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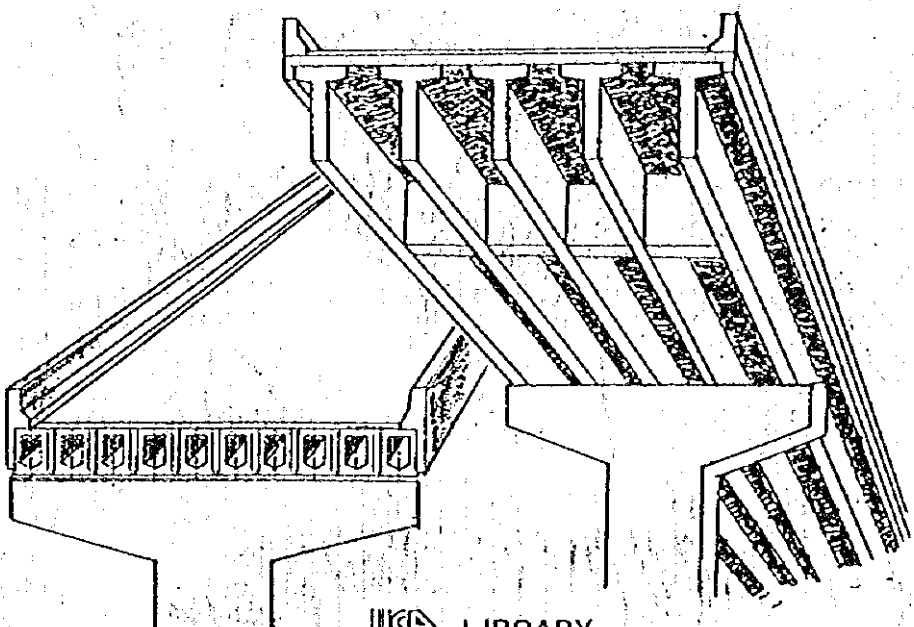
JAPAN INTERNATIONAL COOPERATION AGENCY
PUBLIC WORKS DEPARTMENT
MINISTRY OF WORKS, MALAYSIA

THE STUDY ON THE STANDARDIZATION OF BRIDGE DESIGN IN MALAYSIA

FINAL REPORT

VOLUME II

MAIN REPORT



AUGUST 1996

JAPAN BRIDGE & STRUCTURE INSTITUTE, INC., TOKYO
PACIFIC CONSULTANTS INTERNATIONAL, TOKYO

THE STUDY ON THE STANDARDIZATION OF BRIDGE DESIGN IN MALAYSIA FINAL REPORT VOLUME II MAIN REPORT AUGUST 1996

CURRENCY EQUIVALENT

(As of 1st February, 1996)

Currency Unit: Ringgit (RM)

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PREFACE

In response to a request from the Government of Malaysia, the Government of Japan decided to conduct the Study on the Standardization of Bridge Design in Malaysia and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Malaysia a study team headed by Mr. Isamu HISADA from Japan Bridge & Structure Institute, Inc., four times between August 1994 and July 1996.

The team held discussions with officials concerned of the Government of Malaysia, and conducted field surveys, design and drawing works at the study area. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of Malaysia for their close cooperation extended to the team.

August 1996

Kimio Fujita
President
Japan International Cooperation Agency

Letter of Transmittal

August, 1996

Mr. Kimio Fujita
President
Japan International Cooperation Agency

Dear Sir,

It is a great honor for me to submit herewith the final reports of the Study on the Standardization of Bridge Design in Malaysia.

A study team, which consists of Japan Bridge and Structure Institute Inc. and Pacific Consultants International and headed by me, conducted field surveys, design and drawing works in Malaysia based on the terms of references instructed by the Japan International Cooperation Agency (JICA) from August, 1994 to July, 1996.

The study team held thorough discussions and investigations with officials concerned of the Government of Malaysia, accordingly, developed computerized design and drawing systems for the standard bridges, conducted the designs, prepared standard drawings and also design manuals. The results were collected in the final reports, Volume I to IV

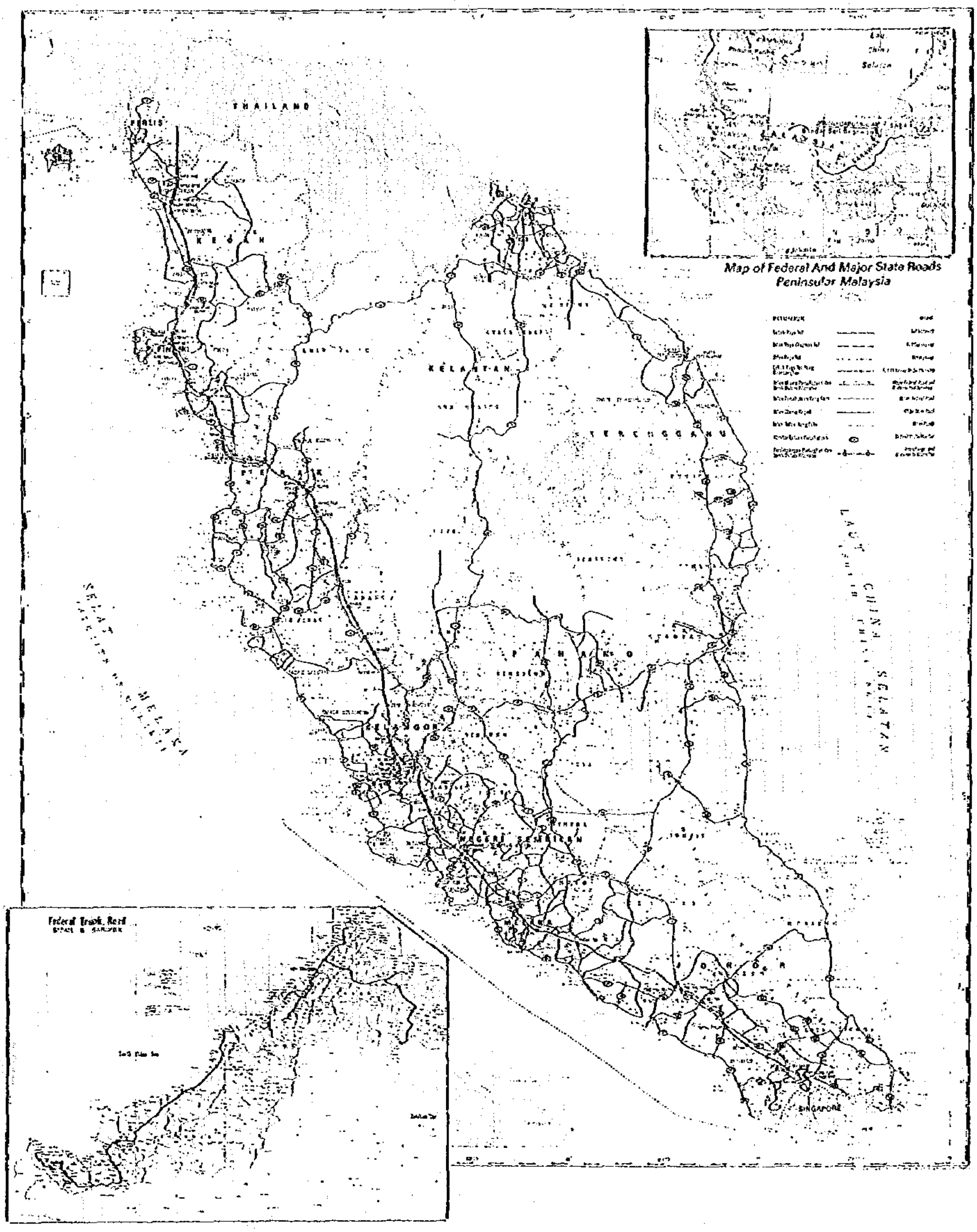
On behalf of the team I wish to express my heartfelt appreciation to the Officials concerned of the Government of Malaysia for their warm friendship and cooperation extended to us during our stay in Malaysia.

Also, I wish to express my sincere appreciation to JICA, the Ministry of Foreign Affairs, the Ministry of Construction, the Embassy of Japan in Malaysia and other concerned government authorities for their valuable advice and cooperation given to us in the course of the site surveys and preparation of the final reports.

Yours faithfully,

ISAMU HISADA
Team Leader
The Study on the Standardization of
Bridge Design in Malaysia

LOCATION MAP



VOLUME II - MAIN REPORT

CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATION

(In Alphabetical Order)

AR	Arch
BC	Box Culvert
BL	Bailey Bridge
BS	British Standard
BX	Concrete Box Girder
C & CA	Cement & Concrete Association, UK
CADD	Computer Aided Design and Drafting System
CG	Continuous Girder
CS	Cable Stayed Bridge
CT	Cantilever
Co., Ltd.	Company Limited
DID	Drainage and Irrigation Department
DRG	Drawing
EPU	Economic Planning Unit
EUDL	Equivalent Uniformly Distributed Load
FR	Frame
GOJ	Government of Japan
GOM	Government of Malaysia
HPU	Highway Planning Unit
HR	Hour
HWL	Design High Water Level
ISO	International Organization Standardization
IT	Inverted Tee Beam
JICA	Japan International Cooperation Agency
JKR	Jabatan Kerja Raya (Public Works Department)
JS	Japanese Standard
JSCE	Japan Society of Civil Engineering
KEL	Knife Edge Load
LTAL	Long Term Axle Load
MMS	Malaysian Meteorological Services
MOT	Ministry of Transport
MS	Malaysian Standard

MTAL	Medium Term Axle Load
NALS	National Axle Load Study
OT	Others
OJT	On the job training
P.C.	Prestressed Concrete
PC	Pipe Culvert
PCDG	Prestressed Concrete Development Group, UK
R.C.	Reinforced Concrete
S/W	Scope of Work
SAR	Steel Arch Bridge
SBX	Steel Box Girder
SG	Simple Girder
SIRIM	Standards and Industrial Research Institute of Malaysia
SLS	Serviceability Limit State
SMP	Sixth Malaysia Plan
SPT	Standard Penetration Test
SSAL	Substandard Axle Load
STG	Steel Simple Girder
TR	Truss
UDL	Uniformly Distributed Load
UK	United Kingdom
UPV	Ultrasonic Pulse Velocity
ULS	Ultimate Limit State

