THE KINGDOM OF THAILAND

# STUDY REPORT

ON

THE PROJECT OF STRENGTHENING AND/OR REPLACEMENT
OF STEEL BRIDGES ON THE STATE RAILWAY OF THAILAND

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JANUARY 19[illegible]

JAPAN INTERNATIONAL COOPERATION AGENCY

Volume 1/4

THE KINGDOM OF THAILAND

# STUDY REPORT

ON

THE PROJECT OF STRENGTHENING AND/OR REPLACEMENT OF STEEL BRIDGES ON THE STATE RAILWAY OF THAILAND

A Sub-Project for The Trans-Asian Railway Project of The Economic and Social Commission for Asia and The Pacific (ESCAP)



JANUARY 1977

JAPAN INTERNATIONAL COOPERATION AGENCY

# PREFACE

The Government of Japan, in response to the request of the Government of the Kingdom of Thailand and the Economic and Social Commission for Asia and the Pacific (ESCAP), decided to conduct a study for the project of strengthening and/or replacement of steel bridges on the State Railway of Thailand and Japan International Cooperation Agency (JICA) conducted the study.

The study is concerned with the 214 spans of steel bridges which are located along the 4,000 Km length of the Thai State Railway network and this project is designated as a high priority project in the Fourth National Economic and Social Development Plan of Thailand.

The Agency carried out its preliminary survey in October 1975, and executed the detailed field survey based on the report of the former survey from February to March 1976. Thereafter the interim report and the draft final report were prepared and explained to the authorities concerned in the Kingdom of Thailand and ESCAP in August and November, 1976, respectively.

I am very happy to note that the final report is now submitted to the Thai Government and ESCAP after completing the necessary corrections and revisions in compliance with suggestion of the authorities concerned in the Kingdom of Thailand and ESCAP.

Altogether 26 staffs were involved in the survey and the study was carried out in a very smooth manner with full cooperation of the authorities concerned in the Kingdom of Thailand and ESCAP authorities concerned.

It is quite a long time since a railway expansion programme was proposed in Thailand and now the request for the strengthening of the railway transportation is stronger than ever.

I believe that the project has a great importance and sincerely hope that this report will contribute to a further progress of the project in future and promote friendly relations between Japan and Thailand.

Finally, I would like to express my deep appreciation to all the staffs who have participated in this study and also to express my heartfelt gratitude to the authorities concerned in the Kingdom of Thailand for the cooperation extended to the team.

January 1977

Shinsaku Hogen

Shinsaku Hogen
President
Japan International Cooperation Agency
Tokyo Japan

## LETTER OF TRANSMITTAL

Mr. Shinsaku Hogen
President,
Japan International Cooperation Agency,
Tokyo, Japan

Dear Sir,

We have the pleasure of submitting the final report on Study on Strengthening and/or Replacement of Steel Bridges on the State Railway of Thailand, in compliance with an agreement between the Government of Japan and the Government of Thailand.

The primary purpose of the study was to present the methods of improvement of the 214 spans of bridges of the State Railway of Thailand and to estimate an approximate cost to be required for the improvement work.

To attain the above purpose, a survey mission conducted field investigation three times from October 1975 to August 1976 and collected necessary data. In Japan, based on the field survey and information obtained in Thailand, the strength of each bridge was calculated, improvement methods such as repair, strengthening and replacement were studied, and the cost for the improvement was estimated.

We are confident that if those bridges are improved according to the methods recommended in this report, they will restore sufficient strength and will greatly improve the operation of the State Railway of Thailand.

It is our sincere hope that the improvement work will be implemented as soon as possible, based on the suggestions presented in this report.

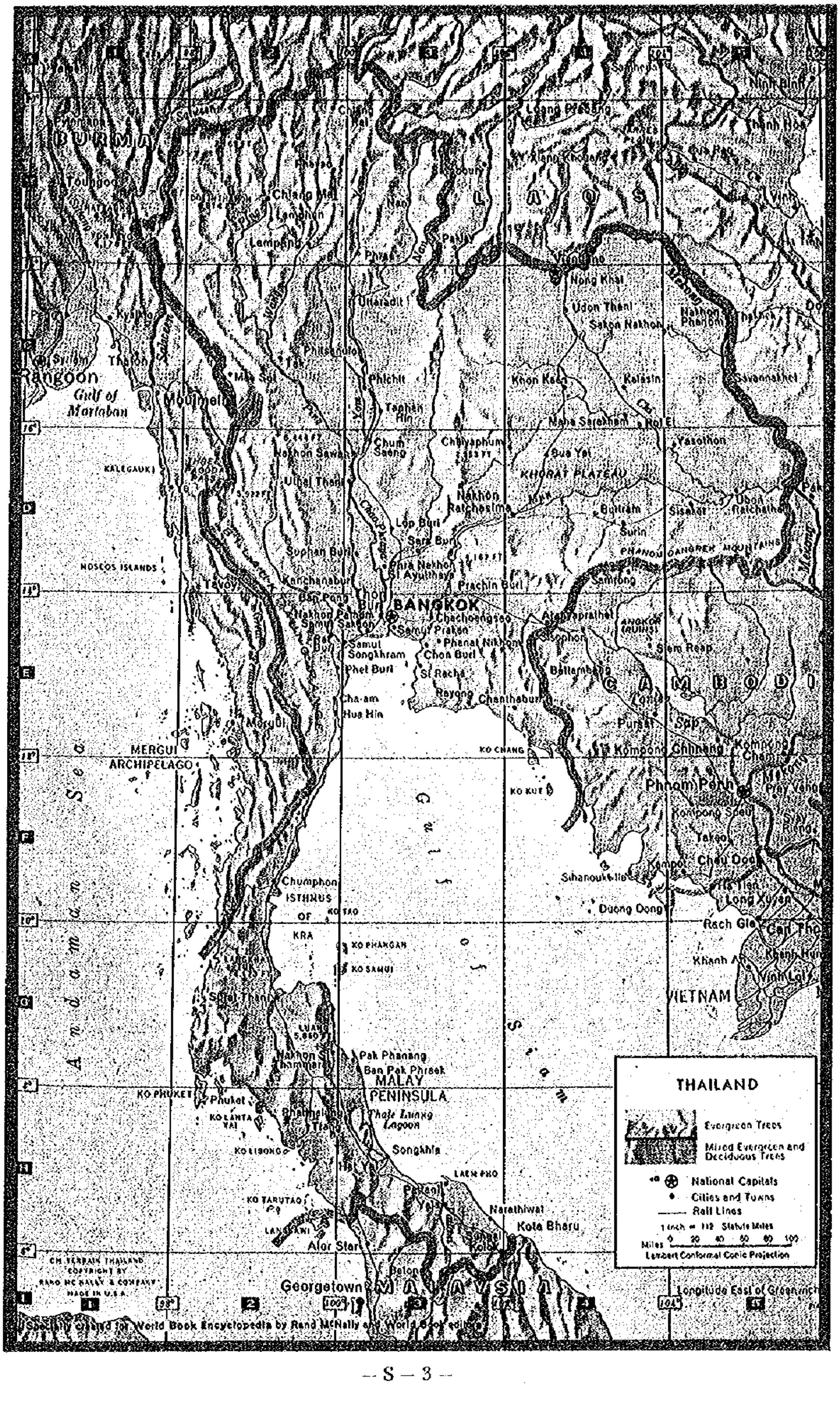
In submitting this report we wish to express our sincere appreciation and gratitude to the personnel of your Agency, the Japanese Embassy of Thailand, the authorities concerned of the Government of Thailand, the State Railway of Thailand and the coordination of ESCAP for the courtesies and cooperation afforded during our field survey and home office work.

Very truly yours

Hidehiko Abe

Hidehiko ABE
Team Leader
JICA Survey Team

Fig. S–1 LOCATION MAP



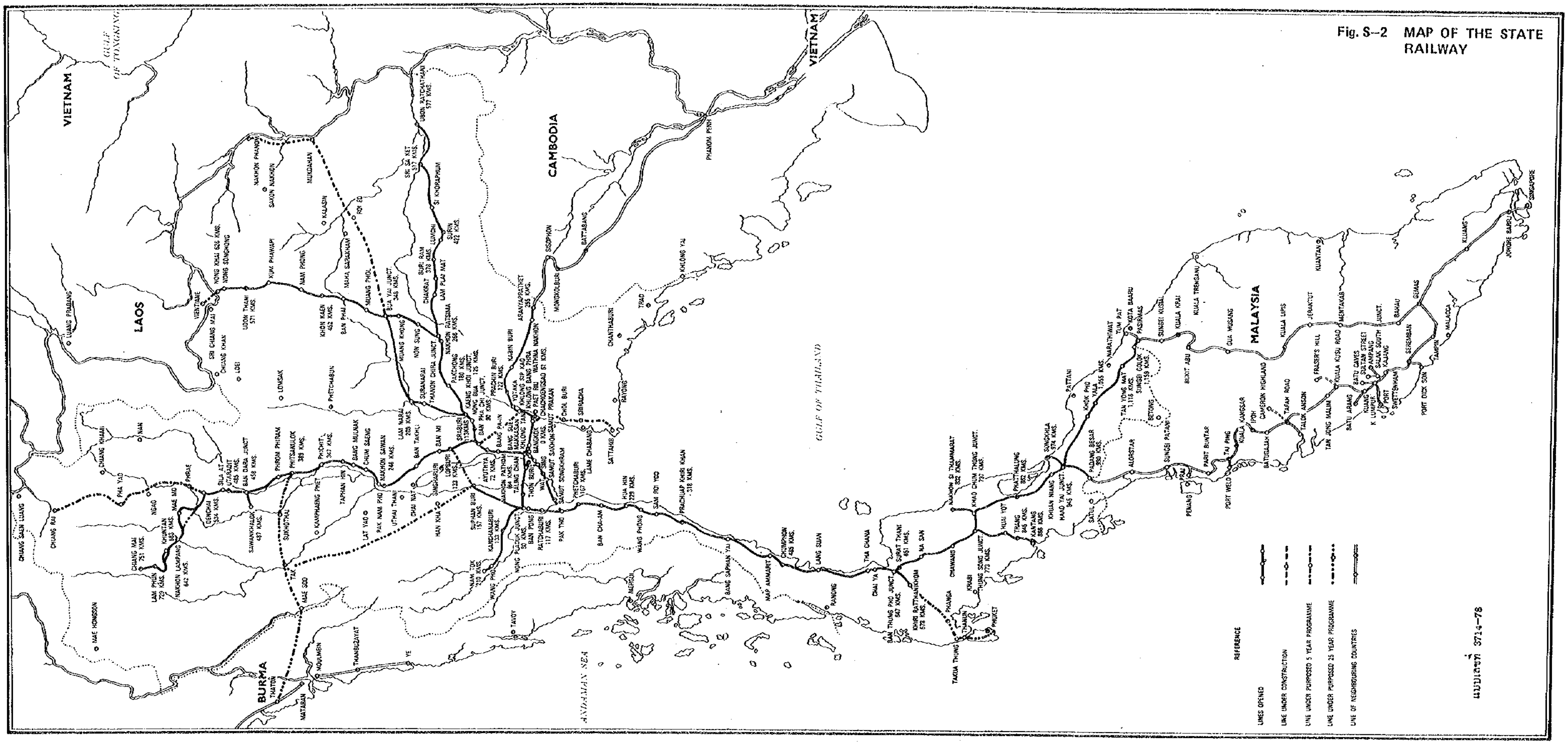
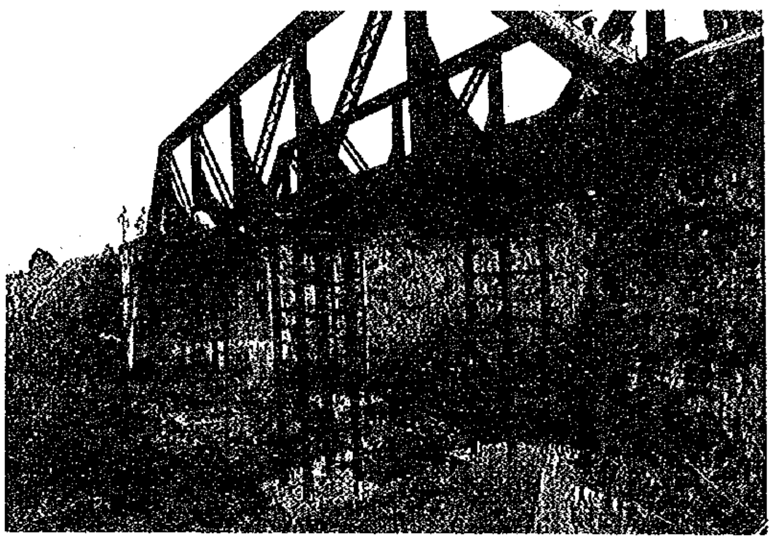



Fig. S-2 MAP OF THE STATE RAILWAY

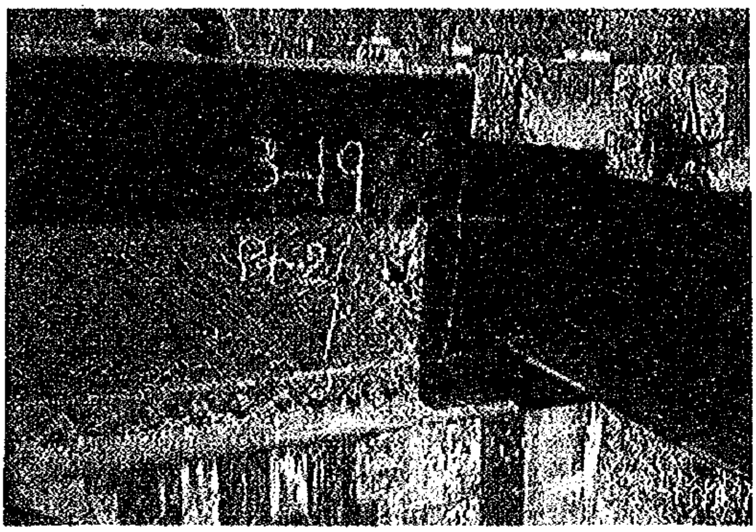
Field inspection work

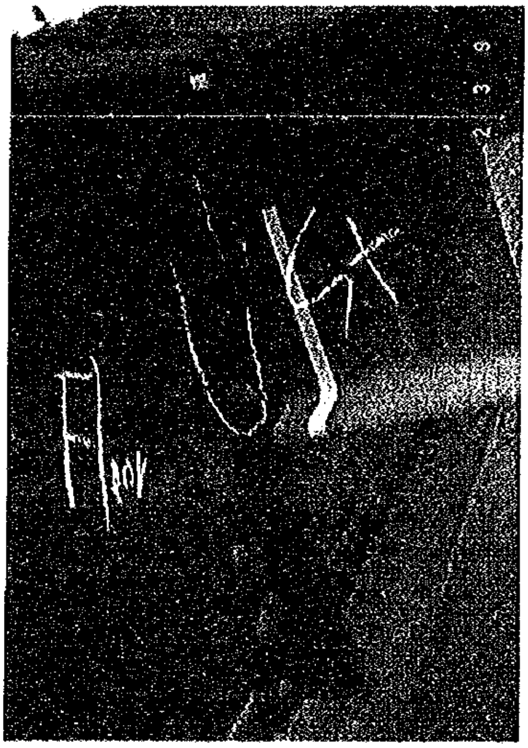
Reinforcement by means of staging



Timber bridge

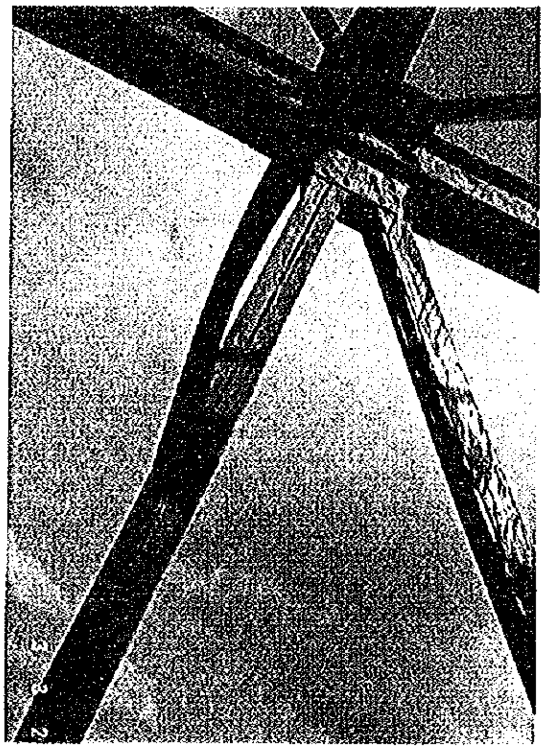
Corrosion of floor beam



Loose rivets of connection for stringer

Deformation of sway bracing



# SUMMARY AND RECOMMENDATIONS

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# I. FOREWORD

This report summarizes the results of the field survey, evaluation of the load-carrying capacity, design and methods for strengthening, repair or replacement and estimation of the cost required for the purpose of improvement of the existing 214 spans of steel bridges owned by the State Railway of Thailand (RSR).

The State Railway of Thailand has a plan to strengthen, repair and replace inadequate steel bridges as part of Investment Program 1977 - 1981, to be incorporated in the Fourth National Five-Year Social and Economic Development Plan of Thailand (hereafter called the Fourth Plan).

This study was carried out by the Japan International Cooperation Agency (JICA) at the request made by the Government of Kingdom of Thailand and accepted by the Japanese Government through the Economic and Social Commission for Asia and the Pacific (ESCAP), and mainly consists of the technical investigation concerning the abovementioned project.

Moreover, the study was executed on the basis of agreements regarding the investigation targets, signed by JICA, RSR and ESCAP.

Field inspection of bridges and collection of data were carried out three times starting from October 1975. Based thereon, assessment of the results of these field surveys, studies of standard design drawings and construction methods, together with cost estimation, etc., were performed to complete the task.

JARTS (Japan Railway Technical Service) undertook the work by contract after the preliminary investigation.

## II. CONCLUSION AND RECOMMENDATIONS

(1) According to the results of technical studies such as estimation of the load-carrying capacity of bridges following the field survey, every one of the 214 spans of steel bridges subjected to investigation was ascertained to require some kind of improvement work.

(2) The improvement project regarding repairs, strengthening or replacement should be made, taking into consideration the economical effects resulting from such projects, comparison of importance and requirement of each rail line route, etc., in addition to the results of this technical investigation.

(3) The 214 spans of steel bridges require not only repair/strengthening because of corrosion, deformation and excessive stress, but also improvement because of structural defects. In preparation of the standard designs, elimination of all these inadequacies was taken into consideration. However, priority should be placed on bridges which have undergone severe corrosion and large deformation, from a view point of traffic a safety.

(4) Nine bridges should preferably be replaced in view of traffic safety, difficulty in repairs, and their degree of deterioration if the bridges must be provided with a carrying capacity sufficient for DL-15 Loading passing at a normal speed.

(5) Eleven bridges have localized but severe defects and require urgent repair before the start of the improvement project, to ensure safety of current train operations.

(6) Repair and/or strengthening work will be carried out in such a manner as to minimize interference with train operation.

(7) The construction cost required for improvement of the 214 spans is as shown in Table S-1. Here it is assumed that 197 spans are repaired and/or strengthened and 17 spans are replaced with new ones and that the construction period is five years.

Table S - 1 Construction Cost

| Item | Foreign Currency | | Domestic Currency | Total |
|---|---|---|---|---|
| | Bahts | (US Dollars) | Bahts | Bahts |
| Construction Cost | 160,536,000 | (8,027,000) | 173,127,000 | 333,663,000 |

Notes: Rate of exchange; 1 US Dollar = 20 Bahts
Year of estimation; 1976
Rate of price escalation; 10% per year

(8) There would be practically no structural problem if all of the 214 spans were replaced with new bridges but the cost in this case would be some 2.5 times the cost for repair and/or strengthening.

(9) The difference between construction costs for strengthening by DL-15 Loading and DL-14 Loading would be as low as 3%. Accordingly, we recommend DL-15 Loading as the design loading to be used for the improvement work. Also it would be advisable

to allow a slight load margin to increase safety, especially against fatigue.

(10) It is preferable to carry out the following investigations:

i ) Test to ascertain the frictional coefficient of contact surfaces of steel elements to be cleaned at site and connected by high-strength bolts.

ii ) Test for applicability of flame cleaning for increasing the frictional coefficient of steel elements to be connected by high-strength bolts.

iii) Periodical measurement for displacement of substructures in question.

(11) It is suggested that it may be beneficial for RSR in implementing the recommendations contained in the report, to obtain a few advisors for technical and financial requirements for a first new initial years.

# III. OUTLINE

## 1. Background

Before World War II, RSR adopted a bridge design loading diagrams as shown in Drg. 1965 and Drg. 1965 - 2 and most of the bridges to be improved under this project were designed according to a loading diagram shown in Drg. 1965, which consisted of two steem locomotives accompanied by tenders and trailing load with maximum axle load of 10.5 tons.

In 1946, 15-ton British standard loading (TS-15), which permitted a maximum axle load of 18.75 tons, was adopted and approximately 30% of RSR bridges were replaced with new ones conforming with TS-15 Loading during the period 1946 through 1971. From that period, RSR implemented a dieselization plan and in 1969 the British mission of the United Kingdom Railway Advisory Service (UKRAS) recommended a design load based on two CO-CO diesel locomotive units with maximum axle load of 13.75 tons, which was more or less equivalent to the 11 tons standard loading (TS-11), and reported that most of the existing bridges were strong enough for TS-11 Loading, except the 214 spans of steel bridges under investigation.

On the other hand, in 1972 the ECAFE/Japanese mission proposed DL type loading, which involves an axle load of 14 tons, as the load for the meter-gauge track of the Trans-Asian Railway network. This load also has approximately the same effect on a bridge as TS-11 Loading. The current investigation for the steel bridge improvement project was carried out on the basis of the load proposed by the abovementioned mission (Fig. S-3).

Thus, the current project is by no means a new project, but is rather a continuation of a series of bridge improvement projects started after the end of World War II, and its main target is to eliminate traffic operation trouble due to time-related deterioration of the bridges.

## 2. Project Area

The current total length of the four routes of RSR is 3,765 kilometers (excluding the Meklong Line). Each route runs radially from Bangkok, the capital of Thailand. The Eastern Line connects with Cambodian Railways at Aranyaprathet and the Southern Line connects with Malaysian Railways at Padang Besar and Sungai Korok. The Northeastern Line is planned to connect with Laotian Railways at Nong Khai in future (Fig. S-2).

RSR has been implementing the modernization project as a part of Investment Program 1972 - 1976 integrated in the Third National Five-Year Social and Economic Development Plan (hereinafter called the Third Plan). In the Fourth Plan, too, modernization including strengthening and replacement of bridges is listed as a project of top priority.

At the end of the 1976 fiscal year, RSR has 1397 steel bridges (2,853 spans) on its operational routes including the 214 spans judged by UKRAS to require strengthening and/or replacement due to deterioration.

The 214 steel bridge spans are distributed on the four routes and many timber bridges, amounting to 834 at the end of 1976, still exist on the lines, except for the Northern Line. Of the timber bridges, 240 are scheduled to be replaced in the period 1977 through 1981.

The current steel bridge improvement project will be executed in conjunction with the timber bridge replacement plan.

At present, the replacement of timber bridges is carried out independently by RSR, but training of bridge technicians is urgently necessary to contend with the increase in work required for realization of the current project.

## 3. Study

### 3-1 Purpose of Study

The purpose of the study is to indicate standard methods for repair/strengthening or replacement to improve the abovementioned 214 steel bridge spans and to calculate the construction cost.

### 3-2 Outline of Study

The scope of the work is outlined below.

1) Site inspection and study of bridges to determine repair and strengthening requirements based on corrosion and/or deterioration.
2) Collection of data necessary for estimating the construction costs and selecting the optimum construction method.
3) Stress analysis based on RSR drawings, to evaluate the load-carrying capacity of the existing bridges.
4) Preparation of standard drawings with the detail necessary for cost estimation of repair, strengthening or replacement of the bridges.
5) Preparation of construction plans and determination of construction costs on the basis of the standard drawings.
6) Preparation of design specifications and technical specifications for construction.
7) Technical training of personnel of RSR for bridge works and cost estimation.

### 3-3 Execution Plan

The execution plan for the improvement work will not be decided only by technical studies.

For this project, however, we propose a draft execution plan based on the following conditions, for the purpose of ensuring traffic safety, minimizing speed limitations and achieving cost effectiveness:

1) Improvement of bridges constituting greater danger to train operation will be given high priority.
2) Disturbance to train operation during the works will be minimized.
3) According to the current traffic density, the lines considered likely to generate more profit through improvement work will be given priority.
4) The work is scheduled to be accomplished in five years.
5) The work is planned in relation to the schedule for replacement of timber birdges.
6) Steel materials will be imported, but the processing of the members for repair and strengthening will be done by fabricators in Thailand.
7) The new bridges required for replacement will be imported from foreign countries.

Table S - 2 Bridge Improvement Plan by year Assumed for Cost Estimation

| Year | Northern Line | Northeastern Line | Southern Line | Eastern Line | Branch Lines | Total |
|---|---|---|---|---|---|---|
| | Number of bridge span to be improved | | | | | |
| lst | 5 | 6 | 9 | - | 2 | 22 |
| 2nd | 10 | 13 | 17 | - | - | 40 |
| 3rd | 6 | 13 | 20 | 13 | - | 52 |
| 4th | - | 13 | 20 | 13 | 5 | 51 |
| 5th | - | - | 16 | 11 | 22 | 49 |

3-4 Construction Costs

The construction costs are as shown in Table S-3. The cost estimation is based on prevailing rate during April 1976, with assumption of 10% per year as the rate of subsequent price escalation.

Table S - 3 Construction Costs

| Item | Foreign Currency | | Domestic Currency | Total |
|---|---|---|---|---|
| | Bahts ('000) | (US Dollars) ('000) | Bahts ('000) | Bahts ('000) |
| Basic Construction Cost | 118,522 | (5,926) | 127,600 | 246,121 |
| Escalated Cost | 160,536 | (8,027) | 173,127 | 333,663 |

Rate of exchange: 1 US Dollar = 20 Bahts

## 4. Technical Studies

4-1 Result of Field Survey

Most of the 214 steel bridge spans covered by the survey had been imported from France, England and Germany, and had been used for more than 45 years after erection. The oldest was constructed in 1895 and have been used for more than 80 years.

Structurally speaking, all of the bridges are of riveted structure, and the span lengths vary from 16m to 80m. (Table S-4).

Table S - 4 Number of Spans by Span Length and Type of Steel Bridges

| Span Length (m) | Deck Plate Girders | Through Plate Girders | Through Trusses | Deck Trusses |
|---|---|---|---|---|
| 16.00 | | 1 | | |
| 17.50 | 1 | | | |
| 20.00 | | 8 | | |
| 20.75 | | | 8 | |
| 25.00 | 2 | 1 | 25 | |
| 25.50 | | | 1 | |
| 30.00 | | | 67 | 1 |
| 31.40 | | | 2 | |
| 31.70 | | | 3 | |
| 33.52 | | | 1 | |
| 35.00 | | | 27 | |
| 40.00 | | | 9 | |
| 45.00 | | | 9 | |
| 48.00 | | | 2 | |
| 50.00 | | | 26 | |
| 60.00 | | | 5 | |
| 65.00 | | | 2 | |
| 70.00 | | | 5 | |
| 80.00 | | | 8 | |
| | 3 | 10 | 200 | 1 |

Corrosion and deformation, which are inherent causes of weakness in steel bridges, were detected in virtually every bridge. Routine maintenance, however, is well done and for the most part the bridges are considered to be sufficiently good for use, if adequate repair and/or strengthening works are performed. Deterioration and structural defect frequently observed in the survey were:

1) Corrosion of members
2) Loose rivets
3) Deformation of members
4) Inadequacy of the cross-sectional area of members and insufficient rigidity
5) Lack of secondary members
6) Dislocation of shoe rollers
7) Others

Due to environmental conditions, the bridges on the Northern and Northeastern Lines have comparatively less corrosion, whilst those on the Southern Line generally are more damaged by corrosion. The bridges on the Eastern Line are affected by displacement of abutments and, as a result, have dislocation of shoe rollers.

(1) Corrosion

Floor beams and lower lateral bracings are locally but severely corroded due to waste and garbage dropped from trains. This kind of corrosion exists on every line, and is an important point for repair and future maintenance (Photo S-3). Corrosion of main trusses and main girders occurs in only a few cases, but local corrosion of lower chord members at the part adjacent to the gusset plates can be observed in many bridges on the Southern Line.

(2) Connections

A considerable number of loose rivets were observed in the connections of principal members such as stringers and main trusses, and in the connections of secondary members such as lateral bracings and stringer struts (Photo S-4). These defects are considered to be mainly due to inadequate design.

(3) Deformation of members

Deformation of members was frequently observed in the web plates of lower chord members and lateral members, and likely to have been caused by heavy impacts (Photo S-5) or by improper erection work.

Many of the secondary members are too slender and accordingly not rigid enough. Even some of the principal members such as diagonal members are obviously of inadequate rigidity. Judged from the current level of technology, the original design appears to lack adequate consideration, especially in the case of compression members and secondary members.

(4) Stagings

According to the report of UKRAS, some bridges with insufficient load-carrying capacity have been strengthened with stagings (Photo S-1), but others, which are not furnished with stagings, are subject to speed limitation. Reinforcement by staging is comparatively simple, but the load portion borne by the stagings is not clear, and the actual effectiveness of this process is doubtful. This reinforcement is provisional and will be removed upon completion of the strengthening work of this project.

(5) Shoes

Dislocation or misalignment of shoe rollers was found in many bridges, in some cases, rollers are completely out of the shoe nest. The main cause of roller dislocation is displacement of the abutments or piers. Displacement of such substructures may still be in progress, but is generally proceeding at a very slow rate now.

Most of the dislocations are considered to have taken place during or soon after the construction work, and it is necessary to investigate the cause and ensure safety in future by periodic inspections. Moreover, some high piers require special attention.

(6) Bases of shoes

Faulty work in the laying of concrete under the shoe sole has caused gaps between the shoe sole and the concrete base, and sometimes cracks in the shoes.

Repair or replacement of defective shoes will be necessary.

## 4-2 Load-carrying Capacity of Existing Bridges

In general, the original design lacks sufficient safety factors for compression members and the lateral bracings are so slender that the whole bridge vibrates transversely when trains pass.

In the main trusses, some compressive diagonal members are weak due to excessive slenderness. Also, excessive stress in lower chord members was found in a few instances. Generally, however, the amount of excess of stress is small in members of the main trusses.

As for the floor system, excessive stress in the connecting rivets of stringers was found in many bridges, and most of the connecting rivets of struts were loose and ineffective. This reduces the allowable strength of the stringers. Few floor beams are subject to excessive stress due to corrosion, but there are many corroded floor beams which need to be repaired, taking the effect of fatigue into consideration.

## 4-3 Methods for Repair and/or Strengthening

All of the repair and/or strengthening works for the bridges lacking in load-carrying capacity as well as structural defects will be carried out on the basis of DL-15 loading.

As a rule, a constructional method which minimizes interference with train operation should be adopted, but in some cases train speed limitation and control of train intervals must be enforced to some extent. In principle, the works will be carried out during train intervals.

Repair and/or strengthening of bridge members will be done by adding new members to the original ones or by replacing original members with new ones. In each case, the new members or the added members must work effectively against the train load only, the dead load stress being borne by the original members.

## 4-4 New Bridges Considered for Replacement

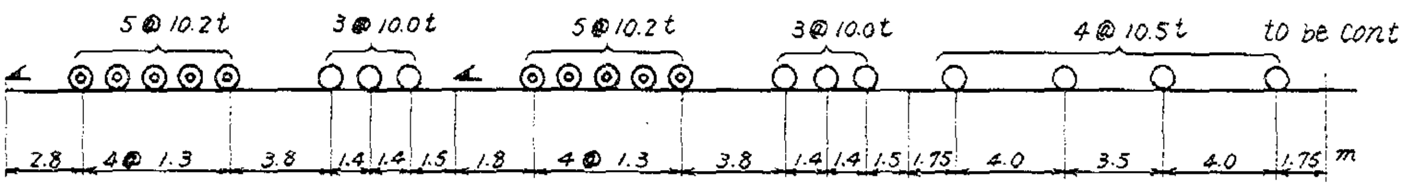
Preliminary designs have been prepared for the bridges for which replacement was considered necessary. For this purpose, through-plate girder bridges are planned because their span lengths are only 35 meters or less. The members of bridges are to be fabricated by welding at shops, and assembled with high-strength bolts at site.

The method to be used for replacement of bridges is generally the transverse sliding method.

Fig. S - 3 Representative Loading Diagrams for Railway Bridge Design in Thailand

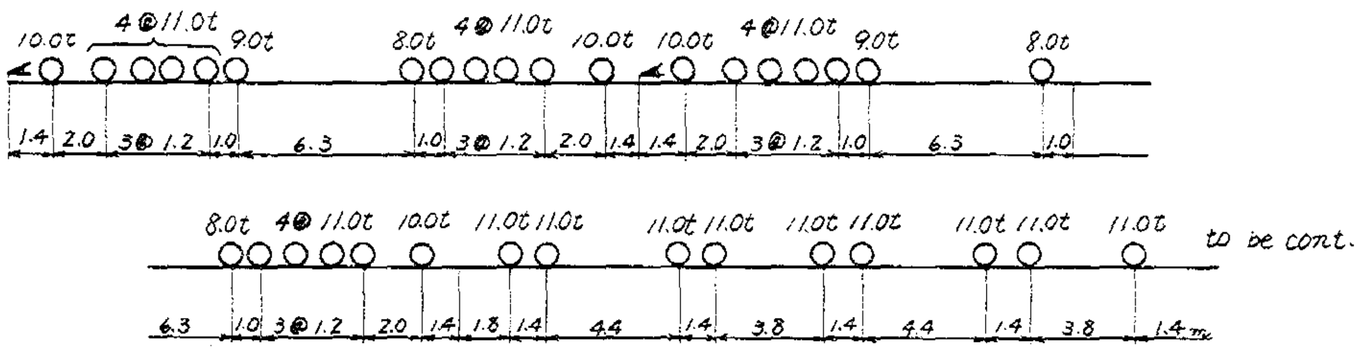
Remarks

"1965 Load"



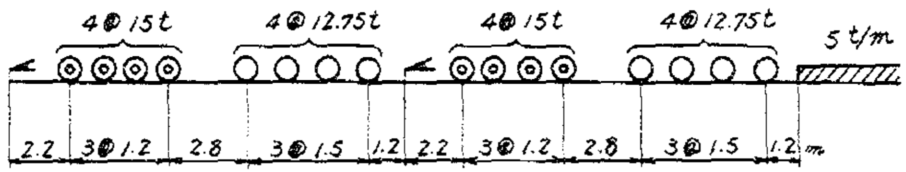

Loading diagram adopted during a period of 1912 to 1934

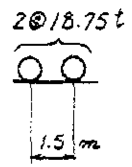
"1965 - 2 LOAD"




Loading diagram adopted during a period of 1934 to 1946.

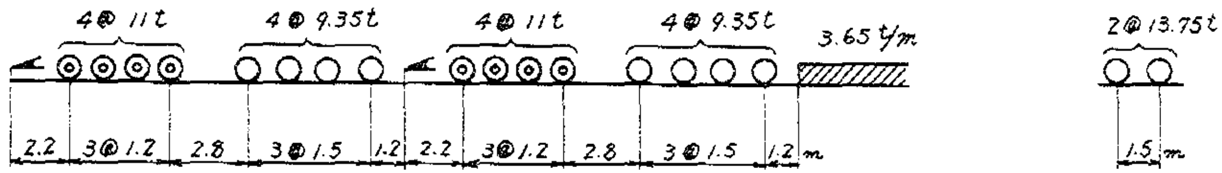
"1965 - 8 Load (TS 15)"



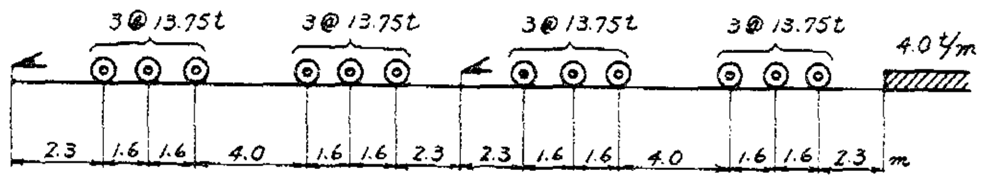

Loading diagram used since 1946

"1965 - 12 Load (TS-11)"



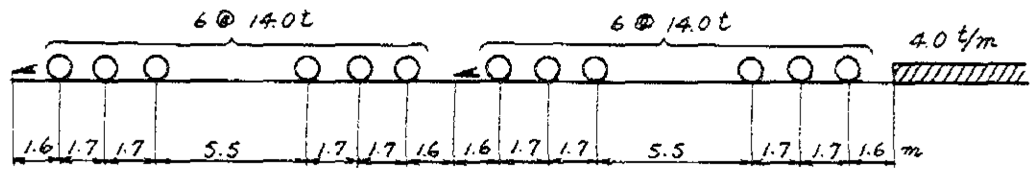

Loading diagram used for reference in purchase of locomotives (the same axle arrangements as "1965 - 8 Load," but the weight is eleven-fifteenths).

