLAN". The scale of the plants were also planned in the Chapter.

In this section, the construction costs of PC sleeper plant, temporary site workshop for welding and ballast crushing plant were estimated. These costs are included in the project cost.

1) PC sleeper plant

Based on the track improvement plans, the facilities plans of PC sleeper plant are prepared as follows:

Plan A : (Phase 1)

4-new PC plants, total number of production = 1,400 ea./day

(Phase 2)

3-PC plants will be relocated to new locations.

Total number of production = 1,200 ea./day

Plan B : (Phase 1)

4-new PC plants, total number of production = 1,400 ea./day

(Phase 2)

3-PC plants will be relocated to new locations.

Total number of production = 1,000 ea./day

Plan C : (Phase 1)

3-new PC plants, total number of production = 600 ea./day

(Phase 2)

3-PC plants will be replace to new locations.

Total number of production = 600 ea./day

Construction Cost for PC Sleeper Plant

(Million Kyats)

Alternative	Cost			
	F/C	L/C	Tax	Total
A	38.009	4.056	18.349	60.414
B	36.523	3.432	17.632	57.587
C	20.658	1.872	9.972	32.502

Note: Relocation cost is included.

2) Temporary site workshop for welding

Based on the number of rail weldings, the temporary site workshops (two to five shops at a time) shall be set at 30 km interval along the track. Each site workshop will be relocated to new location after the welding works for each area are completed.

Construction Cost of Temporary Site Workshop

(Million Kyats)

Alternative	Cost			
	F/C	L/C	Tax	Total
A	9.700	0.290	3.968	13.958
B	9.700	0.230	3.968	13.898
C	8.200	0.230	3.354	11.784

3) Ballast crushing plant

The facility plan was described in Chapter 5. For the project 2-new crushing plants are necessary to the quarry sites. The cost of plants is as follows:

Construction Cost of Crushing Plants

(Million Kyats)

Alternative	Cost			
	F/C	L/C	Tax	Total
A, B, C	11.000	0.306	5.310	11.837

8-6 Investment Cost for Rolling Stock

Based on the future traffic demand and the new train operation plan which is described in Chapter 4, the additional investment cost for rolling stock is shown below. This cost is excluded in the project cost.

Investment Cost for Rolling Stock

(Million Kyats)

Rolling Stock	Investment Period				Total
	by 1993/94 (Phase-1)	by 1996/97 (Phase-2)	by 2005/06	by 2016/17	
Loco	-	-	-	470.580	470.580
PC	-	-	3.072	144.384	147.455
FC	140.420	-	781.929	1,701.087	2,623.436
Total	140.420	-	785.001	2,316.051	3,241.472

Note: Loco. = Locomotive DF1600
PC = Passenger Coach
FC = Freight Wagon

Unit Cost for Rolling Stock 1/

(Million Kyats)

	Loco		PC	FC
	DF1600	DF1200		
1987/88 - 96/97	17.303	13.31	1.12	0.34
1997/98 - 2/	15.686	12.093	1.024	0.307

1/: Including L/C, Tax

2/: Semi Knock Down

Table 8.3.1 Summary of Economic Costs in 1986 Prices

(Million Kyats)