ABBREVIATIONS FOR MEASUREMENTS

mm	millimeter
cm	centimeter
m	meter
km	kilometer
mm2	square millimeter
cm2	square centimeter
m2	square meter
cm3	cubic centimeter
m3	cubic meter
kg	kilogram
ton	metric ton
N	newton (9.8067 N = 1 kgf)
kN	kilo newton
t.m.	ton meter (1 t.m. = 9.8067 kN m)
kN.m	kilo newton meter
kgf/cm2	kilogram (force) per square centimeter (1 kgf/cm2 = 98.067 Kpa)
N/mm2	Newton per square millimeter (1 N/mm2 = 1,000,000 Pa = Mpa)
Pa	pascal (1 Pa = 1 N/m2)
KPa	kilo pascal
MPa	mega pascal (1 MPa = 10.197 kgf/cm2)
V	velocity
A	area
L	length
r	radius of gyration
psi	pounds per square inch (1 psi = 0.07031 kgf/cm2)
°C	degree centigrade
%	percent
m/s	meter per second
sec	second
RM	Ringgit Malaysia

CHAPTER 1 INTRODUCTION

1.1 General

This Main Report, as Volume II of Final Report, was prepared for the Study on the Standardization of Bridge Design in Malaysia and submitted to the Public Works Department (JKR), Ministry of Works, Malaysia in accordance with the agreement between JKR and Japan International Cooperation Agency (JICA).

The Report presents the results of all the Study Phases from the Phase I to VI carried out during the Study period (August, 1994 - July, 1996) in accordance with the flow chart of the Study shown in Fig. 1.1.

1.2 *Background of the Study*

Of the national transportation system in Malaysia, road is the most dominant transportation mode for both passenger and freight. The traffic survey in 1991 shows that road carried as high as 99.8% of total passengers and 98.5% of total freight in the country and it is also expected that in the next decade the role of road will become increasingly important.

In an effort to improve the efficiency of the road transportation of the country, the Government of Malaysia (GOM) undertook the National Axle Load Study, Phase I in 1986 to 1988 and which reported that the loading capacity of bridges was becoming a major constraint due to the increasing number of heavy vehicles. To cope with the aging of the bridges, GOM carried out the Bridge Rehabilitation and Maintenance Study in 1992 by receiving the technical assistance of JICA. The study pointed out various problems of the bridges and some of which came from lack of the standard design and construction. The study, therefore, recommended another study for standardization of the bridge to improve the bridge design, construction and maintenance in the country.

In response to the above recommendation and the request of GOM, JICA dispatched the scope-of-work mission in December, 1993 to confirm the outline of the next study to GOM.

Thus, the JICA Study on the Standardization of Bridge Design in Malaysia was started from August, 1994.

1.3 Objective of the Study

The main objectives of the Study are:

(1) Preparation of standard bridge design,
(2) Development of computer aided design and drafting (CADD) system for standard bridge design, and
(3) Preparation of manuals for bridge planning, design, construction and cost estimate.

Additional objective is the transfer of technology to the Malaysian counterparts through the Study.

1.4 Scope of the Study

1.4.1 Bridge Type

The bridge type to deal with in the Study is limited to concrete beam bridges with span length of up to 45 m but does not cover steel bridges. Although the design of superstructure is the primary objective of the Study, the design of substructure will also be carried out for typical cases, partially by computerized analysis.

1.4.2 Design Standard

The design standard was discussed in the Technical and Steering Committee and confirmed as follows:

(1) Design Standard

The British standard based on the limit state design theory was adopted in line with JKR's usage. However JKR understood that the Japanese standard could be used in areas which are not covered by the British Standard.

(2) Design Load

The latest British loading specification, BD 37/88 was adopted according to the load strengthening plan of JKR.

1.5 Schedule of the Study

The Study is divided into six phases and consists of the following study components. The overall schedule of the Study is shown in Fig. 1.1 – Flow Chart of the Study.

Phase I Data Collection and Survey

(1) Review of standards and specifications
(2) Survey on current practice of bridge design and construction
(3) Bridge site survey
(4) Survey on computer use

Phase II Selection of Bridge Types and Computer System

(5) Establishment of design standards and conditions
(6) Selection of bridge types and span range
(7) Selection of computer system

Phase III Development of Design Analysis System

(8) Defining of design analysis system
(9) Development of computer programme for design analysis

Phase IV Development of Drawing System

(10) Defining of drawing system
(11) Development of computer programme for drawing

Phase V Execution of Standard Design Work and Preparation of Manual

(12) Execution of standard design analysis
(13) Execution of standard drawings
(14) Preparation of manuals

Phase VI Presentation of Design and Drawing System, Preparation and Submission of Final Report

(15) Preparation of draft final report
(16) Preparation of final report
(17) Presentation of standard design and drawings

1.6 Organization for the Study

For smooth implementation of the Study, GOM set up the Steering Committee and under it the Technical Committee in the JKR headquarters. JKR designated the Bridge Unit of Roads Branch as the counterpart agency to the Study Team and assigned two counterpart engineers.

JICA organized the Advisory Committee to provide advice and guidance for the execution of the Study, and the Study Team comprises eleven specialists under the Team Leader.

The above organizations are illustrated in Fig. 1.2.

1.7 Major Activities

1st Fiscal Year

24th Aug. 1994 : Technical Committee meeting for Inception Report and design standard.

25th Aug. : Steering Committee meeting for Inception Report and design standard (the Minutes of Meeting in Appendix A).

26th Aug. : Visit PC beam factory – Hume Industry.

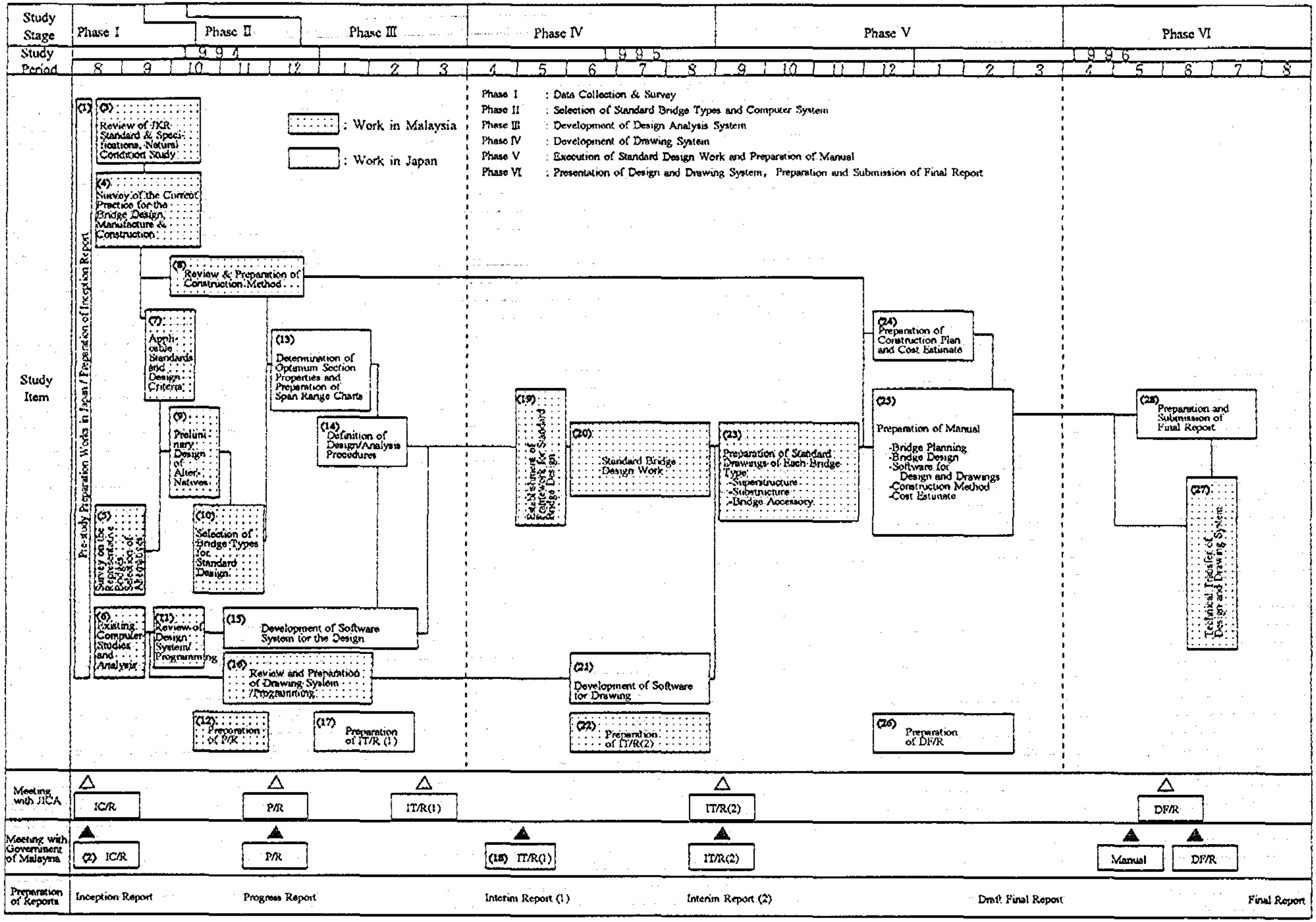


Fig. 1.1 Flow Chart of the Study

The Organizations are illustrated in Fig. 1.2.