"Load Proposed by UKRAS"



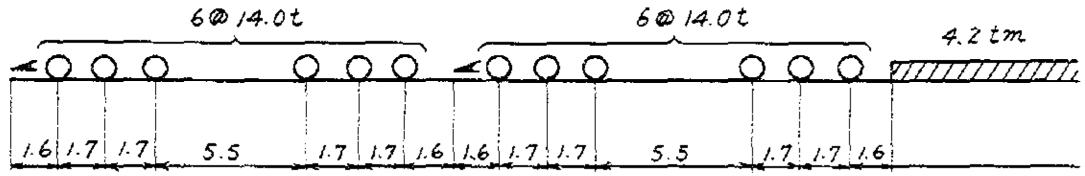

Loading diagram proposed by UKRAS, England in December, 1969

"Load Proposed by MINISTRY OF TRANSPORT, JAPAN 1972"



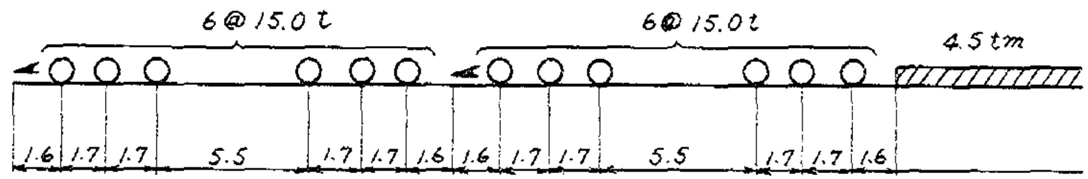

Loading diagram proposed for bridges for metre-gauge railways in the south-east Asian region in 1972

"DL - 14 Loading Present Improvement Project"




Loading diagram used for checking the load-carrying capacity of the 214 span steel bridges under investigation

"DL - 15 Loading Present Improvement Project"




Loading diagram used for strengthening, repair and replacement of those bridges.

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* Summary Sheets of Stress Check and Field Survey on 214 Spans of Steel Bridges (in Blueprint)
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# I. INTRODUCTION

# I. INTRODUCTION

## 1. Object of the Study

As of the end of fiscal year 1976, the State Railway of Thailand (RSR) had 1,397 steel bridges (2,853 spans) over its whole operating system. Of these there are 214 spans (169 bridges) which require improvement, as recommended by the United Kingdom Railway Advisory Service (UKRAS) in its 1972 survey.

The State Railway of Thailand is planning to repair, strengthen or replace a majority of these bridges under Investment Program 1977 - 1981, and this program is incorporated into the Fourth Plan of Thailand.

Since the State Railway of Thailand will form a part of the Trans-Asian Railway Project, the Government of the Kingdom of Thailand requested the Japanese Government through the Economic and Social Commission for Asia and the Pacific (ESCAP) to provide technical cooperation in investigation for improvements such as repair, strengthening or replacement of the 214 spans of steel bridges. In response to the official request, the Japanese Government decided to accord its cooperation and assigned the investigation work to the Japanese International Cooperation Agency (JICA).

The present study was carried out to evaluate the load-carrying capacities of 214 spans of steel bridges, to propose standard design and methods for repair and strengthening of them based on the field survey, to outline the structure of bridges for replacement and their construction methods and finally to estimate the cost for the improvement work of the bridges.

## 2. Background

Before World War II, the State Railway of Thailand had in use for its bridge loading diagrams as shown in Drg. 1965-2, and most of the bridges to be improved under this project were designed according to a loading shown in Drg. 1965, which consisted of two steam locomotives accompanied by tenders and a trailing load with maximum axle load of 10.5 tons. In 1946 the British 15-ton standard loading (TS-15, Drawing No. 1965-68), which permitted a maximum axle-load of 18.75 tons, was adopted and the project for bridge improvement involving replacement of all existing steel bridges was drawn up and implementation began thereafter.

In the meantime, bridges that were put into service prior to 1946 were investigated and found to be adequate for the British 11-ton standard loading (TS-11, permissible maximum axle-load of 13.75 tons) when the impact factor according to the JNR's formula was applied.

In 1969, the first UKRAS's report recommended that a loading based on two CO-CO diesel locomotive units with 4 tons per meter trailing load (maximum axle-load of 13.75 tons), which is more or less equivalent to TS-11 loading, should be adopted as standard in future for various reasons including, among others, the high investment cost which would result if heavier loading were to be adopted, and the fact that for the foreseeable future the train operations of RSR would not require any heavier loading standard.

In 1970, on the recommendation of the then ECAFE's Working Party of Experts for the Trans-Asian Railway (November 26 to December 3, 1970), a standard loading that would be the most suitable for the meter gauge part of the Trans-Asian Railway was further investigated. A Joint ECAFE/Japanese Study Team was dispatched in March 1972 to Thailand, Indonesia and Malaysia. The recommended loading proposed by this study was based on two CO-CO diesel locomotive units, each of which is 15.5 meters long, having 14 tons axle-load with a trailing load of 4.0 tons per meter. (See Fig. S-3)

The RSR, after studying the proposed loading, found that it was almost identical to the loading proposed by UKRAS and more or less equivalent to the 11-ton standard loading (TS-11) which is considered the most suitable for the circumstance and, through the auspices of ESCAP, obtained the Japanese Government's co-operation to undertake the present study/ survey on the strengthening and/or replacement of the steel bridges of RSR to suit the recommended loading standard.

### 3. Contents of Each Chapter

Chapter I presents an introduction involving the development and background of the Improvement Project, the object of the study and the personnel who contributed to accomplishment of the study.

Chapter II explains the necessity of the project and how much time for travel is saved on completion of the improvement project.

Chapter III deals with the outline of RSR, the current situation of its steel bridges and the past achievements of improvement projects.

Chapter IV deals with the contents and progress of the recent study.

Chapter V summarizes the results of the field survey and provides details of stress analysis under DL-14 Loading for each type and span of bridges, based on field data and basic general data.

Chapter VI deals with the results of survey and analysis, bridge members requiring repair and/or strengthening, selection of the standard methods for improvement and special instructions for constructional works.

Chapter VII deals with factors concerning replacement of bridges, basic design standards and bridge construction plans.

Chapter VIII deals with general policy, repair/strengthening plans, replacement plans and a system for implementing the necessary constructional works for the proposed improvement program.

Chapter IX presents the construction cost and the method for cost estimation for the Improvement Project.

Chapter X deals with the present condition, the causes of deterioration and improvement methods for the deteriorated substructures (abutments and piers).

Chapter XI deals with recommendations to be presented to RSR on the basis of results of the recent survey.

Chapter XII gives the summary of data obtained and utilized for this survey.

Appendices:

Appendix I presents the design criteria to be applied to the improvement designs for repair, strengthening or replacement of bridges.

Appendix II gives instructions for fabrication and erection.

Appendix III explains procedures for cost estimation including unit prices and rates overhead charges, which have been adopted for the present study.

Appendix IV gives an example of experiment on high-strength bolt joint, using plates of old dismantled bridge.

Appendix V deals with a relation between bridge strength and train speed restriction which is currently used in JNR.

Appendix VI presents illustrations of the results of stress check under DL-14 Loading and summary of observation of bridges.

Appendix VII are standard drawings for repair and/or strengthening.

Appendix VIII are preliminary drawings and schematic representations, including their erection methods, for new bridges considered for replacement.

Appendix IX are detail drawings and their instructions for work for repair and/or strengthening of 12 bridges.

## 4. Organization of Japanese Survey Team

The survey team includes the following members:

Headed by: Dr. H. Abe,
Deputy Director, Structural Design Office of Japanese National Railways (JNR), Member of JARTS

Members: Mr. T. Honda, in charge of transportation and planning,
Deputy manager, Civil Engineering & Electric Section, Ministry of Transport

Mr. I. Tanaka, in charge of bridge construction planning,
Structural Design Office, JNR, Member of JARTS

Mr. M. Furumichi, in charge of business coordination, Social Development Cooperation Dept., Japan International Cooperation Agency (JICA)

Mr. T. Iijima, deputy-leader of Main Survey Team, Disaster Prevention Laboratory, Railway Technical Research Institute, JNR, Member of JARTS

Mr. M. Ohtsuki, group head of Main Survey Team,
Structural Design Office, JNR, Member of JARTS

Mr. K. Sugai, in charge of design & construction of bridges,
Structural Design Office, JNR, Member of JARTS

Mr. S. Arai, in charge of bridge construction and cost estimation,
Tonichi Kotsu Consultant Co., Ltd., Member of JARTS

Mr. H. Mito, in charge of bridge design & construction, Tonichi Kotsu Consultant Co., Ltd., Member of JARTS

Mr. K. Hioki, group head of Main Survey Team, Nihon Kotsu Gijutsu Co., Ltd. (JTC), Member of JARTS

Mr. H. Ikezawa, in charge of bridge design and cost estimation, Steel Structure Dept., JTC, Member of JARTS

Mr. K. Nomizu, in charge of bridge design and construction, Steel Structure Dept., JTC, Member of JARTS

Mr. T. Fukumitsu, in charge of bridge design, Steel Structure Dept., JTC, Member of JARTS

Mr. T. Morishige, in charge of investigation of substructure. Structural Design Office, JNR, Member of JARTS

Mr. M. Amamiya, in charge of Planning of erection of substructure, Member of JARTS

Mr. K. Mogi, in charge of business coordination, Social Development Cooperation Dept., JICA

Mr. T. Ogawa, in charge of business coordination, Social Development Cooperation Dept., JICA

RSR was represented by the following counterpart engineers:

Mr. Prachoom Tanticharoen
Mr. Thavee Thongpan
Mr. Prasit Nildez
Mr. Somsak Yangpreda
Mr. Charnchai Anantasate
Mr. Pongsak Umphornpunth

Coordinater of the Economic and Social Commission for Asia and the Pacific (ESCAP)

Mr. Shwe Shane

## 5. Cooperation by Interested Parties

The Japanese Survey Team conducted three field surveys, i.e., preliminary sruvey, main survey and supplementary survey, and, on this occasion, wishes to thank the concerned organs of the Government of the Kingdom of Thailand, the Economic and Social Commission for Asia and the Pacific (ESCAP) and other private organizations for their most helpful co-operation, which enabled the team to accomplish successful studies for the project. Our acknowledgement is due to the many officials of RSR who accompanied the Japanese survey team members on field surveys in Thailand for long periods of time, whose contribution helped the survey team members to fulfill their assigned tasks and who ensured the safety of the team members.

# II. NECESSITY AND ADVANTAGE OF THE PROJECT

## II. NECESSITY AND ADVANTAGE OF THE PROJECT

As mentioned before, an improvement project for railway bridges in Thailand has been implemented since the end of World War II.

Of all the bridges owned by RSR, approximately 30% of total length was replaced for conformity with TS-15 Loading during a 1946 - 1971 period.

Besides, further investigations of all the bridges with span length over 15m, were performed through the UKRAS in 1969 and again 1971, and improvement of 214 spans of steel bridges was recommended.

Thus, the present project aimed at repair, strengthening or replacement of the 214 spans of steel bridges in the country may be considered a continuation of the improvement project which was started in the early part of the postwar period by RSR.

Strengthening based on DL-14 Loading System is not intended to increase substantially the original load-carrying capacity of the 214 spans of bridges covered by this project. Rather it is intended to eliminate the train speed limits and load restrictions which have been necessitated by fatigue and corrosion or other defects of structural members, to repair those bridges presenting an immediate threat to the safety of train operations, and to correct the imbalance among the existing structural members resulting from their outdated design.

The standard live load adopted for the present project is DL-14 Loading, which has practically the same effects on bridges as the loading recommended by UKRAS and the TS-11 Loading established by RSR for evaluation of the load-carrying capacity of those railway bridges built before 1947.

This study proposes a method whereby those bridges which are not capable of meeting the DL-14 Loading condition will be strengthened so as to have an adequate load-carrying capacity to withstand DL-15, Loading instead of DL-14 Loading. This method will involve only a small cost increase, i.e., 3% as explained in Chapter VI, and is expected to provide considerable advantages.

For the reasons stated above, the present study of the RSR steel bridge strengthening and/or replacement project is limited primarily to the technical and cost aspects of the project.

As an example of advantage of implementation of the present project, improvement and others will eliminate the speed restriction of trains which is necessiated due to their deterioration. A grater part of time losses shown in Table 2-1 will be recovered in result.

Table 2 - 1

| Line | Section | Time Loss in minutes | | Distance (km) |
|---|---|---|---|---|
| | | Single headed | Double headed | |
| Northern Line | Bangkok - Chiang Mai | 123 | 180 | 751 |
| Northeastern Line | Bangkok - Uban Ratchathani | 66 | 273 | 577 |
| | Bangkok - Nong Khai | 27 | 133 | 626 |
| Southern Line | Thon Buri - Sungai Kolok | 64 | 223 | 1159 |
| Eastern Line | Bangkok - Aranyaprathet | 22 | 136 | 255 |

# III. GENERAL DESCRIPTION OF THE STATE RAILWAY OF THAILAND AND ITS INVESTMENT PROGRAM

# III. GENERAL DESCRIPTION OF THE STATE RAILWAY OF THAILAND AND ITS INVESTMENT PROGRAM

## 1. Outline of the State Railway of Thailand

The State Railway of Thailand (RSR) is a state-owned enterprise which was inaugurated as a department of the Government in 1890. RSR was subsequently established as an autonomous organization on July 1, 1951.

RSR entered into operation of its first line in 1892 and the line reached Nakhon Ratchasima from Bangkok in 1900. All of the earlier lines had a 4'8 1/2" track gauge, but the meter gauge was introduced in the construction of Southern Main Line from 1900 onwards, as this line was intended to be linked with the Malaysian system.

It was decided in 1919 that the other lines should be converted to the meter gauge, and this project was completed in April 1936. In September 1969 RSR expanded its routes to a total of 3,765 kilometers. RSR is planning to link its Northeastern Line with Laos via Nong Khai. RSR and the Malaysian lines have a mutual trackage. RSR plays an active role in the Trans-Asian Railway network. The railway system radiates from Bangkok, with Eastern Line connected with Cambodian Railways at Aranyaprathet and Southern Line linked with Malaysian Railways at Padang Besar and Sungai Kolok as follows (see Fig. S-1):

| | | | |
|---|---|---|---|
| (1) | Souther Line: | Bangkok - Sungai Kolok | (1,159 km) |
| (2) | Northern Line: | Bangkok - Chiang Mai | ( 751 km) |
| (3) | Northeastern Line: | Bangkok - Nong Khai | ( 624 km) |
| | | Bangkok - Ubon Ratchathani | ( 575 km) |
| (4) | Eastern Line: | Bangkok - Aranyaprathet | ( 255 km) |

RSR operates a total of 3,765 route kilometers (excluding the Meklong Line), with a total track length of 4,438 km, including 3,855 km of main tracks and 583 km of sidetracks. At the end of fiscal year 1974, RSR owned 2,701 spans of bridges with a total length of 58,903 meters, accounting for 1.53 percent of the total running track kilometers.

All of the route have a single track, except for the section from Bangkok to Ban Phachi, with a route length of 90 km, which has a double track.

Table 2-1 shows the principal statistical data for the years 1974 and 1975.

Fig. 2-1 illustrates the breakdown of 1974 traffic volume by section.

At present, RSR is promoting a number of projects under the 1972 - 76 Investment Program, laying primary emphasis on increasing transportation capacity, dieselization of locomotives, replacement of obsolete equipments and facilities and streamlining of the railway system.

## 2. Present Situation and Proposed Improvement Program of Steel Bridges

Table 3-2 shows the breakdown of steel bridges by route as of the end of fiscal year 1976. Out of 1,397 steel bridges, 613 bridges will have been replaced with new ones that are capable of withstanding TS-15 Loading by then.

Table 3 - 1 PRINCIPAL STATISTICS

| | | | Fiscal Year 1975 | Fiscal Year 1974 |
|---|---|---|---|---|
| 1. | Route kms. | | 3,765 | 3,765 |
| 2. | Length of tracks | | 4,443 | 4,438 |
| 3. | Railway stations | | 588 | 588 |
| 4. | Rolling stock: | | | |
| | Steam locomotives | | 218 | 222 |
| | Disel locomotives | | 244 | 205 |
| | Diesel railcars | | 45 | 45 |
| | Passenger cars | | 1,001 | 982 |
| | Freight cars | | 9,631 | 9,486 |
| 5. | Train kms.: | | | |
| | Passenger train | (thousand) | 15,198 | 14,449 |
| | Freight train | (thousand) | 7,970 | 8,250 |
| | Mixed train | (thousand) | 4,028 | 4,108 |
| 6. | Passenger car kms. | (thousand) | 150,759 | 142,118 |
| 7. | Freight car kms. | (thousand) | 338,638 | 322,650 |
| 8. | Railway traffic volume: | | | |
| | Passenger carried | (thousand) | 61,567 | 61,409 |
| | Ton carried | (thousand) | 5,052 | 5,117 |
| | Passenger kms. | (million) | 5,640 | 5,376 |
| | Net ton kms. CL | (million) | 2,353 | 2,296 |
| 9. | Operating revenues | (million Bahts) | 1,171 | 1,081 |
| 10. | Operating expenses | (million Bahts) | 1,398 | 1,147 |
| 11. | Operating ratio | ( % ) | 119.42 | 106.05 |
| 12. | Number of employees | | 29,549 | 32,954 |

Table 3 - 2 Breakdown of Steel Bridges by Line

| Line | Bridges capable of withstanding 15 tons standard loading (TS 15) | | | Bridges capable of withstanding 11 tons standard loading (TS11, DL13.75 or DL14) | | | Bridges to be strengthened/ replaced to carry DL.15 loading | | |
|---|---|---|---|---|---|---|---|---|---|
| | No. of bridges | No. of spans | Total Length | No. of Bridges | No. of Spans | Total Length | No. of bridges | No. of spans | Total Length |
| Northern | 154 | 459 | 5552.35 | 146 | 336 | 2596.12 | 20 | 22 | 744.42 |
| North-eastern | 179 | 333 | 3831.40 | 81 | 156 | 2097.96 | 37 | 45 | 1740.50 |
| Southern | 255 | 550 | 6676.00 | 367 | 730 | 7898.07 | 82 | 110 | 4056.30 |
| Eastern | 25 | 27 | 293.00 | 21 | 48 | 496.30 | 30 | 37 | 1301.70 |
| Total | 613 | 1369 | 16352.75 | 615 | 1270 | 13088.45 | 169 | 214 | 7842.92 |

Note; Bridges of rail-girder type are excluded.

RSR commenced replacement of bridges of low load-carrying capacity shortly after the end of World War II, but a vast sum of money is required to complete replacement of all of the bridges with ones that can withstand TS-15 Loading and it will take a long time to complete this project. In this circumstances, complete implementation of this program is considered difficult. Moreover, as mentioned above, ECAFE as well as UKRAS reported, on the basis of surveys, that TS-15 Loading would be too large for the design base.

However, UKRAS's report pointed out that 214 spans of bridges should be strengthened in the 1977 - 81 Investment Program and the 16 bridges should be replaced in the 1972 - 76 Investment Program. Table 3-3 shows the number of spans needed to be strengthened and particulars on the bridges concerned are listed in the appendices.

Table 3 - 3 Breakdown of 214 by Line

| Span length (m) | Number of spans needing to be strengthened on various lines | | | | Total |
|---|---|---|---|---|---|
| | Northern | Eastern | Northeastern | Southern | |
| 15.01 - 25.00 | 1 | 7 | 4 | 32 | 44 |
| 25.01 - 30.00 | 9 | 6 | 27 | 29 | 71 |
| 30.01 - 45.00 | 11 | 19 | 2 | 19 | 51 |
| 45.01 - 60.00 | 1 | 4 | 7 | 21 | 33 |
| 60.01 - 80.00 | - | 1 | 5 | 9 | 15 |
| Total | 22 | 37 | 45 | 110 | 214 |

At present, trains either run at a low speed on some of these bridges or run at a regular speed on others after they have been temporarily supported by stagings.

Therefore, permanent measures should be adopted to improve these bridges.

Most of the top-priority civil engineering projects under the 1977 - '81 Investment Program are extensions of the 1972 - 76 Program, including the following major items:

(1) Strengthening/replacement of steel bridges.
(2) Strengthening of tracks
(3) Replacement of timber sleepers with concrete ones
(4) Replacement of timber bridges with concrete bridges

In order to make RSR functioning more efficient, it is becoming increasingly necessary to streamline track maintenance operations and modernize related operations so as to reduce operating expenses.

Other key projects include the strengthening and/or replacement of steel bridges, such as the aforementioned 214 spans, in order to allow passage of trains at a regular speed.

Table 3 - 4 Timber Bridge Replacement Program

| Lines | Number of timber bridges at the end of 1976 | | Number of timber bridges to be replaced during 1977 - 81 | | | Number of timber bridges by 1982 | |
|---|---|---|---|---|---|---|---|
| | | | New bridges | | Earth-filling | | |
| | Main | Branch | Main | Branch | Main | Main | Branch |
| Southern | 350 | 121 | 194 | 1 | - | 156 | 120 |
| Eastern | 214 | - | - | - | 28 | 186 | - |
| Northeastern | 146 | 2 | - | - | 17 | 129 | 2 |
| Northern | 1 | - | - | - | - | 1 | - |
| Total | 711 | 123 | 194 | 1 | 45 | 472 | 122 |

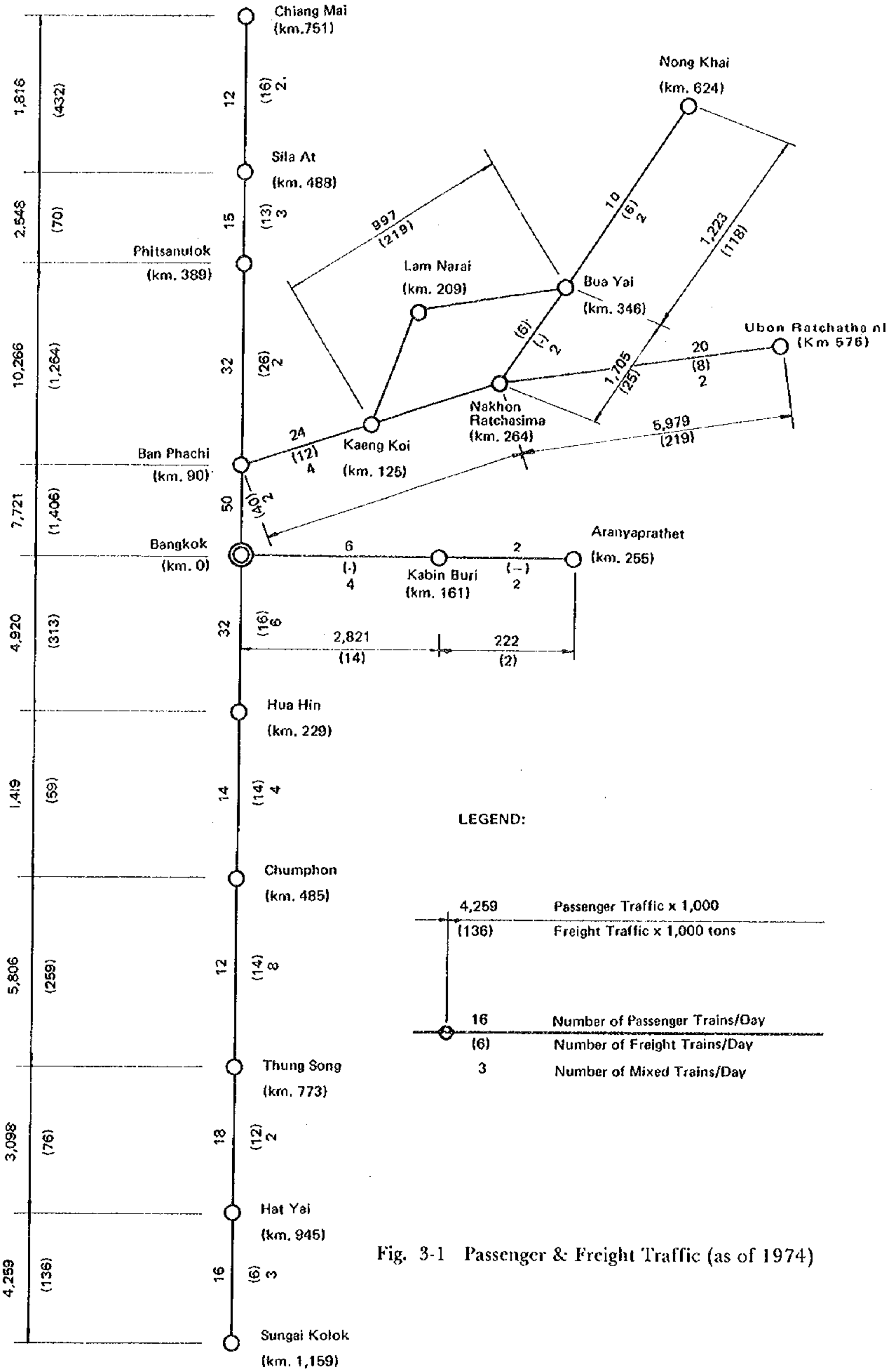



Fig. 3-1 Passenger & Freight Traffic (as of 1974)

# IV. STUDY

# IV. STUDY

## 1. Scope of Work

Scope of work to be carried out in this study is as follows;

### 1-1 Field Survey

(1) Investigation of situation and condition of the existing bridges and examination of relevant drawings.

(2) Investigations necessary for repair and/or strengthening works.

(3) Survey for cost estimation.

(4) Investigation of design standards

### 1-2 Office Work in Japan

(1) Preparation of design criteria for improvement work.

(2) Stress analysis for assessment of bridge strength

i ) To check stresses in members under DL-14 Loading for each type and span of bridge in accordance with the original or field drawings.

ii ) To make similar checks with respect to the cross sections of structural members taking into account the extent of corrosion or deterioration.

(3) Assessment for necessity of repair, strengthening, or replacement.

Assessment for the necessity of repair, strengthening or replacement was made on the basis of results obtained from the stress analyses.

(4) Standard design of repair, strengthening or replacement

The standard drawings with sufficient details for cost estimation for repair, strengthening or replacement were prepared based on the stress analyses. They were provided for each combination of typical bridge types and typical condition of corrosion.

In this case, the bridges were designed to be capable of carrying DL-15 Loading.

(5) Standard construction methods

The standard construction methods with their technical details were planned for the standard types of steel bridges.

(6) Construction cost

Based on the standard types of steel bridges and construction methods, the cost estimation for each type and span was prepared, and then the total cost was estimated.

Furthermore, the following items were prepared for reference.

i ) To make a comparison between the construction cost of strengthening by DL-15 Loading and that by DL-14 Loading.

ii ) To calculate an approximate construction cost on the assumption that all of the 214 spans of steel bridges be replaced.

(7) Design specifications

The design specifications were prepared for repair, strengthening and new bridges for replacement in this project.

(8) Explanation for application of the standard design

The methods how to apply the standard designs for repair and/or strengthening to the actual constructional work were explained.

(9) Detail designs for repair and strengthening

Drawings with sufficient details for execution of the repair and/or strengthening works were prepared for the twelve bridges listed in Table 4-1. Technical details for constructional works were also provided.

Table 4 - 1

| | Span (m) | Type | Line | Location | Manufactucer | Note |
|---|---|---|---|---|---|---|
| (1) | 20.0 | T.P. | S-Line | 1122+255 | Cleveland | |
| (2) | 25.0 | T.T. | S-Line | 897+174 | Cleveland | |
| (3) | 30.0 | T.T. | S-Line | 929+903 | Cleveland | |
| (4) | 30.0 | T.T. | N-Line | 263+335 | Daydé | |
| (5) | 30.0 | D.T. | N-Line | 577+622 | | |
| (6) | 35.0 | T.T. | S-Line | 403+257 | Cleveland | |
| (7) | 40.0 | T.T. | N-Line | 311+599 | Daydé | |
| (8) | 45.0 | T.T. | S-Line | 672+874 | Cleveland | |
| (9) | 50.0 | T.T. | S-Line | 1063+810 | Cleveland | |
| (10) | 60.0 | T.T. | S-Line | 930+931 | Cleveland | |
| (11) | 70.0 | T.T. | S-Line | 297+063 | Cleveland | |
| (12) | 80.0 | T.T. | NE-Line | 479+741 | Daydé | |

## 2. Progress of Study

(1) From October 19 to November 7, 1975, a four-member survey team carried out a preliminary investigation of 16 typical bridges on the Northern, Southern and Northeastern Lines of RSR. Moreover, a memorandum of the course and scope of works for detailed investigation described in next paragraph was made by the Japanese team, RSR and ESCAP.

(2) Detail field survey was carried out by a survey team consisting of 11 members from February 2 to March 31, 1976. The investigation was mainly devoted to activities for obtaining data on the actual condition of the 214 existing bridges.

During the term of field survey, daily meetings were held between the Japanese survey team members and the RSR engineers after daily investigation work to discuss the results and to obtain the informations from Thai engineers on maintenance of railway bridges, the history of bridge deterioration, etc.

In addition to the field inspection of bridges, the team studied the technical ability and production capacity of the RSR bridge shop and private fabricators in Thailand in order to collect data for estimation of construction cost and preparation of construction planning.

Moreover, the stress measurement was conducted for two bridges in order to train up the RSR engineers during the last two days of the investigation term.

(3) From April to October 1976 continuously after the field survey, the office work in Japan was implemented, as described in the previous section "Office Work in Japan." Also six engineers from RSR were trained in Japan for bridge works on the basis of agreements signed by JICA, RSR and ESCAP.

(4) In the mean while, explanation of the interim report was made in Thailand from August 12 to August 24, 1976, together with supplementary investigation and confirmation of the content of the final report as well as the unit cost necessary for the cost estimation of the project.

The supplementary investigations were directed to the re-inspection of several bridges which have noticeable displacement of piers and abutments.

(5) Since then, the work in Japan for finalizing the report was conducted in line with the agreement which was made after discussion on the interim report.

# V. DISCUSSION ON THE INVESTIGATION RESULTS

# V. DISCUSSION ON THE INVESTIGATION RESULTS

## 1. Summary of Field Survey Results

### 1-1 General

Among the existing bridges investigated by the survey team, almost all of them were constructed during the period of 1914 to 1929 but some of them were constructed as far back as 1894. Most of them are through-type trusses, and the span lengths range from 16m to 80m (See Table S-4). The existing bridges can be classified roughly into 22 different types according to span lengths and kind of bridges. In detail, they are classified into approximately 60 different types, according to their manufactures and construction years.

In some cases, the types are different due to difference of time of construction even though they were manufactured by the same fabricator. Original drawings for a considerable number of bridges are still in the safekeeping of the RSR. For the bridges for which original drawings are not available, field drawings were provided instead.

However, visual checks of the existing bridges with their relevant drawings or field drawings revealed that some of such drawings had insufficient or different detail indications of the structure from the existing bridges.

Therefore, the strengthening work of such bridge has to be done after careful check and confirmation of each detail dimensions. According to classification by their manufacturers, 192 spans out of the 214 spans were manufactured by Cleveland, Daydé and De Vries Robbe Companies, 109, 68 and 15 respectively. Each manufacturing company has its own design and construction features for the bridge. As a general trend, it was noticed that bridges fabricated by a specific manufacturer are utilized on specific railway lines. For instance, most of the bridges used on the Southern Line were fabricated by Cleveland, and a few bridges of such different types as fabricated by Daydé or other manufacturers exist between them at some intervals. The Daydé-fabricated bridges has a smaller spacing between the main trusses as compared with that fabricated by Cleveland.

The majority of the bridges existing on the North-eastern Line and Northern Line is of the Daydé-type. The Eastern Line can be divided largely into three sections, and in each of them bridges fabricated by each of those specific fabricators are located. This fact will afford an advantage in performance of the strengthening work.

Principal items for the field survey were to investigate corrosion or deformation of the bridge members and any structural drawbacks or defects, and to observe the surrounding site conditions in order to determine the method for the repair/strengthening work. The result of our observation is summarized as follows.
All the bridges are aged at more than 45 years since its completion. However, they seem, as a whole, to be still serviceable if properly repaired and strengthened. It seems that most of them are well maintained with periodical cleaning and painting, although in each district the methods for maintenance are somewhat different.

However, some of them present problems due probably to the suspension of maintenance during World War II or due to the local climatic condition.

(1) Corrosion

Corrosion of the members can be classified into two categories. One is corrosion of floor beams and lateral bracings which may be attributable to waste water discharged from the trains. This phenomenon is observed all over the whole lines, and should be regarded as the most important item of the repair work. Some bridges have the web plates of floor beam perforated, though localized, from excessive corrosion, and in some the greater part of flange plates are lacking (Photos 1, 2). A considerable number of floor beams were once repaired but some of them have again been corroded (Photo 3). Generally speaking, the common phenomenon of severe corrosion is noticeably concentrated in a few particular districts. Though this may be attributable to the operating schedule of trains, special maintenance method should be enforced after repair or replacement. As a general trend, the bridge members on the Southern Line are more severely corroded than those on the other Lines. This may be due to the combination of waste water from trains and other causes of corrosion to be described hereafter. The other remarkable phenomenon of corrosion is observed at the bottom of lower chord members of the main trusses, localized at the parts adjacent to the gusset plates (Photo 4). As a matter of course, corrosion extends over to the gusset plates. This phenomenon is noticed only on the Southern Line and concentrated in specific districts. This may be attributable especially to the local climatic condition in the Southern part of Thailand, where it is characterised by high temperature and high humidity near the sea coast and also the aciduous soil. Therefore, a special care should be paid for maintenance of bridges in this district.

Besides the above, there is a trace of corrosion due to human-waste in the truss-end lower chord members, which can be protected with cover plates or the like.

(2) Rivets

Every bridge had, without exception, some loose rivets somewhere on its members. Among the main members of the bridge structure, rivets were found loose in stringers (Photo 5), diagonal and vertical members (Photo 6 and 7). Furthermore, most of the rivets used for connection of secondary members, such as struts of stringers and lateral members, were also discovered to be loose. Many rivets have to be replaced on the lateral members (Photo 8).

This is considered attributable mainly to defects in structural detail, though excessive stress also may have had an adverse effect. To further explain this, there are various causes to be considered, such as insufficient rigidity in the lateral direction due to slenderness of lateral or other secondary members, shortage in rigidity of knee bracings in the pony-truss and structural drawbacks as noticeable at struts of the stringers or connections of laterals with stringers (Photo 9). It is pointed out that at such old stage of design a sufficient consideration might not have been given to the compressive buckling strength.

(3) Deformation of Members

Deformation of members is divided into two different patterns. One is deformation which might have arisen from impact by any external force. This is evidently discernible from the other pattern of deformation (Photo 10). The other pattern covers deformation as was observed on the web plates of lower chord members, laterals and lacing bars. Those are attributable entirely to defects in structural design, such as large portion of free-standing web or excessive slenderness ratio.

Although this may not necessarily be regarded as the buckling phenomenon from excessive stressing, it deserves further review.

(4) Stagings

In the State Railway of Thailand, temporary stagings are provided for strengthening of bridges which have excessive stressed members, as recommended by the UKRAS's Report, and, if not strengthened by such measures, limitation is put to the speed of trains on the bridges in question. The stagings are divided into three kinds by materials, namely, use of old rails, timbers and old sleepers (Photo S-1).

At present, the stagings consisting of old sleepers are being replaced with old rails. Those staging materials are used just temporarily for the time being and are destined to be removed after completion of the permanent work for strengthening.

The stagings are designed, ideally, for close contact between the lower chord members and the stagings under no-load condition. Certainly, as observed at the site, elaborate efforts seem to be paid toward satisfying such design requirement, but it may be rather difficult to meet that requirement when viewed from a practical aspect.

As a matter of fact, wood sleepers are used instead of shoes and there is a possibility of causing settlement of the staging foundation. Some of them create gaps between the lower chord members and the stagings. Thus, the effect of such staging is questionable in some instances. However, it is undoubtedly true that the stagings should take a share of the load, more or less, in a form of the elastic supports, when a train passes over the bridge.

The strengthening method in use with stagings presents the following two problems.

One is that bending stresses may be caused in the lower chords of main trusses. Because, too many sleepers are laid for bearing the bridge at intermediate points either in the longitudinal direction or in the transverse direction.
Therefore, the structure of bearings on the stagings must be improved.
The next problem is that strengthening by use of stagings may indeed, be effective for the chord members but, contrarily, may cause some excessive strain on those diagonal members. Especially, in the bridges of Daydé-type or P & W McLellan-type diagonal members are not considered suitable for use as compression members. This problem requires further study for solution.

(5) Shoes and Abutments

The final problem to be taken up for consideration is related to displacement of shoes and abutments.

Although the portion around the shoe was kept clean with good maintenance care, it was also observed that the rollers had been moved to a excessive extent or they had been set irregularly.

Not only the rollers were moved greatly but also the end of stringers or shoes were already in contact with the parapet wall in many cases. Rollers were forced out of the shoe and, thereby, made the shoe lose its own function (Photo 11). The causes to be considered for such phenomena are;

i ) Displacement of abutments or piers
ii ) Error in surveying of spans
iii) Missetting in erection

Among them all, the major cause is the horizontal displacement of the abutment which is observed in many places especially on the Eastern Line, where displacement is still in progress. Because of poor concrete under the shoe sole, many shoes have a gap with their bases and some are cracked for which repair is required (Photo 12).

All the aforementioned are the results of general observation on the Northern, North-eastern, Southern and Eastern Lines. Particular conditions as observed on each of the Lines are described hereunder.