Case	Item	Phase	1st	2nd	Total
Track A Signal A	Track	F/C	231.256	154.618	385.874
		L/C	71.490	60.426	131.916
		Sub-total	309.746	215.044	517.790
(Alternative -1)	Telecom	F/C	97.336	129.030	226.366
		L/C	3.724	4.935	8.659
		Sub-total	101.060	133.965	235.025
	Signal	F/C	75.024	97.881	172.905
		L/C	1.128	1.473	2.601
		Sub-total	76.152	99.354	175.506
	Total	F/C	403.616	381.529	785.145
		L/C	76.342	66.834	143.176
		Sub-total	479.958	448.363	928.321
	Engineering service	F/C	27.920	16.560	44.480
		L/C	0.370	0.280	0.650
		Sub-total	28.290	16.840	45.130
	Contingency (10% of the total)	F/C	40.362	38.153	78.515
		L/C	7.634	6.683	14.317
		Sub-total	47.996	44.836	92.832
	Grand total	F/C	471.898	436.242	908.140
		L/C	84.346	73.797	158.143
		Sub-total	556.244	510.039	1,066.283
Track A Signal B	Track	F/C	231.256	154.618	385.874
		L/C	71.490	60.426	131.916
		Sub-total	302.746	215.044	517.790
(Alternative -2)	Telecom	F/C	97.336	129.030	226.366
		L/C	3.724	4.935	8.659
		Sub-total	101.060	133.965	235.025
	Signal	F/C	84.896	112.536	197.432
		L/C	1.288	1.707	2.995
		Sub-total	86.184	114.243	200.427
	Total	F/C	413.488	396.184	809.672
		L/C	76.502	67.068	143.570
		Sub-total	489.990	463.252	953.242
	Engineering service	F/C	27.920	16.560	44.480
		L/C	0.370	0.280	0.650
		Sub-total	28.290	16.840	45.130
	Contingency (10% of the total)	F/C	41.349	39.618	80.967
		L/C	7.650	6.707	14.357
		Sub-total	48.999	46.325	95.324
	Grand total	F/C	482.757	452.362	935.119
		L/C	84.522	74.055	158.577
		Sub-total	567.279	526.417	1,093.696

Note: F/C = Foreign currency component
L/C = Local currency component

Table 8.3.2 Summary of Economic Costs in 1986 Prices

(Million Kyats)

Case	Item	Phase	1st	2nd	Total
Track B Signal A	Track	F/C	217.409	138.636	356.045
		L/C	65.141	53.052	118.193
		Sub-total	282.550	191.688	474.238
(Alternative -3)	Telecom	F/C	97.336	129.030	226.366
		L/C	3.724	4.935	8.659
		Sub-total	101.060	133.965	235.025
	Signal	F/C	75.024	97.881	172.905
		L/C	1.128	1.473	2.601
		Sub-total	76.152	99.354	175.506
	Total	F/C	389.769	365.547	755.316
		L/C	69.993	59.460	129.453
		Sub-total	459.762	425.007	884.769
	Engineering service	F/C	27.920	16.560	44.480
		L/C	0.370	0.280	0.650
		Sub-total	28.290	16.840	45.130
	Contingency (10% of the total)	F/C	38.977	36.555	75.532
		L/C	6.999	5.946	12.945
		Sub-total	45.976	42.501	88.477
	Grand total	F/C	456.666	418.662	875.328
		L/C	77.362	65.686	143.048
		Sub-total	534.028	484.348	1,018.376
Track B Signal B	Track	F/C	217.409	138.636	356.045
		L/C	65.141	53.052	118.193
		Sub-total	282.550	191.688	474.238
(Alternative -4)	Telecom	F/C	97.336	129.030	226.366
		L/C	3.724	4.935	8.659
		Sub-total	101.060	133.965	235.025
	Signal	F/C	84.896	112.536	197.432
		L/C	1.288	1.707	2.995
		Sub-total	86.184	114.243	200.427
	Total	F/C	399.641	380.202	779.843
		L/C	70.153	59.694	129.847
		Sub-total	469.794	439.896	909.690
	Engineering service	F/C	27.920	16.560	44.480
		L/C	0.370	0.280	0.650
		Sub-total	28.290	16.840	45.130
	Contingency (10% of the total)	F/C	39.964	38.020	77.984
		L/C	7.015	5.970	12.985
		Sub-total	46.979	43.990	90.969
	Grand total	F/C	467.525	434.782	902.307
		L/C	77.538	65.944	143.482
		Sub-total	545.063	500.726	1,045.789

Note: F/C = Foreign currency component
L/C = Local currency component

Table 8.3.3 Summary of Economic Costs in 1986 Prices

(Million Kyats)