Steering Committee

Chairman : Dato' Ir. Chua Soon Poh
Director of Roads
Branch, JKR HQ
Member : Economic Planning Unit
Member : Ministry of Works
Member : Asst. Director, Bridge Unit
Member : Engineer, Bridge Unit
Member : Engineer, Bridge Unit

Japan International Cooperation Agency (JICA)

Social Development Study Division
Coordinator : Mr. Y. Ikeda
Malaysia Office : Mr. Y. Yamamoto

JICA Advisory Committee

Chairman : Mr. K. Nishikawa
Member : Mr. Y. Inokuma
Member : Mr. H. Hoashi

Technical Committee

Chairman : Ir. Rohani Abdul Razak
Asst. Director, Road Branch
Member : Ir. Ismail B. Mohd Taib
Member : Mr. Amir Ismail
Member : Mr. Zainuddin Jasmani
Member : Ms. Normala Hassan

JICA Study Team

Team Leader : Mr. I. Hisada
Dep. Team Leader (System Engineer) : Mr. H. Sakai
Dep. Team Leader (Bridge Engineer) : Mr. H. Honda
Cost Estimation/Construction Planner : Mr. T. Tokozumi
Bridge Engineer : Mr. T. Chujyo
Bridge Engineer : Mr. H. Takaura
Hydrology/River Engineer : Mr. T. Furukawa
System Design : Mr. C. Kanemitsu
System Design : Mr. C. Ogiwara
System Design (Programming) : Mr. H. Suzuki
System Design (Programming) : Mr. T. Hanajima
Assistant : Mr. K. Kataoka

Counterparts

Engineer : Mr. Amir Ismail
Engineer : Mr. Zainuddin Jasmani
Engineer : Ms. Normala Hassan
Engineer : Ms. Rozita Mat Senapi
Engineer : Mr. Mohd. Fairuz bin Mohamad
Engineer : Mr. Mohd. Yunos Ali

Fig. 1.2 Organization for the Study

1st–25th Sep.	:	Bridge site survey trip to west and east coasts of peninsular Malaysia and Sabah/Sarawak.
5th–27th Oct.	:	Discussion and exchanging ideas with Malaysian consultants and contractors.
25th Oct.	:	Visit PC pile factory – Petro–pipe–Daido.
24th, 27th, 29th Oct. & 3rd Nov.	:	Technical Committee meetings for design standard (design load, combination of loads, grade/class of material, etc.)
4th & 15th Nov. 22nd Nov.	:	Technical Committee meetings for Draft Progress Report.

2nd Fiscal Year

11th May, 1995	:	Technical Committee meeting for technology transfer, workshop and training of counterpart in Japan.
25th May	:	Technical Committee meeting for explanation of Interim Report (1).
29th May	:	A set of personal computers were procured by JICA and set at the Study Team site office.
1st June	:	The Steering Committee for the Interim Report (1) (The Minutes of Meeting in Appendix J).
13th June	:	Two JKR engineers were posted to the Study Team for OJT on the design of the standard bridge.
28th June, 3rd & 4th July	:	Visiting sites of LRT, expansion joint and Middle Ring Road projects
4th & 14th July	:	Technical Committee meetings for substructure design.
24th July	:	Meeting with Alcom on proposed bridge hand rail.
1st Aug.	:	Additional two JKR engineers were posted to the Team for OJT on the design work.
4th Sep.	:	Two JKR draughtmen were posted to the Study Team for OJT on the drawing work.
2nd Oct.	:	Dialogue with the local Manufacturers of precast beams.
12th–14th Oct.	:	Visiting PC beam factory and the Second Ring Road in Johor

Bahru.

23rd Nov.	:	Technical Committee meeting for the Interim Report (2).
24th Nov.	:	The Steering Committee meeting for the Interim Report (2). (The Minutes of Meeting in Appendix K)
27th Nov.	:	One day Seminar for the Standardization of Bridge Design.

3rd Fiscal Year

27th–28th May, 1996	:	Explanation and discussion on the Design Manual with JKR Bridge Unit
1st July	:	Pre-technical committee meeting on Draft Final Report and other related subjects
4th July	:	Technical Committee meeting for explanation of Draft Final Reports and the final seminar
5th July	:	Steering Committee meeting for explanation of Draft Final Reports
8th July	:	Signing ceremony of the Minutes of Meeting (Appendix L)
9th July	:	The seminar on the Standardization of Bridge Design in Malaysia at Hotel Equatrial, K. L.

CHAPTER 2 DATA COLLECTION AND SURVEY (PHASE I)

2.1 Review of Existing Standards and Specifications

2.1.1 General

Due to historical relation with United Kingdom (UK), Malaysia has adopted the British standards for bridge design and construction since the 1940's. However, in such condition of the bridges in the country in recent years as the accumulation of highway bridges and the number of heavy vehicles have increased rapidly, there is a growing concern in JKR (Public Works Department) to set up the own bridge loading specification reflecting the actual traffic condition and foreseeing the future highway development of the country. Meanwhile, DID (Drainage and Irrigation Department) has recently started preparing a guideline of the hydrological requirements for the bridge construction crossing rivers and canals.

The standards, specifications, and guidelines of Malaysia for bridge planning and design were reviewed both of being in use and planned to adopt, and that became the grounding in establishing the design standard for the Study.

2.2 Outline of Introduction of British Standards

The first introduction of the British standard in Malaysia was BS153 in 1945: that was for the design of steel girder bridge and the standard introduced for the first time the general idea of HA loading - equivalent uniformly distributed load with a knife edge load. In 1954, BS153 added another live load concept of HB loading for the passage of exceptional industrial vehicles, but the application of HB loading in Malaysia was not put into practice until the early 1970's. The practice of HB loading in Malaysia, seemed to be from around 1972, was conditioned to be guided along the center-line of the bridge deck with no other vehicles allowed on the bridge, being different from the practice in UK.

For the design of foundations of bridges, CP2004 was used and the revised edition, BS8004 was put into practice from around 1980.

In the early 1980's, JKR adopted BS5400 as an official standard for design and construction of bridges. The BS5400 was a first comprehensive standard published in 1978 in UK combining the design and construction of steel, concrete and composite bridges and specifications for loads, materials and workmanship. It incorporated for the first time the idea of limit state design method, and made modification on the live load specification i.e. (1) the intensity of HA loading was reduced in the loaded length of less than 30m and vice versa for over 30m and (2) variable spacing as introduced to the inner axle spacing of HB loading.

BD 21/84 was introduced into Malaysia in the mid 1980's for the assessment of highway bridges and structures. It increases the HA loading intensity for the span range of less than 30m.

The revised HA loading curb of BD21/84 was used as the basis of the Long Term Axle Load (LTAL) in the JKR's live load specification of 1990.

In 1988, the British live load specification was revised by BD37/88 taking into account the results of the research in UK since the loadings specified in BS153 and BS5400-Part2 such as (1) there has been a significant increase in the number of heavier vehicles, (2) the maximum weights of normal commercial vehicles permitted have increased, and (3) impact, overloading and lateral bunching were revealed to influence the loading in the shorter span range higher than what was envisaged before.

2.1.3 Bridge Design Standards in Malaysia

As above outlined of the introduction of British Standards, the following latest editions of the British Standards and their modifications are in use in Malaysia as the general standards for design and construction of highway bridges:

(1) BS5400:

For design and construction of steel, concrete and composite bridges except Section 6 - Highway Bridge Live Loads of Part2 (1978) - Specification for Loads which is superseded with JKR Specification for Bridge Live Load (1990).

(2) JKR Specification for Bridge Live Load (1990):

Prepared by JKR based on BS5400 Part 2, BD21/84 and National Axle Load Study - Phase I.

(3) BS8004:

For the design and construction of foundations.

(4) BS8110:

For the design and construction of concrete structure.

Besides the general standards mentioned above, many of other British industrial standards for materials, tests and workmanship, some of which have already been introduced into the Malaysian standards, are in use as well including the followings, for examples:

BS4447:

Specification for the performance of prestressing anchorages for post-tensioned construction.

BS4449:

Specification for carbon steel bars for the reinforcement of concrete,

BS4461:

Specification for cold worked steel bars for the reinforcement of concrete,

BS4466:

Specification for bending dimensions and scheduling of bars for the reinforcement for concrete,

BS4486:

Specification for hot rolled and processed high tensile alloy steel bars for the prestressing of concrete,

BS4757:

Specification for nineteen-wire steel standard for prestressed concrete, and so on.

2.1.4 JKR Specification for Bridge Live Load

The JKR Specification for Bridge Live Load was formulated in 1990 through the review in the Bridge Loading Committee set up in the Bridge Unit of JKR of the results of the National Axle Load Study (NALS), Phase I in 1986 to 1988. The NALS Phase I warned that insufficient loading capacity of the bridges was becoming a major constraint of the road transportation in the country and recommended to have own traffic loading specification to meet the traffic condition and in accordance to the future road development plan of Malaysia.

The JKR live load specification was prepared in line with the general concept of the highway bridge live loads of BS5400-Part 2 and taken into account the revision of the HA loading curve in the shorter span range of less than 30m by BD21/84, but did not take up a drastic change of the concept of BS5400-Part 2 to coordinate with the long use of the British standards in the past in Malaysia. However, instead of the HB loading of BS5400-Part 2, the JKR live load specification worded out the special vehicle loading consisting of a tractor and a multi-axle trailer based on the past application records to JKR of abnormal vehicle passing.

The main features of the JKR live load specification in comparison with BS5400-Part 2 are as follows:

(1) The JKR live load specification shall be applied in conjunction with all the other parts of BS5400 except Section 6-Highway Bridge Live Load of BS5400 Part 2.

(2) The limit of applicable loaded length of 50m was introduced based on the fact that most bridges in Malaysia are not over 50m in span length, while BS5400 Part 2 is applicable in longer span length.

(3) The JKR live load consists of Long Term Axle Load (LTAL) as normal loading and Special Vehicle (SV) load as abnormal loading being replaced with the concept of HA and HB loadings of BS5400 Part 2 respectively.