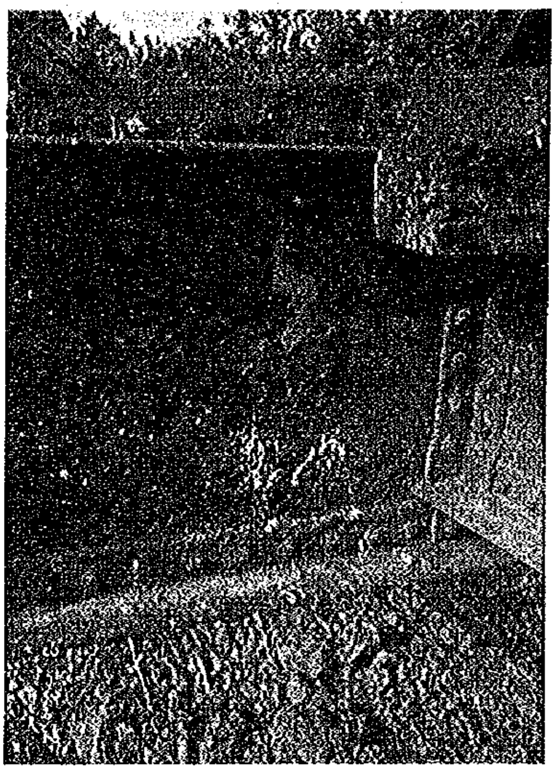


Photo 1

Corrosion of Web Plate of Floor Beam

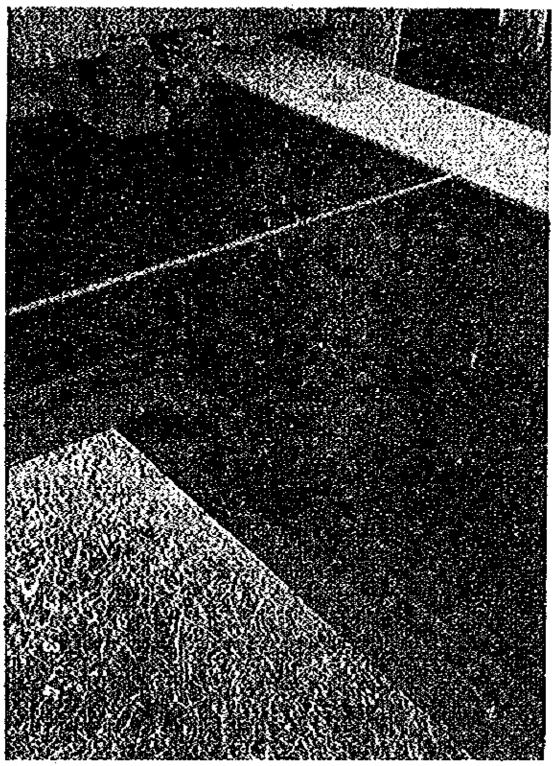


Photo 3

Corrosion of Strengthening Plate

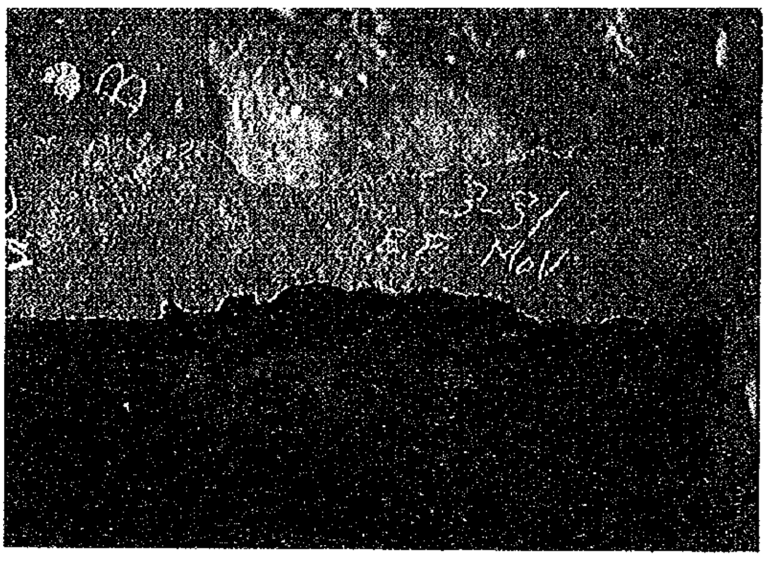


Photo 2

Corrosion of Fl'g Plate of Floor Beam

Photo 4

Corrosion of Lower Chord

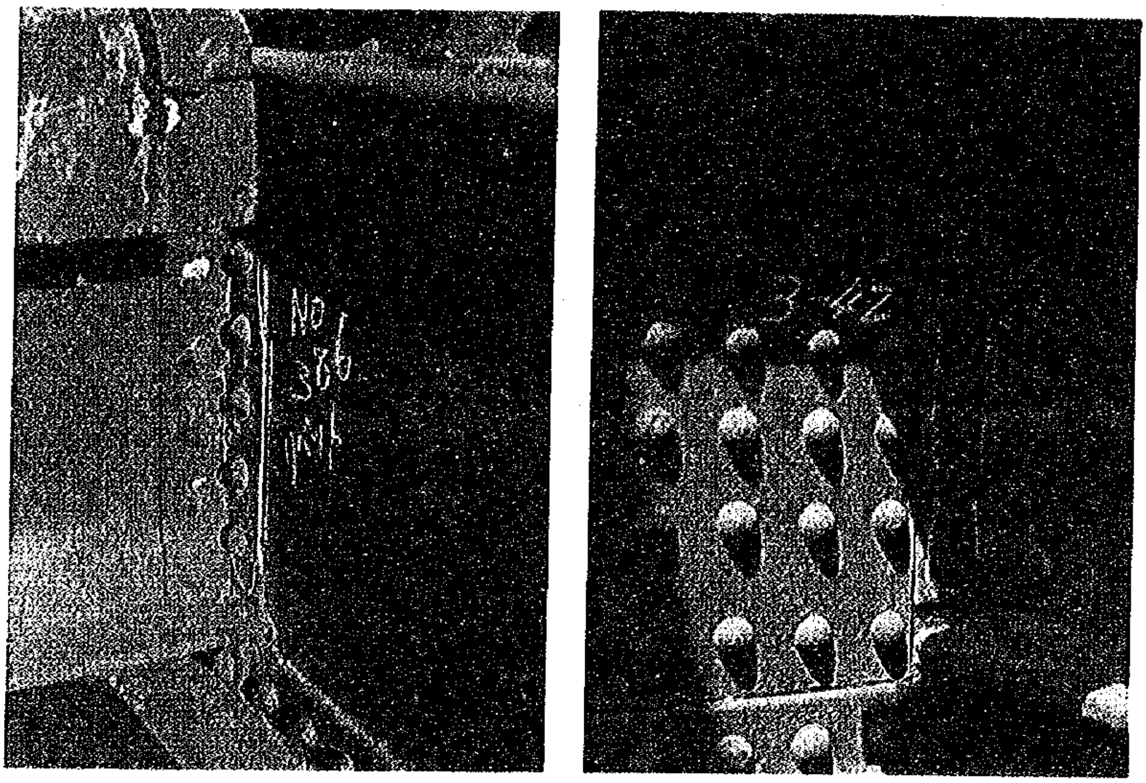
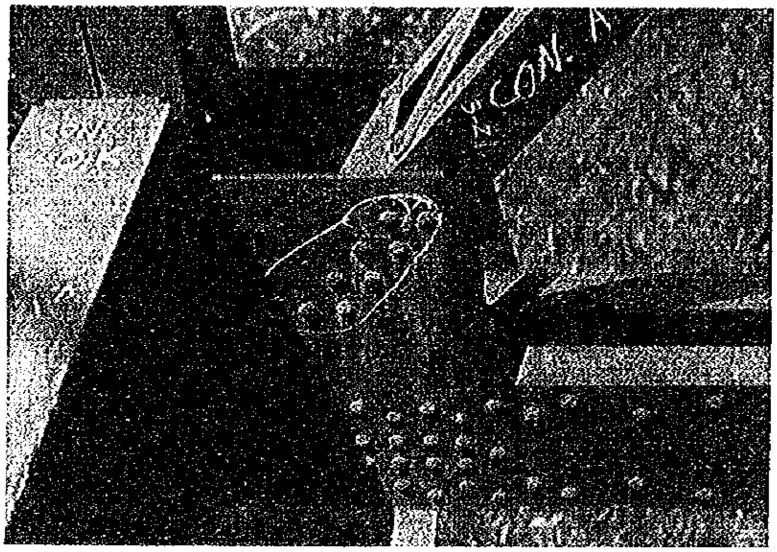


Photo 5

Loose Rivets for Connection of Stringer with Floor Beam



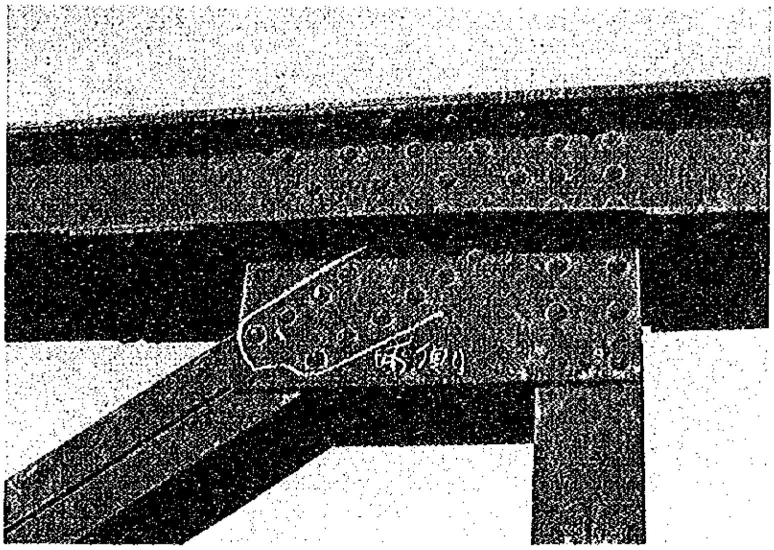


Photo 6, 7

Loose Rivets for
Connection of
Diagonal Members

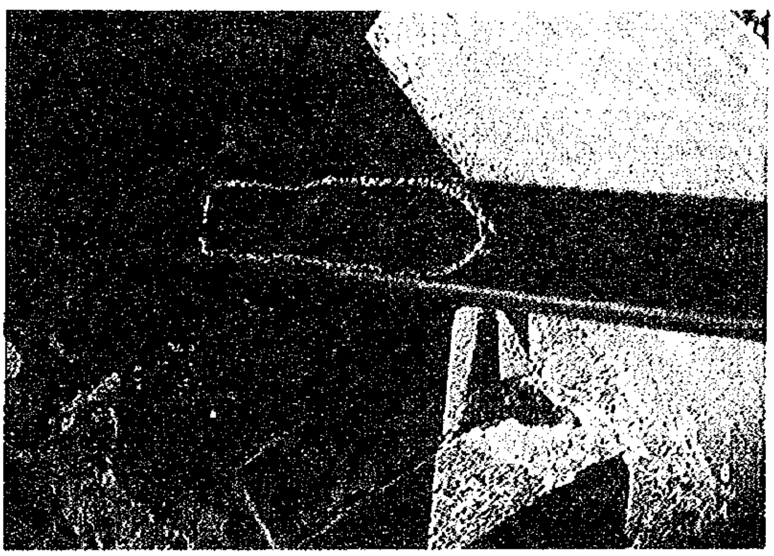


Photo 8

Loose Rivets for
Connection of
Lateral Members

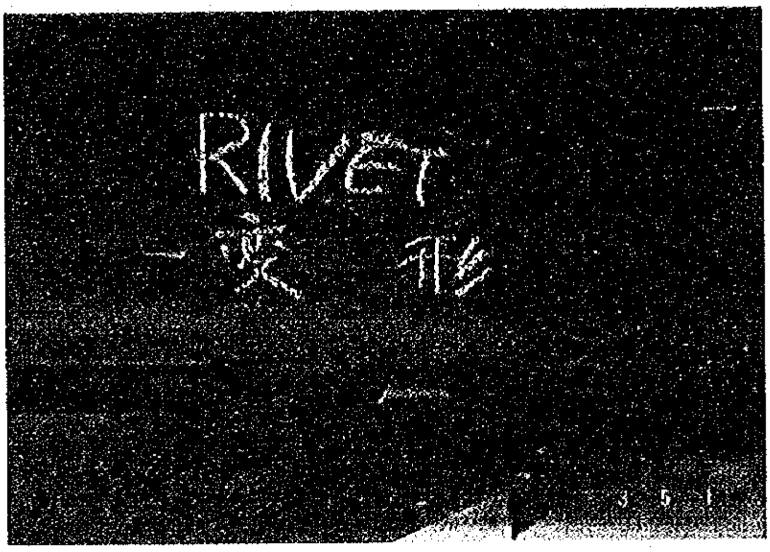



Photo 9

Loose Rivets for Connection of Lateral Member with Stringer

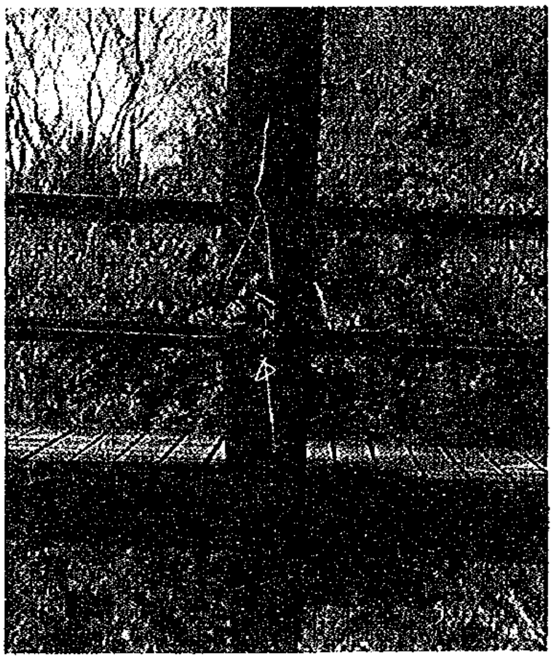


Photo 10

Deformation of Vertical Members

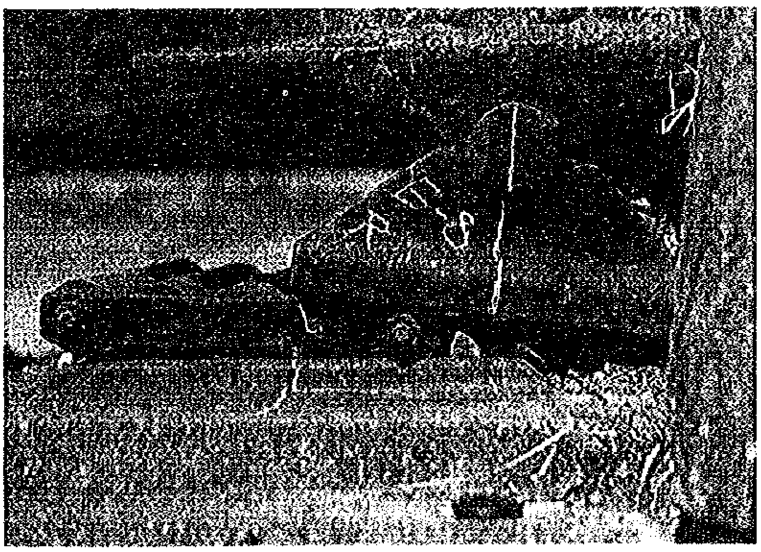


Photo 11

Damage of Shoe due to Displacement of Abutment

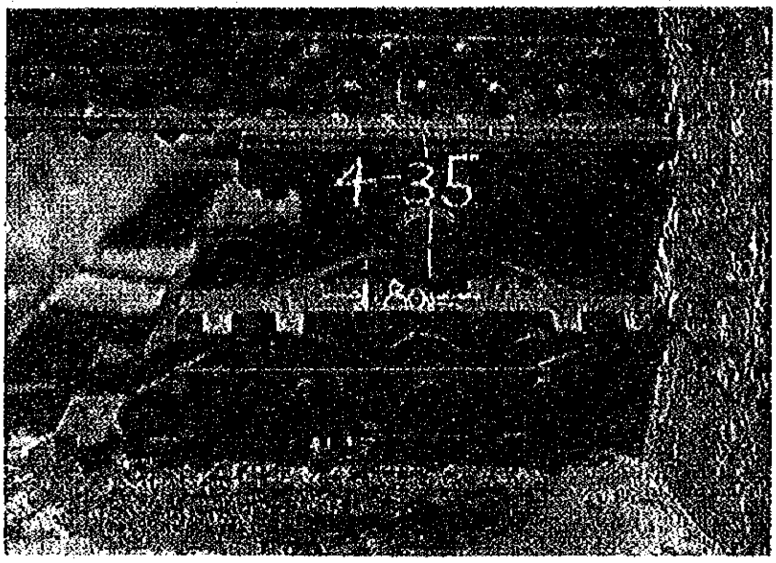



Photo 12

Damage at the Base of Shoe

Photo 13

Deformation of Lower Chord

1-2 Northern Line

Since most of the bridges on the Northern Line have already been replaced, there are only a few bridges investigated by the survey team. As far as the corrosion problem is concerned, it is comparatively less on those bridges, due mainly to a relatively good climatic condition as well as a relatively good maintenance. However, loose rivets are found here and there in the bridges, for which some repair or strengthening will have to be done eventually. A special care is required during strengthening of bridges on the specific section between Bangkok and Ban Phachi, where the highest traffic volume is recorded throughout Thailand, as observed from the result of the loading test previously conducted at Km 4 + 216. The bridge fabricated by De Vries Robbe, which is located at Km 7 + 000, has a road passage directly under the bridge. Since there is only a small clearance of 1.9m under the bridge, the lower chord members of the bridge is deformed by collision of loaded trucks on the road. The protection as provided for safeguard at present shoulbe be strengthened.

The 31.7m span bridge located at Km 70 + 866 is aged at about 80 years since the time of erection and the tracks was modified from the standard gauge to the meter gauge. The bridge is, as a whole, superannuated, being apt to sway transversely to a large extent while trains are passing over the bridge.

The diagonal members are composed of flat plates, the lateral members are short of an adequate sectional area and the floor beams are much corroded.

Since it is located near the station, trains pass on the bridge at a lower speed, which reduces the effect on the bridge. However, some measures must be taken for strengthening of the bridge, since there are some non-stop trains running without slowdown of speed. At least the lower lateral bracings should be strengthened as soon as possible. Since the bridge has also a lot of inherent structural defects in addition to deterioration, it is considered desirable to replace it with a new one for restoration of load-carrying capacity and high speed operation of trains.

As for the 30m span bridge located at Km 265 + 206 loose rivets of the diagonal members have already been replaced with ordinary bolts. Although this may be regarded as temporary measures, all such bolts should be replaced with rivets or high strength bolts.

The 40m span bridge at Km 311 + 599 has a reversed camber in the main trusses. There seems to be no special reason to bring such reversal into existence from a structural drawbacks, such deformation must have been caused at the time of construction. It is recommendable, anyway, that careful observation should be continued to see how and to what extent this deformation will develop.

As for the 17.5m span deck plate girder at Km 510 + 309, the concrete padding under the base plates of the bearings are cracked largely because of inadequate concrete bed block of the abutments, for which the repair work is required promptly.

The 40m span bridge at Km 465 + 609 is of pintruss type which contains some defective characteristics peculiar to this type of structure.

Besides that, a part of the parapet wall is broken due to displacement of the abutment.

However, this bridge is located on a branch line and only a few trains pass through the bridge daily, it may, therefore, be not repaired nor strengthened for the time being.

1-3 Northeastern Line

The main trusses of the bridges on this line are a little corroded but noticeable corrosion is observed on the web plates of some floor beams. Many rivets are loose in the web members of the main trusses as well as in the connections between stringers and floor beams. The bridges on this line are mostly fabricated by Daydé. All the rivets used for connection between cover plates of the floor beams and flange plates of the stringers remain loose, apparently due to some structural defects.

Although there are some traceable marks of repair on these rivet connections, it appears that these efforts are ineffective. On this line there are four bridges of 80m span each, where almost all of the web plates of the lower chord members are deformed (Photo 13). These defective members should be repaired.

As for the bridge of 40m span at Km 560 + 392, both end posts and vertical members are deformed two years ago when a door of a goods wagon bumped against those members. Prompt repair is required.

1.4 Southern Line

Generally all the bridges on this line are corroded to a considerable extent, and these are remarkable in Chumphon, Thung Song and Hat Yai districts. In particular, the floor beams are corroded severely on all the bridges. Such phenomena are especially noticeable in the northern part of Chumphon District, for which prompt repair work must be done.

Bitumen mixed with sand is used for anticorrosive purposes. This is considered to be a good method but an effective way to apply bitumen over the members still needs to be elaborated.

As pointed out at a latter part of this chapter replacement of the loose rivets of diagonal members, stringers and floor beams is required to be carried out at the earliest date.

The 25m span bridge at Km 77 + 844, which was relocated to the present position, has reached an age of 80 years since the time of manufacturing. At present it is reinforced with stagings. However, this has caused both diagonal and lower chord members to be deformed. Since it has many structural defects in addition to deterioration, replacement is recommended instead of strengthening.

Bearings on both ends are movable with resultant movement of the whole bridge by about 20 cm.
At this stage, any device to stop further movement of the bridge is needed.

The eight 20.75m span bridge at Km 120 + 195 crossing the Kwai River, were transferred from Java during World War II. The section on which this bridge is located is a branch line and the traffic density is low. The question of replacement should, therefore, be carefully considered.

This bridge, because of its historical background, is one of the best tourist attraction of Thailand. For this reason, it should preferably be kept as it is, even with restricted train operational speed. But in order to improve it for DL-15 Loading and for train operation at normal speed, replacement with new bridge would be more effective than repair of the old bridge.

The 16m span bridge at Km 153 + 788 is of through tyep plate girder, which seems to be dangerous because of its narrow spacing between the main girders.

The bridge of 70m span at Km 377 + 210 has vertical members in a state of deformation and its floor system is severely corroded. Therefore, a high priority should be given for its repair in the project.

As for the 35m span bridge at Km 497 + 613 one of the sway bracings is deformed by collision against goods in transit with resultant deformation of the vertical member.

Though such deformation is not an immediate problem affecting the load-carrying capacity of the bridge, it is advisable that prompt action should be taken for repair, since corrosion is setting to a great extent.

The 30m span bridge at Km 807 + 786 has almost all the web plates of the lower chord members deformed. Its laterals are also buckled. Since similar deformation is observed on the other bridges of identical type. Further follow-up studies on this problem are desired to identify the cause.

### 1-5 Eastern Line

The main problem involved on the Eastern Line is the displacement of the shoe rollers resulting from movement of the abutments.

To improve this condition a few bridges require immediate measures for repair, or otherwise it is feared that the rollers would get entirely out of place. Some abutments seem to be still moving and bridges themselves may be resisting their movement.

Therefore, a careful check is required to determine the true causes. The bridge existing at Km 187 + 240 is composed of 3 spans with relatively high piers. One of the piers was scoured and titled during flood in the past, and was repaired some ten years ago.

Displacement of the piers and abutments of these bridges on Eastern Line will be discussed more in detail in Chapter X.

## 2. Observation from Stress Check Results

As the result of stress check it is revealed that all the 214 bridge spans under investigation by the survey team will require various extent of repair/strengthening or replacement. The result of stress calculation on the DL-14 loading basis is shown in Summary Sheet and Table 4.1.

### 2-1 Stresses of Main Trusses

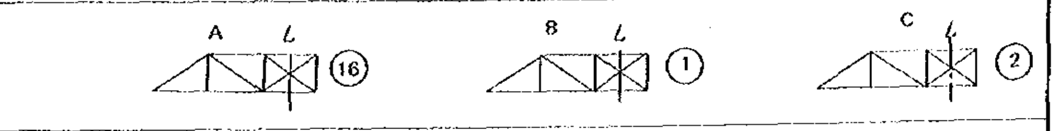
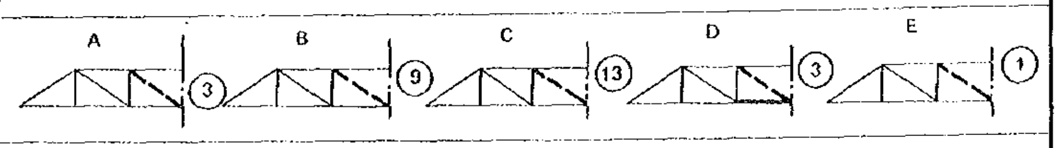
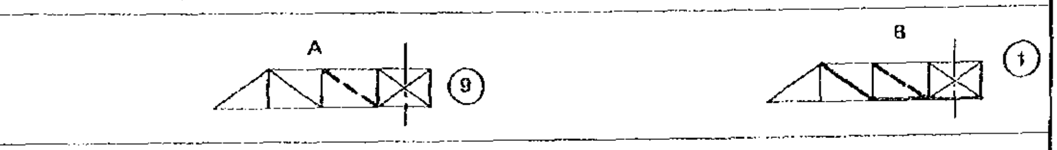
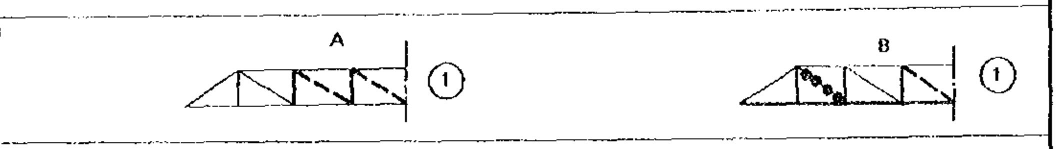
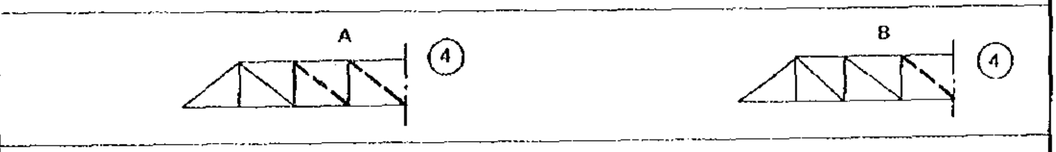
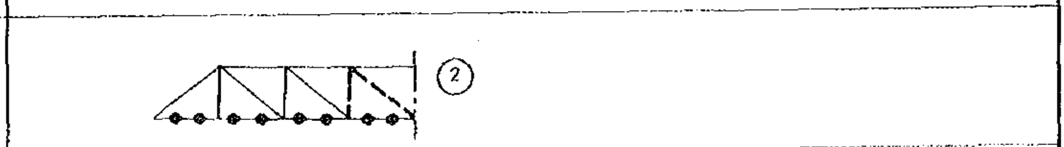
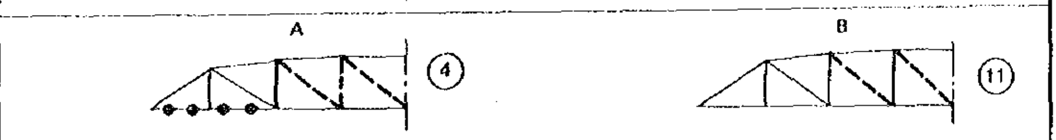
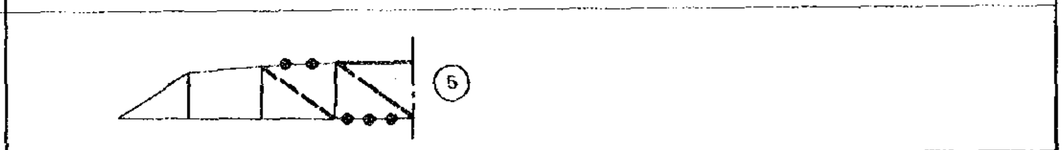
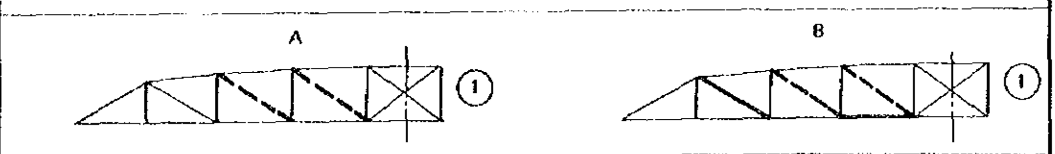
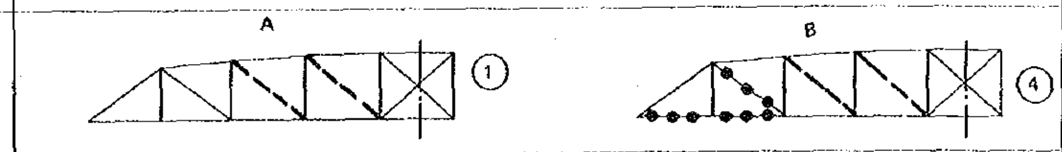
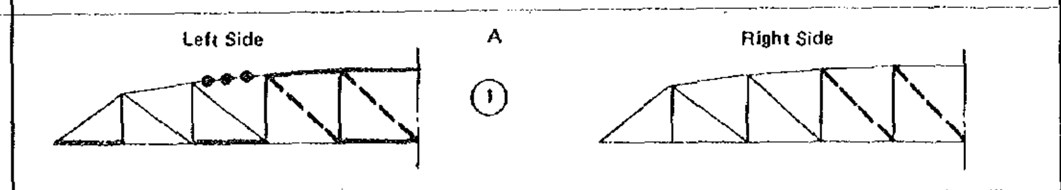
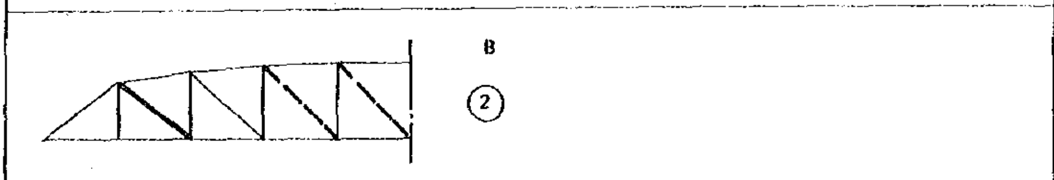
In the main trusses, many diagonal and vertical members and a few lower chord members are noticed to be stressed excessively. Especially, as far as the bridges of Daydé and McLellan types are concerned, the diagonal members used for these bridges have a relatively large slenderness ratio, and their allowable stresses are lowered accordingly.

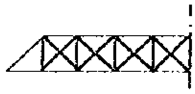
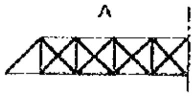
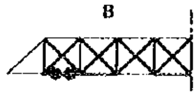
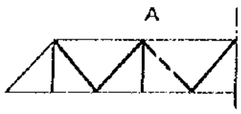
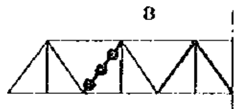
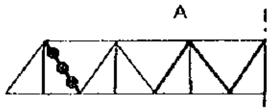
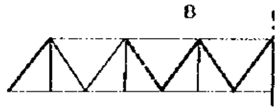
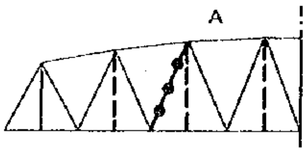
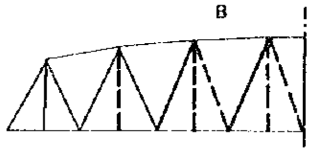
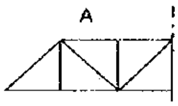
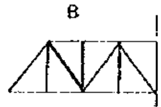
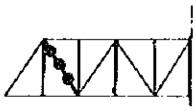
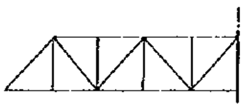
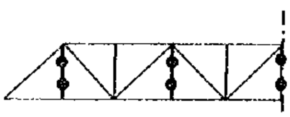
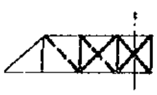
In result, the stresses in a large number of them exceed the limit of allowable stress, though the working stresses are fairly small. This is one of the main items for repair and improvement. As far as the main trusses are concerned, there is no problem of excessive stress due to corrosion.

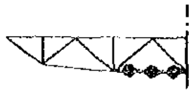
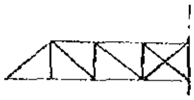
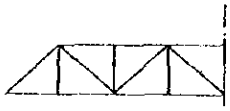
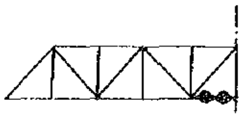
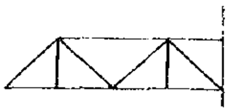
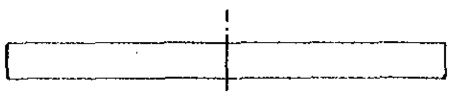
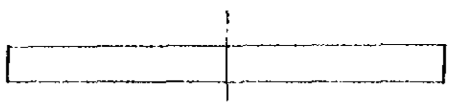
### 2-2 Structural Defects

Some members are deformed due to long spacing between tie plates and it is another main item for improvement. It is thought, however, that such deformation may be attributable

Fig. 5.1 Members required to be improved

| Maker | Span | |
|---|---|---|
| Cleveland | 25 |  |
| | 30 |  |
| | 35 |  |
| | 40 |  |
| | 45 |  |
| | 48 |  |
| | 50 |  |
| | 60 |  |
| | 65 |  |
| | 70 |  |
| | 80 |  |
| | |  |

| Maker | Span | |
|---|---|---|
| Daydé | 25 |  (4) |
| | 30 |  (31) |
| | 35 | A  (3) B  (9) |
| | 40 | A  (3) B  (3) |
| | 50 | A  (5) B  (3) |
| | 80 | A  (3) B  (2) |
| De Vries Robbe | 30 | A  (3) B  (4) |
| | 35 |  (4) |
| | 45 |  (1) |
| | 50 |  (3) |
| P & W McLellan | 25.5 |  (3) |
| | 31.7 |  (3) |

| Maker | Span | |
|---|---|---|
| Unknown | 30 | Deck Truss  1 |
| Unknown | 31.4 |  2 |
| Japan | 36 |  1 |
| Unknown | 40 | Pin Truss  1 |
| Daydô | 33.5 | 3-Track  1 |
| Unknown | 20.75 |  8 |
| Unknown | 16 |  1 T.P |
| Unknown | 17.5 |  1 D.P |
| Cleve-land | 20 |  7 T.P |
| Daydô | 20 |  1 T.P |
| Cleve-land | 25 |  2 D.P |
| Unknown | 25 |  1 T.P |

LEGEND

2 denotes number of bridge spans

denotes members of excessive stress due to both DL-14 and DL-15 loadings

denotes members of excessive DL-15 loading

denotes members of excessive slenderness ratio to the working stress at the time of erection, and not necessarily attributable to the secondary stress caused by train load. The lacing bars also present remarkable deformation which was made, probably, during erection or transportation to the site.

It is proper that improvement on these secondary members should be done.

## 2-3 Loose Rivets of Main Trusses

Loose rivets in connection for diagonal and vertical members can be observed not only in overstressed members but also in many other members of lower nominal stress.

Another contributory cause to be considered with respect to the loosening of those rivets may be large lateral oscillation due to lack of design allowances for securing stiffness. Of course, the insufficiency of design consideration should not be overlooked also with respect to members subject to alternating stresses.

## 2-4 Floor Systems

Members for the floor system need not to be strengthened any more if the struts of the stringers are strengthened. However, many of the rivets used for connection between stringers and floor beams are overstressed and loosened as discovered during the site survey.

The problem lies in the fact that the rivets driven into the web of the floor beam get loose, although a sufficient number of rivets are provided there according to ordinary design calculation.

The reason for this seems to be that the rivets there are subject not only to shearing but also to tensile force, due to bending of the stringers. To solve this problem, it is advisable to use instead of rivets high strength bolts which are strong against tensile force, as well as shearing force.

Some floor beams are overstressed due to severe corrosion, which causes reduction of effective sectional areas. Although the web plate can be kept safe from excessive stress theoretically as assured by calculation even with some 40% lack of its sectional area, the perforated corrosion may cause stress concentration. This should be repaired consequently.

## 2-5 Others

Some of the lateral members have extremely large slenderness ratio. They contain structural problems rather than stress problems. Since the structural design is quite outdated, it lacks necessary design considerations for compression members. The pony truss bridge of Daydé type has especially small knee-bracings. It should be strengthened from both the aspects of stiffness and stress.

As for the portal bracings, the problem lies, not only in the stress, but rather in the slenderness of the members which seem to be unable to perform their function satisfactorily. Especially, the end posts seem to have been designed without allowance for possible lateral forces.

## 3. Evaluation of Load-Carrying Capacity of Existing Bridges

### 3-1 Guidelines of Stress Analysis

The stress analyses for evaluation of load-carrying capacity of the existing bridges were carried out on the basis of the original or field drawings prepared by R.S.R.

The stress calculations of corroded members were carried out for each kind of member of a bridge, on the assumption that the one with the severest corrosion as observed in the field survey should represent the other similar members of the same type of bridge (e.g. floor beams, stringers, lateral members).

The load-carrying capacity will be judged in accordance with the Specifications for Design–Steel Bridge Improvement Project of R.S.R.

It covers the following items:

i ) Main members, such as main truss members, main girders, floor beams and stringers
ii ) Secondary members, such as upper and lower laterals, portal bracings, knee bracings, etc.
iii) Joints and splices for the main and secondary members or elements
iv) Reaction on bearing shoes
v ) Slenderness ratio of members of elements

As a rule, the above checks should be carried out for all the bridges of 214 spans. In addition some bridges which have badly deformed members or which are supported by temporary stagings are checked in regard to the following items also.

i ) Secondary stresses in main truss members
ii ) Effect caused by stagings
iii) Influence of contact between abutment and truss end

The calculation of stress is done in reference to DL-14 Loading for checking the load-carrying capacity, and to DL-15 Loading for the purpose of strengthening.

### 3-2 Determination of Allowable Stress for Existing Bridges

The allowable stresses for steel structural materials used in existing bridge members were determined as follows:

The 214 bridge spans were fabricated of various kinds of structural steel materials from different suppliers. The design specifications also vary in accordance with bridge manufacturers and in some cases, the names of steel manufacturers are not clear.

It is impractical to establish unified allowable stresses for these different structural steel materials.

However, according to the results of tensile tests conducted by the UKRAS, the structural materials used in the existing bridges are of strength equivalent to structural steel SS41 specified in JIS G3101.

Therefore, the allowable stresses are chosen to be essentially the same as the former design specifications for riveted railway steel bridges of Japanese National Railways, 1956, assuming that welding is not adopted.

As for the allowable fatigue strengths, those in the current JNR design standard were quoted and the allowable stresses were determined as shown below.

The allowable stresses for rivets were determined in relation to the structural steel materials to be fastened.