Case	Item	Phase	1st	2nd	Total
Track C Signal A	Track	F/C	165.019	116.406	281.425
		L/C	47.178	39.376	86.554
		Sub-total	212.197	155.782	367.979
(Alternative -5)	Telecom	F/C	97.336	129.030	226.366
		L/C	3.724	4.935	8.659
		Sub-total	101.060	133.965	235.025
	Signal	F/C	75.024	97.881	172.905
		L/C	1.128	1.473	2.601
		Sub-total	76.152	99.354	175.506
	Total	F/C	337.379	343.317	680.696
		L/C	52.030	45.784	97.814
		Sub-total	389.409	389.101	778.510
	Engineering service	F/C	27.920	16.560	44.480
		L/C	0.370	0.280	0.650
		Sub-total	28.290	16.840	45.130
	Contingency (10% of the total)	F/C	33.738	34.332	68.070
		L/C	5.203	4.578	9.781
		Sub-total	38.941	38.910	77.851
	Grand total	F/C	399.037	394.209	793.246
		L/C	57.603	50.642	108.245
		Sub-total	456.640	444.851	901.491
Track C Signal B	Track	F/C	165.019	116.406	281.425
		L/C	47.178	39.376	86.554
		Sub-total	212.197	155.782	367.979
(Alternative -6)	Telecom	F/C	97.336	129.030	226.366
		L/C	3.724	4.935	8.659
		Sub-total	101.060	133.965	235.025
	Signal	F/C	84.896	112.536	197.432
		L/C	1.288	1.707	2.995
		Sub-total	86.184	114.243	200.427
	Total	F/C	347.251	357.972	705.223
		L/C	52.190	46.018	98.208
		Sub-total	399.441	403.990	803.431
	Engineering service	F/C	27.920	16.560	44.480
		L/C	0.370	0.280	0.650
		Sub-total	28.290	16.840	45.130
	Contingency (10% of the total)	F/C	34.725	35.797	70.522
		L/C	5.219	4.602	9.821
		Sub-total	39.944	40.399	80.343
	Grand total	F/C	409.896	410.329	820.225
		L/C	57.779	50.900	108.679
		Sub-total	467.675	461.229	928.904

Note: F/C = Foreign currency component
L/C = Local currency component

Table 8.3.4 Summary of Project Costs in 1986 Prices

(Million Kyats)

Case	Item	Phase	1st	2nd	Total
Track A Signal A	Track	F/C	231.256	154.618	385.874
		L/C	171.363	137.417	308.780
		Sub-total	402.619	292.035	694.654
(Alternative -1)	Telecom	F/C	97.336	129.030	226.366
		L/C	47.744	63.288	111.032
		Sub-total	145.080	192.318	337.398
	Signal	F/C	75.024	97.881	172.905
		L/C	33.440	43.629	77.069
		Sub-total	108.464	141.510	249.974
	Total	F/C	403.616	381.529	785.145
		L/C	252.547	244.334	496.881
		Sub-total	656.163	625.863	1,282.026
	Engineering service	F/C	27.920	16.560	44.480
		L/C	0.370	0.280	0.650
		Sub-total	28.290	16.840	45.130
	Contingency (10% of the total)	F/C	40.361	38.153	78.514
		L/C	25.255	24.433	49.688
		Sub-total	65.616	62.586	128.202
	Grand total	F/C	471.897	436.247	908.139
		L/C	278.172	269.047	547.219
		Sub-total	750.069	705.289	1,455.358
Track A Signal B	Track	F/C	231.256	154.618	385.874
		L/C	171.363	137.417	308.780
		Sub-total	402.619	292.035	694.654
(Alternative -2)	Telecom	F/C	97.336	129.030	226.366
		L/C	47.744	63.288	111.032
		Sub-total	145.080	192.318	337.398
	Signal	F/C	84.896	112.536	197.432
		L/C	37.836	50.154	87.990
		Sub-total	122.732	162.690	285.422
	Total	F/C	413.488	396.184	809.672
		L/C	256.943	250.859	507.802
		Sub-total	670.431	647.043	1,317.474
	Engineering service	F/C	27.920	16.560	44.480
		L/C	0.370	0.280	0.650
		Sub-total	28.290	16.840	45.130
	Contingency (10% of the total)	F/C	41.349	39.618	80.967
		L/C	25.694	25.086	50.780
		Sub-total	67.043	64.704	131.747
	Grand total	F/C	482.757	452.362	935.119
		L/C	283.007	276.225	559.232
		Sub-total	765.764	728.587	1,494.351

Note: F/C = Foreign currency component
L/C = Local currency component

Table 8.3.5 Summary of Project Costs in 1986 Prices

(Million Kyats)