(4) Loads to be considered were specified as the selection of more severe effects of either a) design LTAL loading or b) design SV loading controlled or c) design SV loading uncontrolled combined with design LTAL loading. That is, in addition to the selection of a) or c) as similar as stipulated similarly in BS5400 Part 2, another selection of b) was added.

(5) Notional lane width was fixed to 2.5m, while BS5400 Part 2 takes variable width according to carriageway widths.

(6) LTAL loading consists of a Uniformly Distributed Load (UDL) and a Knife Edge Load (KEL), or of a Twin Wheel Load (TWL).

(7) UDL was derived from the loading curve in BD21/84 modified to suit 2.5m fixed lane width. The equation of UDL and its loading curve is given in Appendix C.

(8) KEL per notional lane width was taken as 100 KN modified from 120 KN in BS5400-Part 2 to suit 2.5m fixed lane width.

(9) TWL alternative to UDL and KEL was specified to apply two 112 KN wheel loads spaced at 1.8m apart, each placed on the carriageway and distributed over a circular contact area of 360mm diameter, while BS5400-Part 2 specified a single wheel load of one 100 KN over a circular contact area of 340mm diameter.

(10) SV loading consists of a tractor and a multi-axle trailer. The plan and axle arrangement are shown in Appendix C. The weight and the dimensions of a tractor are constant with a 60 KN and two 120 KN axles. The length of trailer and the number of trailer axles are variable depending on to cause the most severe effect in maximum 20 axles. One unit per trailer axle load is taken as 10 KN.

(11) SV loading was specified to apply in two ways following the loads to be considered mentioned above in the item (4) of this section.

(i) The SV loading controlled shall, under the load case b), be applied along the center-line of the bridge carriageway with no other vehicles allowed on the bridge. The appropriate number of units of trailer axle load shall be 20.

(ii) The SV loading uncontrolled shall, under the load case c), be applied together with the LTAL loading. The appropriate number of units of trailer axle load shall be 7. The configuration of the combined application of SV and LTAL loadings, shown in Appendix C was derived by simplifying the HA and HB loading combination method of BS5400-Part 2.

2.1.5 Hydrological Guidelines and Regulations for Bridge Design

2.1.5.1 Guideline of JKR

JKR has the guideline "Buku Panduan Rekabentuk Jambatan" for planning and designing of bridges formulated in 1985 mainly from the river hydrological view points.

Major contents of the guideline are as follows:

(1) Runoff and Hydraulic Analyses

Both runoff for the estimation of flood discharge and hydraulics to decide flood water level and velocity, shall be analyzed by the method authorized by DID.

(2) Design Discharge

100 year probability flood is adopted for the estimation of design discharge of river and drainage channel. 50 years is adopted for the design discharge of culvert.

(3) Bridge Opening

There is a provision of freeboard between HWL (high water level) and soffit of bridge beam to be taken as 0.3 to 1.0 m.

(4) Abutments and Piers

For abutments acting as retaining walls against approaching embankment of bridges, they shall be built with enough safety to current of flood.

Piers in rivers shall not affect flood flow adversely. Solid wall pier is the most favorable for it either traps drifting logs nor causes local scouring.

(5) Bank Protection

Bank protection shall be provided around abutments where scouring is anticipated.

2.1.5.2 Guideline of DID

DID is responsible for river planning and implementation of flood control. At present, DID is in preparation of a guideline of the hydrological requirements for the bridge construction across rivers, drainage channels and canals.

Major points of the guideline are as follows:

(1) Hydrological Check for Bridge Design

Preceding construction of bridge, the plan and design of the bridge shall be examined from the hydrological view point and approved by State DID.

(2) Direction of Bridge

Bridges shall be so planned as to cross river flow in perpendicular but shall not be planned in skew angle as much as possible.

(3) Design Discharge

The following return periods are recommended for the estimation of design discharge:

1)	Rivers in urban area	100 year
2)	Rivers in rural area	50 year
3)	Drainage channels	20 year
4)	Sewerage (including culverts) in residential area	2–3 year
5)	Sewerage culverts across main roads	25 year

(4) Bridge Opening

Abutments shall not be located inside of water way of river or drainage.

Freeboard between HWL and soffit of bridge beam is considered to take 0.6m for the rivers in rural area and 1.0m in urban area.

(5) Abutments and Piers

The location of abutments is specified as above in (4).

In bridge planning, it is required to minimize the number of piers inside of river as much as possible. The shape of pier shall be so design as to minimize resistance and disturbance to river flow. Along with that, oval-shape is recommendable.

Foundations of abutments and piers shall be embedded below river bed deeper than estimated scouring level with appropriate allowance.

2.1.5.3 River and Water Regulations

The following existing river and water regulations in Malaysia seem to be involved for the planning and designing of bridges across rivers and waters:

(1) Water Act–1920

Section 5 of Caption 146–Control of Rivers and Streams stipulated in 1989 prohibits any activities affecting rivers such as falling of any tree into river, obstructing or interfering with any river, building any bridge, jetty or landing stage over or beside any river (width more than 20 feet) except under a license. Water Act–1920 or its similar enactment is put into effect in most of the states in Peninsular Malaysia.

(2) Sarawak Land Code

Caption 81 stipulates that the State has sole property in rivers, streams, lakes and water courses.

(3) The Sabah Land Ordinance

Caption 68 stipulates that the State has sole property in rivers.

2.2 Current Practice of Bridge Design and Construction in Malaysia

2.2.1 General

The current practice of the bridge design and construction in Malaysia were studied such as in planning and construction planning for bridge construction.

The information summarized here was obtained from the discussions with JKR, local consultants and contractors, and from the surveys of construction sites and concrete factories.

2.2.2 Bridge Design

2.2.2.1 Bridge Planning

When a bridge proposal was drawn up, all necessary data for bridge planning including topographic, geological and hydrological surveys as well as geometric conditions were collected by the hands of States JKR engineers. In this stage, technical judgments made by the State engineers in charge were very important to take or to reject the data into future design work.

Recently, it became an obligation for the bridges of crossing rivers or channels to obtain the approvals of DID. The bridge design shall be examined hydrologically along the guideline of DID such as of location of abutments and piers, freeboard on HWL, from direction of piers, etc. The draft guideline has been completed to start applying from new bridge designs.

On public utility fixtures it is a basic concept that attachment of utilities to structures is not preferred and is prohibited from the view points of safety of structure and other publics and also of an aesthetical consideration. Only exception may be granted with approval from the Headquarters.

Geometric design of bridge is based on "the Guide on Geometric Design of Roads of JKR".

2.2.2.2 Bridge Design

Bridge design work for the federal routes in Malaysia is generally carried out by the Bridge Unit of JKR or by the Consultants appointed by the department.

The Bridge Unit on average carry out the design of about 40 bridges annually.

2.2.2.3 Standard Drawings of JKR

JKR owns standard drawings (lukisan-lukisan Tipikal Dan Piawai Untuk Projek Jambatan) for the following beams, abutments and piles:

(1) Beams

- Pre-tensioned inverted T-beam (span length of 12.5m, 14.93m, 16.76m and 18.9m)

- Post-tensioned I-beam (span length of 25m and 31.24m)

(2) Abutments (bank-seat type, width R5 (13m), H=2m and 2.15m with wing walls)

- For Inverted T-beam (12.5m span length)

- For Inverted T-beam (14.93m span length)

- For Inverted T-beam (16.76m, span length)
  Type I for RC square pile
  Type II for PC spun pile

(3) Piles

- RC square pile (250 x 250mm - 400 x 400mm)

- PC spun pile (Diameter 350mm - 700mm)

- Steel pipe pile (Diameter 570mm and 750mm)

- 'H' universal bearing pile

2.2.2.4 Details for Bridge Design

For design details JKR has their own design manual (Buku Panduan Rekabentuk Jambatan 1985) which explains design method, design procedure and sample design calculations in accordance with BS153 or BS5400.

(1) Influence of Earthquake

In Malaysia, earthquake force is not considered to the ordinary bridge designs except for the design of special bridges like channel bridge.

(2) Soil Investigation

Disturbed sampling is sometimes practiced for bridge design, but undisturbed sampling is seldom carried out.

Standard penetration test (SPT) is carried out according to BS1377. The value of the SPT is similar to that used in Japan.

Also vane shearing test (VST) is often carried out in soft ground.

In laboratory, triaxial compression test is carried out more than unconfined compression test.

(3) Raked Piles

In Malaysia, piles are generally designed for vertical load only but horizontal force to pile is not considered. To resist horizontal force, raked piles are always adopted in abutments and piers. Bearing force of piles in JKR are estimated based on the N-values of SPT test. Gearing force of piles is estimated by skin friction and point bearing support according to the Meyerhof formula.

The safety factor of bearing force of a pile is taken as 2.5 for point bearing piles and 2.0 for friction piles in JKR.

(4) Earth Pressure

Earth pressure against abutment is estimated by the earth pressure at rest (K0) of 0.50 in JKR. Although the value K0 is greater than the active earth pressure (Ka). Ka is usually used for the stability analysis of inverted T-type abutment in UK and Japan.

2.2.2.5 Construction Consideration

It is favorable to take account of construction method from the design stage. However, it is difficult for design engineers to consider the construction method in their design works because the construction method is generally the choice of contractors after contract in Malaysia.

2.2.3 Construction Materials and Precast Concrete Products

The information of construction materials and precast concrete products are mainly obtained from JKR and precast concrete factories in Malaysia.

2.2.3.1 Construction Materials

Raw and manufactured materials are produced or manufactured in accordance with MS complying to BS Code. The main construction materials of cement, reinforcing bars, prestressing tendons and timber are hundred percent supplied in Malaysia. These are adequate for current needs. Other materials like elastometric bearing, guard rail/hand rail, steel angle/channel, steel form, pipe scaffolding are also manufactured locally. Heavy steel productions like steel pipe pile, sheet pile and H-section pile have been recently manufactured in Malaysia.