Allowable stresses of structural steel materials of existing bridges

(1) Structural steel:

| | |
|---|---|
| Tensile stresses (In net section) | Axial tension and tension due to bending 1,300 kg/cm$^2$ |
| Compressive stresses (In gross section) | Axial compression<br>$1{,}200 - 0.05\,(\ell/r)^2$ kg/cm$^2$ for $\ell/r \leq 110$<br>$7{,}200{,}000/(\ell/r)^2$ kg/cm$^2$ for $\ell/r > 110$<br>Compression due to bending<br>$1{,}200 - 0.5\,(\ell/b)^2$ kg/cm$^2$ for $\ell/b \leqq 30$ |

(2) Rivets:

| | |
|---|---|
| Shearing stresses (Shop) | 1,000 kg/cm$^2$ |
| (Field) | 800 kg/cm$^2$ |
| Bearing stresses (Shop) | 2,200 kg/cm$^2$ |
| (Field) | 1,800 kg/cm$^2$ |

(3) Allowable Fatigue Stresses:
(assuming 2 million cycles)

1) Base metal with rivets:

| | |
|---|---|
| Tension | $\frac{1275}{1-0.7K}$ kg/cm$^2$ but smaller than 1,300 kg/cm$^2$ |
| Compression | $\frac{1575}{1-1.1K}$ kg/cm$^2$ but smaller than 1,200 kg/cm$^2$ |

2) Rivets:

| | |
|---|---|
| Shearing stresses (Shop) | $\frac{1020}{1-0.7K}$ kg/cm$^2$ but smaller than 1,000 kg/cm$^2$ |
| (Field) | 80% of shop rivet |
| Bearing stresses (Shop) | $\frac{2200}{1-0.7K}$ kg/cm$^2$ but smaller than 2,200 kg/cm$^2$ |
| (Field) | 80% of shop rivet |

where;

$$K = \frac{|\sigma|\ \text{min.}}{|\sigma|\ \text{max.}} \quad \text{or} \quad \frac{|\tau|\ \text{min.}}{|\tau|\ \text{max.}}$$

### 3-3 Method for Stress Analysis

The stress analysis to be adopted was the influence line analysis of small deformation theory which meets any type of structural system, such as pony truss, double Warren truss and rigid frame truss.

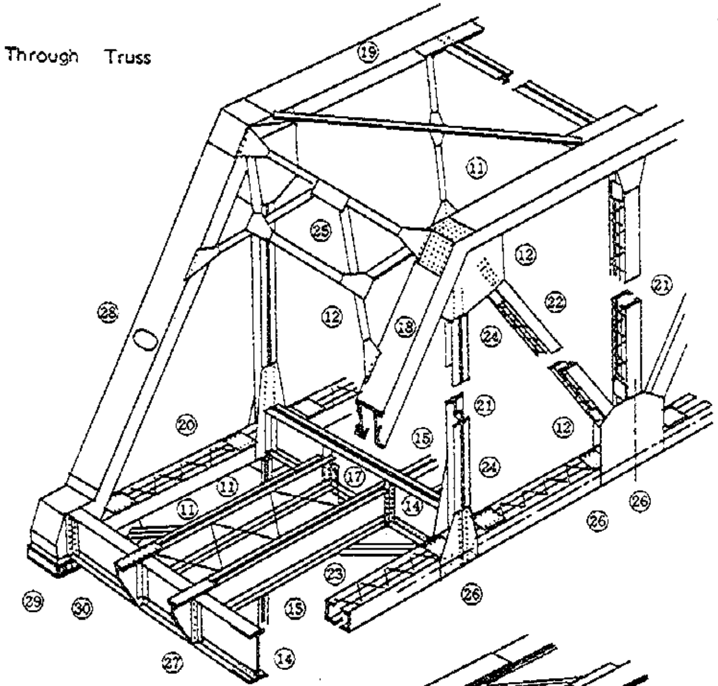
Calculation of stresses was performed by means of an electronic computer, FACOM 230-38 System.

<u>3-4 Results of Stress Analysis</u>

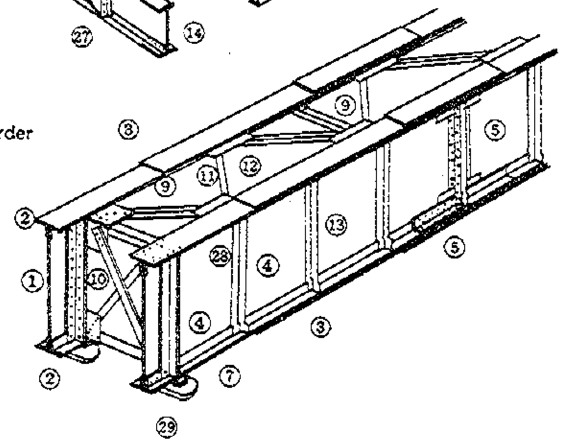
The results of the stress analysis for each type and span due to DL-14 Loading are shown in the summary sheets in detail (see Appendix VI).
Structural steel members whose actual stresses exceed the allowable stresses are summarized in Table 5.1 for each of the 214 spans.
The notations in the table are as follows:

| | |
|---|---|
| T.P.; | Through plate girder |
| D.P.; | Deck plate girder |
| T.T.; | Through truss |
| D.T.; | Deck truss |
| U.C.; | Upper chord |
| L.C.; | Lower chord |
| D.; | Diagonal member |
| V.; | Vertical member |
| P.B.; | Portal bracing |
| M.; | Member |
| R.; | Rivet |
| UL.; | Upper lateral member |
| L.L.; | Lower lateral member |
| St; | Stringer |
| EF; | End floor beam |
| IF; | Intermediate floor beam |
| X.; | Members of excessive stress or excessive slenderness ratio, |

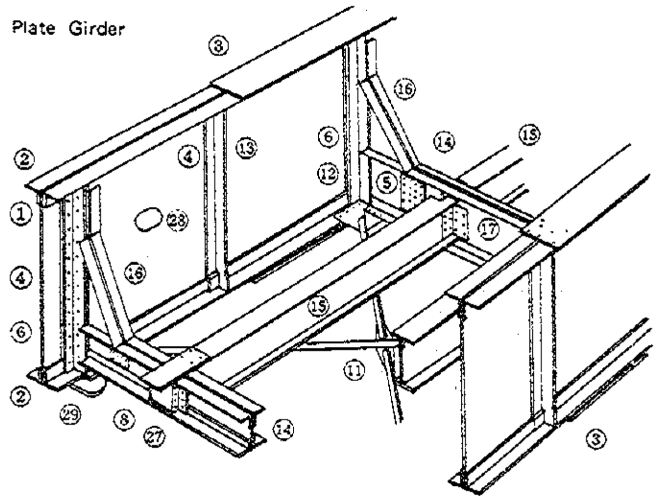
Through Truss



Deck Plate Girder



Through Plate Girder



(1) Web plate
(2) Upper flange angle
(2) Lower flange angle
(8) Upper cover plate
(8) Lower cover plate
(4) End stiffener
(4) Intermediate stiffener
(5) Splice plate
(5) Splice angle
(6) Filler
(7) Sole plate
(8) Moment plate
(9) End strut
(9) Intermediate strut
(10) Sway bracing
(11) Upper Lateral bracing
(11) Lower Lateral bracing
(12) Gusset plate
(13) Main girder
(14) End floor beam
(14) Intermediate floor beam
(15) Stringer
(15) End stringer
(16) Knee brace
(17) Connection angle
(18) End post
(19) Upper chord member
(20) Lower chord member
(21) Vertical member
(21) Hip vertical or Hanger
(22) Diagonal member
(23) Lacing
(24) Tie plate
(25) Portal bracing
(26) Panel point
(26) Panel length
(27) Bracket
(28) Name plate
(29) Shoe
(30) Roller

Fig. 5.2 Designation of bridge members

Table 5-1 Stress Check and Situation of Corrosion or Deformation

No - 1

| Span length | Type | Maker | Year | Span No. | Stress Check for Original Section (DL 14 loading) | | | | | | | | | | | | | | | | | | | | Situation of Corrosion | | | | | | Stress Check due to Corrosion | | | Deformation | | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Main Truss | | | | | | | | | | Lateral | | | | Floor System | | | | | | L.C | Stringer | Floor Beam | | | | | | | | | | |
| | | | | | U.C | | L.C | | D | | V | | P.B | | U.L | | L.L | | St. | | E.F | | I.F | | | | Cov. PL. | U.Flg | Web | L.Flg | St. | E.F | I.F | V | D | L.C | |
| | | | | | M | R | M | R | M | R | M | R | M | R | M | R | M | R | M | R | M | R | M | R | | | | | | | | | | | | | |
| 16.0 | T.P | ? | ? | S- 10 | | | | | — | — | — | — | — | — | — | — | | x | x | | x | | x | | | | | x | | | | x | x | | | | Replacement |
| 17.5 | D.P | ? | ? | N- 20 | x | | x | | — | — | — | — | — | — | x | x | | | — | — | — | — | — | — | | | | | | | | | | | | | |
| 20.0 | T.P | C.L | 1914 | S- 15 | | | | | — | — | — | — | — | — | — | — | | x | | x | | | | x | | | | | | | | | | | | | |
| | | | 20 | 74 | | | | | — | — | — | — | — | — | — | — | | x | | x | | | | x | | | | | | x | | | | | | | |
| | | | | 75 | | | | | — | — | — | — | — | — | — | — | | x | | x | | | | x | | | | | x | | | | | | | | |
| | | | | 76 | | | | | — | — | — | — | — | — | — | — | | x | | x | | | | x | | | | | | | | | | | | | |
| | | | | 106 | | | | | — | — | — | — | — | — | — | — | | x | | x | | | | x | | | | | | x | | | | | | | |
| | | | | 107 | | | | | — | — | — | — | — | — | — | — | | x | | x | | | | x | | | | | | | | | | | | | |
| | | | | 108 | | | | | — | — | — | — | — | — | — | — | | x | | x | | | | x | | | | | | | | | | | | | |
| 20.0 | T.P | D.D | 1927 | NE-33 | | | | | — | — | — | — | — | — | — | — | x | x | | x | | | | | | | x | | x | | | | | | | | |
| 20.75 | T.T | ? | ? | S 2 | x | x | x | x | x | x | | | — | — | — | — | | | | x | | | | | | | | | | | | | | | | | |
| | | | | 3 | x | x | x | x | x | x | | | — | — | — | — | | | | x | | | | | | | | | | | | | | | | | |
| | | | | 4 | x | x | x | x | x | x | | | — | — | — | — | | | | x | | | | | | | | | | | | | | | | | |
| | | | | 5 | x | x | x | x | x | x | | | — | — | — | — | | | | x | | | | | | | | | | | | | | | | | |
| | | | | 6 | x | x | x | x | x | x | | | — | — | — | — | | | | x | | | | | | | | | | | | | | | | | Replacement |
| | | | | 7 | x | x | x | x | x | x | | | — | — | — | — | | | | x | | | | | | | | | | | | | | | | | |
| | | | | 8 | x | x | x | x | x | x | | | — | — | — | — | | | | x | | | | | | | | | | | | | | | | | |
| | | | | 9 | x | x | x | x | x | x | | | — | — | — | — | | | | x | | | | | | | | | | | | | | | | | |
| 25.0 | T.T | C.L | 1913 | S 52 | | | | | | | | | — | — | — | — | x | x | | x | | | | x | | | | | | | | | | | x | | Knee Deform |
| | | | 20 | 57 | | | | | | | | | — | — | — | — | x | x | | x | | | | x | x | | | | x | x | | x | | | | | Tie, Lacing Deform |
| | | | 〃 | 45 | | | | | | | | | — | — | — | — | x | x | | x | | | | x | x | | | | | | | | | | | | |
| | | | 14 | 28 | | | | | | | | | — | — | — | — | x | x | x | x | | | | | x | x | | | | | | | | | | | |
| | | | 〃 | 35 | | | | | | | | | — | — | — | — | | | | | | | | | x | x | | | x | x | x | | | | | | Tie, Lacing Deform |
| | | | 〃 | 42 | | | | | | | | | — | — | — | — | | | | | | | | | x | | | | | x | | | | | | | |
| | | | 〃 | 64 | | | | | | | | | — | — | — | — | | | | | | | | | | | | | x | | | | | | | | |
| | | | 20 | 65 | | | | | | | | | — | — | — | — | | | | | | | | | x | | | | | x | | | | | | | |
| | | | | 66 | | | | | | | | | — | — | — | — | | | | | | | | | | | | | | x | | | | | | | |
| | | | | 67 | | | | | | | | | — | — | — | — | | | | | | | | | | | | | | x | | | | | | | |
| | | | | 70 | | | | | | | | | — | — | — | — | | | | | | | | | | x | | | x | | x | | | | x | | Knee Deform |

M: Member
Connection Rivet
Portal Bracing
Stringer
End Floor Beam
Int. Floor Beam

| Span length | Type | Maker | Year | Span No. | Stress Check for Original Section (DL 14 loading) | | | | | | | | | | | | | | | | | | | | Situation of Corrosion | | | | | | Stress Check due to Corrosion | | | Deformation | | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Main Truss | | | | | | | | | | Lateral | | | | Floor System | | | | | | L.C | Stringer | Floor Beam | | | | | | | | | | |
| | | | | | U.C | | L.C | | D | | V | | P.B | | U.L | | L.L | | St. | | E.F | | I.F | | | | Cov. PL. | U.Flg | Web | L.Flg | St. | E.F | I.F | V | D | L.C | |
| | | | | | M | R | M | R | M | R | M | R | M | R | M | R | M | R | M | R | M | R | M | R | | | | | | | | | | | | | |
| 25.0 | T.T | C.L | 1920 | E 2 | | | | | x | | | | — | — | — | — | x | x | x | x | | | | | x | | | | | | | | | | | | |
| | | | | 5 | | | | | x | | | | — | — | — | — | x | x | x | x | | | | | | | | | | | | | | | | | |
| | | | | 6 | | | | | x | | | | — | — | — | — | x | x | x | x | | | | | | | | | | x | | | | | | | |
| | | | | 7 | | | | | x | | | | — | — | — | — | x | x | x | x | | | | | | | | | | | | | | | | | |
| | | | | 8 | | | | | x | | | | — | — | — | — | x | x | x | x | | | | | | | | | | x | | | | | | | |
| | | | | 9 | | | | | x | | | | — | — | — | — | x | x | x | x | | | | | | | | x | | | | | | | | | |
| | | | ? | 27 | | | | | x | | | | — | — | — | — | x | x | x | x | | | | | x | | | | | x | | | | | | | Tie, Lacing Deform |
| | | | 1914 | S 16 | | | | | x | | | | — | — | — | — | x | x | x | x | | | | | | | | x | x | x | | | | | | x | Knee Deform |
| 25.0 | D.P | C.L | 1920 | S 77 | | | | | — | — | — | — | — | — | — | — | x | x | | | | | | | x | | | | | | | | | | | | |
| | | | 〃 | 78 | | | | | — | — | — | — | — | — | — | — | x | x | | | | | | | | | | | | | | | | | | | |
| 25.0 | T.T | D.D | 1928 | S 41 | x | x | | x | x | | | | — | — | — | — | x | | | x | | | | | | x | x | x | x | x | x | | | | | | |
| | | | 〃 | 59 | x | x | | x | x | | | | — | — | — | — | x | | | x | | | | | | | | | | | | | | | | | |
| | | | 1923 | NE 12 | x | x | | x | x | | | | — | — | — | — | x | | | x | | | | | | | x | | | | | | | | | | |
| | | | 〃 | 13 | x | x | | x | x | | | | — | — | — | — | x | | | x | | | | | | | | | x | | | | | | | | |
| 25.0 | T.P | ? | ? | NE 11 | | | | | — | — | — | — | — | — | — | — | x | | | x | | | | | | | | x | x | x | | | | | | | |
| 25.5 | T.T | P.W.M | 1895 | S 1 | | | | x | x | x | | | — | — | — | — | x | x | | x | | | | | | | | | | | | | | | x | | Replacement |
| | | | | 30 | | | | x | x | x | | | — | — | — | — | x | x | | x | | | | | | x | x | | x | | | x | | | | | 〃 |
| | | | | NE 45 | | | | x | x | x | | | — | — | — | — | x | x | | x | | | | | x | | | | x | | | x | | | | x | 〃 |
| 30.0 | T.T | D.V.R | ? | N 2 | | | | x | | | | | | | | | x | x | x | x | | | | | x | x | | x | | | | | | | | | |
| | | | 〃 | 3 | | | | x | | | | | | | | | x | x | x | x | | | | | | | | x | | | | | | | | | W.Track |
| | | | 〃 | 4 | | | | x | | | | | | | | | x | x | x | x | | | | | | | | x | | | | | | | | | |
| | | | 1920 | E 30 | | x | | x | x | x | | x | | | x | | x | | x | x | | | | | | | | | | | | | | | | x | |
| | | | 〃 | 31 | | x | | x | x | x | | x | | | x | | x | | x | x | | | | | | | | | | | | | | | | x | |
| | | | 〃 | 34 | | x | | x | x | x | | x | | | x | | x | | x | x | | | | | | | | | | | | | | | x | | |
| | | | 〃 | 35 | | x | | x | x | x | | x | | | x | | x | | x | x | | | | | | | | | | | | | | | x | | |
| 30.0 | T.T | D.D | 1927 | N 10 | | x | | x | x | x | | | — | — | — | — | x | x | | x | | | | | | | x | | | | | | | | | | |
| | | | 29 | 11 | | x | | x | x | x | | | — | — | — | — | x | x | | x | | | | | | | | | | x | | | | | | | |
| | | | 〃 | 12 | | x | | x | x | x | | | — | — | — | — | x | x | | x | | | | | | | | | x | x | | | | | x | | |
| | | | 〃 | 16 | | x | | x | x | x | | | — | — | — | — | x | x | | x | | | | | | | | | | | | | | | | | |

M: Member

Connection Rivet

Portal Bracing

Stringer

End Floor Beam

Int. Floor Beam

No - 3

| Span length | Type | Maker | Year | Span No. | Stress Check for Original Section (DL 14 loading) | | | | | | | | | | | | | | | | | | | | Situation of Corrosion | | | | | | Stress Check due to Corrosion | | | Deform-ation | | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Main Truss | | | | | | | | | | Lateral | | | | Floor System | | | | | | L.C | Strin-ger | Floor Beam | | | | St. | E.F | I.F | V | D | L.C | |
| | | | | | U.C | | L.C | | D | | V | | P.B | | U.L | | L.L | | St. | | E.F | | I.F | | | | Cov. Pl. | U.Flg | Web | L.Flg | | | | | | | |
| | | | | | M | R | M | R | M | R | M | R | M | R | M | R | M | R | M | R | M | R | M | R | | | | | | | | | | | | | |
| 30.0 | T.T | D.D | 1929 | S 84 | | x | | x | x | x | | | — | — | — | — | x | x | | x | | | | | | | x | | x | x | | | | | | | Replacement |
| | | | " | 102 | | x | | x | x | x | | | — | — | — | — | x | x | | x | | | | | | | | | | | | | | | | | |
| | | | 23 | NE 36 | | x | | x | x | x | | | — | — | — | — | x | x | | x | | | | | | | | | | | | | | | | | |
| | | | 29 | 37 | | x | | x | x | x | | | — | — | — | — | x | x | | x | | | | | | | x | | | | | | | | | | |
| | | | " | 38 | | x | | x | x | x | | | — | — | — | — | x | x | | x | | | | | x | | | | | | | | | | | | |
| | | | " | 39 | | x | | x | x | x | | | — | — | — | — | x | x | | x | | | | | | | | | | | | | | | | | |
| | | | 27 | 40 | | x | | x | x | x | | | — | — | — | — | x | x | | x | | | | | | | | | x | | | | | | | | |
| | | | 1925 | NE 14 | | x | | x | x | x | | | — | — | — | — | x | x | | x | | | | | | | | x | x | x | | | | | | | |
| | | | | 16 | | x | | x | x | x | | | — | — | — | — | x | x | | x | | | | | | | | x | x | x | | | | | | | |
| | | | | 18 | | x | | x | x | x | | | — | — | — | — | x | x | | x | | | | | | | | | x | | | | | | | | |
| | | | 27 | 20 | | x | | x | x | x | | | — | — | — | — | x | x | | x | | | | | x | | | | | | | | | | | | |
| | | | 25 | 24 | | x | | x | x | x | | | — | — | — | — | x | x | | x | | | | | | | | | x | | | | | | | | |
| | | | " | 25 | | x | | x | x | x | | | — | — | — | — | x | x | | x | | | | | | | | | x | | | | | | x | | |
| | | | 1923 | NE 5 | | x | | x | x | x | | | — | — | — | — | x | x | | x | | | | | | | | | x | | | | | x | | | |
| | | | | 7 | | x | | x | x | x | | | — | — | — | — | x | x | | x | | | | | | | | | | | | | | | | | |
| | | | | 8 | | x | | x | x | x | | | — | — | — | — | x | x | | x | | | | | | | | | | | | | | | x | | |
| | | | | 9 | | x | | x | x | x | | | — | — | — | — | x | x | | x | | | | | | | | | x | | | | | | | | Replacement |
| | | | | 10 | | x | | x | x | x | | | — | — | — | — | x | x | | x | | | | | | | | | | | | | | | | | |
| | | | | E 28 | | x | | x | x | x | | | — | — | — | — | x | x | | x | | | | | | | | | | | | | | | x | | |
| | | | 1928 | N 18 | | x | | x | x | x | | | — | — | — | — | x | x | | x | | | | | | | | x | | x | | | | | | | |
| | | | 1926 | NE 19 | | x | | x | x | x | | | — | — | — | — | x | x | | x | | | | | | | | | x | | | | | | | | |
| | | | 27 | 21 | | x | | x | x | x | | | — | — | — | — | x | x | | x | | | | | | | | | x | | | | | | | | |
| | | | " | 26 | | x | | x | x | x | | | — | — | — | — | x | x | | x | | | | | | | | x | x | x | | | | x | x | | |
| | | | 28 | 34 | | x | | x | x | x | | | — | — | — | — | x | x | | x | | | | | | | | x | | | | | | | | | |
| | | | " | 35 | | x | | x | x | x | | | — | — | — | — | x | x | | x | | | | | | | x | x | | x | | | | | | | |
| | | | 1925 | NE 23 | | x | | x | x | x | | | — | — | — | — | x | x | | x | | | | | | | | | x | | | | | | | | |
| | | | 1927 | NE 42 | | x | | x | x | x | | | — | — | — | — | x | x | | x | | | | | | | | | x | | | | | | | | |

M: Member
R: Connection Rivet
P.B: Portal Bracing
St.: Stringer
E.F: End Floor Beam
I.F: Int. Floor Beam

No - 4

| Span length | Type | Maker | Year | Span No. | Stress Check for Original Section (DL 14 loading) | | | | | | | | | | | | | | | | | | | | Situation of Corrosion | | | | | | Stress Check due to Corrosion | | | Deformation | | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Main Truss | | | | | | | | | | Lateral | | | | Floor System | | | | | | L.C | Stringer | Floor Beam | | | | St. | E.F | I.F | V | D | L.C | |
| | | | | | U.C | | L.C | | D | | V | | P.B | | U.L | | L.L | | St. | | E.F | | I.F | | | | Cov. PL. | U.Flg | Web | L.Flg | | | | | | | |
| | | | | | M | R | M | R | M | R | M | R | M | R | M | R | M | R | M | R | M | R | M | R | | | | | | | | | | | | | |
| 30.0 | T.T | C.L | 1914 | S 17 | | | × | | × | | | | — | — | — | — | × | × | | × | | × | | × | | | | | | | | | | | | | Tie, Lacing, Knee Deform |
| | | | 〃 | 18 | | | × | | × | | | | — | — | — | — | × | × | | × | | × | | × | | | | | × | | | | | | | | |
| | | | 〃 | 19 | | | × | | × | | | | — | — | — | — | × | × | | × | | × | | × | | | | | × | | | | | | | | |
| | | | 〃 | 20 | | | × | | × | | | | — | — | — | — | × | × | | × | | × | | × | | | | | × | × | | | | | | | |
| | | | 〃 | 23 | | | × | | × | | | | — | — | — | — | × | × | | × | | × | | × | | | | | × | | | | | | | | |
| | | | 〃 | 24 | | | × | | × | | | | — | — | — | — | × | × | | × | | × | | × | × | | | × | × | | | | | | | | |
| | | | 〃 | 26 | | | × | | × | | | | — | — | — | — | × | × | | × | | × | | × | | | | | × | | | | | | | | |
| | | | 1920 | 46 | | | × | | × | | | | — | — | — | — | × | × | | × | | × | | × | | × | | × | | | × | | | | | | |
| | | | | 47 | | | × | | × | | | | — | — | — | — | × | × | | × | | × | | × | × | | | | | × | | | | | | | |
| | | | | 62 | | | × | | × | | | | — | — | — | — | × | × | | × | | × | | × | | × | | × | × | × | × | | | | | | |
| | | | | 81 | | | × | | × | | | | — | — | — | — | × | × | | × | | × | | × | | × | | × | | × | × | | | | | | |
| | | | | 82 | | | × | | × | | | | — | — | — | — | × | × | | × | | × | | × | | × | | × | | × | × | | | | | | |
| | | | 1914 | 29 | | | × | | × | | | | — | — | — | — | × | × | × | × | | × | | × | | | | | | | | | | | | | |
| | | | 1924 | NE 1 | | × | × | | × | | | | — | — | — | — | × | × | | × | | × | | × | | | | × | | | | | | | | | |
| | | | | 2 | | × | × | | × | | | | — | — | — | — | × | × | | × | | × | | × | | | | × | | | | | | | | | |
| | | | | 3 | | × | × | | × | | | | — | — | — | — | × | × | | × | | × | | × | | | | × | | | | | | | | | |
| | | | 1920 | S 86 | | × | × | | × | | | | — | — | — | — | × | × | | × | | × | | × | | × | | × | × | | × | | | | | | |
| | | | | 87 | | × | × | | × | | | | — | — | — | — | × | × | | × | | × | | × | | × | | | × | | × | | | | | | |
| | | | | 88 | | × | × | | × | | | | — | — | — | — | × | × | | × | | × | | × | | × | | × | × | | × | | | | | | |
| | | | | 99 | | × | × | | × | | | | — | — | — | — | × | × | | × | | × | | × | | | | × | × | × | | | | | | | |
| | | | | 103 | | × | × | | × | | | | — | — | — | — | × | × | | × | | × | | × | × | | | | × | | | | | | | | |
| | | | | E 3 | | × | × | | × | | | | — | — | — | — | × | × | | × | | × | | × | | | | | × | | | | | | | | |
| | | | | S 68 | | × | | | × | | | | — | — | — | — | × | × | | × | | × | | × | × | | | | × | | | | | | | | |
| | | | | 71 | | × | | | × | | | | — | — | — | — | × | × | | × | | × | | × | | | | × | | × | | | | | | | |
| | | | | 54 | | × | | | × | | | | — | — | — | — | × | × | | × | | × | | × | | | | | | | | | | | | | |
| | | | 1911 | 13 | | × | | | × | | | | — | — | — | — | × | × | | | | | | | × | | | | | | | | | | | | |
| | | | 1914 | 40 | | × | × | | × | | | | — | — | — | — | × | × | × | × | | × | | × | × | | | | × | × | | | × | | | | |
| | | | 20 | 51 | | × | × | | × | | | | — | — | — | — | × | × | × | × | | × | | × | | | | | | | | | | | | | |
| | | | 〃 | 56 | | × | × | | × | | | | — | — | — | — | × | × | × | × | | × | | × | | | | | | × | | | × | | | × | |

M: Member
R: Connection Rivet
Portal Bracing
Stringer
End Floor Beam
Int. Floor Beam

No - 5

| Span length | Type | Maker | Year | Span No. | Stress Check for Original Section (DL 14 loading) | | | | | | | | | | | | | | | | | | | | Situation of Corrosion | | | | | | Stress Check due to Corrosion | | | Deformation | | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Main Truss | | | | | | | | | | Lateral | | | | Floor System | | | | | | | | | | | | | | | | | | |
| | | | | | U.C | | L.C | | D | | V | | P.B | | U.L | | L.L | | St. | | E.F | | I.F | | L.C | Stringer | | | | | | | | | | | |
| | | | | | M | R | M | R | M | R | M | R | M | R | M | R | M | R | M | R | M | R | M | R | | | Cov. PL. | U.Flg | Web | L.Flg | St. | E.F | I.F | V | D | L.C | |
| 30.0 | D.T | ? | ? | N 22 | | | x | x | | | | | | | x | x | | | x | | x | x | x | x | x | x | | | | | | | | | | x | Replacement |
| 31.4 | T.T | ? | ? | S109 | | | | | | | | | — | — | — | — | x | x | | x | | | | | x | | | | | | | | | | | | Knee Deform |
| | | | | 110 | | | | | | | | | — | — | — | — | x | x | | x | | | | | x | | | | | | | | | | | | ” |
| 31.7 | T.T | P.W.M | 1894 | E 37 | | | x | x | x | x | | | — | — | — | — | x | x | | x | | | | | | | | | | | | | | | | | |
| | | | ” | N 5 | | | x | x | x | x | | | — | — | — | — | x | x | | x | | | | | | | x | | | x | | | | | | | Replacement |
| | | | ” | 6 | | | x | x | x | x | | | — | — | — | — | x | x | | x | | | | | x | | x | | | x | | | | | | | |
| 33.52 | T.T | D.D | 1923 | N 1 | | | | | | | | | | | x | x | x | x | | x | | | | | x | x | | x | | x | | | | | | | |
| 35.0 | T.T | C.L | 1920 | E 1 | | x | x | | x | | | | | | x | x | x | x | x | x | | | | | | | | | x | | | | | | | | |
| | | | ” | 10 | | x | | x | x | | | | | | x | x | x | x | x | | | x | | x | | x | | | | | | | | x | | | |
| | | | ” | 11 | | x | | x | x | | | | | | x | x | x | x | x | | | x | | x | | | | | | x | | | | x | | | |
| | | | 1915 | S 27 | | x | | x | x | | | | | | x | x | x | x | x | | | x | | x | x | x | | | x | | x | | | | | | |
| | | | ” | 32 | | x | | x | x | | | | | | x | x | x | x | x | | | x | | x | x | x | | | x | x | | | | x | | | Sway Defram |
| | | | 1920 | S 12 | | x | x | | x | | | | x | | x | x | x | x | | | | | | | | | | | | | | | | | | | |
| | | | 15 | 55 | | x | x | | x | | | | x | | x | x | x | x | | | | | | | x | | | | | x | | | | | | | |
| | | | 20 | 79 | | x | x | | x | | | | x | | x | x | x | x | x | | | x | | x | x | | | | x | x | | | | | | | Sway Deform |
| | | | ” | 80 | | x | x | | x | | | | x | | x | x | x | x | x | | | x | | x | | x | | | | | x | | | | | | Sway Deform |
| | | | ” | 89 | | x | x | | x | | | | x | | x | x | x | x | x | | | x | | x | | x | | x | | x | x | | | | | | |
| 35.0 | T.T | D.V.R | 1924 | E 24 | | x | | x | x | x | x | x | | | x | x | x | x | x | x | | | x | | x | | | | | | | | | x | | x | |
| | | | ” | 25 | | x | | x | x | x | x | x | | | x | x | x | x | x | x | | | x | | x | | | | | | | | | x | | x | |
| | | | ” | 29 | | x | | x | x | x | x | x | | | x | x | x | x | x | x | | | x | | x | | | | x | | | | | | x | | Sway Deform |
| | | | ” | 36 | | x | | x | x | x | x | x | | | x | x | x | x | x | x | | | x | | | | | | | | | | | | | | Sway, Tie, Lacing Deform |
| 35.0 | T.T | D.D | 1929 | N 7 | x | x | x | x | x | x | | x | — | — | — | — | x | x | | x | | | | | x | | | | | x | | | | x | | | Knee Deform |
| | | | ” | 8 | x | x | x | x | x | x | | x | — | — | — | — | x | x | | x | | | | | x | | | | x | | | | | | | | ” |
| | | | ” | 14 | x | x | x | x | x | x | | x | — | — | — | — | x | x | | x | | | | | | | | | | | | | | | | | ” |
| | | | 1923 | E 12 | | x | x | x | x | x | | x | — | — | — | — | x | x | | x | | | | | | | | | | | | | | | | | |
| | | | ” | 13 | | x | x | x | x | x | | x | — | — | — | — | x | x | | x | | | | | | | | | | | | | | | | x | |
| | | | ” | 15 | | x | x | x | x | x | | x | — | — | — | — | x | x | | x | | | | | | | | x | x | | | | | x | | | |
| | | | ” | 17 | | x | x | x | x | x | | x | — | — | — | — | x | x | | x | | | | | | | | | | | | | | | x | | |
| | | | ” | 18 | | x | x | x | x | x | | x | — | — | — | — | x | x | | x | | | | | | | x | | | | | | | | | | |

M: Member
Connection Rivet
Portal Bracing
Stringer
End Floor Beam
Int. Floor Beam

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | No - 6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Span length | Type | Maker | Year | Span No. | Stress Check for Original Section (DL 14 loading) | | | | | | | | | | | | | | | | | | | | Situation of Corrosion | | | | | | Stress Check due to Corrosion | | | Deformation | | | Remarks |
| | | | | | Main Truss | | | | | | | | | | Lateral | | | | Floor System | | | | | | | | | | | | | | | | | | |
| | | | | | U.C | | L.C | | D | | V | | P.B | | U.L | | L.L | | St. | | E.F | | I.F | | L.C | Stringer | Floor Beam | | | | | | | | | | |
| | | | | | M | R | M | R | M | R | M | R | M | R | M | R | M | R | M | R | M | R | M | R | | | Cov. PL. | U.Flg | Web | L.Flg | St. | E.F | I.F | V | D | L.C | |
| 35.0 | T.T | D.D | 1923 | E 21 | | × | × | × | × | × | | × | — | — | — | — | × | × | | × | | | | | | | | | | | | | | | | | |
| | | | | 22 | | × | × | × | × | × | | × | — | — | — | — | × | × | | × | | | | | | | | | | | | | | | | × | |
| | | | | 23 | | × | × | × | × | × | | × | — | — | — | — | × | × | | × | | | | | | | | | | | | | | | | | Knee Deform |
| | | | | 26 | | × | × | × | × | × | | × | — | — | — | — | × | × | | × | | | | | | | | | | | | | | | | | |
| 35.0 | T.T | JAPAN | 1933 | S 105 | | | | | | | | | × | | × | × | × | × | × | × | | | | | | | | | | | | | | | | | |
| 40.0 | T.T | D.D | 1923 | E 33 | | × | | | × | × | | | × | | × | | × | × | | × | | | | | | | | | × | | | | | × | × | | |
| | | | 27 | NE 30 | | × | | | × | × | | | × | | × | | × | × | | × | | | | × | | | | | | | | | | | × | × | |
| | | | 〃 | 32 | | × | | | × | × | | | × | | × | | × | × | | × | | | | × | | | | | × | × | | | | × | × | | |
| | | | 28 | N 9 | | × | | × | × | × | | × | × | | × | × | × | × | | × | | | | × | | | | | | | | | | | | × | |
| | | | 〃 | 15 | | × | | × | × | × | | × | × | | × | × | × | × | | × | | | | × | | | × | | | | | | | | | | |
| | | | 〃 | 17 | | × | | × | × | × | | × | × | | × | × | × | × | | × | | | | × | | | | × | × | | | | | | | | |
| 40.0 | T.T | C.L | 1920 | S 60 | | | × | | × | | | | × | | × | | × | × | | × | | × | | × | | | | | | | | | | | | | |
| | | | | 11 | | | | | | | × | | × | | × | | × | | × | | | × | | × | × | × | | × | × | | × | | | | | | |
| 40.0 | T.T | ? | ? | N 21 | | | × | | | × | | | × | | × | | × | | | × | | | | | | × | | | | × | | | | | | | Pin Truss |
| 45.0 | T.T | D.V.R | ? | N 13 | | | | | × | × | × | × | | | | × | × | | × | × | × | | | | × | | | | | | | | | | | | Knee Deform |
| 45.0 | T.T | C.L | 1914 | S 38 | | | | | × | | | | × | | × | | × | × | × | × | | × | | × | × | × | | | × | × | × | | | | | | |
| | | | 20 | 100 | | | | | × | | | | × | | × | | × | × | × | × | | × | | × | × | | | | | × | | | | | | | |
| | | | 〃 | 101 | | | | | × | | | | × | | × | | × | × | × | × | | × | | × | | | | | × | × | | | | | × | × | Tie, Lacing Deform |
| | | | 〃 | E 4 | | | | | × | | | | × | | × | | × | × | × | × | | × | | × | | | | | | × | | | | | | | |
| | | | 1914 | S 31 | | | | | × | | | | × | | | | × | | × | × | | | | | × | × | | × | × | × | × | | | | | | |
| | | | 20 | 43 | | | | | × | | | | × | | | | × | | × | × | | | | | | × | | | × | | × | | | | × | | |
| | | | 〃 | 44 | | | | | × | | | | × | | | | × | | × | × | | | | | | | | | | × | | | | | | | |
| | | | 〃 | 53 | | | | | × | | | | × | | | | × | | × | × | | | | | | | | | | × | | | | | | | |
| 48.0 | T.T | C.L | 1920 | S 58 | | | | × | | | | | × | | | | × | | × | × | | | | | | | | | × | | | × | × | | | | |
| | | | 〃 | 73 | | | | × | | | | | × | | | | × | | × | × | | | | | | × | | | × | | × | × | × | × | × | | |
| 50.0 | T.T | D.V.R | ? | N 19 | | | | | × | | | | × | | | × | × | | × | | × | | | | | | | | | | | | | | | | Tie, Lacing Deform |
| | | | 〃 | NE 17 | | | | | × | | | | × | | | × | × | | × | | × | | | | | | | × | × | × | | | | | | | Knee Deform |
| | | | 1920 | E 32 | | | | | × | | | | × | | | × | × | | × | | × | | | | | | | | | | | | | | | | |

M: Member
R: Connection Rivet
P.B: Portal Bracing
St.: Stringer
E.F: End Floor Beam
I.F: Int. Floor Beam