Case	Item	Phase	1st	2nd	Total
Track B Signal A	Track	F/C	217.409	138.636	356.045
		L/C	158.056	110.369	268.425
		Sub-total	375.465	249.005	624.470
(Alternative -3)	Telecom	F/C	97.336	129.030	226.366
		L/C	47.744	63.288	111.032
		Sub-total	145.080	192.318	337.398
	Signal	F/C	75.024	97.881	172.905
		L/C	33.440	43.629	77.069
		Sub-total	108.464	141.510	249.974
	Total	F/C	389.769	365.547	755.316
		L/C	239.240	217.286	456.526
		Sub-total	629.009	582.833	1,211.842
	Engineering service	F/C	27.920	16.560	44.480
		L/C	0.370	0.280	0.650
		Sub-total	28.290	16.840	45.130
	Contingency (10% of the total)	F/C	38.977	36.555	75.532
		L/C	23.924	21.729	45.653
		Sub-total	62.901	58.284	121.185
	Grand total	F/C	456.666	418.662	875.328
		L/C	263.534	239.295	502.829
		Sub-total	720.200	657.957	1,378.157
Track B Signal B	Track	F/C	217.409	138.636	356.045
		L/C	158.056	110.369	268.425
		Sub-total	375.465	249.005	624.470
(Alternative -4)	Telecom	F/C	97.336	129.030	226.366
		L/C	47.744	63.288	111.032
		Sub-total	145.080	192.318	337.398
	Signal	F/C	84.896	112.536	197.432
		L/C	37.836	50.154	87.990
		Sub-total	122.732	162.690	285.422
	Total	F/C	399.641	380.202	779.843
		L/C	243.636	223.811	467.447
		Sub-total	643.277	604.013	1,247.290
	Engineering service	F/C	27.920	16.560	44.480
		L/C	0.370	0.280	0.650
		Sub-total	28.290	16.840	45.130
	Contingency (10% of the total)	F/C	39.964	38.020	77.984
		L/C	24.364	22.381	46.745
		Sub-total	64.328	60.401	124.729
	Grand total	F/C	467.525	434.782	902.307
		L/C	268.370	246.472	514.842
		Sub-total	735.895	681.254	1,417.149

Note: F/C = Foreign currency component
L/C = Local currency component

Table 8.3.6 Summary of Project Costs in 1986 Prices

(Million Kyats)

Case	Item	Phase	1st	2nd	Total
Track C Signal A (Alternative -5)	Track	F/C	165.019	116.406	281.425
		L/C	117.564	88.292	205.856
		Sub-total	282.583	204.698	487.281
	Telecom	F/C	97.336	129.030	226.366
		L/C	47.744	63.288	111.032
		Sub-total	145.080	192.318	337.398
	Signal	F/C	75.024	97.881	172.905
		L/C	33.440	43.629	77.069
		Sub-total	108.464	141.510	249.974
	Total	F/C	337.379	343.317	680.696
		L/C	198.748	195.209	393.957
		Sub-total	536.127	538.526	1,074.653
	Engineering service	F/C	27.920	16.560	44.480
		L/C	0.370	0.280	0.650
		Sub-total	28.290	16.840	45.130
	Contingency (10% of the total)	F/C	33.738	34.332	68.070
		L/C	19.875	19.521	39.396
		Sub-total	53.613	53.853	107.466
	Grand total	F/C	399.037	394.209	793.246
		L/C	218.993	215.010	434.003
		Sub-total	618.030	609.219	1,227.249
Track C Signal B (Alternative -6)	Track	F/C	165.019	116.406	281.425
		L/C	117.564	88.292	205.856
		Sub-total	282.583	204.698	487.281
	Telecom	F/C	97.336	129.030	226.366
		L/C	47.744	63.288	111.032
		Sub-total	145.080	192.318	337.398
	Signal	F/C	84.896	112.536	197.432
		L/C	37.836	50.154	87.990
		Sub-total	122.732	162.690	285.422
	Total	F/C	347.251	357.972	705.223
		L/C	203.144	201.734	404.878
		Sub-total	550.395	559.706	1,110.101
	Engineering service	F/C	27.920	16.560	44.480
		L/C	0.370	0.280	0.650
		Sub-total	28.290	16.840	45.130
	Contingency (10% of the total)	F/C	34.725	35.797	70.522
		L/C	20.315	20.173	40.488
		Sub-total	55.040	55.970	111.010
	Grand total	F/C	409.896	410.329	820.225
		L/C	223.829	222.187	446.016
		Sub-total	633.725	632.516	1,266.241