Four kinds of Portland Cement like ordinary, ordinary rapid hardening, moderate sulphate resisting and sulphate resisting cement are manufactured. Granite crashed coarse aggregate with maximum size of 20mm and fine aggregate graded size of 5mm down from river sand or washed mining sand are normally used for concrete structures in Peninsula. On the other hand, the quality of sandstone coarse aggregate in the states of Sabah and Sarawak is not hard enough for high strength prestressed concrete. The ready-mixed concrete of grades 15 to 50 ($50N/mm^2$ at 28 days strength) are available in the major cities of Peninsula.

Mild steel round bar ($250N/mm^2$ yield stress) and high yield deformed bar ($460N/mm^2$ yield stress) of size range 8mm to 32mm with 12m standard length are manufactured for the use of concrete structures. For use of post-tensioning, VSL, Freyssinet and BBRV anchorages are available according to user's requirement.

2.2.3.2 Precast Concrete Products

(1) Pre-tensioned Prestressed Concrete Beam

The pre-tensioned prestressed concrete beams are manufactured by two companies whose factories are located in the major cities of Peninsula. Three types of beams are designed and manufactured in accordance with BS5400 (steel, concrete and composite bridge 1984) and they are widely used throughout Peninsula, as follows:

- M-Beams (for spans from 16 to 29m)

  These beams were developed by the C&CA (Cement & Concrete Association), UK. The beams are laid at 1.0m center.

- I-Beam (for spans from 18.3 to 27.4m)

  These beams were developed by the C&CA, UK. They are spaced at 1.5m center and constructed with diaphragm beams.

- Inverted T-Beam (for spans from 5.5 to 19.3m)

  These beams were developed by PCDG (Prestressed Concrete Development Group), UK. These beams are spaced at 508mm center.

Required concrete cube compressive strength of beams are between 45 and $50N/mm^2$ at 28 days and prestressing strand of 7 - 12.9mm ($1860N/mm^2$ yield stress) is used. Beams are cured by covering and maintaining them in a wet condition by the application of low pressure steam until the specified cube strength is reached.

(2) Precast Concrete Pile

Prestressed spun concrete piles and reinforced square cross section piles are manufactured by several companies whose factories are located in the major cities of Peninsular and are widely used for the construction projects. These piles are designed and manufactured in accordance with BS and MS code.

Prestressed spun concrete piles are joined on site to form piles of various required lengths and come in diameters of 250mm to 800mm and in length of 6m to 18m. Prestressed spun piles are precast product manufactured by a centrifugal compactness process. The use of steam curing allows the piles to achieve the necessary strength faster, compressive concrete cube strength reaches 50N/mm^2 at 28 days. Generally the piles can be driven after 14 days. One of the pile company products prestressed spun piles are applied with autoclave curing processing which produced concrete compressive strength of 80N/mm^2 within 1 day of casting.

Precast reinforced concrete piles with square cross section are manufactured in sizes ranging from 150mm to 400mm square and joined on site to form piles of required length with the use of plate welded joint. Minimum pile concrete cube strength is 45N/mm^2 at 28 days.

(3) Quality Control in Factory

The major precast concrete production factories have been awarded the ISO 9002 certified by the Standards and Industrial Research Institute of Malaysia (SIRIM). Quality control procedures, including the regular testing and inspections are carried out continuously by the relevant MS and BS Codes of Practices and Quality Assurance System (ISO 9002).

2.2.4 Construction Method

The information of current bridge construction methods, the launching of precast concrete beams and construction of piling are mainly obtained from JKR and the local/foreign contractors. In addition, field survey was conducted at several existing bridge sites and at a few construction sites.

(1) Contractors

The various types of contractors usually involved on construction projects are: main contractor, special contractors/nominated sub-contractors and labour sub-contractors. The nominated sub-contractors concerning bridge construction are piling sub-contractors and prestressing sub-contractors.

The use of heavy construction equipment procuring from overseas have become popular particularly in the big cities. Bull-dozers, tractors, pile driving for precast and cast-in-situ, track cranes, crawler cranes etc. are quite commonly used. The contractor can either rent or lease particular equipment of sheet pile/H-section pile for temporary works from the equipment leasing companies.

(2) Typical Type of JKR Bridge

The relatively new bridge construction and replacement for short and middle spans in the late 1980's and the early 1990's are commonly precast prestressed concrete beams which are supported on the pile-bent type piers and the bank seat type abutments with prestressed spun piles or steel piles forming 1:5 to 1:4 rake in Peninsula, whereas, in Sabah and Sarawak the imported rolled steel I-beams composited with reinforced concrete slab have been usually constructed because of poor quality of sandstone. These beams are supported on the pile bent type piers and the bank seat type abutments with steel piles or precast reinforced concrete piles.

(3) Launching of Precast Prestressed Concrete Beams

Most of the precast prestressed concrete beams with lengths of up to 30m are lifted and launched by a single truck crane or two truck cranes depending on the weight of beams and site conditions. Truck cranes with the lifting capacities of 15 ~ 50tons are commonly used for handling and placing precast beams. Big truck cranes with the lifting capacities of 60 ~ 150tons are available but there are a very limited number of these particular cranes in Malaysia at the present time.

Launching method by the specialized launching girder is applied especially for the multi-span bridge with 20m to 40m span length.

(4) Pile Driving

Prestressed spun concrete piles are regularly used for JKR projects because the advantages over precast reinforced concrete piles are the large bearing capacity for the same section, large bending capacity and high durability due to great density of the concrete. Steel pipe piles are especially used at either deep depth of river water or deep penetration to reach a bearing stratum, or hard soil layer in between ground and bearing stratum.

Diesel hammers are commonly used for the driving of precast piles because this method is very advantageous e.g. the equipment is relatively simple, the construction speed is high, the materials are reliable, and the bearing capacity can be confirmed. However, they are becoming difficult to use in urban areas as this method generates noise and vibration.

(5) Bored and Cast-in-Place Piles

Bored cast-in-place piles are normally constructed in locations where noise and vibrations are restricted i.e. in urban areas or large scale bridge foundations. Micropiles are classified as small diameter (less than 300mm) bores cast-in-situ piles which are the desirable foundation in fractured rocks where the cracks/fractures can be grouted at the same as the grouting of the micropiles. Therefore, these piles are usually used for the ground of lime stone stratum.

(6) Expansion Joint

The most common type of joints are the buried joints for short span bridges and applied either elastometric joint on sliding steel plate joint for middle span bridges. The finger type joint is also applied mainly for long span bridges.

Asphaltic plug type joint (thorma joint) has been recently employed for the middle span bridges. This type gives a more comfortable ride and low noise level which is particularly used in urban area.

(7) Bank Protection

The river bank protections around the abutments are mostly made by grouted rip-rap with footing of wiremesh stone gabion or dumped stone. However, the shallow footing or insufficient length of bank protection allows local scouring thus affecting the stability of abutments. The retaining walls for the over bridges in urban area are commonly constructed by the Reinforced Earth method (Terre Armee method).

2.3 Bridge Site Survey

2.3.1 General

Bridge site survey was carried out to obtain general views on the existing bridges in Malaysia and that would help the Study understand actually what type of and how standard bridge designs were required in the particular environment of the country.

(1) Survey Area

The survey was planned to cover major representative areas in the geography and the road network of Malaysia.

The west coast of Peninsula Malaysia north and southward from Kuala Lumpur was indispensable as the area where the most populated, industrialized and developed of road network in the country, as well as there were expected to see the geological problems of irregular spread of limestone from the north of Kuala Lumpur to and soft alluvial deposits along the coastal plains southward.

Secondly, the east coast of the north half peninsula was chosen to see the influences of the monsoon and the ocean currents from South China Sea. Along the trans-peninsular route of Kuala Lumpur to Kuantan, the bridges situated in mountainous terrain could be surveyed.

The last was Sabah and Sarawak. The two states, as they were for apart from Peninsula, were also indispensable to study their characteristics of natural conditions, road and bridge constructions, administration system, and so on. It was a great interest to know if there were specific problems to the States in bridge construction in particular.

(2) Bridges Surveyed

Candidate bridges were picked up in advance from the bridge inventory of JKR adjusting to the survey schedule in each area chosen. The bridges were picked up so as to represent various aspects of the bridges large rivers, single and multi-span, poor and good rating of soundness, and so on. However, during the survey, some bridges were changed and added depending on the itinerary and by the recommendations of each State JKR. For Sabah and Sarawak, no bridge list could be prepared before, so, the survey there was carried out by the arrangement of the both states JKR.

A total of a little over 100 bridges were actually surveyed: 41 in the west coast of Peninsula, 34 along the trans-peninsular route and in the east coast, and 28 in Sabah and Sarawak. The itinerary and the bridge list surveyed are attached in Appendix together with the field reports.

(3) Method of Survey

The survey team, consisting of team leader, three bridge specialists (two for bridge structures and one for geological condition), a hydrology specialist and a JKR counterpart engineer, moved as a group and the state JKR officers joined the team in each area.

A bridge site was totally surveyed by dividing the job among the specialist into superstructure, substructure, geological and hydrological conditions. The survey was carried out in general on the following points:

1) General Data (to confirm the bridge inventory)

- Bridge name, No., and location.
- Year of construction and loading specification.
- Total and span lengths.
- Bridge and carriageway widths.
- Types of super and substructures.
- Normal or skew angle.
- Traffic load restriction or not.

2) Problem of Superstructure

- Problem, bridge rails, expansion joints and drains.
- Main beams, cross beams, and deck slab.
- Bearings.

3) Problem of Substructure

- Abutments.
- Piers.

4) Geological Problem

- Ground settlement.
- Approach road embankment.

5) Hydrological Problem

- River course, straight or curve.
- Bridge direction, normal or skew to river.
- Width and height of under-bridge opening, and freeboard on HWL.
- Type of pier and abutment structure, wall or pile bent.
- Direction of pier and abutment, parallel or skew to water flow.
- pier location and ratio of total pier widths to river width.
- Embedding of footing.
- Scour protection around pier and abutment.
- Location of abutment, out or inside of water way.