No - 7

| Span length | Type | Maker | Year | Span No. | Stress Check for Original Section (DL 14 loading) | | | | | | | | | | | | | | | | | | | | Situation of Corrosion | | | | | | Stress Check due to Corrosion | | | Deformation | | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Main Truss | | | | | | | | | | Lateral | | | | Floor System | | | | | | L.C | Stringer | Floor Beam | | | | St. | E.F | I.F | V | D | L.C | |
| | | | | | U.C | | L.C | | D | | V | | P.B | | U.L | | L.L | | St. | | E.F | | I.F | | | | Cov. PL. | U.Flg | Web | L.Flg | | | | | | | |
| | | | | | M | R | M | R | M | R | M | R | M | R | M | R | M | R | M | R | M | R | M | R | | | | | | | | | | | | | |
| 50.0 | T.T | C.L | 1914 | S 36 | | | | | x | | x | | x | | x | | x | | x | | | | | | | x | | | x | | | | | | | | |
| | | | " | 37 | | | | | x | | x | | x | | x | | x | | x | | | | | | x | | | | x | | | | | | | | |
| | | | 20 | 90 | | | | | x | | x | | x | | x | | x | | x | | | | | | | | | | | x | | | | x | x | | |
| | | | " | 91 | | | | | x | | x | | x | | x | | x | | x | | | | | | | | | x | x | x | | | | | | | |
| | | | 14 | S 22 | | | | | x | | | | x | | x | x | x | | x | x | | | | | | x | | | | | x | | | | | | Sway Detrom |
| | | | 20 | 49 | | | | | x | | | | x | | x | x | x | | x | x | | | | | | | | | x | x | | | | | | | Sway, Tie Deform |
| | | | | 50 | | | | | x | | | | x | | x | x | x | | x | x | | | | | x | | | | | | | | | | | | |
| | | | | 69 | | | | | x | | | | x | | x | x | x | | x | x | | | | | | | | | x | x | | | | | | | Sway Detrom |
| | | | | 85 | | | | | x | | | | x | | x | x | x | | x | x | | | | | | | | | x | | | | | | | | |
| | | | | 93 | | | | | x | | | | x | | x | x | x | | x | x | | | | | | x | | x | x | x | x | | | | | | |
| | | | | 94 | | | | | x | | | | x | | x | x | x | | x | x | | | | | | x | | x | x | x | x | | | | x | | |
| | | | | 95 | | | | | x | | | | x | | x | x | x | | x | x | | | | | | | | x | x | x | | | | | | | |
| | | | | 96 | | | | | x | | | | x | | x | x | x | | x | x | | | | | | x | | x | x | x | x | | | | | | |
| | | | | 97 | | | | | x | | | | x | | x | x | x | | x | x | | | | | | x | | x | x | x | x | | | | | | |
| | | | | 98 | | | | | x | | | | x | | x | x | x | | x | x | | | | | | | | x | x | x | | | | | x | | |
| 50.0 | T.T | D.D | 1923 | NE 6 | | x | | x | x | x | | x | x | | x | x | x | x | | x | x | | | | | | | | x | | | x | | | | | |
| | | | | 27 | | x | | x | x | x | | x | x | | x | x | x | x | | x | x | | | | | | | | x | | | x | | | x | | |
| | | | | E 16 | | x | | x | x | x | | x | x | | x | x | x | x | | x | x | | | | | | | | | | | | | | | | |
| | | | | 19 | | x | | x | x | x | | x | x | | x | x | x | x | | x | x | | | | | | | | | | | | | | | | |
| | | | | 20 | | x | | x | x | x | | x | x | | x | x | x | x | | x | x | | | | | | | x | | | | x | | | | x | |
| | | | 1927 | NE 29 | x | x | | x | x | x | | x | x | | x | x | x | | | x | x | x | | | | | | | x | | | x | | | | | |
| | | | 29 | 41 | x | x | | x | x | x | | x | x | | x | x | x | | | x | x | x | | | | | | | x | | | x | | | x | | |
| | | | " | 44 | x | x | | x | x | x | | x | x | | x | x | x | | | x | x | x | | | | | | | | | | | | | | | |
| 60.0 | T.T | C.L | 1914 | S 25 | x | | | | x | | | x | x | | x | x | x | x | x | x | | | | | | | | x | x | x | . | | | | | | |
| | | | 20 | S 63 | x | | | | x | | | x | x | | x | x | x | x | x | x | | | | | | x | | x | x | x | x | | | | | | |
| | | | " | 72 | x | | | | x | | | x | x | | x | x | x | x | x | x | | | | | | x | | | | x | x | | | | | | |
| | | | " | 92 | x | | | | x | | | x | x | | x | x | x | x | x | x | | | | | | | | x | x | x | | | | | | | |
| | | | 24 | NE 4 | x | | | | x | | | x | x | | x | x | x | x | x | x | | | | | | | | x | | | | | | | | | |

M: Member
Connection Rivet
Portal Bracing
Stringer
End Floor Beam
Int. Floor Beam

No - 8

| Span length | Type | Maker | Year | Span No. | Stress Check for Original Section (DL 14 loading): Main Truss U.C M | U.C R | L.C M | L.C R | D M | D R | V M | V R | P.B M | P.B R | Lateral U.L M | U.L R | L.L M | L.L R | Floor System St. M | St. R | E.F M | E.F R | I.F M | I.F R | Situation of Corrosion: L.C | Stringer | Floor Beam Cov. PL. | U.Flg | Web | L.Flg | Stress Check due to Corrosion St. | E.F | I.F | Deformation V | D | L.C | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 65.0 | T.T | C.L | 1914 | S 34 | | | | x | x | | | | x | | x | | x | | x | x | | | | | x | | | | | | | | | | x | | |
| | | | | S 39 | | | x | | x | | | | x | | x | x | x | x | x | x | | | | | x | x | | x | x | x | | | x | | | | Tie, Lacing Deform |
| 70.0 | T.T | C.L | 1911 | S 14 | | | x | x | x | | | | x | | x | | x | x | x | | x | | x | | x | | | | | | | | | | | | |
| | | | 14 | 48 | | | x | x | x | | | | x | | x | | x | x | x | | x | | x | | x | | | | x | x | | | | | | | Tie, Lacing Deform |
| | | | 20 | 104 | | | | | | | | | | | | | | | | | | | | | | | | x | | | | | | | | | No Drawings |
| | | | 〃 | E 14 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 〃 |
| | | | 14 | S 21 | | | | | | | | | | | | | | | | | | | | | | x | | x | | x | x | | | x | | | 〃 |
| 80.0 | T.T | C.L | 1914 | S 33 | | | | | x | | | | x | | x | x | x | x | x | x | | | | | x | x | | x | x | x | x | x | x | | | | |
| | | | 20 | S 61 | x | | x | | x | | x | | x | | x | x | x | x | x | x | | | | x | x | x | | x | x | x | x | | x | | | | Sway Deform |
| | | | 〃 | S 83 | | | | | x | | | | x | | x | x | x | x | x | x | | | | | | x | | x | x | x | x | | | | | | |
| 80.0 | T.T | D.D | 1925 | NE 22 | | x | | x | x | | x | | x | | x | | x | x | x | x | | | | | | | | | x | | | | | | x | x | Tie, Lacing Deform |
| | | | 27 | 28 | | x | | x | x | | x | | x | | x | | x | x | x | x | | | | | | | | | x | | | | | | | x | 〃 |
| | | | 28 | 15 | | x | | x | x | | x | | x | | x | | x | x | | x | | | | | | | | | x | | | | | | x | x | |
| | | | 27 | 31 | | x | | x | x | | x | | x | | x | | x | x | | x | | | | | x | | | | | x | | | | | | x | |
| | | | 29 | 43 | | x | | x | x | | x | | x | | x | | x | x | | x | | | | | | | | | x | | | | | | | | |
| | | Σ = 214 Br. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

M: Member
Connection Rivet
Portal Bracing
Stringer
End Floor Beam
Int. Floor Beam

# VI. DESIGN FOR REPAIR AND STRENGTHENING

# VI. DESIGN FOR REPAIR AND STRENGTHENING

## 1. Fundamental Policy

The results of the investigation of the existing bridges and the evaluation of their load-carrying capacities revealed necessity of various improvement works as stated in the previous section. Of these necessary works, the repair and strengthening works will be described in relation with fundamental policies thereof in this section.

### 1-1 General

(1) Repair and strengthening works are intended to improve bridge members so that they can withstand DL-15 Loading. (Refer to VI 2.3).

(2) It is intended that the strengthening of members is effective only for the live load, while all of the dead load is carried by the original members.

(3) The improvement works are so scheduled and methods are so chosen that they can be, in principle, carried out during the interval of the passage of trains carried out during the interval of the passage of trains without interrupting the operation of trains.

(4) The load of passing trains allowed during the improvement works is assumed to be at most equivalent to a loading diagram consisting of one of the locomotive of the DL-14 loading and its trailing uniform load.

### 1-2 Improvement of Members

(1) Members are improved by adding new members to original members or by replacing the latter with the new members.

(2) In the improvement work, methods chosen are those which are easier to be carried out and which have a higher degree of safety both for train operation and workers. In principle, new members or components are added to old members without disassembling them, but by only cutting the existing rivets.

(3) Original structural system is utilized as far as possible when replacing original members with new ones (for example, the diagonal members of Daydé type, Double-Warren Truss).

(4) Even when corroded floor systems are not subjected to excessive stress according to ordinary calculation, they are to be repaired in accordance with degree of corrosion to safe-guard against adverse effects, such as stress concentration.

(5) Defective structures of original design are to be improved, as far as possible.

(6) Deformed members are to be repaired so that original shape of members can be attained.

(7) Those portions in which repair and strengthening works in future will become difficult because of the present improvement works are to be improved at this time.

### 1-3 Improvement of Connection Rivets

(1) Rivets or high strength bolts are used for connecting the members of additional members in the field. Welding in the field is not to be adopted for this purpose.

(2) Some rivets are loosened in actual use, although they are deemed to be subjected to no excessive stresses by ordinary calculation, and all of them are to be replaced.

(3) Those rivets which do not show any deterioration are to remain, even though they are deemed to be somewhat overstressed according to calculation.

## 2. Design Criteria for Repair and Strengthening

### 2-1 Basic Guide

The improvement plan includes the following categories.

| Kinds of Improvement | Causes |
|---|---|
| Strengthening | · Excessive stress<br>· Structural defect |
| Repair | · Corrosion<br>· Deterioration due to fatigue<br>· Deformation of member |
| Replacement | · Difficulty or excessive costs for strengthening<br>· Other reasons, such as insufficient distance between main girders, etc. |

Primary major factors to be incorporated into the plan and schedule for strengthening and repair are as listed hereunder.

(a) Loading condition such as train load and wind load, etc.
(b) Construction gauges
(c) Materials
(d) Working condition

In addition to the above factors, there are some other factors to be considered, such as the priorities of railway lines and bridges for improvement, the efficiency of work progress, and the method of tendering or awarding the contract.

They are interconnected with each other and, therefore, make it rather difficult to set up fixed conditions applicable to the plan and design for the improvement works. Herein only the standardized methods for repair, strengthening or replacement are introduced, based on the following conditions.

(1) The order of bridges and the number of bridges to be improved under each tender will not incorporated in the present consideration.

(2) The work covering both repair and strengthening will be classified into several categories according to the contents of work and structures for simplification. Such classification will be made only from a general aspect, and irrespective of any individual structural condition and site condition.

(3) Standard drawings for repair and strengthening will be prepared in reference to the original drawings. The members to be supplemented for repair and strengthening are assumed to be all newly procured and of the JIS standards, though reuse of old members available from the replaced bridges may be possible in certain cases.

(4) Prior to start of the work, detail drawings for repair and strengthening works will be prepared after actual survey of the site condition, dimensions of members, rivet pitches and corrosion condition of each bridge involved.

2-2 Loading Conditions

Repair and strengthening will be, in any case, made on the basis of the Specifications for Design (Appendix I).

It is assumed that no double headed engine would be allowed during the construction period, the train speed would be limited within 5 kilometers per hour if necessary, and there would be no limitation in the length of the trailing load.

Moreover, it is assumed that the principal load will not be accompanied with other loads.

2-3 Reasons for Using DL-15 Loading for the Improvement of Bridges

The load of trains used in RSR at present and in the future is decided to be, in principle, not greater than the DL-14 Loading (the loading of two CO–CO diesel locomotives whose axle load is 14 tons plus a uniformly distributed trailing load of 4.2 t/m). Thus, the DL-14 Loading is used for checking the strength of bridges in this study. (Fig. S-3)

Nevertheless, the design for repair or strengthening of old bridges should be carried out in such a manner that all the members of a bridge be improved to be strong enough for the DL-15 loading, if any members of the bridge are subject to excessive stress under the DL-14 Loading. The design load for new bridges to be used in replacement of old bridges should be also the DL-15 Loading.

This idea is considered to be advantageous for the reasons mentioned below. Here, the DL-15 Loading and the DL-14 Loading have the same axle spacings and the ratio of weight is 15 to 14 including the trailing load.

(1) Some safety margin over the check loading should be provided to take care of future deterioration.

(2) Extending of service life of some 50% can be expected, so far as fatigue is concerned.

(3) There is a possibility to be more economical in view of the efficiency of freight transportation, if the DL-15 Loading which trails a 4.5 t/m loading is employed, instead of the DL-14 Loading which trails a 4.2 t/m loading.

(4) In general, the design live load having additional marginal safety is adopted in every country. For instance, bridges designed with KS-18 are used for trains equivalent to at most about KS-15 by the Japanese National Railways. This practically enables the speed-up of trains and the reduction of influence on the fatigue of the floor system of bridges.

Moreover, the adoption of this practice in respect of improvement of these 214 spans, would involve an additional cost only 7.7 million baths or 3.0% over the cost of improvement to DL-14 Loading.

## 2-4 Construction Gauge

According to the RSR's established standard of construction gauge (Dwg. No. 1966-15), all the bridges under this improvement plan except those of deck type should provide a greater width (horizontal clearance) to meet the requirement and, accordingly, the distance between the main girders should be increased. Although it is not impossible to apply the above requirement to the existing bridges, it is not absolutely necessary at this juncture. Therefore, general concept concerning the construction gauge will be as specified below unless otherwise revised for any other special reasons.

(1) No change will be made to main members of the existing bridges but additional members for repair and strengthening will be provided as far as possible in accordance with the RSR's construction gauge rules.

(2) Any main members in the existing bridges, which are considered to be vitally essential will be corrected for improvement.

(3) Any repairable secondary members will also be corrected.

## 2-5 Structural Members

As stated earlier, the design for repair and strengthening will be based upon the newly procured materials. However, such additional elements will be inevitably subject to a less stress than the existing ones unless the prestressing methods are applied or stagings are used. For this reason, even the old members out of the dismantled bridges may be reusable if they can meet the requirements in size, type and shape of the section.

Indeed, there are lots of dismantled bridges in the State Railway of Thailand, for which the inventory list is prepared. However, since it is difficult, at this stage, to formulate the plan into such details as using materials from those old members to the members to be improved, the design is all based upon the newly furnished materials. The materials should comply with the JIS standards and the number of their sizes are reduced as far as possible; for instance, steel plates to be used except filler plates will be of 8, 9, 10, 12, 15, 16, 19 and 22mm in thickness.

In fact, the steel cost takes a large share in the total work cost for this project. Therefore, how to use steel materials economically will have an important effect upon the overall project planning. It is for this reason that reusability of the old steel members will be evaluated later at the stage of cost estimation.

## 2-6 Connecting Materials

Materials to be used for connections or joints of the component members are welding, riveting and bolting with high strength bolts.

They have their own special characteristics by purposes.

However, the following policy will be adopted in general as to their usages:

(1) Welding will apply to all the members to be fabricated in shop.

(2) Field welding will not be allowed, except for water-proof purpose or the like.

(3) Even in case where the contact surface of members can be sufficiently cleaned up to secure the required coefficient of friction in order to use high strength bolts for connecting the members together at the construction site, the allowable stress will be assumed as being equal to the allowable shearing stress for rivets.

(4) In all other cases than specified above, rivets will be used in principle. However, when the friction coefficient can be determined from the experimental result, they will be replaced with high strength bolts of exact quantity as calculated, based on the experiment.

## 2-6-1 Welding

Application of welding to either repair or strengthening work will present the following problems:

(1) Availability of skilled welders

(2) Weldability of materials of the existing bridge members, welding position and surrounding conditions for welding.

(3) Resisting strength against fatigue of welded parts.

(4) Quality control and inspection after welding.

Especially, there are lots of difficulty involved in field welding. The present plan does not include, in principle, application of field welding, taking into account the local climatic condition, the technical level of welders and some other related conditions.

On the other hand, with respect to shop fabrication of members, the result of survey at factories of the State Railway of Thailand and other private companies has made us conclude that shop welding will be applicable technically to its fullest extent.

## 2-6-2 High Strength Bolts

The results of site survey and stress check disclose some common drawbacks. One is that bearing stress of the rivets at the connection is in excess of the required limit. The other is that the rivets being subjected to tensile stress for structural reason tend to get loose. Those drawbacks can be improved greatly by using high strength bolts instead of rivets. Besides, the high strength bolts excels in both workability and efficiency of work.

Connections by high strength bolts may be divided roughly into the following categories according to types for connection applied to: (see Fig. 5.1)

| | | |
|---|---|---|
| Friction type connection | Bolt of an ordinary shape<br>Grip bolt<br>PI-nut bolt<br>TC bolt | (ref. Fig. 5.1) |
| Tension type connection | | |
| Bearing type connection | Bearing bolt connection<br>Polished bolt connection<br>Driven bolt connection | |

The design for this project incorporates adoption of the friction type high strength bolt connection method for such reason as mentioned in the latter part. The general term "high strength bolt" refers to this type of connection hereafter.

When this method is used for repair and strengthening, it has a great advantage but, on the other hand, it may pose some problems as follows:
Firstly, it will become a very time-consuming troublesome work at the site to remove rust and coating paint on the connection surfaces. If time and space are limited severely, such preparatory work can not be done at all or satisfactorily. High strength bolts can not be used with full confidence unless the friction coefficient is clearly known.

Therefore, there is no guarantee, for security of adequate friction between the members when the loose rivets or overstressed rivets are replaced with high strength bolts without cleaning the contact surfaces.

It is normally assumed that the contact surfaces between members or elements may remain rusty or painted and, therefore, it is probable that the frictional coefficient may be considerably reduced.

However, fortunately, there are a number of old bridges dismantled in the State Railway of Thailand, which can be used for the experiment to ascertain the frictional co-efficient. If such an experiment can successfully be carried out, it is advisable to adopt high strength bolts of a proper quality in conformity with the frictional coefficients obtained from the experiment. (cf. Appendix IV)

The bearing type connection is an alternative method to cover the drawbacks of the friction type connection. However, the plan for this project will preclude use of the bearing type bolt connection, in principle, for the following reasons:

(1) Elements of members of the existing bridges are thin. In such a case, the required number of bolts is the same as those of rivets, thus bringing no advantage.

(2) Bolt holes should conform strictly to required accuracy. Therefore, the re-aming is required for all of the holes before the bolts are driven. Some holes can not accept such pre-setting by reamer for structural reason.

(3) Some of the existing holes may already have discrepancies in size and shape. Therefore, such holes must be expanded to a larger size and bolts of large diameter must be used.

(4) Requirement for adequacy of bolt length is very severe and bolts are rather expensive in price.

The driving type bolts are typical ones representing the bearing type bolts. For reasons mentioned above, their usage is very much limited eventually. For those frictional connection bolts it is of particular importance to give them the required tensile stress as well as to treat the frictional surface properly. However, both of the work and its subsequent check are quite troublesome. To solve this problem, various kinds of clamping tools or fasteners have been developed; some clamping machines are automatically operable for torque adjustment by either hydraulic oil or motor driven system. There are also high strength bolts which are devised elaborately to meet this purpose; the most typical ones are so-called grip bolts, TC bolts or PI nuts. They are so deviced that bolt clamping force to be introduced can be automatically adjusted by twisting off a part of bolt or nut.

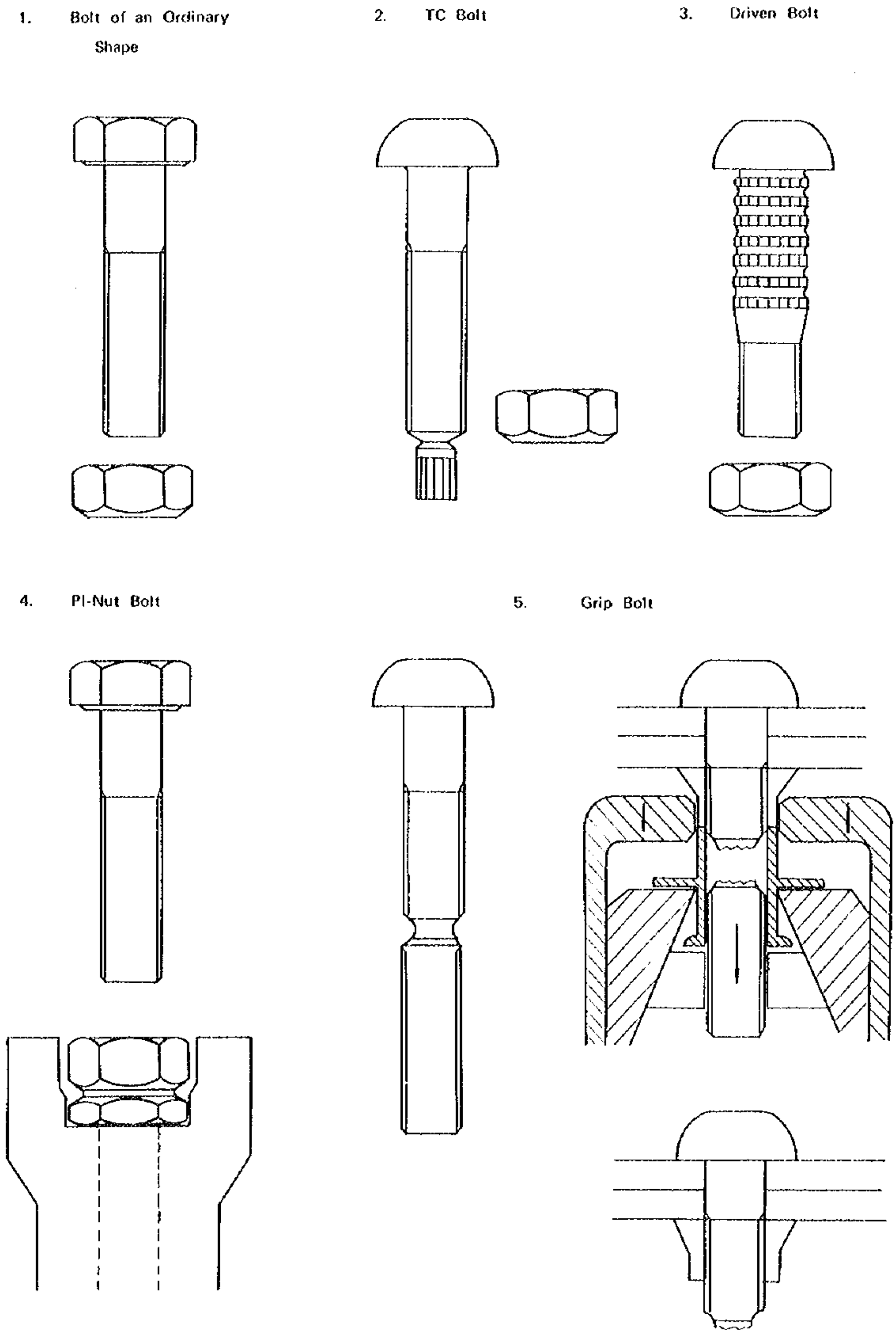



Fig. 5.1 The Group of High Strength Bolts

Those bolts or nuts contribute much toward facilitating the field operation and maintenance. Although they are rather costly, it may be offset by the advantage that skilled workers are not particularly required. However, because the existing members, unlike the newly made ones, are often small-sized or existing rivets are often located inconveniently, it is not practical to adopt such peculiar type of bolts entirely for all members.

Therefore, the friction type connection with ordinary high strength bolts is to be used mainly for this project.

It should be noted that any mixture with different type bolts in one connection group should be avoided and also that various connection methods should not be mixed within one span of bridge.

## 2-7 Working Method

The working method may be divided largely into the categories as charted below:

- Open line system .......
  - *Load restriction
  - *Speed limit
  - *Keeping long intervals between trains
- Diversion system ........
  - *Improvement in site
  - *Improvement after removal

- Strengthening for live load only
- Strengthening for both dead and live loads ........
  - *Stagings
  - *Prestressing

The work can be done by the two alternative methods. In the open line system, trains can pass through the bridge during the period of improvement work of bridge, while in the diversion system, trains pass on a separate provisional line during the improvement work of bridge.

Selection of the method is closely related to how much work should be done or the site condition under which the work has to be performed.

The result of stress check reveals that those components to be strengthened are mostly the diagonal members and only a few are the chord members. Besides, the chord members require only a little addition of sectional area for strengthening.

Connections which required strengthening were found in diagonal members of main trusses, stringers and lateral bracings.

On the other hand, the repair work for corrosion is needed mostly for the floor beams and only a few of the main girders and trusses.

As far as strengthening of members is concerned, there are two objectives; whether it aims at effective strengthening against live load only, or both of live and dead loads.
As for the bridges under this plan, members of long span bridges have already sufficient sectional areas in general, while the members of small span bridges have less stress from dead load. It is, therefore, decided that the effective strengthening method should be adopted for live load only both for long bridges and short bridges.

At present, many bridges are provided with temporary stagings. There is an idea of utilizing these stagings as a means of strengthening. However, this may make if difficult, if used for this purpose, to evaluate exactly the amount of working stress which may arise in the members of the bridge when trains pass over it.

It is, indeed, much easier to carry out the work by use of a separate line or by provision of a temporary line. Then, the work can be performed to the highly accurate level, thus ensuring strengthening against dead load as well, if necessary. However, in this case, increase in cost may not compensate the advantages gained.

For the reason mentioned above, the open line system is adopted in principle for any repair and strengthening work of the bridges.

It is desirable to keep long intervals of train operation from the view point of ease and safety for working. It is, however, improper to suspend the train operation for a long time in behalf of work for each of many bridges. Unreasonable plan and schedule for the work should be avoided for safety sake. Therefore, in view of the above, the working conditions are given as follows:

(1) The train speed is to be lowered so as to reduce the dynamic effect, if necessary.

(2) Radical change should be avoided on the operating time schedule of trains unless otherwise specifically required. However, it is assumed that train intervals of at least two hours, once a day, could be secured.

(3) Although the work may be suspended while the train is passing, the work must be performed in such a condition as may permit the passage of trains at a low speed all the time.

(4) The design and work for strengthening and repair are to be done, in principle, in such a manner that the removal of the existing rivets in members to be strengthened will be limited to the possible minimum, in adding new elements to the existing members.

## 3. Standard for Strengthening and Repair

### 3-1 General

Works for improving the main members of truss mainly consist of strengthening works for those members which have an excessive stress or an excessive slenderness ratio and repair works for corroded lower chord members or for loosened rivets in diagonal or vertical members. The strengthening works will constitute main part of the improvement works. Improvement works for floor system comprise strengthening works on account of deficient strength and repair works owing to corrosion.

All of these strengthening and repair works can be effected either by attaching new members to original ones or by replacing original members with new ones.

Main purposes of the strengthening and repair works for the main members of trusses can be classified as follows:

i ) Upper chord members : Strengthening works on account of excessive stress.

ii ) Lower chord members: Repair works owing to corrosion and deformation, and strengthening works owing to excessive stress.

iii) Diagonal and vertical members: Strengthening works owing to excessive stress or excessive slenderness ratio, and repair works for loose rivets.

As for the floor system, the following classification can be given similarly:

i ) Floor beams: Both the strengthening and repair works. Particularly, repair works owing to corrosion constitute considerable amount of works in this improvement plan.

ii ) Stringers: Both the strengthening and repair works. Many sway bracings located between stringers are structurally defective, requiring a large amount of works. Also, the connections with floor beam require a large amount of improvement works.

iii) Lateral bracings: Strengthening works owing to excessive stress or excessive slenderness ratio, and repair works owing to corrosion.

iv ) Movable shoes: Repair works for dislocated rollers or for crack or crush of concrete under shoes.

## 3-2 List of Standard Improved Sectional Shapes in Strengthening and Repair Works

A list of standard for improvement sectional shapes of members in strengthening and repair works is set forth in Fig. 6.2.

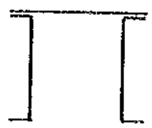
## 3-3 Reasons for Determination of Standard Sectional Shapes and Notes for Improvement Working

### 3-3-1 Upper Chord Members

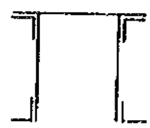
Improvement works for upper cord members comprise only strengthening works owing to excessive stress.

Section of member to be strengthened,

(Cleveland type, $\ell$ = 60 and 80m)

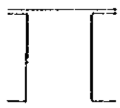
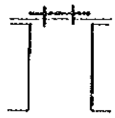
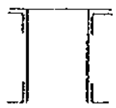
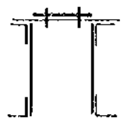
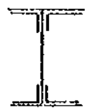
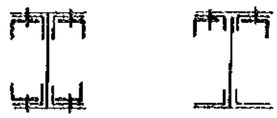
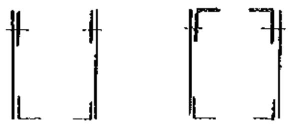
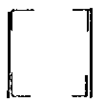
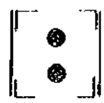
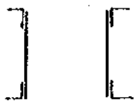
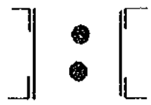
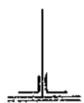
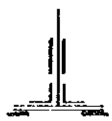
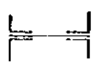
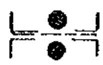
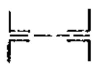
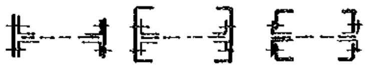
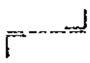
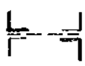
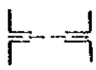
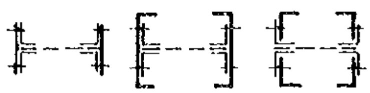
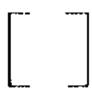
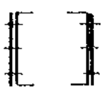


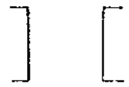
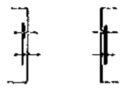
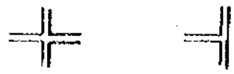
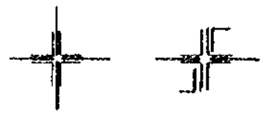
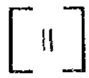
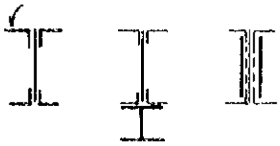
$\ell$ = 60m

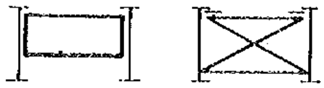
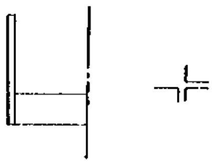
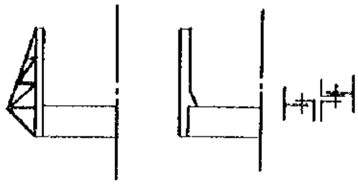
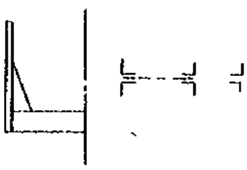
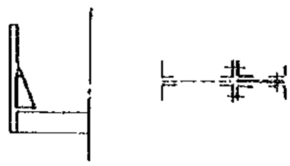
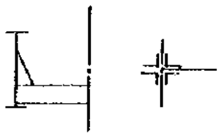
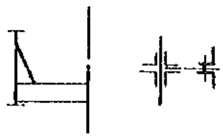


$\ell$ = 80m

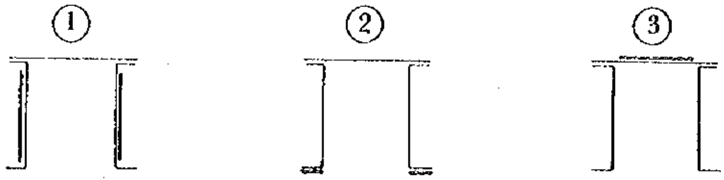
Fig. 6.2 List of Standard Improved Sectional Shapes

| Member | Strengthened Sectional Shape | Strengthened Sectional Shape |
|---|---|---|
| Upper Chord |  |  |
| 〃 |  |  |
| End Post |  |  |
| Lower Chord |  |  |
| 〃 |  |  |
| 〃 |  |  |
| 〃 |  |  |
| 〃 |  |  |
| Vertical Member |  |  |
| 〃 |  |  |
| Diagonal Member |  |  |
| 〃 |  |  |

| Member | Original Sectional Shape | Strengthened Sectional Shape |
|---|---|---|
| Diagonal Member |  |  |
| 〃 |  |  |
| 〃 |  |  |
| 〃 |  |  |
| Main Girder |  |  |
| Vertical and Diagonal Member |  |  To add sub member |
| Lateral Bracing |  |  |
| Stringer |  |  |
| Floor Beam |  | to be replaced  |

| Member | Original Sectional Shape | Strengthened Sectional Shape |
| --- | --- | --- |
| Strut of Stringer |  |  |
| Knee Bracing | Pony Truss Type  |  |
| | Pony Truss Type  |  |
| | Plate Girder Type  |  |

The following strengthening methods can be conceived:




Method ② is not appropriate since it requires removal of existing lacing bars and thus requires an increased amount of works. Methods ① and ③ need a special treatment of additional members at the position of splices of original members.

In view of the number of splices, working property of cutting rivets and of fastening bolts, method ③ is considered the most suitable.

Method of working

i ) Clean the contact surfaces of additional and original members to assure a coefficient of friction f, between surfaces of these members in the range shown below:

For bolts for stitching members: $f \geqq 0.3$
For bolts for transmitting stress: $f \geqq 0.4$

In case the required frictional coefficient is not obtained, the number of bolts should be properly increased or rivets should be used.

ii ) In order to ensure a good alignment of holes between additional members and original ones, temporarily fix both members together using at least three service bolts and then drill the remaining holes through the combined members.

iii) Fully tighten bolts at the portion other than the splice portions of original members.

iv) Cut original rivets at splice portions.

v ) Fit new splice plate by fully tightening bolts.

Notes for working:

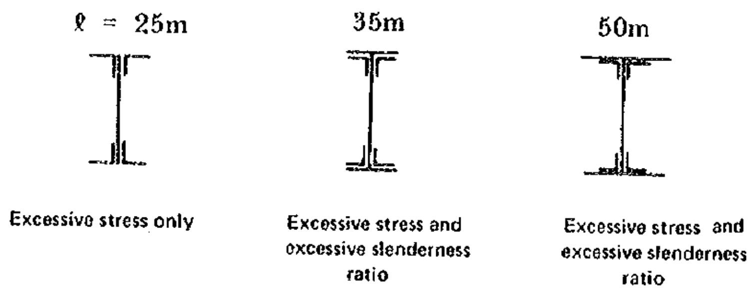
a) Original rivet holes should be reused for spliced portions.

b) Pitch of stitch bolts at general portion should not exceed the smaller value of either 12 times plate thickness or 150mm.

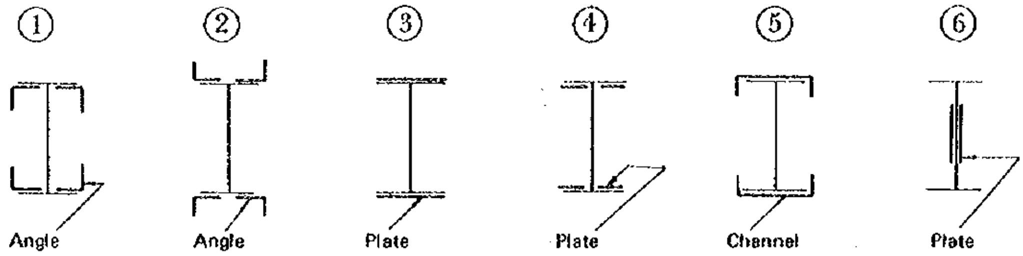
3-3-2 End Post

For end posts, strengthening works owing to excessive stress or excessive slenderness ratio are required.

Section of member to be strengthened and purpose of strengthening (Daydé type only)



The following strengthening methods can be conceived:



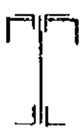

i ) Strengthening method for $\ell$ = 35m and 50m types
For improvement work both sectional area and stiffness must be taken into consideration, since excessive stress and excessive slenderness ratio are observed.

Methods ④ and ⑥ are not very effective for increase of bending resistance and method ③ and ⑤ present structural difficulties in panel point portion.

Of the remaining methods ① and ②, the former gives better final shape and should be employed.

$\ell$ = 35m $\ell$ = 50m

ii ) Strengthening method for $\ell$ = 25m type
This type needs strengthening owing to excessive stress only. Although the strengthening methods as described in i) can be applied, the following method should be selected since sectional area of as much as four angles is not necessary:



Notes for working:

All of the additional angles should be attached with use of original rivet holes for $\ell$ = 25m and 35m types, and new holes for $\ell$ = 50m type.

Procedure for working:

i ) Cleaning of members.

ii ) Cutting off original rivets (In the case of $\ell$ = 25m, $\ell$ = 35m)
Drilling of new holes (In the case of 50m)

iii) Full tightening of high strength bolts.

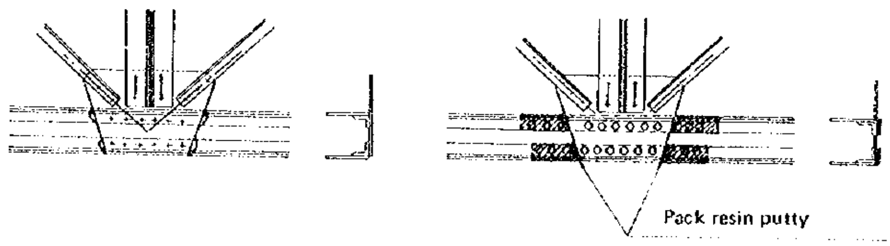
### 3-3-3 Lower Chord Members

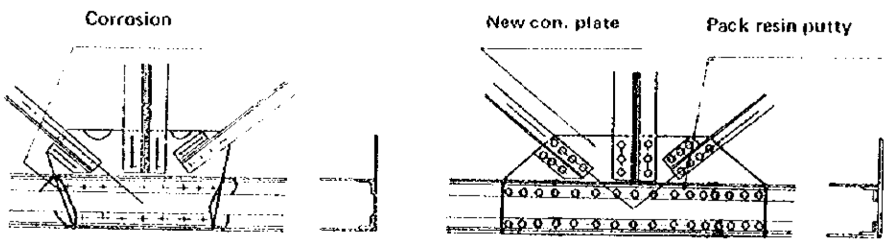
Improvement works for lower chords include repair works owing to corrosion and deformation and strengthening works on account of excessive stress.