Note: F/C = Foreign currency component
L/C = Local currency component

Table 8.3.7 Comparative Table of Economic Costs

(Million Kyats)

Item	Currency \ Alternative	1	2	3	4	5	6
Track	F/C	385.874	385.874	356.045	356.045	281.425	281.425
	L/C	131.916	131.916	118.193	118.193	86.554	86.554
	Sub-total	517.790	517.790	474.238	474.238	367.979	367.979
Telecom-munication	F/C	226.366	226.366	226.366	226.366	226.366	226.366
	L/C	8.659	8.659	8.659	8.659	8.659	8.659
	Sub-total	235.025	235.025	235.025	235.025	235.025	235.025
Signalling	F/C	172.905	197.432	172.905	197.432	172.905	197.432
	L/C	2.601	2.995	2.601	2.995	2.601	2.995
	Sub-total	175.506	200.427	175.506	200.427	175.506	200.427
Total	F/C	785.145	809.672	755.316	779.843	680.696	705.223
	L/C	143.176	143.570	129.453	129.847	97.814	98.208
	Sub-total	928.321	953.242	884.769	909.690	778.510	803.431
Engineering service	F/C	44.480	44.480	44.480	44.480	44.480	44.480
	L/C	0.650	0.650	0.650	0.650	0.650	0.650
	Sub-total	45.130	45.130	45.130	45.130	45.130	45.130
Contingency (10% of the total)	F/C	78.515	80.967	75.532	77.984	68.070	70.522
	L/C	14.317	14.357	12.945	12.985	9.781	9.821
	Sub-total	92.832	95.324	88.477	90.969	77.851	80.343
Grand total	F/C	908.140	935.119	875.328	902.307	793.246	820.225
	L/C-total	158.143	158.577	143.048	143.482	108.245	108.679
	Sub-total	1,066.283	1,093.696	1,018.376	1,045.789	901.491	928.904

Note: F/C: Foreign Currency Component
L/C: Local Currency Component

Table 8.3.8 Comparative Table of Project Costs

(Million Kyats)

Item	Currency \ Alternative	1	2	3	4	5	6
Track	F/C	385.874	385.874	356.045	356.045	281.425	281.425
	L/C	308.780	308.780	268.425	268.425	205.856	205.856
	Sub-total	694.654	694.654	624.470	624.470	487.281	487.281
Telecom-munication	F/C	226.366	226.366	226.366	226.366	226.366	226.366
	L/C	111.032	111.032	111.032	111.032	111.032	111.032
	Sub-total	337.398	337.398	337.398	337.398	337.398	337.398
Signalling	F/C	172.905	197.432	172.905	197.432	172.905	197.432
	L/C	77,069	87.990	77.069	87.990	77.069	87.990
	Sub-total	249.974	285.422	249.974	285.422	249.974	285.422
Total	F/C	785.145	809.672	755.316	779.843	680.696	705.223
	L/C	496.881	507.802	456.526	467.447	393.957	404.878
	Sub-total	1,282.026	1,317.474	1,211.842	1,247.290	1,074.653	1,110.101
Engineering service	F/C	44.480	44.480	44.480	44.480	44.480	44.480
	L/C	0.650	0.650	0.650	0.650	0.650	0.650
	Sub-total	45.130	45.130	45.130	45.130	45.130	45.130
Contingency (10% of the total)	F/C	78.514	80.967	75.532	77.984	68.070	70.522
	L/C	49.688	50.780	45.653	46.745	39.396	40.488
	Sub-total	128.202	131.747	121.185	124.729	107.466	111.010
Grand total	F/C	908.139	935.119	875.328	902.307	793.246	820.225
	L/C-total	547.219	559.232	502.829	514.842	434.003	446.016
	Sub-total	1,455.358	1,494.351	1,378.157	1,417.149	1,227.249	1,266.241

Note: F/C: Foreign Currency Component
L/C: Local Currency Component