- Bank protection adjacent to abutment.

The results were recorded on the preformed bridge survey sheet with photographs per bridge. A sample of the sheet was attached in Appendix. Besides, the information of the state JKR staff and from the local people obtained during the survey was another good source to know the problems of the bridges deeper, such as the of past repair and reconstruction, construction method, past flood damage and water level, etc.

(4) Results

The field reports for the results of the survey prepared by the bridge and hydrology specialists were attached in Appendix D. The bridge survey sheets with photographs were compiled separately from this Report and were submitted to JKR.

The findings and recommendations obtained though the survey were summarized in the sections 2.3.2 and 2.3.3 hereinafter.

2.3.2 Summary of Bridge Survey

(1) Typical Bridges in Malaysia

In Peninsula Malaysia, most were concrete bridges. In particular precast PC beam bridges in span length not over 30m were dominant but steel bridge was very few seen except for some historic bridges.

Also in the Peninsula particularly along the west coast, many old RC beam bridges were still in service although they were aged, narrow of carriage way and inadequate of load carrying capacity. These old bridges were going to be replaced with wider and longer PC beam bridges.

In Sabah and Sarawak, steel bridges have been constructed more than concrete bridges. At small to medium river crossings, rolled steel I-beam or welded steel plate girder bridges were often used like precast PC beam bridges in Peninsula.

However, in Sarawak, at large river crossings where large navigation clearance was required near to sea, large-scale PC cantilever or segmental box girder bridges were observed. They were comparatively recent constructions of the late 1980's or the 1990's and based on individual designs.

(2) Application of JKR Standard PC Beams

The JKR recent standard designs of M-beam, I-beam and inverted T-beam were widely seen at the comparatively new constructions of the 1980's and the 90's in Peninsula.

However, the application of the standard beams at some bridges were not adequate: the spacings of the beams at many bridges were too conservative and less than the standard spacings.

(3) Cross Beams

Some bridges did not have a cross beam at the middle of span but certain bridges had. Although the main function of cross beams was to distribute loads among longitudinal beams, it was very difficult to explain clearly why cross beams were and weren't designed. There were many examples both of with and without cross beams.

For designing precast PC beam bridges, attention is to be given to the transverse integration of main beams. In the Study it will be carefully considered as the minimum requirement of transversal rigidness to integrate main beams.

(4) Beam Coupling

To eliminate expansion joints, the beam coupling method was adopted in several multi-span PC beam bridges. The joint gaps between neighboring beams on pier were integrated in longitudinal direction by filling concrete so as to construct deck slab continuously after simple beams were erected individually. Beam coupling was often seen at the relatively recent constructions of PC post-tension beam bridges both in the Peninsula and Sabah/Sarawak.

The beam coupling method will be studied further and adopted in the Study.

(5) Pile-bent Pier and Abutment

Most piers and abutments surveyed were pile-bent structure even that of important bridges crossing large rivers. The construction of pile-bents to drive piles and then cast a pile cap above water level was much easier than to embed a footing into river bed which should involve costly and difficult cofferdam work specially in deep water. However, careful attention should be paid to the change of river bed by scouring which would undermine the stability of piers.

For hydrological and stability problem the pile-bent structure will not be adopted in the Study. Instead, wall type structure with embedded footing is to be adopted.

(6) Salt Water Damages

Salt damage was seen along the east coast on piers and abutments rather than superstructures.

The columns and piles near on the tidal level were severely damaged by salt water. However, the damages of PC beams by sea breeze were not seen both in the Peninsula and Sabah/Sarawak.

(7) Settlement of Embankment

The west coast of Johor along the national road Route 5 is covered with soft marine alluvial deposits resulting to the settlement of embankment behind abutment and the sinking of slope protection which were seen here and there.

The installation of approach slab will be considered in the Study. In connection with this, however, the construction method and backfill material behind abutment is also needed to be considered in a specification.

2.3.3 Summary of Bridge Hydrology Survey

(1) River Course and Bridge Direction

- There were many bridge crossing rivers at curved reach and with skew angle. Moreover, bank protections were not provided sufficiently adjacent to abutments.

(2) Under--bridge Opening

- There were many bridges which had insufficient under–bridge opening: some abutments were located inside of water way. That seemed to narrow flood flow and cause severe erosion and scouring around bridges.

(3) Structure and Direction of Piers

- Most piers supporting short span bridges were pile bent structures. Some piers supporting long span bridges at large rivers had pile caps or footings but they were constructed above water.

- Some pile bent piers were found skew to water flow. Such piers would disturb flood flow and catch drifts easily as well as accelerate erosion and scouring by turbulence.

(4) *Location and Direction of Abutments*

- There were many abutments located inside of water way. Most abutments were pile bent structures and some were situated skew to water flow. That would cause erosion and scouring at abutments.

(5) Bank Protection around Bridge

- Bank protections were not provided sufficiently at many bridge sites. There were many bank erosion problems observed particularly in Sabah and Sarawak.

(6) Obstacles under Bridges

Some piers and abutments were damaged by drifting logs. Old pier and abutment concretes remained under new bridge. Such drifting logs or concrete remains under bridge would block flood flow and threaten the safety of bridges.

2.4 Computer Use for Bridge Design in Malaysia

2.4.1 General

In Malaysia, computers have come into wide use in the business world. Personal computers of world major brands are available at computer shops in Kuala Lumpur and many computer magazines at book stores.

For engineering use, most hardwares are product of the United States but the softwares from the United Kingdom are widely used in Malaysia. The computer use for bridge design has been practiced in the JKR Bridge Unit and in local consultants by using personal computers and programmes available in the market.

2.4.2 Computer use in JKR Bridge Unit

Each engineer and draftman is equipped with a personal computer for his exclusive use. These machines are interconnected by LAN system. On every floor of the Bridge Unit there is a plotter.

These computers were used mainly for documentation, structural analysis and data preparation. Nowadays, all drawings were prepared by drawing programmes and plotting machines. All the softwares the Bridge Unit owns are available in the market in Kuala Lumpur including the programmes from structural analysis to drawing system. Even the topographic map was being prepared by drawing programme.

2.4.3 Computer Use in Consultants

Local consultants also have used computers for bridge design mainly for design analysis.

Among many application programmes they have for bridge design, the followings are the bridge analysis programmes which are recently most used in Malaysia.

Table 2.1 Computer Software Used by Bridge Consultants in Malaysia

Programme	OS	Supplier	Object
Superstress (Structural Engineering System)	Windows	INTEGER (UK)	Plane truss, Plane frame, Plane girder, Space truss and Space frame
GTSTRUDL	MS DOS 6.2 AEGIS-DOMAIN 10.3	QE DESIGN PTE Ltd. (Singapore)	General 3D analysis, FEM analysis
AIT			Pile design
STAAD 3	MS DOS 6.2	Ceanet Sdn. Bhd. (Malaysia)	Analysis/design
LUCAS	MS DOS	FEA Ltd, (UK)	Analysis of deck slab, beam, capping beam, frame (3D & 2D), plate, etc.
PILE 3D	MS DOS	In-house	Analysis for forces and displacements for a 3-dimensional pile group
Other In-house Programme			

CHAPTER 3 SELECTION OF STANDARD BRIDGE TYPE AND COMPUTER SYSTEM (PHASE II)

3.1 Establishment of Design Standards and Conditions

3.1.1 General

Determination of design criteria and deign condition were made based on the survey described in the Section 2.1 on this report, the discussion on the Technical Committee and the agreement in the Steering Committee Meeting.

Design criteria are the basic elements applied to carry out standard design, and design conditions are the agreed details that are necessary in implementing the design in detail.

In this chapter design standards, design criteria, and design conditions for design of standardized bridge in this study were determined.

3.1.2 Design Standards

The design standards to be applied in this Study are based on the British Standard's "Limit State Design Method" and the design live load to be applied is based on BD37/88, which were agreed upon as recorded in the Minutes of Meeting at the Steering Committee meeting held on 25th August 1994.

Other loads to be applied, besides the above-mentioned design live load, were also discussed at a series of the Technical Committee meeting held and determined to apply BD37/88 on 24th October 1994 (Reference: Appendix F).

Therefore, the standards to be applied in this Study are as follows:

Bridge Design Standard	BS5400
Design Load Standard	BD37/88
Foundation Design Standard	BS8004
Geometrical Structure Standard	A Guide on Geometric Design of Roads, JKR

However, in instances whereby it is impossible to comply with the above-mentioned standard, it was also agreed to adopt Japanese design standard.

3.1.3 Design Conditions

The design conditions were established to attain standard designs in consideration of simplicity, clearness, safety and easiness in application and management of the design by a wide range of engineers.

After thorough discussion at the Technical Committee meeting, the major decisions were made as follows:

3.1.3.1 Method of Design Analysis

Elastic method of analysis beam theory shall be used in the design.

3.1.3.2 Width Composition

A bridge width of 13 metres for R5/U5 and 11 metres for R3/U3 has been decided upon respectively, but an improvement in type of parapet and kerb stones will be decided upon pending further investigation.

3.1.3.3 Material to be Used

(1) Grade of concrete

Reinforced Concrete Beam	:	Grade 40
Pretension Concrete Beam	:	Grade 50
Posttensioned Concrete Beam	:	Grade 50
Substructure	:	Grade 40
RC Pile	:	Grade 40
Bore Pile	:	Grade 30
PC Pile	:	Grade 60

(2) Reinforcement bar : Y460, R250

(3) PC Steel

Basically T12.7 and T15.2 will be used. But a design was carried out by using the dimensions of the material normally used in Malaysia.