(1) Repair works

(a) Repair works owing to corrosion

Corrosion occurs in some cases at the general portion of lower chord or at the backside of gusset plate at panel point portion. These corroded portions should be repaired to maintain regular sectional area by adding members or changing the corroded gusset plate and pack resin or zinc rich putty for waterproof to these corroded portion.

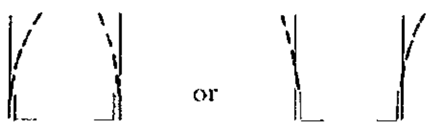



(See photo 4.)

(b) Repair works owing to deformation

Many bridges have deformation along the edge of web plates in the vicinity of panel points or at the general portion.




(See photo 13.)

In Daydé type bridge $\ell$ = 80m, such deformation is particularly observed.

The deformation may have been brought about by the following three causes:

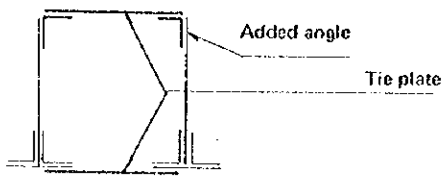
i ) Action of a large force on web plates during bridge erection.

ii ) Collision of something with web plates.

iii) Action of compressive stress due to secondary bending moment on edge of web plate, which can produce local buckling of web plates.

Problems due to Cause i) can be solved by collecting data and investigate the method of works employed during erection.
As to Cause iii), calculation of stress in member sections of several representative bridges under the influence of the secondary bending moment due to the rigidity at the panel point connection revealed that, if the concurrent axial tensile force is added, any compressive stress should not remain along the edge of web plate. In a case of bad sectional configurations of original members, however, some compressive stress may be produced at the edge of web plate.

In any way, in order to repair the deformation of members, angles should be increased. Specifically, Daydé type, ℓ = 80m bridges have many and badly deformed portions and thus required repair works over the whole length of lower chord members.




Section of repaired member of Daydé type, ℓ = 80m

(2) Strengthening works

New members are added to original members in order to relieve excessive stress. Methods for this purpose are classified into the following two items:

(a) Addition of plates or angles to original members.

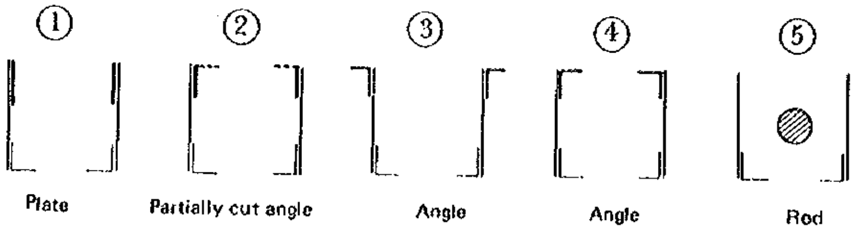
(b) Addition of rods to original members by anchoring them in the vicinity of panel points.

In general, Method (a) is employed when the depth of outstanding web plates is excessive, and the sectional configuration of original members is not adequate. Method (b) is used when the sectional configuration of original members is satisfactory, but the sectional area of members is not sufficient for the axial force. Method (b) is effective and easy to carry out working, requiring only a small amount of works for cutting original rivets, tightening new bolts and treating original members.

i ) Cleveland type, ℓ = 30m, 40m and 48m,

Shape of original section

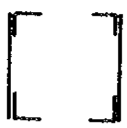
The following strengthening methods can be conceived.



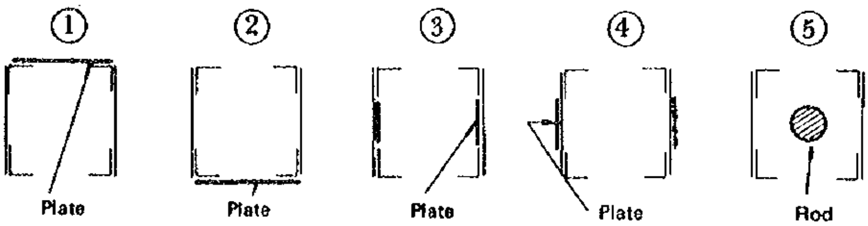

Method ③ presents structural difficulties in relation to floor beams at panel point portion.
Method ⑤ is not employed when the configuration of original section is not adequate. In view of the shape of the original sections, Method ④ is effective as a strengthening method. However, Method 1 should be employed when adding new angles is impossible for structural reasons due to narrow spacing between web plates as in the cases of $\ell$ = 30m and 40m type. Method ②, which uses partially cut angles, should not be employed since it requires a large amount of works for processing angles, anthough it is better in the final configuration than Method ①. In the case of $\ell$ = 48m type, Method ④ should be employed, since there is a sufficient spacing between the web plates.

ii ) Cleveland type, $\ell$ = 65m and $\ell$ = 80m

Shape of original section



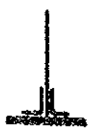
The following strengthening methods can be conceived.



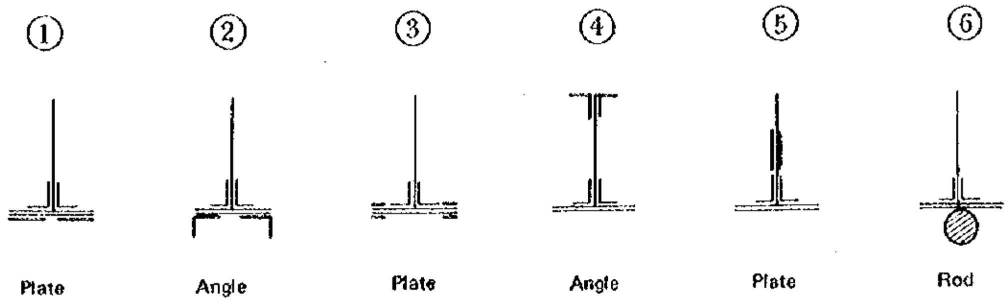

Methods ① and ④ present structural difficulties in relation with other members at panel point portion. Methods ② and ③ may be used if structural conditions of members including gusset plate and splice plate are taken into consideration in an appropriate manner. However, method ⑤ should be employed for the same reasons as stated previously.

iii) Daydé type, $\ell$ = 35m and P & W McLellan type, $\ell$ = 31.7m.

Shape of original section



The following strengthening methods can be conceived.




Methods ① and ② should not be used, since they require an increased amount of field works for cutting original rivets.
Method ③ needs original rivet cutting works half the amount of those in Methods ① and ②, but yet the field works in Method ③ are not easy. Method ④ is intended to repair faulty configuration of original sections due to deep outstanding web plates, but continuity of angles to be added is interrupted over a long distance at panel point portion for structural reasons.
In Method ⑤, however, such an interrupted portion is shorter than in Method ④ and is effective for strengthening an undesirable configuration of original section. And Method ③ may be used for strengthening the portions interrupted at panel points in Method ⑤.
Namely, strengthening methods of this type are illustrated as follows:

General portion　　　　Panel point

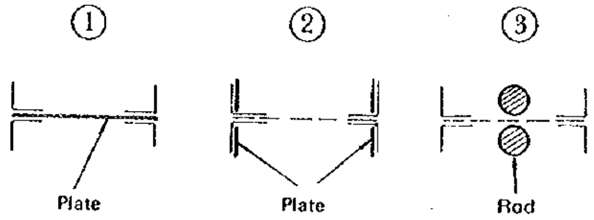
Method ⑥ is good from a field working viewpoint, since only the treatment of anchor portion of the rods requires field working. However, Method ⑥ is not adequate, since it further lowers the neutral axis of original sections, thus worsening the uniformity of stress in the section.

iv) Cleveland type, $\ell$ = 35m

Shape of original section


(Owing to excessive stress)

The following strengthening methods can be conceived:



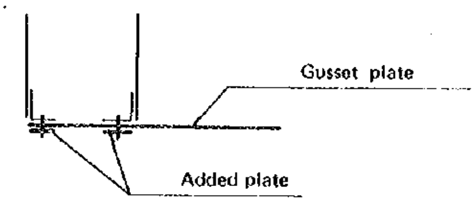

Method①, which is intended to replace existing tie plates with new plates, is not appropriate since it requires a large amount of field works.
Method②should not be employed, since it also needs a great amount of field works, although less than in Method①.
In Method③an anchor plate is fixed for the rod, and for this purpose the lacing bars of the lower chord should be removed only in the vicinity of the anchor.
Thus Method ③ is relatively easy to carry out and should be employed.

v ) Fabricator unknown, $\ell$ = 40m, Pin truss
(Northern Line 465km + 609)

Strengthening is not required.
Slight loosening is observed at pin and pin hole of lower chord members. This can be repaired by shortening members by means of heating and cooling, in cases where repair is necessary in view of transportation conditions of trains, such as high speed operation.

(3) Note for undertaking repair works for lower chord members

(a) Repair works owing to corrosion




i ) Since added plates serves as a splice plate, the number of stitch rivets corresponding to at least the full strength of the added plates is needed.

ii ) Resin putty should be packed for waterproof at corroded portions.

iii) In replacing gusset plates, bolt holes for new gusset plates should be drilled after adjustment at site.

iv) Connecting materials should be selected as follows:
When gusset plates are to be replaced ............. High strength bolts
When gusset plates are not replaced.................. Rivets

(b) Repair works for deformation

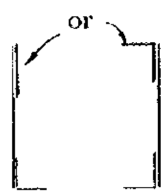
i ) Remedy by heating.

ii ) Remedy by attaching angles and using vises.

As a rule Method ii) should be used but, if necessary, combined with Method i).

(4) Note for undertaking strengthening works for lower chord members.

(a) Cleveland type

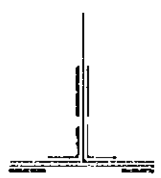



i ) The length of additional members should be not more than panel length for reasons of insertion of additional members into original members.

ii ) At least two intermediate tie plates should be attached at the upper and lower portions of web plates in each panel.

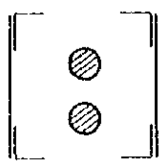
iii) Holes for bolts for stitching additional and original members should be drilled through both of these members at one time after fixing these members together by tightly pressing them with vises in order to obtain good alignment of holes between these members.

(b) Daydé and P.W. McLellan types



Plates to be added to web plates in the neighborhood of panel points should be extended as long as structurally possible, in order to shorten the length of additional members for bottom plates at the panel point.

(c) Cleveland type



Note should be taken of the following items in carrying out strengthening work for this type of bridges.

i ) Anchors

- At least three steel anchor plates of 10mm in thickness should be used.
- Double nuts should be used in order to prevent loosening.

ii ) Supports

At least two supports for rods in each panel should be set to prevent rods from bending and swinging. The supports should be set before inserting rods into original members, and then be fixed to lower chord members.

iii) Couplers

The length of the rods to be used should be shorten than the panel length, because of the intermediate tie plates attached to the existing lower chord. Therefore, rods should be connected by couplers.

iv ) Tightening of rods

In principle no prestressing need not be introduced to rods from the view point of strengthening effect. But the minimum stress necessary to prevent them from bending due to their own weight and from swinging should be given. The tightening can be effected by using impact wrenches.

### 3-3-4 Vertical Members

Improvement works for vertical members include repair works owing to deformation and loosening of connecting rivets and strengthening works on account of excessive stress or excessive slenderness ratio.

(1) Repair works

i ) Repair works owing to deformation

Some vertical members are considered to have been deformed by collision with goods on passing trains. Of these, vertical members having a local and small deformation many remain as it is without any trouble. However, those having severe deformation (like NE-Line 560km + 292-40m T.T. Daydé type, S-Line 377km + 210-70m T.T. Cleveland type, and S-Line 497km + 613-35m T.T. Cleveland type) require replacement of members.

ii ) Repair works owing to loosening of rivets

In general, rivets in the vicinity of the span center of Daydé type truss are loosened, though they are not to be highly stressed according to ordinary design calculation. It should be decided on the basis of test results of high strength bolts for old steel materials whether rivets or high strength bolts are to be used for replacement of old rivets.

Similarly, rivets are used, in principle, at the portion where cleaning cannot be conducted properly in strengthening works. High strength bolts may be used though use of rivets is indicated in the standard drawings, if good treatment of contact surfaces of plates can be expected.

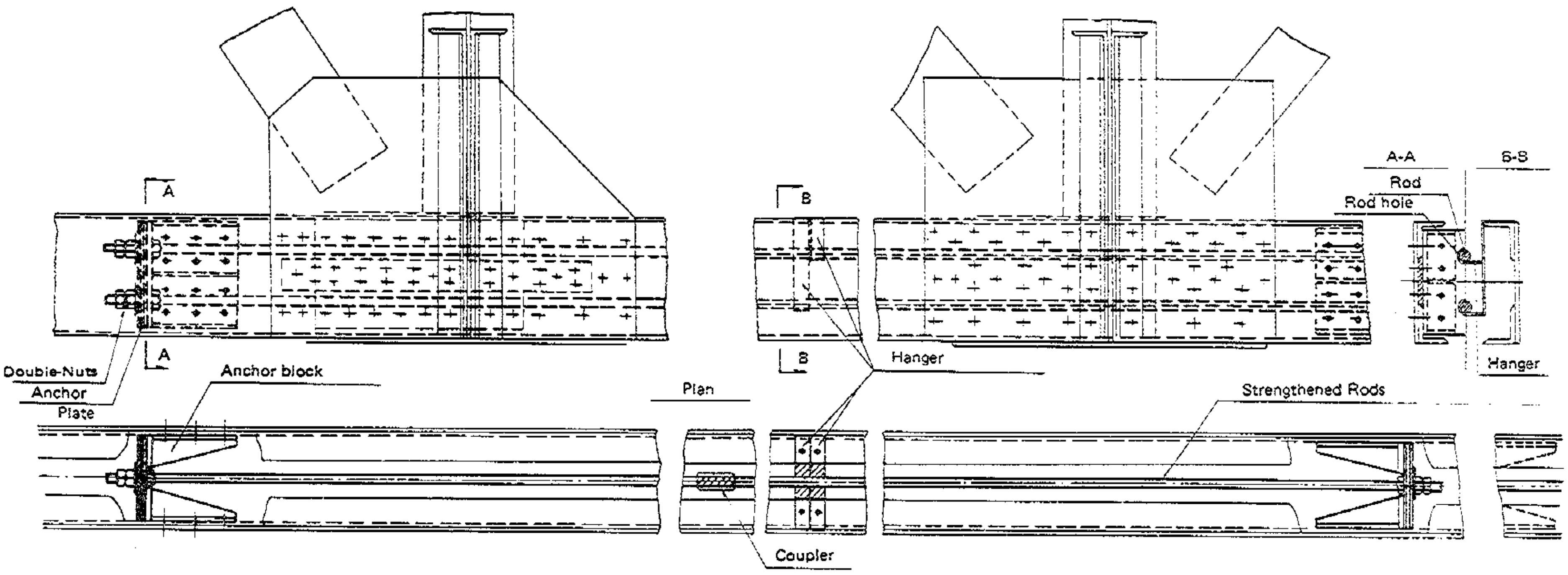
(2) Strengthening works

Causes of necessity of strengthening work can be classified as follows:

1) Excessive stress
2) Excessive slenderness ratio
3) Combination of 1) and 2)

Fig. 6.3

Strengthening of Lower Chord



The following countermeasures can be effectively taken for these causes.

| Causes | Countermeasures |
|---|---|
| ⓐ Excessive tensile stress | Addition of new members |
| ⓑ Excessive compressive stress | Connecting the midpoint of those member with horizontal members to increase the allowable compressive stress, or addition of members |
| ⓒ Excessive slenderness ratio | Connecting midpoints of diagonal and vertical members with horizontal members |

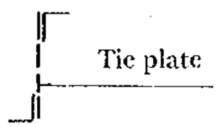
ⓐ Strengthening of members having an excessive tensile stress

Plates, angles or channels should be added, depending on the shape of section of members.

Section of member to be strengthened

De Vries Robbe $\ell$ = 35m and 50m

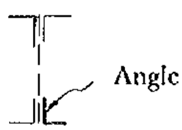
Shape of original section




The following strengthening methods can be conceived:

①


②




Method ② is preferable from the viewpoint of sectional shape, although Methods ① and ② do not largely differ from each other in quality and quantity of field work to be required.

ⓑ Strengthening of members having an excessive compressive stress

The following two improvement methods can be conceived:

i ) Increasing of allowable compressive stress intensity.

ii ) Decreasing of working stress intensity.

Namely, Method i) is intended to increase the allowable compressive stress intensity by decreasing the slenderness ratio as described in Item ⓒ (i.e. to connect the midpoints of diagonal and vertical members with horizontal members.)

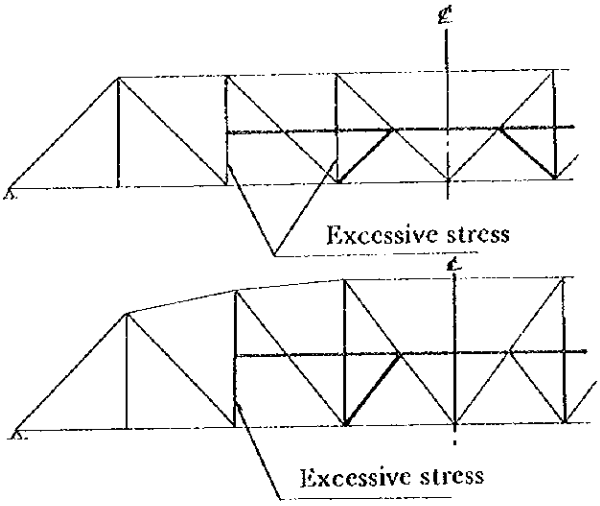
Method ii) is intended to decrease working stress intensity by increasing the sectional area of members, and at the same time to increase the radius of gyration of section.

In principle, Method i) should be used.

Members to be strengthened
Cleveland type, $\ell$ = 40m and 50m

$\ell$=40m

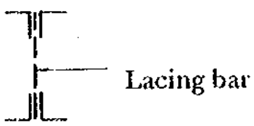
$\ell$=50m




ⓒ Strengthening of members having an excessive slenderness ratio

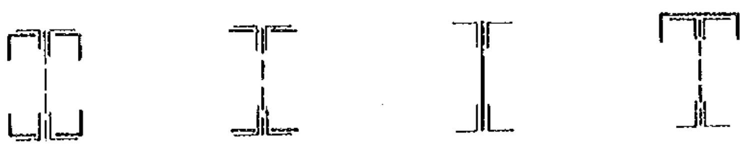
Section of member to be strengthened
Cleveland type, $\ell$=48m and 50m,
Daydé type, $\ell$=80m

Shape of original section

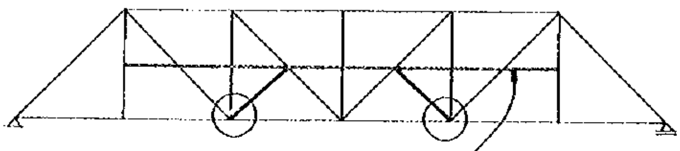



The following two ideas can be presented as methods for improving the excessive slenderness ratio of members:

i ) Increasing of sectional area of member to increase the radius of gyration and decrease the stress.



ii ) Connecting midpoints of diagonal and vertical members with horizontal members to shorten the free length of the members.




Method ii) should be employed for the following reasons:

- Methods i) and ii) do not much differ from each other in quantity of additional members to be required.
- The field work for Method ii) is far easier than that for Method i).
- In Method iii), some care should be taken of the structural detail at the portions marked by circles in the above figure.

(3) Note for undertaking improvement works for vertical members

Repair works owing to deformation

As to replacement of the deformed members, two methods are available:

i ) Replacement of full length of the member.

ii ) Cutting off deformed portion only, followed by replacing with new members.

In any case, since vertical members must be temporarily removed, works must be started after having prepared alternative temporary members.

Simple methods for this purpose is to install a counter member for compressive force or to hang the lower chord panel point from the upper chord panel point with shape steel.

3-3-5 Diagonal Members

Almost the same methods as described for vertical members can be applied to repair and strengthening works for diagonal members.

(1) Repair works

Some diagonal members have severe deformation or loose rivets. Repair works can be carried out similarly to those for vertical members.

(2) Strengthening works

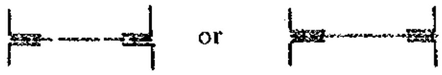
The strengthening works differ from those for vertical members in that some diagonal members must be replaced completely with new members for strengthening against excessive stress, since there is no space in configuration of the original member sections to increase the sectional area.

(a) Strengthening of members having an excessive tensile stress

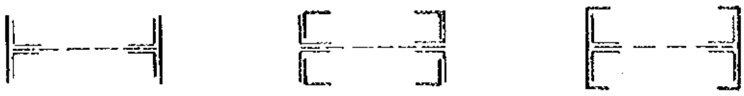
Plates, angles or channels should be added, depending on the shape of section of member.

i ) Cleveland type, ℓ=40, 65, 70 and 80m

Shape of original section



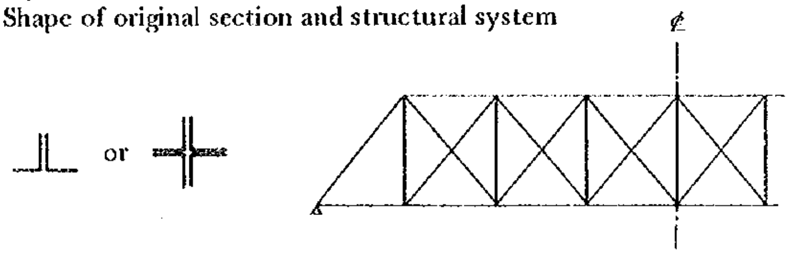
The following methods of adding members can be conceived:



Each method should be selected appropriately, depending on structure of panel points or sectional configuration. However, the method in which lacing bars are replaced by plates is not used, since it needs to remove original rivets.

ii ) Daydé type, ℓ=25, 30 and 35m

Shape of original section and structural system



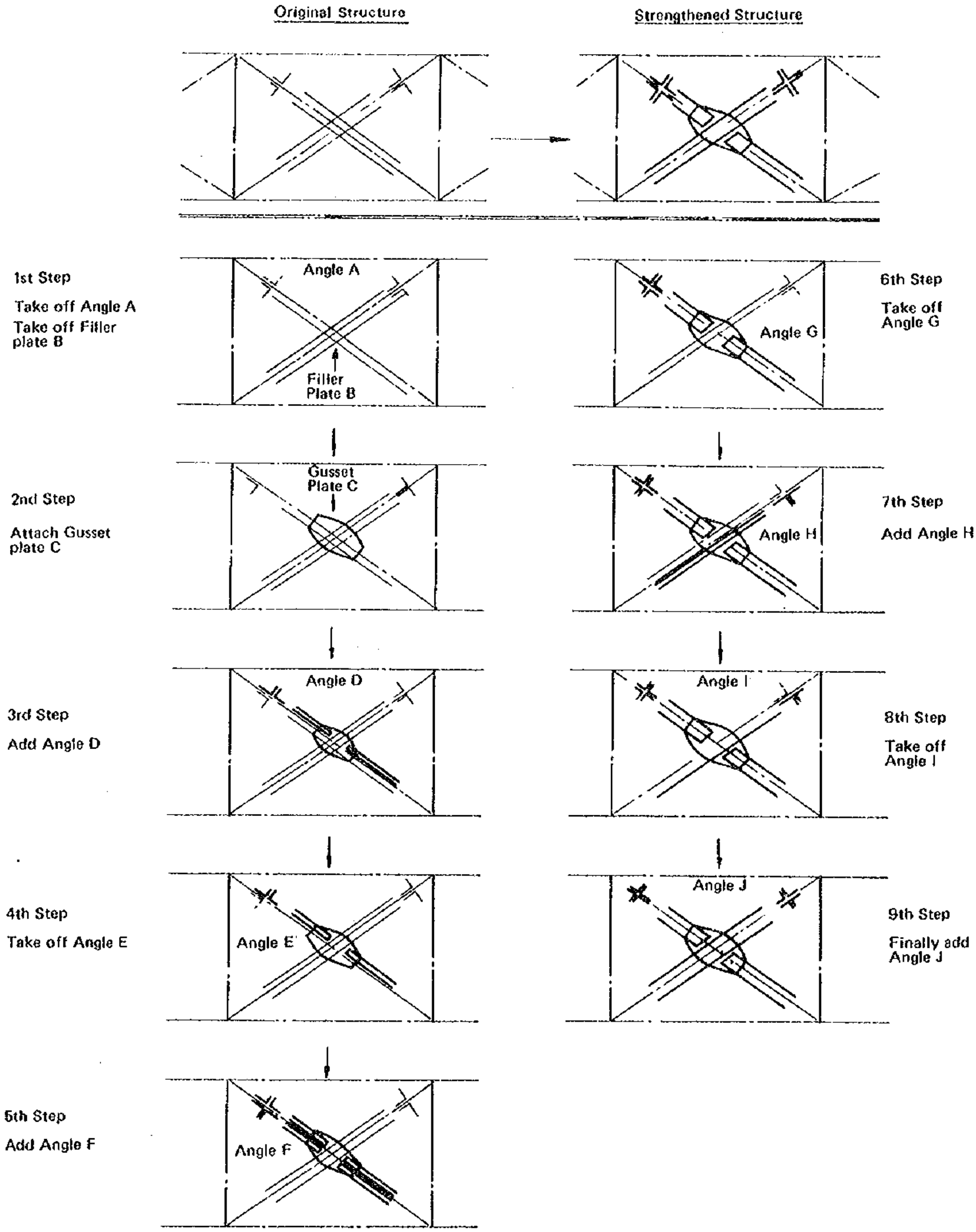

Almost all of the diagonal members have an excessive stress and a considerably excessive slenderness ratio.

As to this type of bridges, studies have been made on the possibility of changing the structural system from Double-Warren truss type to Plat truss type. However, this method does not appear to be a satisfactory method because it requires a great amount of new members and because it may cause unexpected stresses in the members due to changing of the structural system as a whole.

Therefore, strengthening works should be done only to the members of the original structure.

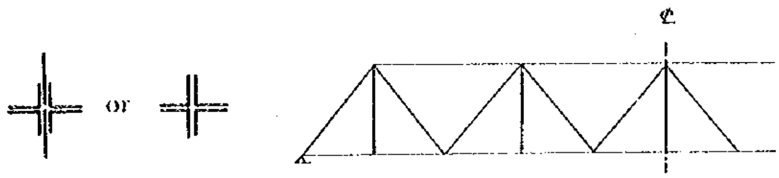
In a Warren truss manufactured in Daydé , it is possible to replace the existing diagonal members without closing the track for work, on the conditions that either one of the two diagonal members crossing each other in a panel is left, while the other is being replaced, and that the effect of train loading is reduced by either lowering its speed or decreasing the limit of the wheel weight. (see Fig. 6.4.)

Fig. 6.4 Strengthening of Diagonal members of Daydé Type Double-Warren Trusses



iii) Daydé type, ℓ=40m and 50m

Shape of original section and structural system



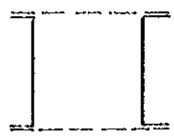

As in the case described in Item ii), most of the diagonal members have excessive stress or excessive slenderness ratio.

Although the shapes of sections are equal to those in Item ii), strengthening should be attained by adding more steel area to the members, since the original members can not be removed and accordingly can not be replaced with new members of a larger section due to the structural system and details at the panel point portion.

Section of member to be strengthened.

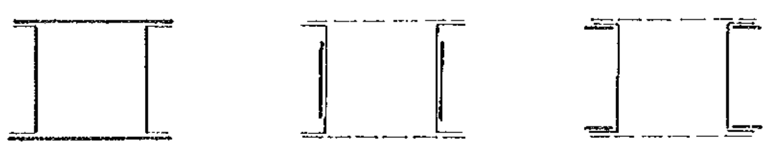
iv) De Vries Robbe type, ℓ=30 and 35m

Shape of original section



The following strengthening methods can be conceived:

① ② ③

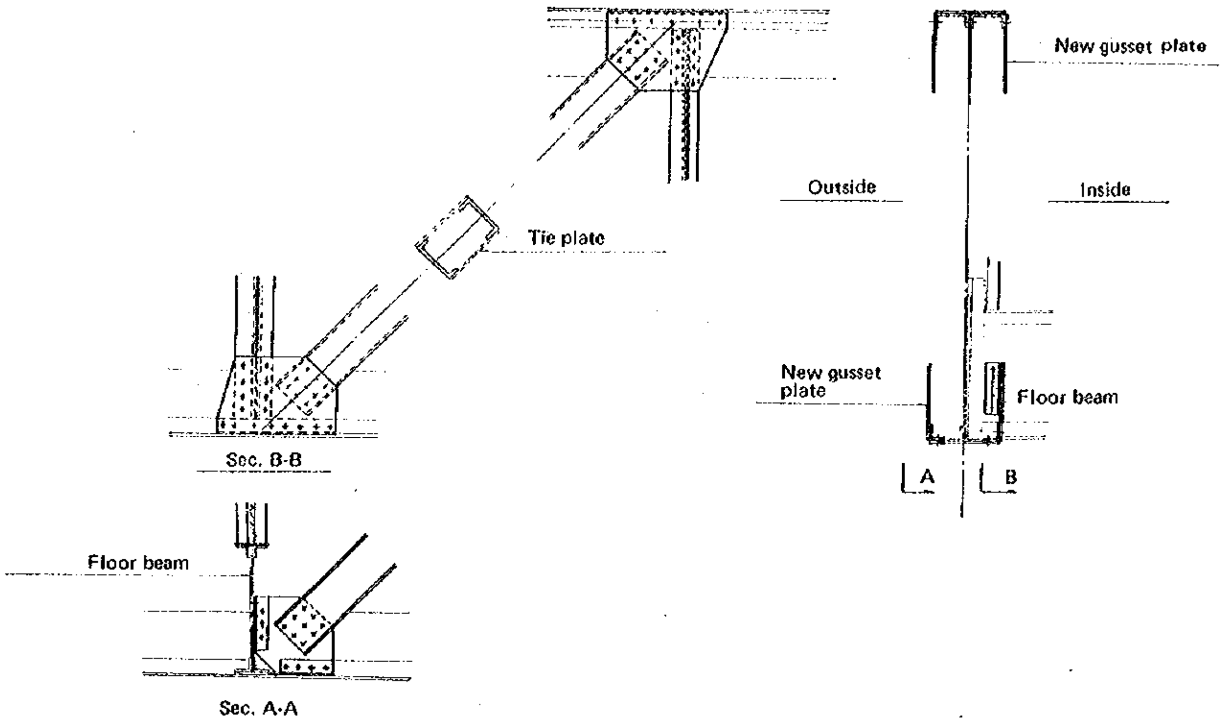


Method ② should be employed, judging from the amount of field work and the amount of excessive stress of the original sections.

v) P & W McLellan type, ℓ=25.5 and 31.7m

Almost all of the diagonal members have an excessive stress and an excessive slenderness ratio.

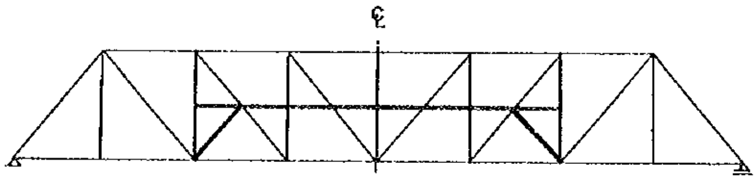
New gusset plates should be added, and new diagonal members should be attached as shown in the figure below since no space for addition of plates or angles is available because of the configuration of the original sections.




(b) Strengthening of members having an excessive slenderness ratio

Horizontal members should be attached to connect the diagonal and vertical members with each other at mid-height, thereby decreasing their free lengths.

Cleveland type, ℓ=30, 35, 40, 45, 48, 50 and 60m
Daydé type, ℓ=80m




Example: Cleveland type, ℓ=40m

(c) Strengthening of members having an excessive compressive stress

The excessive stress in Daydé type, ℓ=80m bridges can be well within the allowable stress by attaching horizontal members in the same way as described in Item (b), because it increases the allowable compressive stress intensity of the original sections.

As for Daydé type, $\ell$=25, 30, 35, 40 and 50m bridges, addition of members or replacement with new members should be carried out.

(3) Note for undertaking improvement of diagonal members

(a) Strengthening works

i ) Addition of members in Cleveland type, $\ell$=40, 65, 70 and 80m
All of the original rivets at panel point portions must be cut for adding new members. In order to minimize the interruption of operation of trains, the procedure mentioned below should be adopted, some rivets should first be cut and replaced by service bolts, and then, on completion of removal of all rivets, additional members should be attached by using rivets or high strength bolts. The holes for stitch bolts should be drilled though new and original members at a time after connection at the panel point portions is completed.

ii ) Daydé type, $\ell$=25, 30 and 35m
Original gusset portion should be cleaned properly since high strength bolt is used for connection.
High strength bolts should be applied to all the original rivet holes, although the number of bolts at panel point portion may not be the same as that of rivets due to the difference of allowable values. The position of these holes should be accurately measured beforehand.

iii) P & W McLellan type, $\ell$=25.5 and 31.7m
Gussets of the original vertical members should be replaced by new ones and then new diagonal members be attached, while the original diagonal members are left as they are without any modification. Therefore, bolt holes in chord members for the attachment of new gusset plates should be pre-drilled.

### 3-3-6 Portal Frames

Strengthening of portal frames includes the following items:

(1) Strengthening against excessive stress and excessive slenderness ratio in end posts and struts.

(2) Replacement of sway bracings at corner portions. As for Item (1), strengthening against excessive slenderness ratio is effected by adding more steel area over the whole length of members or by replacing with new members.
Strengthening against excessive stress is carried out over the portion which has an excessive stress.

(a) Daydé type

Portal bracings exist at end vertical members. Studies on the possibility of transferring portal bracings to the end posts revealed that the transfer is difficult for structural reasons. Therefore, strengthening is carried out without such transfer. Thus the lower lateral bracings in the end panel must have a structure which can withstand the force from the upper lateral bracings through the portal bracings.

The original bracing at the corner has a configuration as shown in Fig. 5-5. It is replaced with the one as shown in Fig. 5-6, in which the pitches of stitch rivets at the portions marked by (*) are shortened.

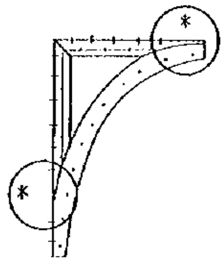



Fig. 5-5

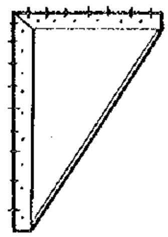
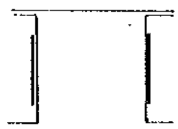


Fig. 5-6

(b) Cleveland type

Some bridges have a local excessive stress. Strengthening is effected by partially adding plates.

Section of strengthened member



3-3-7 Plate Girders

Strengthening and repair works for plate girders include the following items:

Repair;

i ) Absence of shoes in some bridges.
ii ) Loosening of connecting rivets in struts.
iii) Corrosion of lower flanges near the shoes.

Strengthening;

i ) Excessive stress in main girders.
ii ) Deformation of web plates.
iii) Inadequate structure of sway bracings.

(1) Repair Works

(a) Shoes

Some plate girder bridges have no shoes, and rest on the abutments using bearing plates only. Since the bridges in question are about 20m in length, they require regular shoes.

(b) Corrosion in the vicinity of shoes

Some bridges have corrosion in lower flanges of main girders and floor beams in the vicinity of shoes. The corroded flanges should be repaired simultaneously with the repairing of shoes. The methods for this purpose include addition of new members or cutting of parts of the original members to replace them with new members.

(c) Loosened rivets of struts
This subject will be explained later.

(2) Strengthening Works

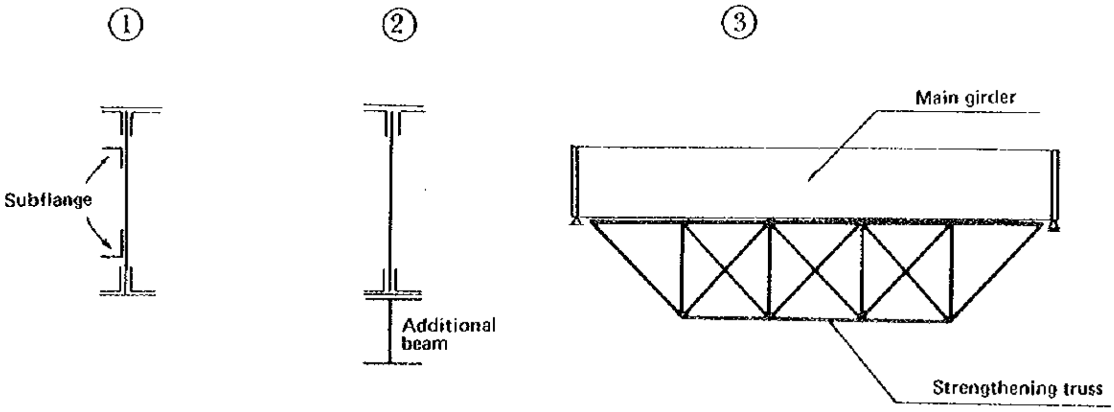
(a) Excessive stress in main girders
The following three methods can be conceived:

① Attaching of subflange angles to the web plate of main girders.

② Addition of members to the portions under the lower flanges to increase the efficiency of section.

③ Attaching of trusses under the main girders.

Method i) should be employed, judging from the quantity of excessive stress in the original members and the amount of working required.




(b) Deformation of web plates
Some bridges have web plates deformed,caused by an excessively wide distance of vertical stiffeners. Hence new vertical stiffeners should be added for strengthening and also for repair.

(c) Inadequate structure of sway bracings
Angles having a short leg are originally incorporated in the sway bracings in such a manner as shown in Fig. 6-7. Therefore, the strengthening work should be carried out as illustrated in Fig. 6-8.