3.1.3.4 Load to be Considered

(1) Design load

Material	Unit Weight (KN/m3)
Steel, Cast Steel, Forged Steel	78.5
Reinforced and Precast Concrete	25.0
Mass Concrete	23.5
Premix Pavement	23.0
Cover Soil	19.0
Water	10.0

(2) Superimposed dead load

The crossfall of the bridge shall be 2.5% and the thickness of premix shall be minimum constant t=60mm on the plain concrete of adjusting the crossfall so that the beam shall be set in a true vertical position.

The load by water–pipe and light post shall be ignored.

(3) Live load

The number of notional lanes shall be 4 lanes for both R5/U5 and R3/U3. A nominal live loading and its application shall comply with regulation BD37/88.

(4) Collision load

The collision load shall not be applied for the design of superstructure but only for piers. The bridge over the road shall maintain a clearance of more than 5.7 metres.

The vehicle collision load shall be considered in accordance with Clause 6.8 of BD37/88.

(5) Prestressing force

The design shall basically comply with regulation BS5400 by using the dimensions of the material normally used in Malaysia, but in the case of post–tension beam, the design plan shall be planned in such a manner that the beam will be stressed on two stages – at the time of manufacture and after transportation but before construction.

(6) Effects of shrinkage and creep

The design shall comply with CEB manual. The humidity to be considered in the design shall be taken as 80% from the meteorological data studies.

(7) Wind load

Based on meteorological data, the mean hourly wind gust speed shall be 40 metres per second. It shall be applied to the transversal direction of superstructure and substructure. However, the wind load was ignored for the superstructure design because the influence was not a major factor compared to other loads.

(8) Temperature

(i) Temperature change

Temperature change shall be considered for the design of bearing, expansion joint and substructure, and the magnitude shall be 20 degrees.

(ii) Temperature difference

Design for superstructure shall be carried out in consideration of the temperature difference in accordance with BS5400. But the temperature difference was ignored, because its influence was not a major factor compared to the other loads in determining the structural material.

(9) Earth pressure

The calculation of active earth pressure working on the abutments shall be carried out in accordance with the Coulomb's equation. No consideration of the resistance by passive earth pressure working on the abutment shall be estimated.

(10) Longitudinal load

More severe longitudinal load resulting either from HA or HB due to traction of breaking shall be taken. This force acts at one notional lane and parallel to road traffic.

(11) Accidental load due to skidding

The accidental load due to skidding shall be considered for the design of piers, acting in any direction on and parallel to the surface of road in accordance with 6.11 of BD37/88.

(12) Effects of stream, current and floating drift wood

Since this is not specified by BS5400, the design shall comply with Japanese design criteria, which takes into consideration of the collision force carried by floating logs.

3.1.3.5 Combination of Loading and Design Classification

Described below are the loading combination and the design limitation classifications determined to be applied for the design of reinforced concrete and prestressed concrete under Serviceability Limit State (SLS).

Design crack width is applied for design of reinforced concrete members and limitation of tensile stress (Class 1, Lc1 & Class 2, Lc2 of BS5400) is applied for design of prestressed concrete member.

(1) Class 1 under load combination 1
(2) Class 2 under load combination 2 to 5
(3) Design crack width for reinforced concrete beam : 0.25mm
(4) Design crack width for slab : 0.15mm
(5) Design crack width for substructure : 0.25mm

3.1.3.6 Detailing

Required minimum concrete coverage for reinforcement bars and the minimum ratio of reinforcement bar to concrete for each structural members shall be considered as shown below.

(1) Cover for reinforcement bars

(i) Girder	: 50mm
(ii) Slab	: 50mm
(iii) Abutment and walls	: 50mm
(iv) Piers	: 50mm
(v) Footing	: 70mm
(vi) Piles	: 70mm

(2) Minimum percentage of reinforcement bars

(i) Slabs and beams	: 0.15%
(ii) Columns	: 1.0% or 0.15N/fy
(iii) Walls	: 0.4%
(iv) For temperature	: As>Kr (Ac−0.5Acor)

3.1.3.7 Stability Analysis of Foundation

Stability analysis of spread and piled foundation shall be made as described below.

(1) Spread foundation

The design shall be carried out in accordance with BS5400 and BS8004.

(2) Piled foundation

The BS5400 and BS8004 do not specify the design method for analysis of piled foundation. The displacement method which is commonly used in Japan shall be adopted.

3.1.3.8 Structural Design of Substructure

The structural design of each component of substructures shall be basically carried out in accordance with BS5400.

Since the actual procedure to obtain sectional forces of parapet wall, wing wall and approach slab are not described in BS5400, the forces, therefore, shall be calculated with applicable JS with modification.

3.2 Selection of Standard Bridge Types and Span Range

3.2.1 General

In order to determine the bridge types for standard design, a preliminary design and comparative study were conducted on a total of 10 types of superstructure.

They are composed of the five types as indicated in the Minutes of Meeting on the Scope of Work (26th January, 1994) and the other five types which were selected from the result of the visual inspection survey on the representative existing bridges.

The preliminary design was conducted from the view point of structural characteristics which be clarified by the result of design calculations.

The preliminary design was carried out in the following manner.

(i) classification of the comparative bridge types by span range,

(ii) assumption of limited scope of design condition, i.e. span, width, combination of loading, design cross section, for the purpose of preliminary design,

(iii) determination of the calculation method of cross sectional forces, mainly for the distribution of the live load,

(iv) design calculation.

The comparative study was conducted from the view point of economy, construction difficulties, maintenance, rehabilitation, current practice in Malaysia and so on.

The comparative study was carried out in the following manner.

(i) for economic evaluation of each type, a preliminary cost calculation was made based on the calculated material quantities and the construction unit prices which were previously surveyed.

(ii) in addition to the above, construction difficulties, maintenance, repair and general practices in Malaysia were considered in the evaluation.

Based on the results of preliminary design and comparative study, standard bridge types were selected in consideration of effective utilization in future.

However, a general comparative study was conducted for substructure and foundation and continuous bridge without preliminary design process.

The word here, "selected bridge types" means that the objective bridge types for preliminary design and comparative study, and "standard bridge types" refers the bridge types determined finally for standard design.

In this sections, above mentioned Preliminary Design (3.2.2) Comparative Study (3.2.3), Span Range (3.2.5) and also Standard Types and Design Range for Substructure and Foundation are described more in detail.

3.2.2 Preliminary Design for Selected Bridge Types

3.2.2.1 Categorization of Selected Bridge Types for Preliminary Design

In accordance with a span range, each structure type was categorized into different groups as shown below. After that, preliminary designs were carried out based on the representative span length of each group.

Group 1 : (Span range: 5m - 10m)

(1) Reinforced monolithic concrete slab & T beam
(2) Reinforced concrete solid slab
(3) Pretensioned concrete solid slab

Group 2 : (Span range: 10m - 25m)

(1) Pretensioned concrete inverted T beam
(2) Steel I beam
(3) Pretensioned concrete hollow slab
(4) Pretensioned concrete T beam

Group 3 : (Span range: 25m - 35m)

(1) Posttensioned concrete live load composite I beam
(2) Posttensioned concrete live load composite T beam

Group 4 : (Span range: 35m - 45m)

(1) Posttensioned concrete live load composite T beam
(2) Prestressed concrete box girder (cast in situ)

For the above structure types, the preliminary designs were carried out with both the span of 38m and the maximum span of 45m.

3.2.2.2 Main Hypothetical Conditions of Preliminary Designs

(1) Span

The conditions on span are as stated above.

(2) Width

It was assumed that the width for R5/U5 would be 13m carriageway, one side parapet weight 7.315kg/m as superimposed dead load and that the average thickness of premix would be 13cm including the plain concrete to arrange the height.

(3) Materials

As stated in section 3.1, Grade 40 was used for reinforced concrete and Grade 50 for prestressed concrete. Y460 was selected for reinforcement. T12.7mm and T15.2mm was selected for PC tendon respectively.

(4) Load combination

As stated in section 3.1, the load combination was adopted as P + D + 1.2SD + SH + CR + 1.2HA and P + 1.2D + 1.75SD + SH + CR + 1.5HA for S.L.S and U.L.S respectively.

(5) Crack limitation and flexural tensile limitation

Crack limitation for reinforced concrete was adopted as 0.25mm, whereas any flexural tensile shall not be allowed for prestressed concrete.

(6) Cover for reinforcement

Cover for reinforcement was adopted as 50mm.

3.2.2.3 Procedures of Preliminary Designs

(1) Sectional shape

The sectional shape was determined in accordance with the standard designs of JKR as well as those of Japan.

(2) Calculation of sectional force

The calculation of the sectional forces on live load were carried out by using the grillage analysis programme only for post-tensioned T-beam with the span of 30m.

For the types other than the post-tensioned T-beam, the sectional forces were calculated by assuming a load distribution factor based on the calculation results on the representative post-tensioned T-beam.

(3) Design calculation

Design calculation for preliminary design was conducted on bending moments and shear force as shown below.

Check on bending moment at midspan.

- Reinforced concrete:

Check on width of cracks under the serviceability limit state
Check on stability under the ultimate limit state

- Prestressed concrete:

No flexural tensile stress under the serviceability limit state
Check on stability under the ultimate limit state

Check on shear force at around supporting cross sections

- Check on stability under the ultimate limit state

3.2.2.4 The Result of Preliminary Designs

The preliminary designs for 10 types structure were carried out and the results are summarized in following Table 3.1 to Table 3.5.