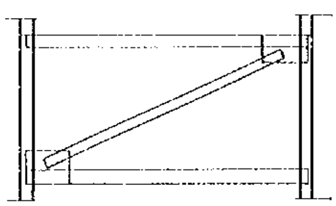


Fig. 6-7

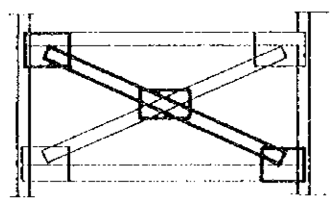


Fig. 6-8

(3) Notes for undertaking works

(a) Repair of shoes
See the item of shoes described hereinafter.

(b) Repair of lower flanges in the vicinity of shoes
The space necessary for work should be secured by jacking up the main girders.

The repair methods are similar to those for floor beams. (see the item of floor beam)

(c) Strengthening of main girders

i ) Vertical stiffeners on outside of the web plates, which can interfere with the work for attaching subflange angles, should be removed.

ii ) The surfaces of new and original members to come in contact should be cleaned.

iii) After the new angles have been temporarily fixed at more than three points by bolts, holes for stitch bolts should be drilled through the new and original members together.

iv ) New vertical stiffeners should be attached together with filler plates at the position of the original vertical stiffeners.

(d) Deformation of web plates
When new vertical stiffeners are attached to repair the deformed web plates, filler plates should be used under the backside of the new vertical stiffeners in order to eliminate the work for crimping their ends.

3-3-8 Upper Lateral Bracings

Strengthening works for excessive stress and excessive slenderness ratio are needed.

The following strengthening methods can be conceived:

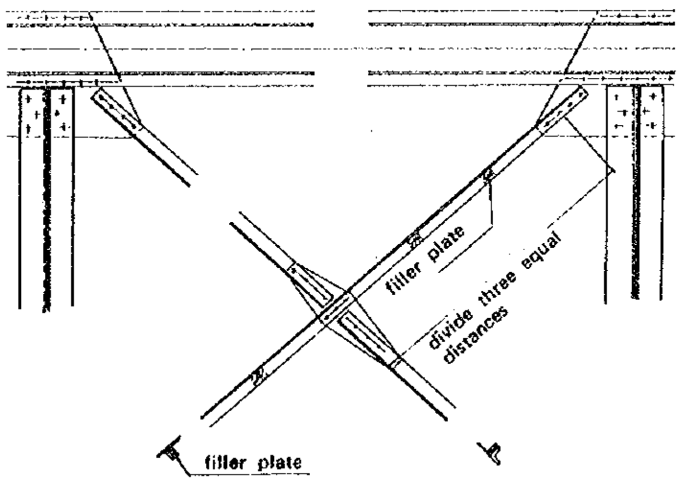
(1) Addition of new angles to the original members.

(2) Replacement of the original members with new angles or with cut-tee steels.

(3) Strengthening of gusset plates at the intersecting portions of lateral bracing members.

The original gusset plates should be used as far as possible for connecting lateral members with the main truss members. New gusset plates are used when the connecting bolts are deficient in number.

In adding members along the original lateral members, filler plates should be inserted between the new and original members at two intermediate positions in equal distances.




3-3-9 Lower Lateral Bracings

Works are similar to those for the upper lateral bracings. The lower lateral bracings should be suspended from the central struts of stringers by means of hangers made of angles or rods, instead of firmity connecting the lower lateral bracings with the lower flanges of stringers.

3-3-10 Floor beams

(1) Methods for repair and/or strengthening

Each element of a floor beam will be repaired and/or strengthened as follows:

| Elements | In the case of insufficient sectional area | In the case of corrosion |
|---|---|---|
| Cover plate | — | Replace the whole plate |
| Flange angle | Fit an additional plate on the existing flange angles to improve its sectional efficiency. (see Fig. 5.9) | The same as the left column, or replace the whole flange angles. |
| Web plate | — | Attach new plates on corroded parts. (see Fig. 6-10, Fig. 6-11) |

(2) Conditions for working

Repair and strengthening works for floor beams should be carried out during the interval time of passing trains, which is assumed to be at least two hours.

(3) Device for jacking up end floor beams

In order to allow jacking up of the entire bridges for repairing the bearings, end floor beams should be previously strengthened by attaching stiffening angles to their webs.

(4) Connection between the upper cover plate of a floor beam and the upper flange of a stringer in Daydé type bridges.

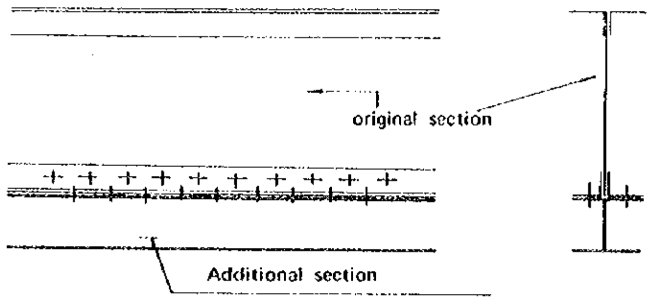



Fig. 6-9

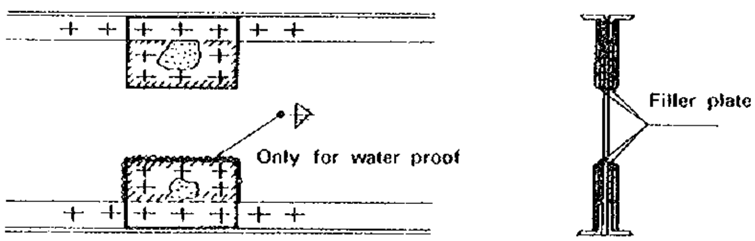



Fig. 6-10

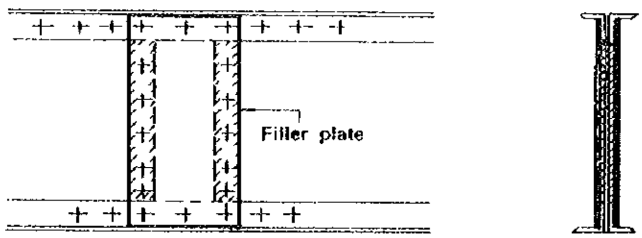



Fig. 6-11

Because the number of rivets used at this part is extremely small for continuity of the stringer, it is a matter of course that those rivets have been getting loose by fatigue. However, if the stringer was originally designed as a simple beam, they are not required for transmission of stress. Instead, they will be replaced by bolts with spring washers for the purpose of waterproofing only.

(5) Repair and strengthening of rivets for the connection with main trusses

In carrying out the works, the following methods should be employed for supporting the floor beam's own weight and the dead-load reaction from stringers.

(a) Hanging of floor beams with wires from the upper chord members.

(b) Provision of temporary floor beams which can also serve as the working stage.

(6) Protection from sewage

The Methods mentioned below should be employed for each floor beam for the protection against sewage discharged from trains. They should be employed, depending on the degree of corrosion possibility.

(a) Attaching of thin steel or reinforced plastic plates which have been subjected to corrosion proof treatment. See Fig. 6-12

(b) Application of a thick paint coating.

(c) Application of an ordinary paint coating for the bridges which are not severely subjected to sewage.

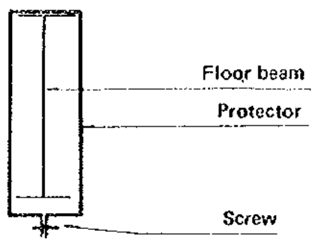



Fig. 5-12

The protectors are to be exchanged at every painting time. Thus, the protectors need not be very thick.

3-3-11 Stringers

The parts to be repaired and/or strengthened of stringers are given as follows:

(1) Stringer itself
(2) Connection between a stringer and a floor beam
(3) Struts between stringers on both the sides

(1) Repairs and/or strengthening of stringers

In principle, angles will be attached to the web plate when the stress in the stringer is excessive. The methods for strengthening are illustrated below.

| | |
|---|---|
|  | The stress in the upper flange only is excessive, and the stringer has no lateral bracings. |
|  | The stress in the upper flange only is excessive.<br>Since the stringer has lateral bracings, an angle can be fitted outside only. |
|  | The stress both in the upper and lower flanges is excessive and the stringer has lateral bracings. |

(2) Strengthening and repair of the rivets for connection between stringers and floor beams.

Improvement works are required for the connection with the web of a stringer and that with the web of a floor Beam.

(a) Methods for strengthening and repair

i ) For connection with stringer

- Replacement of original rivets with new rivets or high strength bolts, using the existing rivet holes. (Fig. 6-13)
- Strengthening by increase of connection plates and increase of rivets or high strength bolts. (Fig. 6-14)

ii ) For connection with floor beam

New rivets or high strength bolts should be provided, using the existing rivet holes. (Fig. 6-14)

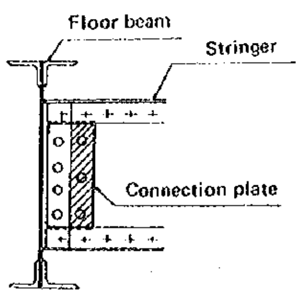



Fig. 6-13

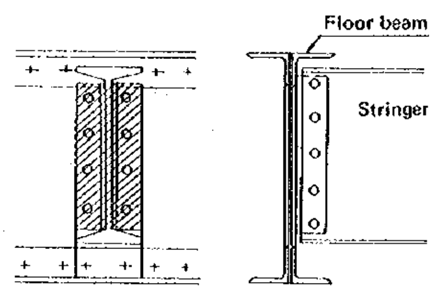



Fig. 6-14

(b) The working methods are as follows:

i ) To conduct works during a two-hour interval of passing trains, as in the case of improvement works for floor beams.

This method allows the use of high strength bolts both for connections of stringer side and floor side.

ii ) To attach brackets to floor beams
In the case of Daydé's type, there is a clearance between the lower flange of a stringer and that of a floor beam, sufficient to attach brackets to the floor beam in order to support the stringers. (see Fig. 6-15)
High strength bolts cannot be used in this method, since cleaning of members is not possible.

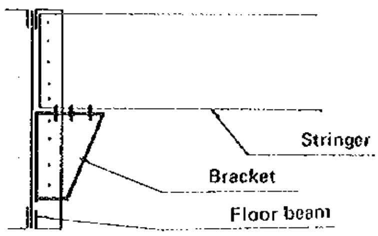



Fig. 6-15

iii) In case there is no sufficient clearance to install a bracket under the lower flange of stringer, the bracket may be installed on the web of the floor beam between the stringer beams on the right and left sides. In this case, however, a diaphragm must be attached at the end of stringers to support the stringers on the bracket. (see Fig. 6-16)

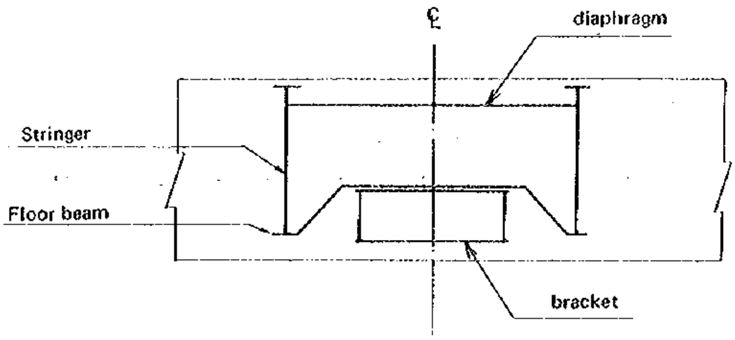



Fig. 6.16

(3) Struts for stringers

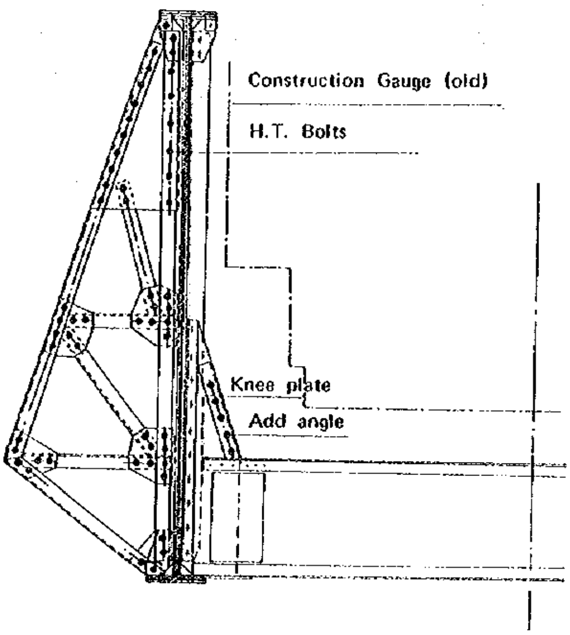
Almost all of the existing struts have an inadequate structure and should be replaced by new struts.

Beam type struts and truss type struts should be used for a shallow stringer and a deep stringer, respectively.

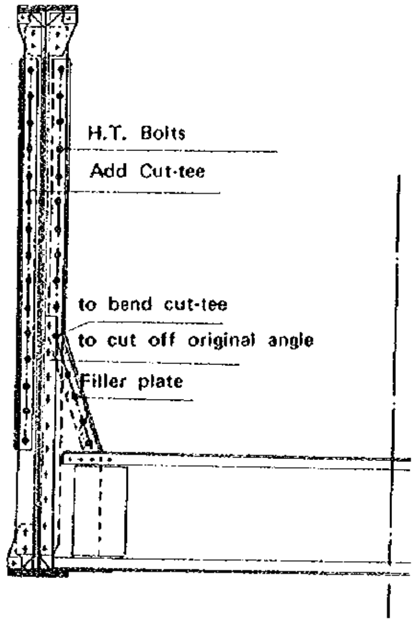
## 3-3-12 Knee Braces

(1) Daydé type ($\ell$=25, 30 and 35)

In pony trusses of Daydé type the transverse rigidity is obviously insufficient, so strengthening must be done as shown in Fig. 6-17




In the case without sidewalk




In the case with sidewalk

Fig. 6-17

(2) Cleveland type ($\ell$=30)

For a pony truss manufactured by Cleveland, a web plate will be added to a knee bracing which consists of angles originally. (see Fig. 6-18)

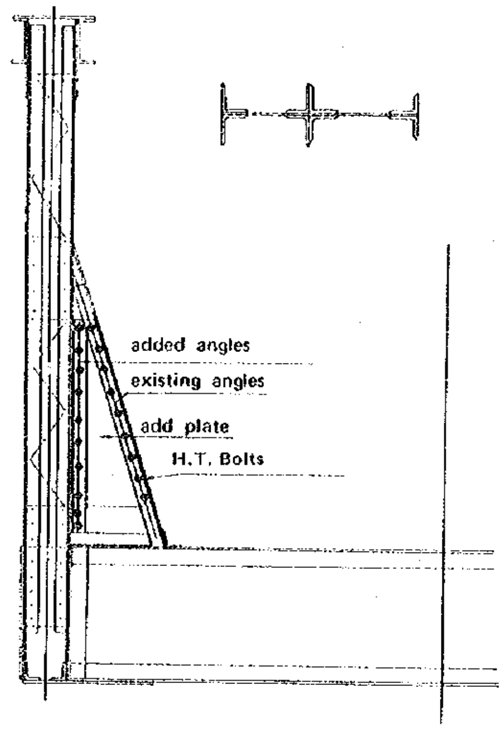


Fig. 6-18

3-3-13 Brake Trusses

The existing bridges have no brake truss which should transfer the force in the longitudinal direction coming from rails to the lower chord of truss when train speed is accelerated or decelerated.

One set of brake trusses should be installed at the middle of the span for bridges of not more than 70m. For bridges of 80m, two sets of brake trusses should be installed.

3-3-14 Tie Plates and Lacing Bars in Members

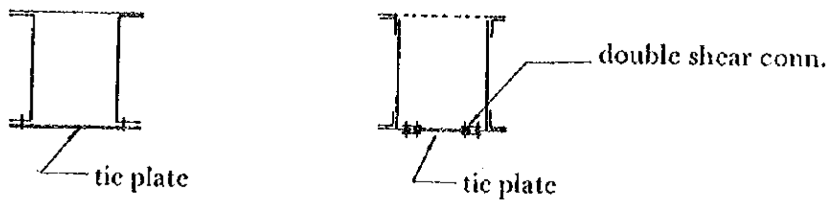
Strengthening and repair methods are as follows:

(1) In principle, end tie plates should be provided for each member in the vicinity of panel points.

(2) Although lower chord members are subject to tension, intermediate the plates should be installed at not less than two positions in a panel length.

(3) When lacing bars attached to compressive members are not strong enough, some of the lacing bars should be replaced by tie plates.

(4) It is possible to use smaller tie plates by adopting double shear bolt connection, if necessary for the reasons of configuration of original sections. (see 6-19)




Single shear bolt connection    Double shear bolt connection

Fig. 6-19

3-3-15 Repair of Shoes

Works are needed for the following three items:

(1) Uneven arrangement of rollers in movable shoes.

(2) Run-off of rollers from the base plate of a movable shoe.

(3) Damage of concrete under the shoe.

As to item (1), the position of rollers should be corrected by jacking up the bridge.

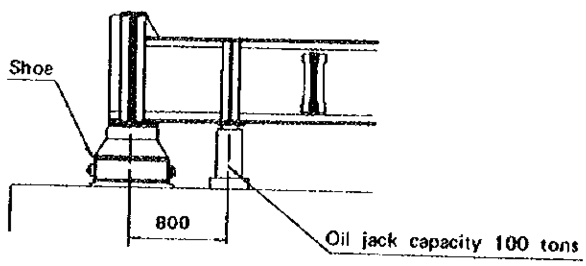
As to items (2) and (3), methods which do not require interruption of passage of trains should be preferably adopted (see Fig. 6-20 for jacking up).

As to item (2), the rollers should be restored to the initial position. If necessary, the base plate should be extended newly.

As for item (3), non-shrinkage mortar is applied into the underside of the shoe, after old defective concrete is eliminated completely.

Method for jacking up or temporary supporting

For Item (1)




For Items (2) and (3)

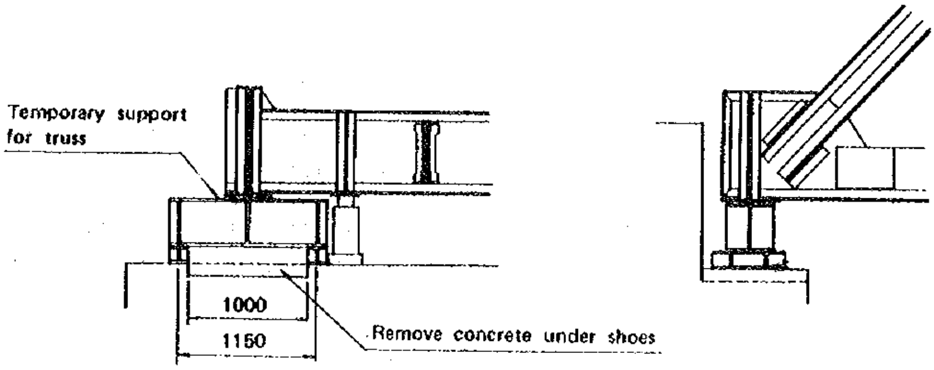



Fig. 5-20

# VII. DESIGN OF BRIDGES CONSIDERED FOR REPLACEMENT

## VII. DESIGN OF BRIDGES CONSIDERED FOR REPLACEMENT

### 1. Selection of Bridges to be Replaced

With respect to those existing bridges in which the factor of safety is considered especially low under train loadings, which have been severely corroded or which have structural defects, preliminary designs and approximate cost estimation for the replacement of such bridges with new ones have been prepared for the purpose of comparison with the repair and/or strengthening plan.

In the design, through plate girder bridges and through truss bridges are adopted for the bridges having a span length of 35m and less, and more than 35m, respectively.

Table 6-1 is a list of the bridges selected for preliminary design.

Table 7 - 1

| | Line | Location | Span | Type | Manufacturer |
|---|---|---|---|---|---|
| ① | Southern Line | 77+844 | 1x25.5 | T.T. | P&W McLellan |
| ② | | 120+195 | 8x20.8 | T.T | Ex Java |
| ③ | | 153+788 | 1x16.0 | T.P | |
| ④ | | 469+428 | 1x25.5 | T.T | P&W McLellan |
| ⑤ | | 993+501 | 1x30.0 | T.T | Daydé |
| ⑥ | Northern Line | 70+886 | 2x31.7 | T.T | P&W McLellan |
| ⑦ | | 577+622 | 1x30.0 | D.T | |
| ⑧ | North Eastern Line | 323+816 | 1x30.0 | T.T | Daydé |
| ⑨ | | 536+969 | 1x25.5 | T.T | P&W McLellan |

### 2. Reasons for Replacement

Bridges ① , ② , ④ , ⑥ and ⑨ exceed the load-carrying capacity, especially bridge ② being weak. Because these bridges were constructed at the end of 19th century, it is desirable to replace them with new ones.

Bridge ③ has only 3.5 meters in the spacing between the main girders and it may be undesirable from the operational point of view.

In the case of Bridge ⑤ , a Daydé type truss bridge is located in between Cleveland truss bridges, as shown in Fig. 7-1. The former has a considerably smaller spacing between the main trusses than the latter and it may cause a danger to passengers on the train.

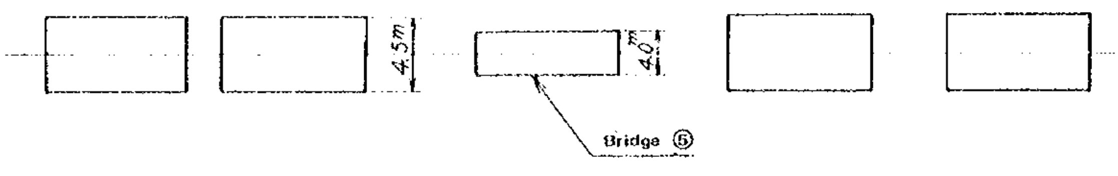



Fig. 7 - 1

Bridge ⑦ has many weak members such as some of lower chord members of truss and most of floor beams and stringers. The cost for repair and/or strengthening is greater than that for a new bridge. Also the abutments have been displaced to the extent that their parapet walls and the ends of the bridge are in contact. Consequently, it is desirable to replace it.

In Bridge ⑧ , most diagonal members of the truss are deficient in strength. Moreover, judging from the surrounding of the location where the bridge is situated, a bridge of such a span length does not seem to be required. It is, accordingly, desirable to replace it with a small concrete viaduct and to make up both ends with embankments.

## 3. Outline of Preliminary Design

(1) The members of bridges designed for replacement and fabricated by welding at bridge shops will be transported to the construction site. The members are assembled with high-strength bolts.

(2) The maximum dimensions of members should be limited to 2.3m in height, 3.2m in width and 12.0m in length, taking the transportation on rail into account.

The maximum weight of members should be about five tons and bigger members should be devided into segments of less than five tons in weight, so that ginpoles (simple cranes) and lifts which are modified from pile drivers can be used for in the work of replacement.

(3) The new bridges for replacement are designed, according to the design specifications which are shown in the Appendix I.

(4) For the longitudinal force due to long rails, one ton per meter per track shall be assumed and sleepers shall be fastened to the flanges of the stringers or the main girders with bolts.

(5) Steel equivalent to SM41 or SMA 41 as specified in JIS G 3106 (Rolled Steel for Welded Structure) and JIS G 3114 (Weather-proof Hot-rolled Steel for Welded Structure) shall be used. High-strength bolts equivalent to M22/F10T as specified in JIS B1186 (Set of High-strength Hexagonal Bolts, Hexagonal Nut and Plain Washer for Friction Joint) shall be used for connection of the members.

(6) A side walk will be provided on one side of a bridge to facilitate maintenance of the track and bridge. Further a jacking-up device will be provided for future repair of shoes.

(7) The gusset plates for lateral members will be separated from the main plate girders in order to avoid damage during transportation to the erection site. Then they will be connected to the main girders by high-strength bolts.

## 4. Planning of Replacement

The bridges are replaced, in principle, by the transverse sliding method as indicated in Appendix VII.

It is assumed that cranes, carriers and other constructional equipments to be used for replacement will be those which can be procured locally and which are familiar to local workers.

# VIII. PLAN FOR EXECUTION

# VIII. PLAN FOR EXECUTION

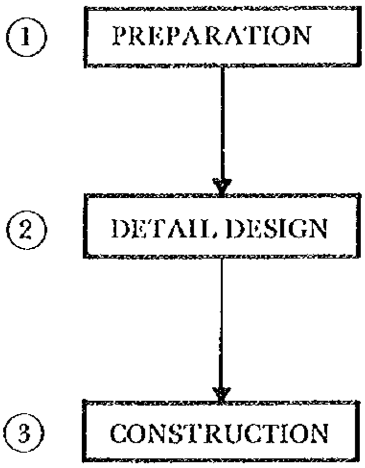
## 1. Policy for Planning

Regarding the phased program for execution of improvement work, the following items will be explained mainly from the technical aspect.

(1) Safety of train operation
(2) Relation with other track modernization plans
(3) Restriction on train speed during execution of works
(4) Frequency of train services and effects of improvement works
(5) Efficiency in execution of works

For the present cost estimation the construction period was assumed as five years, but it may have to be extended in order to be in line with the latest planning policy of RSR.

For implementation of the improvement project, the three stages as illustrated below have to be established.




By RSR officials and advisors;

* Materialization of project
* Selection of consulting firm

By consulting firm;

* Detail design drawings
* Cost estimation for construction
* Preparation for contract award and specifications
* Supervision of construction work

By contractor;

* Shop Drawings
* Detail execution plan
* Construction and erection

### 1-1 Safety of Train Operations

Many of the bridges on the railway lines in operation have their load-carrying capacity reduced due to heavy corrosion, deformation and other causes. This situation will jeopardize train operations sooner or later. Therefore, it is necessary to give the top priority to repair and strengthening of these defective railway bridges.

In case a bridge needs a high priority in improvement work, the adjoining bridges, if not considered severely deteriorated, should preferably be improved at the same time from the standpoint of increasing executing efficiency and minimizing the need for reduced train speed during the execution of the works.

There are some bridges which should be urgently repaired without waiting for implementation of the present project. But their repair work may be carried out for limited members only for the time being. For instance, in the bridge at Km 70 + 880 on the Northern Line at least the lower lateral bracings should be repaired and strengthened.

### 1-2 Relation with Other Track Modernization Plans

At the present time, RSR has a total of 834 timber bridges as shown in Table 3-4. Of these bridges, 240 are scheduled for replacement during the 1977 - 1981 period. However, the improvement plan for steel bridges and the replacement plan of timber bridges should be closely interrelated.

### 1-3 Reduction of Train Speed during Execution of Works

. The methods for repairs/strengthening should be such that interference with train operation will be minimized. In the case of replacement, the transverse sliding erection method involves a very short period in which train operations are restricted. Therefore, it is not necessary to give much consideration to the relation with other work sites.

In the case of repair/strengthening, a certain interval between train operations will be needed according to the amount of work to be done to insure the safety of workers on the site. Load restriction and speed reduction of trains on the bridges under repair work may be required, likewise. In such cases, if the repair/strengthening works are spread over an entire railway division, trains will have to slow down in many sections. For this reason, the works should be limited to as few sections as possible at a time.

### 1-4 Frequency of Train Services and Effects of Improvement Works

The effects of improvement works will be particularly substantial for railway divisions with high train frequency or having a small number of bridges requiring improvement works. From this standpoint, improvement works should be so planned as to be concentrative for each railway division requiring such works.

### 1-5 Efficiency in Execution of Works

From the standpoint of efficiency in execution of works, the following methods are advantage ones:

(1) To carry out simultaneously the works on bridges of the same type or span.

(2) To execute works in a concentrative way

Though Method (1) above has a disadvantage of scattering the work sites, it is recommendable from the viewpoint of increased working efficiency because similar materials and methods can be used and from the standpoint of an ensuring good quality control. However, also a due consideration must be given to the concentration of work sites as Method (2), since it will minimize the necessity for train speed restriction and will also facilitate management of the work.

In result, Methods (1) and (2) should be compared to obtain the best efficiency in each individual case.

## 2. Execution Plan for Improvement Works

Bearing in mind the basic policy described in the foregoing chapter and taking various factors into consideration, the priority of execution must be determined. The recommended priority order many place Northern Line at the top, followed by Southern Line, Northeastern Line, Eastern Line and branch lines in that order. Table 8-1 gives the numbers of bridges requiring repairs, strengthening or replacement, for the different lines.

Table 8 - 1

| | No. of spans assumed to be repaired or strengthening | | No. of spans assumed to be replaced | | Total |
|---|---|---|---|---|---|
| | Main Line | Branch Line | Main Line | Branch Line | |
| Northern Line | 18 | 1 | 3 | - | 22 |
| Northeastern Line | 43 | - | 2 | - | 45 |
| Southern Line | 90 | 8 | 3 | 9 | 110 |
| Eastern Line | 37 | - | - | - | 37 |
| Total | 197 | | 17 | | 214 |

The following preconditions for the preparation of work plan are established on the basis of the prediscribed policy:

(1) Top priority is given to those bridges which constitute greater danger to train operations.

(2) Heavy concentration of works in a certain year should be avoided. However, it is better that the constructional work be carried out for fewer bridges in the first year than average years.

(3) Improvement works of a total of 22 spans of steel bridges on Northern Line will be finished earlier. However, the works may be assumed to be completed in a three year period to minimize the number of sections requiring imposition of train speed restriction.

(4) Northeastern Line has a total of 45 spans of steel bridges requiring improvement works. Out of these spans, 34 spans are located in Nakon Ratchasima-Ubon Ratchathani Section which is about 300km long.

The entire works on Northeastern Line will require at least in a three year period.

In this case, care should be taken to avoid a concentration of the works in the 300km section.

(5) For Southern Line, the main line alone has 95 spans of steel bridges that need improvement work. On this line there are many timber bridges requiring replacement. Severely corroded bridges concentrate in the districts of Chumphon and Had Yai and it is necessary to carry out the improvement work in the two districts on a priority basis.

All improvement works on Southern Line need to be executed over a longer period, in relation to the replacement plan for the timber bridges.

(6) On Eastern Line where train intervals are long, works can be carried out with a relative ease. In view of a low traffic density on this line, the required works will be carried out mainly in the latter part of the project period from the standpoint of overall executing capacity.

(7) Improvement works on the branch lines are to be undertaken also in the latter part of the project period.

Table 8-2 shows an example of the quantities of works by year as considered on the basis of the foregoing conditions.

Table 8 - 2 Phased Program of Improvement Work to be Assumed for the Cost Estimation

| | No. of spans | | Construction year | | | | |
|---|---|---|---|---|---|---|---|
| | Streng-thening | Replace-ment | 1977 | 1978 | 1979 | 1980 | 1981 |
| Detail Design | | | | | | | |
| Northern Line | 18 | 3 | 4 (1) | 8 (2) | 6 | | |
| Northeastern Line | 43 | 2 | 6 | 13 | 13 | 11 (2) | |
| Southern Line | 79 | 3 | 9 | 17 | 17 (3) | 20 | 16 |
| Eastern Line | 37 | 0 | | | 13 | 13 | 11 |
| Branch Line | 20 | 9 | 1 (1) | | | 5 | 14 (8) |
| Total | 197 | 17 | 20 (2) | 38 (2) | 49 (3) | 49 (2) | 41 (8) |
| | 214 | | | | | | |

Legend:

4 Number of spans of steel bridges to be strengthened or repaired

(1) Number of spans to be replaced

## 3. Application of Standard Specifications

### 3-1 Repair and Strengthening

The methods for repair and/or strengthening of typical types and structural members of steel bridges, selected from among the bridges requiring improvement, are shown in the standard drawings (Appendix VII). The bridges covered by the present study can be classified into 60 different types according to span length and structural variation or difference. Besides, these bridges are in varying degrees of corrosion and deformation. The standard designs set forth the basic concepts and approaches to the repair/strengthening of the bridges. Therefore, detail drawings for execution must be prepared for each type and span length, on the basis of the standard drawings.

The strengthening methods proposed in this study are based on the principle that interference with train operations, such as suspension of train service and speed restriction, should be minimized. Nevertheless, in some cases, for example, in the repairs of floor beams, it may be necessary to keep certain train intervals, say two hours for each, during the improvement works.

Actually, the strengthening method varies with span length, extent of corrosion and deformation of structural members, site conditions and other factors. Therefore, the standard designs must be applied in different ways accordingly. The standard drawings show only one representative design proposal for each kind of defects based on the comparison of several different strengthening methods. In particular cases, bridge types and methods for strengthening which are not shown in the standard drawings may prove more effective and realistic. For these reasons, it is important to have a full understanding of the explanation of the repair and strengthening methods before applying the standard designs to the bridges requiring improvement works.

The Standard designs have been prepared on the basis of the original drawings or field drawings of the bridges under study, taking into consideration the outcome of the site investigations carried out by the survey team. However, the existing bridges have different local structures from those presented in their original drawings in some cases. Moreover, it is often discovered that the degree of corrosion varied in the same bridge from section to section.

Detailed field investigation will, therefore, have to be undertaken to know actual structural conditions of the existing bridges.

### 3-2 Replacement

The Standard designs presented in this report for new bridges for replacement of the existing ones have details sufficient only for the approximate estimation of the costs for the required works. It is a prerequisite, therefore, to prepare detailed designs before the actual works are undertaken. For preparation of the standard designs presuppose the use of the existing piers and abutments is assumed. However, some of them may be in different conditions from those shown on the original drawings and some may have been displaced to a considerable extent.

## 4. Arrangement for Execution of Works

### 4-1 System for Execution

It is suggested that it may be beneficial for RSR in implementing the recommendations contained in the report, to obtain a few advisors for technical and financial requirements for a first few initial years.

It is advisable to select, and make a contract with, a proper consulting firm for detail designs, preparatory execution plan, preparation of documents for construction, supervision and inspection during construction work and so on.

Because RSR has not only this improvement project but also the timber bridge replacement project, it is considered difficult to keep so many engineers available for the project throughout its entire period.

If the entire project is to be completed in a short period such as five years, works will always be in progress at a minimum of 15 sites throughout those years. A minimum of seven RSR engineers will have to be on supervisory duty during the period, each of them taking charge of two or three work sites. Since it is impossible to secure trained supervising engineers in a short period of time, well-experienced engineers should preferably be hired from other sources during the project period.

### 4-2 Manufacture and Erection

In Thailand, the only one bridge shop owned by RSR and about three private-owned factories are considered to be capable of manufacturing railway bridges. However, they have no experience in manufacturing railway bridges of welded construction. As for new steel bridges, therefore, it is advisable to import them from abroad.

Steel members for strengthening are obtainable in Thailand and local contractors are considered to have ample capability for erection of bridges.

It is conceivable that RSR may undertake the strengthening works under its direct management. In view of its present executing capacity, however, RSR may not be able to carry out a major portion of the improvement works. Actually, greater parts of the works may have to be carried out by private firms.

### 4-3 Summary of Arrangement

The following arrangement must be made prior to the execution of improvement works:

(1) By RSR officials and advisors

a) Review of the investigations that have been done in the present study.
b) Selection of consulting firm

(2) By consulting firm

a) Review of existing data
  * Original drawings and field drawings.
  * Results of stress calculations of structural members requiring repairs and strengthening
  * Basic methods for execution

b) Investigation of existing bridges
  * Preparation of new drawings to complete the existing drawings
  * Checking of dimensions of structural members with reference to the available drawings

* Detailed investigation of the extent of corrosion, deformation and other defects, including photographing and sketching.
* Detailed site investigation and surveying if necessary.

c) Site investigation
   * Topographical survey and span survey
   * Vertification of the dimensions of piers and abutments
   * Investigation of route and method for transportation

d) Preparation of detail drawings for execution of repair and/or strengthening and detail designs for new bridges for replacement

e) Preparatory execution plan

f) Cost estimation for construction

g) Preparation for contract award and specifications

h) Review of shop drawings and detailed execution plan prepared by contractors.

(3) By contractor

a) Verification of the detailed dimensions and shapes of all structural members with reference to the existing drawings.

b) Preparation of shop drawings for execution if necessary.

c) Preparation of execution plan

# IX. CONSTRUCTION COSTS

# IX. CONSTRUCTION COSTS

## 1. Standard for Estimation of Construction Cost

### 1-1 General

Technical evaluation of these bridges was made on the basis of the data obtained by the site investigation and stress calculations. The total project cost was calculated, assuming the classification as shown in Table 9-1.

Table 9 - 1

| Item | Total number of spans | Location | Span length (m) | Number of spans |
|---|---|---|---|---|
| Bridges which are assumed to be replaced | 17 | S - 77+844 | 25.5 | 1 |
| | | S - 469+428 | 25.5 | 1 |
| | | NE-536+969 | 25.5 | 1 |
| | | S - 153+788 | 16.0 | 1 |
| | | S - 120+195 | 20.75 | 8 |
| | | N - 577+622 | 30.0 | 1 |
| | | S - 993+501 | 30.0 | 1 |
| | | NE-323+816 | 30.0 | 1 |
| | | N - 70+866 | 31.7 | 2 |
| Bridges requiring repair and/or strengthening | 197 | Other than above. | | |

The project cost calculated in this chapter provides a guideline for the determination of the economic and financial feasibility of the project and for the procurement of necessary funds. However, the cost estimates need to be revised on the basis of the data from more detailed preconstruction investigation.

All the cost items were calculated separately for domestic and foreign currencies. The calculated project cost includes the costs for strengthening and replacement of bridges and makes an allowance for 10% price escalation per year under the assumption that the improvement works involving 214 spans of bridges will be completed in a 5-year period. The cost estimation was made according to the quantities of works calculated on the basis of the standard drawings. It is also based on the unit prices in Appendix III. Interest payments on loans are not included in the cost estimates.

### 1-2 Date of Estimation

The estimated cost was taken as of April, 1976.

### 1-3 Works and Methods for Executing the Project

(1) The cost estimates were prepared assuming that the entire construction works would be executed in five years spreading them as evenly as possible over the whole planned period.

(2) It is difficult to determine the priority of execution only on the basis of a technical aspect. The construction costs were estimated for different types and spans of bridges, based on the execution plan previously described. In the cost estimation, overhead charges and some other cost items were assumed to be constant for all works, since at this stage the quantities of works to be carried out were not exactly known.

(3) All the works were assumed to be carried out in a package. However, the domestic transport of structural members of the bridges and construction plant and materials was assumed to be undertaken by RSR.

(4) New bridges for replacement are to be fabricated outside Thailand and processing of materials for repair and strengthening is to be done at bridge workshops in Thailand. All the main materials are to be imported from foreign countries.

(5) The field works except for special cases will be carried out by Thai engineers and workers. However, the construction costs include the costs for two foreign consulting engineers for supervision of the construction works.

## 2. Construction Cost and Quantity of Works

### 2-1 Quantity of Works

Table 9-2 shows the quantities of steel materials required for the improvement works and quantities of old materials to be dismantled during improvement works.

Table 9 - 2

| Item | Type | Weight (t) |
|---|---|---|
| Steel materials required for repair/strengthening | Plate | 560 |
| | Shape | 970 |
| Steel materials required for replacement | Plate | 511 |
| | Shape | 28 |
| Old materials from dismantled bridges | | 710 |

The total number of mandays of the local labor involved in the construction will be 350 thousand.

### 2-2 Construction Costs

Table 9-3 gives the breakdown of the total project cost. The cost breakdowns by work divisions, cost items and years are shown in Table 9-4 to Table 9-8.

Table 9 - 3 Construction Cost

( in thousands )

| Item | Domestic currency | Foreign currency | Total |
|---|---|---|---|
| | Bahts | Bahts (U.S.Dollars) | Bahts |
| Basic construction cost | 127,600 | 118,522 (5,926) | 246,121 |
| Escalated cost | 173,127 | 160,536 (8,027) | 333,663 |

Rate of Rate of exchange: 1 U.S. Dollar = 20 Bahts
Year of estimation: 1976
Rate of price escalation: 10% per year

Table 9 - 4 Breakdown of Construction Cost

( in thousand )

| Items | | Doemstic Currency | Foreign Currency | Total |
|---|---|---|---|---|
| | | Bahts | Bahts (Dollars) | Bahts |
| Basic construction cost | Detail design | - | 13,133 ( 657) | 13,133 |
| | Repair/strengthening | 120,000 | 88,708 (4,436) | 208,708 |
| | Replacement | 7,627 | 16,653 ( 833) | 24,280 |
| | Total | 127,627 | 118,494 (5,926) | 246,121 |
| Escalated cost | Detail design | - | 16,760 ( 838) | 16,760 |
| | Repair/strengthening | 162,727 | 121,469 (6,074) | 284,196 |
| | Replacement | 10,400 | 22,307 (1,115) | 32,707 |
| | Total | 173,127 | 160,536 (8,027) | 333,663 |

Year of estimation: 1976
Rate of price escalation: 10% per year
Rate of exchange: 1 dollar = 20 Bahts

Table 9 - 5 Breakdown of Basic Construction Cost by Items of Work

( in thousand Bahts )

| Items of expenditure | Repair/strengthening | Replacement | Total | Remarks |
|---|---|---|---|---|
| Materials | 17,333 | 3,133 | 20,467 | |
| Fabrication | 15,133 | 6,667 | 21,800 | |
| Transportation | 3,400 | 1,333 | 4,733 | domestic only |
| Net construction cost | 119,322 | 8,333 | 127,655 | |
| Overhead charge in field | 14,933 | 1,067 | 16,000 | 12.5% of net construction cost |
| Total | 170,121 | 20,533 | 190,655 | |
| Overhead charge | 22,133 | 2,667 | 24,800 | 13% of total |
| Shop drawings | 7,368 | 632 | 8,000 | |
| Detail design | 12,424 | 709 | 13,133 | |
| Supervision | 9,086 | 448 | 9,534 | |
| Grand Total | 221,132 | 24,989 | 246,121 | |

Table 9 - 6 Breakdown of Construction Cost by Years

(in thousand Bahts)

| Year | 1977 | | 1978 | | 1979 | | 1980 | | 1981 | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Item | D.C. | F.C. | D.C. | F.C. | D.C. | F.C. | D.C. | F.C. | D.C. | F.C. | D.C. | F.C. |
| Basic Construction Cost | 31,957 | | 50,427 | | 64,765 | | 55,339 | | 46,633 | | 246,121 | |
| | 14,533 | 17,424<br>(871) | 25,600 | 24,827<br>(1241) | 34,200 | 30,565<br>(1528) | 28,533 | 26,806<br>(1340) | 24,733 | 18,900<br>(945) | 127,600 | 118,522<br>(59[illegible]6) |
| Escalated Cost | 35,152 | | 61,017 | | 86,202 | | 81,022 | | 70,270 | | 333,663 | |
| | 16,009 | 19,143<br>(957) | 29,998 | 31,019<br>(1551) | 45,537 | 40,665<br>(2033) | 41,780 | 39,242<br>(1962) | 39,803 | 30,467<br>(1523) | 173,127 | 160,536<br>(8027) |

| | |
|---|---|
| Year of estimation: | 1976 |
| Rate of price escalation: | 10% per year |
| Rate of exchange: | 1 US $ = 20 Bahts |
| D.C. | Denotes domestic currency |
| F.C. | Denotes foreign currency |
| ( ) | Denotes US dollars |

Table 9 - 7 Breakdown of Construction Cost by Operating Lines of RSR

( in thousand Bahts )

| Line | No. of spans | 1977 | 1978 | 1979 | 1980 | 1981 | Total |
|---|---|---|---|---|---|---|---|
| Detail Design | | 3,612 | 3,977 | 4,370 | 4,807 | - | 16,766 |
| Northern Line | 21 | 8,587 | 18,810 | 7,343 | - | - | 34,740 |
| Northeastern Line | 45 | 8,994 | 21,800 | 33,652 | 28,965 | - | 93,411 |
| Southern Line | 82 | 10,198 | 16,430 | 24,062 | 24,758 | 19,505 | 94,953 |
| Eastern Line | 37 | - | - | 16,775 | 16,617 | 20,643 | 54,035 |
| Branch Line | 29 | 3,761 | - | - | 5,875 | 30,122 | 39,758 |
| Total | 214 | 35,152 | 61,017 | 86,202 | 81,022 | 70,270 | 333,663 |
| Domestic Currency | | 16,009 | 29,998 | 45,537 | 41,780 | 39,803 | 173,127 |
| Foreign Currency | | 19,143 | 31,019 | 40,665 | 39,242 | 30,467 | 160,536 |

Year of estimation: 1976
Rate of price escalation: 10% per year

Table 9 - 8 Breakdown of Construction Cost by Districts

( in thousand Bahts )

| Line | District | 1977 | 1978 | 1979 | 1980 | 1981 | Total |
|---|---|---|---|---|---|---|---|
| Detail design | | 3,612 | 3,973 | 4,370 | 4,807 | - | 16,762 |
| Northern Line | Bangkok | 1,366 | 5,476 | 900 | | - | 7,742 |
| | Nakhon Sawan | 5,154 | 10,697 | 5,447 | - | - | 21,298 |
| | Sila At | - | - | 996 | - | - | 3,633 |
| | Lampang | 2,067 | - | - | - | - | 2,067 |
| | Total | 8,587 | 18,810 | 7,343 | - | - | 34,740 |
| Northeastern Line | Kaeng Khoi | - | 5,681 | - | - | - | 5,681 |
| | Lam Chi | 8,994 | 10,029 | 23,002 | 17,472 | - | 59,497 |
| | Khon Kaen | - | 6,090 | 10,650 | 11,493 | - | 28,233 |
| | Total | 8,994 | 21,800 | 33,652 | 28,965 | - | 93,411 |
| Southern Line | Hua Hin | - | - | 3,369 | 1,380 | 1,674 | 6,423 |
| | Chum Phon | 5,535 | 8,855 | 8,401 | 6,214 | 4,577 | 33,582 |
| | Thung Song | - | - | 3,280 | 6,106 | 5,731 | 15,117 |
| | Hat Yai | 1,760 | - | 1,975 | - | - | 3,735 |
| | Yala | 2,903 | 7,575 | 7,037 | 11,058 | 7,523 | 36,096 |
| | Total | 10,198 | 16,430 | 24,062 | 24,758 | 19,505 | 94,953 |
| Eastern Line | Prachin Buri | - | - | 16,775 | 16,617 | 20,643 | 54,035 |
| Branch Line | Hua Hin | 2,315 | - | - | - | 9,455 | 11,760 |
| | Thung Song | - | - | - | - | 5,404 | 5,405 |
| | Hat Yai | 1,446 | - | - | 4,676 | 15,273 | 21,395 |
| | Sila At | - | - | - | 1,199 | - | 1,199 |
| | Total | 3,761 | - | - | 5,875 | 30,122 | 39,758 |
| Grand Total | | 35,152 | 61,017 | 86,202 | 81,022 | 70,270 | 333,663 |

Year of Estimation: 1976
Rate of price escalation: 10% per year

## 3. Cost Comparison

(1) Cost for the case of replacement of 214 spans

An approximate cost for the case where all the 214 spans are assumed to be replaced with new bridges is as much as 590 million Bahts, or nearly 2.5 times the construction costs shown in Section 2.2.

This estimation was obtained through the use of a curved graph (Fig. 9-1) that indicated an average relation between the span length of bridge and its cost to be required for it.

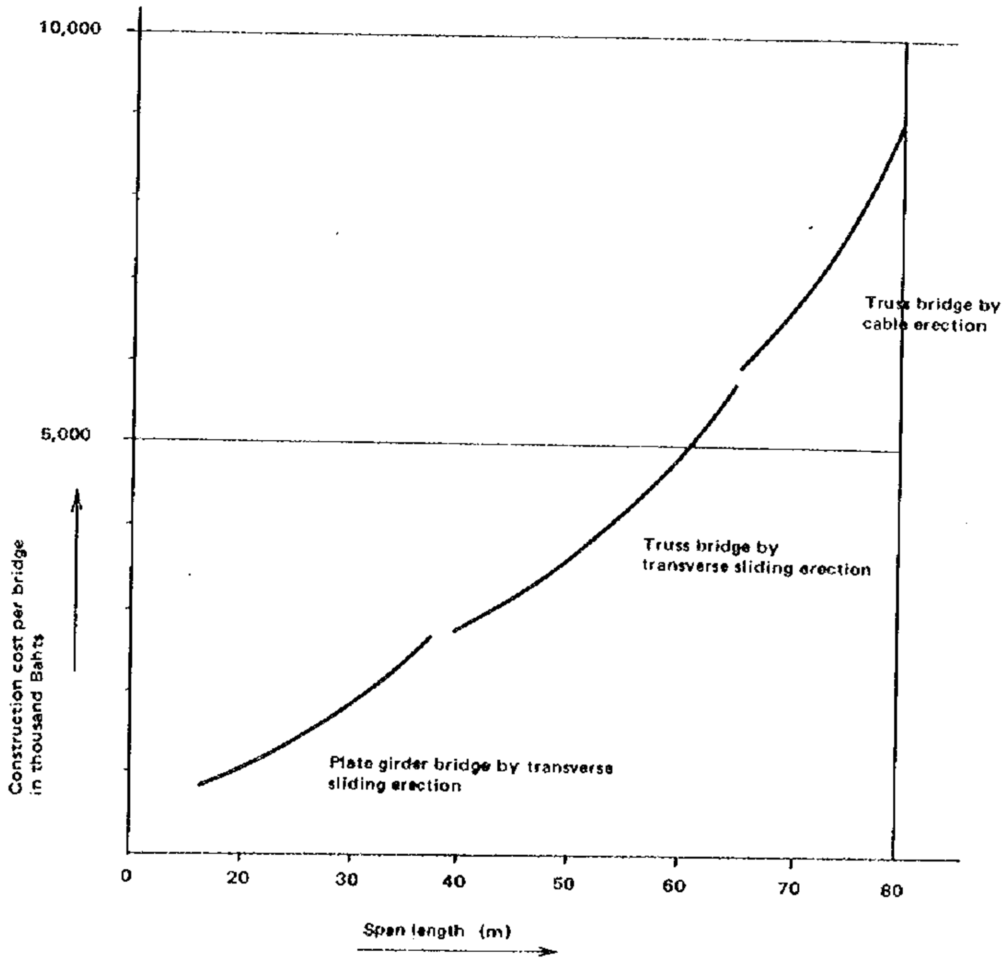



Fig. 9 - 1

(2) Cost saving involved in adopting DL-14 Loading for strengthening and/or replacement, instead of DL-15 Loading

If DL-14 Loading is adopted for the improvement works, a cost saving of 7.7 million Bahts, or only about 3.1% of the total construction cost can be expected as compared with the case of DL-15 Loading. This cost saving represents mainly the elimination of the costs for structural members which need not be strengthened, and their processing and transportation.

(3) Cost saving involved in partial reuse of structural members of dismantled bridges

Steel structural members of the bridges previously dismantled are stored in large quantities. It is unknown to what extent these old materials can be utilized, because their actual conditions are not clearly known. If old steel materials can be reused in an amount equal to 10% of the total material requirements for strengthening/repair purposes, the resulting cost saving will amount to about 1,200,000 Bahts, or 0.4% of the total construction costs.

# X. DISPLACEMENT OF ABUTMENTS

# X. DISPLACEMENT OF ABUTMENTS

## 1. Situation and Condition of Displacement

Through more precise survey is necessary on the situation of the displacement of abutments in order to investigate its causes, according to the information obtained up to the present, the situation will approximately be summarized as follows:

(1) In some cases the forward displacement of abutments is so large that the rollers of a shoe are out of the shoe nest or that the ends of the bridge are in contact with the parapet walls of the abutments. Bridges in which displacement of abutment is remarkable are shown in Table 10-1.

(2) Large vertical settlement does not seem to have arisen in abutments.

(3) Horizontal displacement of abutments has occurred usually in areas with weak ground.

(4) The back fill of abutments consists mainly of clayey soil.

(5) In areas where the water level changes greatly between in the rainy season and in the dry season, abutments tend to move to a greater degree.

(6) The banking behind an abutment has sunk (except the bridge at Km 187 + 240 in Eastern Line).

(7) In the bridge at Km 187 + 240, there is a danger of overturning of the piers by scouring.

## 2. Causes of Displacement

Though further survey and discussion are necessary in order to realize the causes of the displacement of abutments, it is obvious judging from the situation obtained up to now, as is shown in Paragraph 1, that the main cause is that the horizontal resisting strength of the abutment is insufficient against the horizontal force acting on the abutment.

The causes will be explained more in detail as follows:

(1) Case I, where the horizontal resisting strength of the abutment was inherently insufficient;
The causes for this case will be classified as follows:

i ) The surrounding conditions were not properly considered in design.

ii ) The piles are insufficient in number and length.

iii) The footings are not large nor deep enough.

(2) Case II, where the horizontal force acting on the abutment has once increased temporarily;
Possible causes for it are;

i ) At the time of construction, the banking behind the abutment was overloaded with materials, tools, etc. for construction.

ii ) The supporting ground slid forward at the time of construction of the banking or immediately afterwards.

(3) Case III, where a temporary increase in the horizontal force acting on the abutment has repeatedly occurred: It is possible that a high water pressure acts on the abutment from the rear of the abutment, when the water level at the front of the abutment goes down rapidly in the transition from the rainy season to the dry season.

(4) Case IV, where the horizontal force acting on the abutment is continuously increasing; it is conceivable that clayey soil of the banking swells gradually by absorbing water during the high water level period in the rainy season, and that the soil pressure acting on the abutment increases on account of gradual decrease in the adhesive strength of soil.

(5) Case V, where the horizontal resisting strength of the abutment has once decreased temporarily: It is possible that during the construction or in a short period after construction, the base ground moved due to the weight of banking, but the movement has since ceased. It is also conceivable that the ground at abutment front has temporarily been scoured by water flow during the high water level period, but it has already been restored afterwards.

(6) Case VI, where a tempoary decrease in the horizontal resisting strength of the abutment has often occurred; It is conceivable that the scour and restoration of foundation ground at the front have been repeated every year in the transition from the rainy season to the dry season.

(7) Case VII, where the horizontal resisting strength of the abutment is continuously decreasing; It is conceivable that decrease in the resisting strength on account of corrosion of piles, lowering of the river bed and increase in the volume of scour are continuously progressing.

A lot of other causes may exist, and more than two among those causes shown above may concur. Therefore, it is difficult to define the correct causes simply from the conditions shown in Paragraph 1.
However, at present, the most probable cause is supposed to be the movement of the base ground due to the weight of banking during or immediately after construction of the abutment as described in Item (5). The increase in water pressure from the rear due to the water level difference between the rainy season and the dry season as described in Item (3), and the swelling of the soil of the bank at the rear and the decrease in adhesive strength of soil of the bank as described in Item (4) are also likely to be the causes.
In the bridge at Km 187 + 240 in Eastern Line, it is conceivable that scouring of the river bed is still in progress.

## 3. Countermeasures

The countermeasures are classified into temporary ones and permanent ones.

As temporary countermeasure for the case where the end of a bridge is in contact with the parapet wall, and consequently intolerable bad influence to the superstructure is recognized, it is necessary to make a proper gap in between by chipping the parapet wall.

The permanent measures with differ according to the cause of displacement of the abutment.

Even in a case that such a large displacement as to cause the contact between the bridge end and the parapet wall took place in the past due to the cause described in Item (5), any permanent measures will not be needed, if it is so stable at present that no additional displacement is observed when a gap has been made between the bridge end and the parapet wall.

However, even if the amount of the present displacement is small, permanent measures will be necessary, in case the displacement is still in continuous progress and if it is suspected to harm the functions of the abutment in the future. The following methods may be effective as the permanent measures;

1) To increase the horizontal resisting strength of the abutment by driving in piles both at its front and on its sides.
2) To install steel beams as struts between the abutments on both sides.
3) To prevent scour and increase the horizontal resistance by strengthening the foundation ground of the abutment front.
4) To reduce the soil pressure and water pressure acting to the abutment by the methods as shown in Fig. 10-1 and Fig. 10-2.
5) To reform the river condition to increase the resistance against the scouring and control the direction of water flow.

## 4. Actions to be Taken Hereafter

As for the bridges in Eastern Line that abutments have been displaced, the causes of the displacement are supposed to be as described in Item (5), and no excessive or sudden increase of displacement is considered to be possible hereafter. However, it is necessary to continue observation in order to judge whether any countermeasures are needed.

As for the bridge at Km 187 + 240 in Eastern Line, it is desirable to improve the piers, and at least it is necessary for the security of train operation by observing any change in the state of the river and by installing an adequate device to give an alarm to operators as soon as harmful damage or tilting of the piers takes place.

Table 10-1. Bridges with Shoes of Excessive Roller Displacement

| Line | Location | Span Length (m) | Type | Manufacturer | Shoe-Displacement |
|---|---|---|---|---|---|
| Southern | 77+844 | 1x25.00 | T.T. | P&W McLellan | 175 mm |
| Northern | 134+742 | 1x35.00 | " | Daydé | 60 |
| North Eastern | 311+725 | 1x30.00 | " | " | 50 |
| Eastern | 81+475 | 1x25.00 | " | Cleveland | 140 |
| | 81+985 | 1x25.00 | " | " | 180 |
| | 84+393 | 1x25.00 | " | " | 150 |
| | 87+097 | 1x25.00 | " | " | 200 |
| | 89+847 | 1x25.00 | " | " | 200 |
| | 112+795 | 1x50.00 | " | Daydé | 230 |
| | 116+012 | 1x35.00 | " | " | 100 |
| | 119+830 | 1x35.00 | " | " | 70 |
| | 132+634 | 1x50.00 | " | " | 50 |
| | 134+137 | 1x35.00 | " | " | 70 |
| | 134+563 | 1x35.00 | " | " | 50 |
| | 218+823 | 1x30.00 | " | Devries Robbe | 150 |

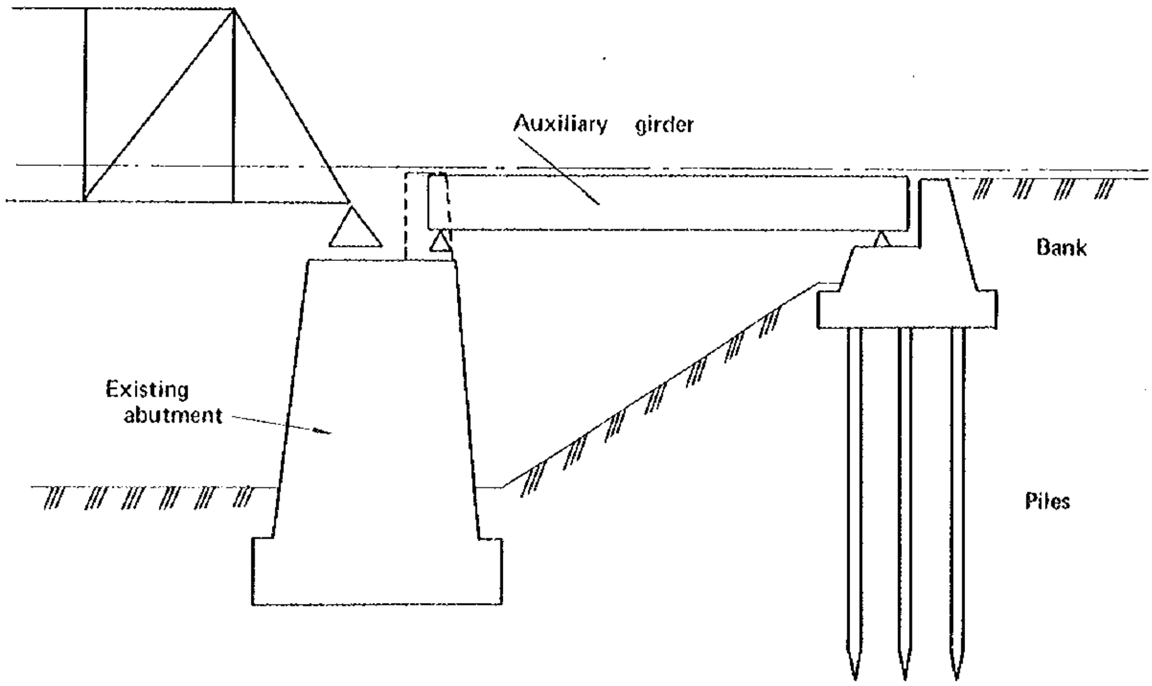



Fig. 10.1 A method to eliminate the earth pressure from the rear of the existing abutment

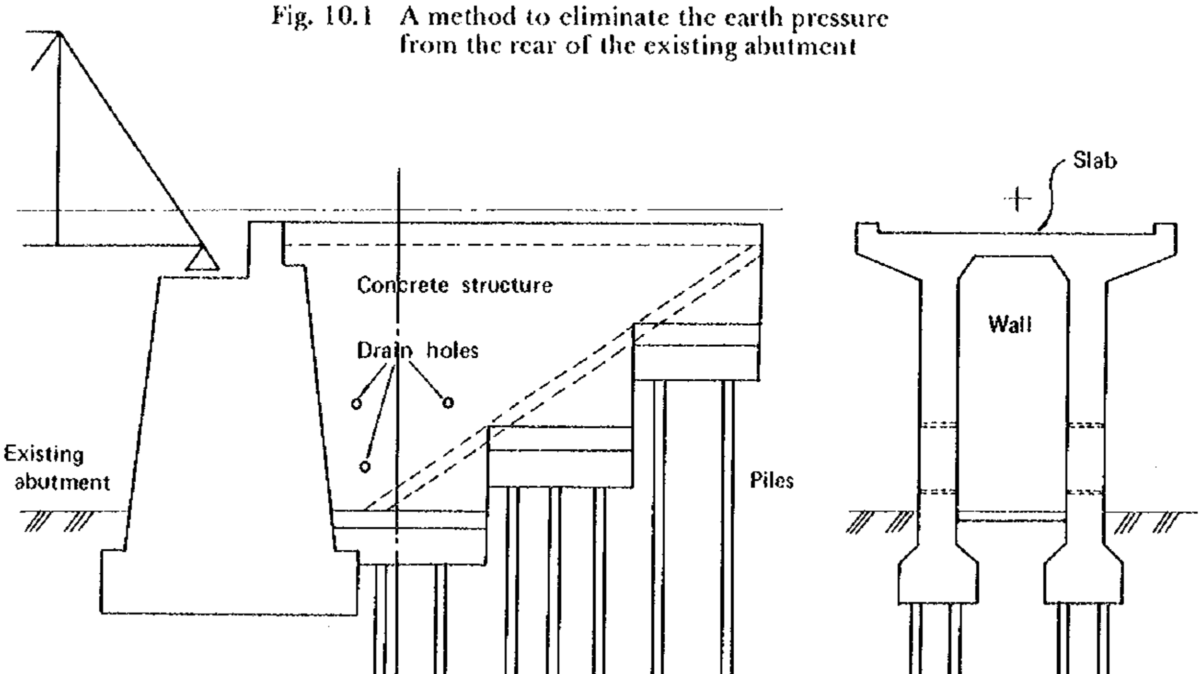



Fig. 10.2 A method to eliminate the water pressure from the rear of the existing abutment

# XI. RECOMMENDATIONS

# XI. RECOMMENDATIONS

(1) The 214 spans of steel bridges covered in this study have some defects or other. For this reason, the improvement project regarding repairs, strengthening or replacement should be made, taking into consideration the economical effects resulting from such projects, comparison of importance and requirement of each rail line route, etc., in addition to the results of this technical investigation.

(2) Until the implementation of this project is undertaken, the bridges should be well maintained to prevent further corrosion of steel members and loosening of rivets.

(3) Urgent temporary repairs should be taken with respect to the bridges listed in Table 11-1.

Table 11 - 1

| Line | Location of Bridges (Span Length) | Parts to be Repaired |
|---|---|---|
| Southern Line | 1035 + 353 (3 x 30.00)<br>1063 + 810 (2 x 50.00)<br>1065 + 064 (4 x 50.00)<br>1103 + 099 (1 x 35.00) | Connection rivets of vertical and diagonal members |
| | 402 + 077 (1 x 30.00)<br>551 + 793 (2 x 50.00)<br>568 + 610 (1 x 45.00)<br>1035 + 353 (3 x 30.00) | Rivets for connection between stringers and floor beams |
| Eastern Line | 87 + 097 (1 x 25.00)<br>89 + 847 (1 x 30.00) | Adjustment of position of rollers in shoes |
| Northern Line | 70 + 847 (2 x 31.70) | Connection rivets of lateral bracings |

(4) The bridges listed in Table 11-2 should preferably be replaced for safety of train operation, difficulty in repairs and their degree of deterioration if the bridges must be provided with a carrying capacity sufficient for DL-15 Loading passing at a normal speed.

Table 11 - 2

| | Line | Location | Type of Bridge | Span length (m) | Manufacturer |
|---|---|---|---|---|---|
| 1. | Northern Line | 70 + 886 | T.T. | 2 x 31.7 | P&W McLellan |
| 2. | " | 577 + 622 | D.T. | 1 x 30.0 | " |
| 3. | Southern Line | 77 + 844 | T.T. | 1 x 25.5 | P&W McLellan |
| 4. | " | 120 + 195 | T.T. | 8 x 20.75 | " |
| 5. | " | 153 + 788 | T.P. | 1 x 16.0 | " |
| 6. | " | 469 + 428 | T.T. | 1 x 25.0 | P&W McLellan |
| 7. | " | 993 + 501 | T.T. | 1 x 30.0 | Daydé |
| 8. | Northeastern Line | 323 + 816 | T.T. | 1 x 30.0 | " |
| 9. | | 536 + 969 | T.T. | 1 x 25.5 | P&W McLellan |

(5) In implementing the improvement project, priority should be placed on the bridges shown in Table 11-3 because they have undergone severe corrosion and large deformation.

Table 11 - 3

| | Line | Location | Type of Bridge | Span length (m) | Manufacturer | Causes |
|---|---|---|---|---|---|---|
| 1. | Northern | 70 + 886 | T.T. | 2 x 31.7 | P&W McLellan | A |
| 2. | Northeastern | 480 + 160 | T.T. | 2 x 30.0 | Daydé | B |
| 3. | " | 560 + 392 | T.T. | 1 x 40.0 | " | |
| 4. | Southern | 77 + 844 | T.T. | 1 x 25.0 | P&W McLellan | A |
| 5. | " | 373 + 273 | T.T. | 3 x 30.0 | Cleveland | C |
| 6. | " | 377 + 210 | T.T. | 1 x 70.0 | " | B, C |
| 7. | " | 386 + 462 | T.T. | 1 x 30.0 | " | C |
| 8. | " | 392 + 471 | T.T. | 1 x 30.0 | " | C |
| 9. | " | 471 + 865 | T.T. | 1 x 45.0 | " | C |
| 10. | " | 497 + 613 | T.T. | 1 x 35.0 | " | B, C |
| 11. | " | 499 + 659 | T.T. | 1 x 80.0 | " | C |
| 12. | " | 568 + 610 | T.T. | 1 x 45.0 | " | C |
| 13. | " | 576 + 330 | T.T | 1 x 65.0 | " | C |
| 14. | " | 595 + 040 | T.T. | 1 x 30.0 | " | C |
| 15. | " | 925 + 165 | T.T. | 1 x 80.0 | " | C |
| 16. | " | 929 + 903 | T.T | 1 x 30.0 | " | C |
| 17. | Southern | 1035 + 353 | T.T | 3 x 30.0 | Cleveland | C |
| 18. | Eastern | 87 + 097 | T.T | 1 x 25.0 | " | D |
| 19. | " | 89 + 847 | T.T | 1 x 25.0 | " | D |

Notes: A: Structural Defect and deterioration
B: Deformation of bridge members
C: Severe corrosion of floor beams
D: Excessive movement of shoes

(6) Prior to enforcing the improvement plan, it is preferable to carry out the following investigations:

i ) Periodical measurement for displacement of substrucutre and to investigate its cause.

ii ) Test in order to ascertain the coefficient of friction between the elements to be connected by high strength bolts, using members of dismantled bridges. The contact surfaces should be treated to the same degree as applicable in the actual work.

iii) Test of applicability of flame cleaning and its contribution for increasing the coefficient of friction between elements to be connected by high strength bolts.

(7) In the bridge at Km 187 + 240 on the Eastern Line, a special attention would be required during and after high water periods for the safety of train operations. The river course had so changed since its construction that the Eastern pier might be endangered during extraordinary floods.

(8) It is suggested that it may be beneficial for RSR in implementing the recommendations contained in the report, to obtain a few advisors for technical and financial requirements for a first few initial years.

# XII. DATA LIST AND ITS SUMMARY

# XII. DATA LIST AND ITS SUMMARY

We provide herein a summary of data required for implementing the proposed improvement program as obtained from the preliminary, final and additional surveys in Thailand and office work in Japan, breaking down such data into 5 major categories as follows:

1) Data outlining the present situation of RSR
2) Data outlining the proposed improvement program of RSR
3) Data showing the Thailand's technical level on steel bridge works
4) Technical evaluation data required for implementing the program
5) Cost calculation Data

(1) Data outlining the present situation of RSR

It outlines the present situation of RSR facilities and provides the breakdown of traffic volume - passengers and freights - by route. The Data show that the northern and the southern lines have a predominant share in passenger transport. Relative data numbers are 6, 19, 23, 45 and 46.

(2) Data outlining the proposed improvement program of RSR

The data pertain to the Third 5-year Plan, the Fourth 5-year Plan, current and future projects.
Relative data numbers are 7, 8, 14 and 44.

(3) Data showing the Thailand's technical level on steel bridge works

These data show the Thailand's technical level on the design, manufacture and erection of steel bridges. The data clarify that most of bridges manufactured and erected by the RSR work shops during the past three years of 1973 through 1975 are of the through plate girder type, and works involving 45 spans and 660 tons of steel were executed.

Up to now, no truss type bridges have been manufactured or fabricated in Thailand. Relative data numbers 10, 11, 24, 25, 33 and 39.

(4) Technical evaluation data required for implementing the program

The data provide bases of technical evaluation in performance of this program. Relative data numbers are 30, 31, 34, 35, 36, 41, 42 and 43.

(5) Cost estimation data

The data pertain to the cost estimation on execution of this program. As a whole, sufficient data have not been collected.

Actual expenditures on repair, strengthening and replacement of bridges in the past show considerable fluctuations, but basic data for assessing standard construction cost have been collected.

Relative data numbers are 9, 10, 12, 20, 21, 22, 27, 28, 29, 32 and 40.

## Data List

| No. | Description of data | Size | Original or Copy | Number | Collection date | Data source |
|---|---|---|---|---|---|---|
| 1. | Further Report on the Survey of Railway Bridges (12.5 & 13.75 tons axle loadings) by UKRAS | Book | Original | Vol. 11<br>Vol. 19 | 75,11,5 | |
| 2. | Location Map of the Bridges | 1-drawing | Copy | 4 | 75,11,5 | |
| 3. | Standard Loading Diagram | Drawing | Copy | 4 | 75,11,5 | |
| 4. | Drawings of the Steel Bridges on This Project | B-1 Size drawings | Copy | 479 | 75,11,5 | |
| 5. | Bridge List on This Project | A–3 | Copy | 1 | 75,11,5 | |
| 6. | Passenger & Freight Traffic | Sheet | Copy | 1 | 75,11,5 | |
| 7. | R.S.R. Investment Program (1972 – 1976) | Sheet | Copy | 1 | 75,11,5 | |
| 8. | Civil Engineering Department Investment Program (1972 – 1976) | Sheet | Copy | 1 | 75,11,5 | |
| 9. | Unit Cost of Material and Labour in Thailand (Oct., 1975) | Sheet | Copy | 1 | 75,11,5 | |
| 10. | Production Old Steel Bridges Repair in the R.S.R. Workshop (1973 – 1975) | Sheet | Copy | 1 | 75,11,5 | |
| 11. | Production Old Steel Bridges Repair in the R.S.R. Workshop (1976 – 1977) | Sheet | Copy | 1 | 75,11,5 | |
| 12. | Standard Wage in R.S.R. Workshop | Sheet | Copy | 1 | 75,11,5 | |
| 13. | The Organization of R.S.R. Workshop (Permanent Way Depot Division only) | Sheet | Copy | 1 | 75,11,5 | |

## Data List

| No. | Description of data | Size | Original or copy | Number | Collection date | Data source |
|---|---|---|---|---|---|---|
| 14. | R.S.R. Investment Program (1977 – 1981) | Sheet | Copy | 1 | 75,11,5 | |
| 15. | Calculation Sheet of UKRAS | Book | Original | 1 | 75,11,5 | |
| 16. | Viaduct (Strengthening of truss) | Sheet | Copy | 1 | 75,11,5 | |
| 17. | Photo Album | Book | Copy | 3 | 75,11,5 | |
| 18. | R.S.R. Civil Engineering Department Investment Program (1977 – 1981) | Sheet | Copy | 1 | 75,11,5 | |
| 19. | Passenger & Freight Traffic | Sheet | Original | 1 | 75,11,5 | |
| 20. | Examples of RSR's Cost Calculation in Bridge Construction Work | Sheet | Copy | 1 | 75,11,5 | |
| 21. | 214 Steel Bridges Improvement Project | Sheet | Copy | 1 | 75,11,5 | |
| 22. | Customs Tariff and Business Tax | Book | Original | 1 | 75,11,5 | |
| 23. | 1974 – Information Booklet | Book | Original | 1 | 75,11,5 | |
| 24. | Specification for the Supply of Steel Superstructure of Railway Bridge BE 2515 | Sheet | Copy | 1 | 76,3,26 | R.S.R. |
| 25. | Specification for the Supply of Steel Superstructure of Railway Bridge BE 2518 | " | " | 1 | " | " |
| 26. | Standard of Round Bars | " | Original | 1 | " | " |
| 27. | Answer to the Questions of Japanese Survey Team | " | Copy | 1 | 76,3,30 | " |
| 28. | List of Dismantled Bridges | " | " | 1 | " | " |
| 29. | List of Dismantled Bridges at Bridge Shop (in Thai) | " | " | 1 | " | " |

## Data List

| No. | Description of data | Size | Original or Copy | Number | Collection date | Data source |
|---|---|---|---|---|---|---|
| 30. | Km 311 + 599 (N-Line) Main Deflection Drawing (in Thai) | Sheet | Copy | 1 | 76,3,30 | R.S.R. |
| 31. | Km 560 + 390 (NE-Line) Topographic View Below Girder (in Thai) | " | " | 1 | " | " |
| 32. | Detail of Repairing Steel Bridge in State Railway of Thailand | " | " | 1 | " | " |
| 33. | State Railway of Thailand Bridge Depot | Book | Copy | 1 | " | " |
| 34. | Drawings of Substructure<br>E-Line km 41 + 764, km 80 + 022, km 84 + 393, km 87 + 110, km 89 + 855 km, 110 + 771, km 112 + 800, km 116 + 010, km 119 + 825 | Drawing | " | 9 | " | " |
| 35. | Bridge Stress Analysis Plan<br>N-Line km 4 + 216, km 10 + 241 | Drawing | " | 2 | " | " |
| 36. | Loaded Train Plan, Axle Load Table | " | " | 2 | " | " |
| 37. | R.S.R. Train Operation Diagram | Sheet | " | | " | " |
| 38. | UKRAS' Stress Analysis Results<br>1. Loading test results<br>2. Material test results | " | " | 1 | " | " |
| 39. | Engineering and Construction Machinery List | " | " | 1 | 76,8,5 | Yokokawa Bridge Construction Works |
| 40. | Cost of Dismantling of Old Bridge and Erection New Bridge | " | " | 1 | 76,8,20 | R.S.R. |
| 41. | Work Progress Chart (in Thai) | " | " | 1 | " | " |

## Data List

| No. | Description of data | Size | Original Copy | Number | Collection date | Data source |
|---|---|---|---|---|---|---|
| 42. | Photos of R.S.R. managed Works | Photo | Copy | 15 | 76,8,20 | R.S.R. |
| 43. | Km 187 + 240 (E-Line) River Bed Plan | Drawing | 〃 | 1 | 76,8,13 | 〃 |
| | 〃 General View | 〃 | 〃 | 1 | 〃 | 〃 |
| 44. | Timber Bridge Replacement | Sheet | 〃 | 1 | 76,8,23 | 〃 |
| 45. | 1975 – Information Booklet | Book | Original | 1 | 76,11,18 | 〃 |
| 46. | Time Loss due to Speed Restriction | Sheet | Copy | 1 | 76,11,18 | 〃 |