Table 3.1 The Result of Preliminary Design (1) (for 5-10 m span)

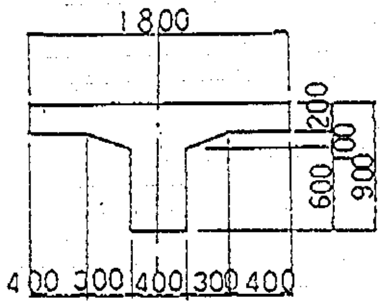
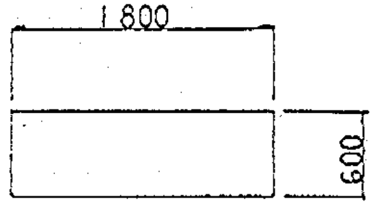
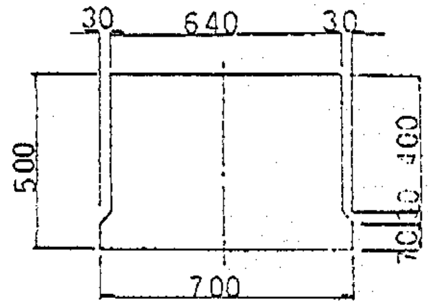
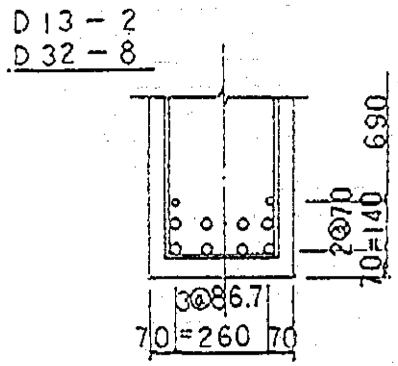
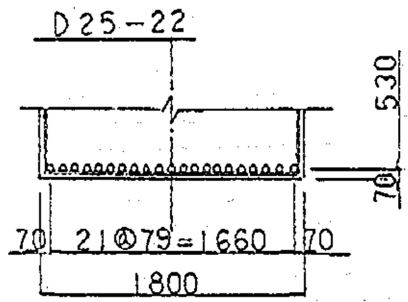
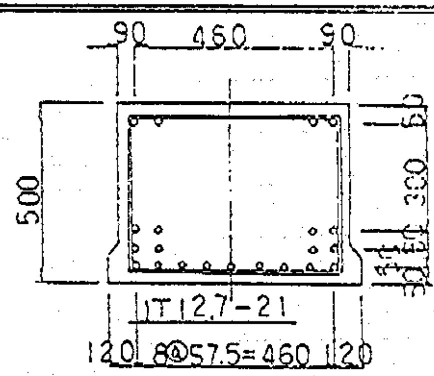
Types of superstructure		Reinforced monolithic concrete slab & T beam	Reinforced concrete solid slab	Pretensioned concrete solid slab
Beam cross section				
Arrangement of reinforcement and PCtendons				
Sectional force	S.L.S (Bending)	M = 812 KN.m	M = 902 KN.m	M = 419 KN.m
	U.L.S(Bending)	M = 1034 KN.m	M = 1142 KN.m	M = 540 KN.m
	U.L.S(Shearing)	S = 456 KN	S = 504 KN	S = 238 KN
Design result	Crack width	Cw = 0.25 < 0.25 mm	Cw = 0.25 < 0.25 mm	
	Stress(tensile)	fc(bl) =	fc(bl) =	fc(bl) = 0.55 > 0 N/mm2
	Stress(compression)	fc(bu) = 6.74 < 20.0 N/mm2	fc(bu) = 11.73 < 20.0 N/mm2	fc(bu) = 14.43 < 20.0 N/mm2
	Mr / (rf3 x M)	r = 1.69 > 1.0	r = 1.59 > 1.0	r = 1.28 > 1.0
	Shear stress	v = 1.5 < 4.7 N/mm2	v = 0.6 < 4.7 N/mm2	v = 0.9 < 5.3 N/mm2

Table 3.2 The Result of Preliminary Design (2) (for 10-25 m span)

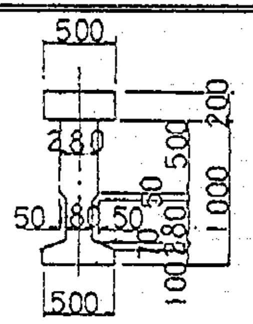
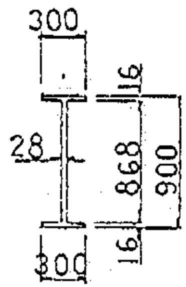
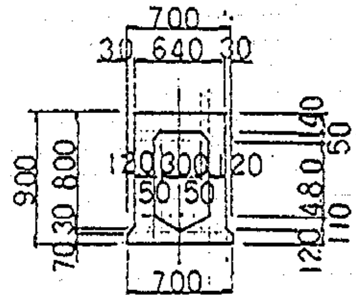
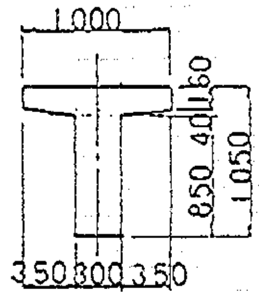
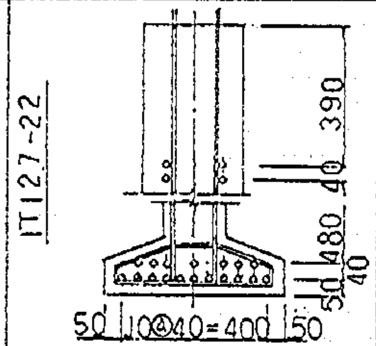
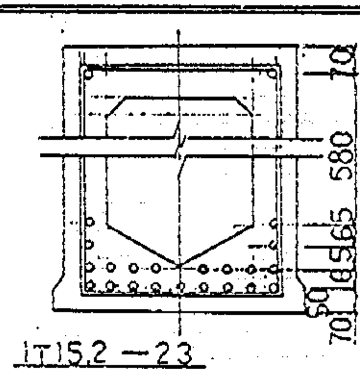
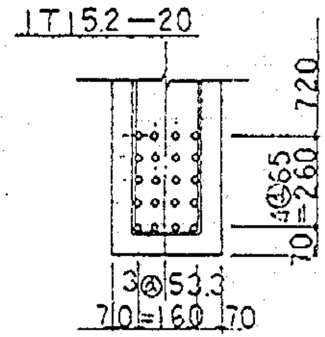
Types of superstructure		Pretensioned Inverted Tbeam	Steel I beam	Pretensioned concrete hollow slab	Pretensioned concrete T beam
Beam cross section					
Arrangement of reinforcement and PCtendons			———		
Sectional force	S.L.S (Bending)	M = 1240 KN.m	———	M = 1507 KN.m	M = 1875 KN.m
	U.L.S(Bending)	M = 1621 KN.m	———	M = 1963 KN.m	M = 2424 KN.m
	U.L.S(Shearing)	S = 344 KN	———	S = 415 KN	S = 514 KN
Design result	Crack width	Cw =	———	Cw =	Cw =
	Stress(tensile)	fc(bl) = 6.25 > 0 N/mm2	———	fc(bl) = 3.22 > 0 N/mm2	fc(bl) = 0.93 > 0 N/mm2
	Stress(compression)	fc(bu) = 8.60 < 15.0 N/mm2	———	fc(bu) = 18.32 < 20.0 N/mm2	fc(bu) = 11.06 < 20.0 N/mm2
	Mr / (rf3 x M)	r = 1.01 > 1.0	———	r = 1.03 > 1.0	r = 1.24 > 1.0
	Shear stress	v = 2.0 < 4.7 N/mm2	———	v = 2.8 < 5.3 N/mm2	v = 1.9 < 5.3 N/mm2

Table 3.3 The Result of Preliminary Design (3) (for 25-35 m span)

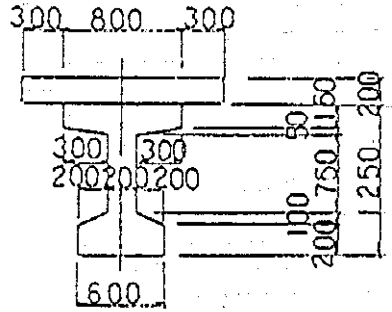
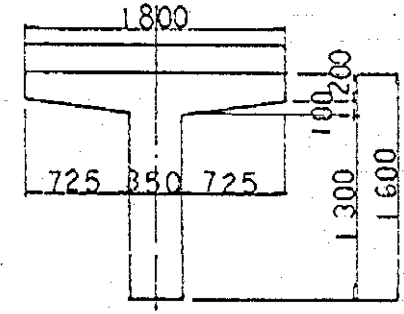
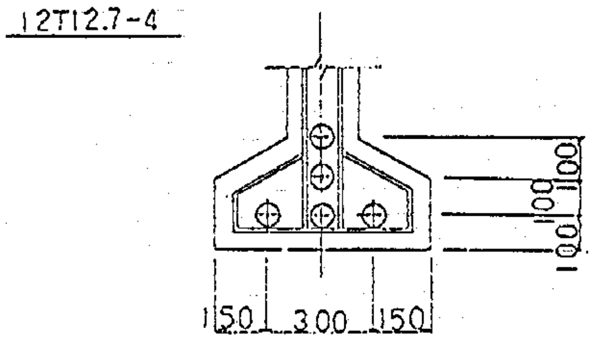
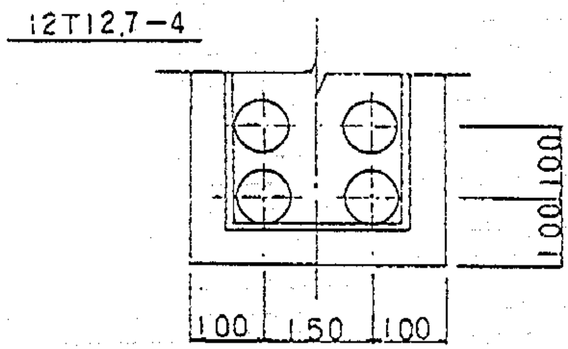
Types of superstructure		Postlensioned live load composite I beam	Posttensioned live load composite T beam
Beam cross section			
Arrangement of reinforcement and PCtendons			
Sectional force	S.L.S (Bending)	M = 5374 KN.m	M = 7456 KN.m
	U.L.S(Bending)	M = 6908 KN.m	M = 9475 KN.m
	U.L.S(Shearing)	S = 964 KN	S = 1323 KN
Design result	Crack width	Cw =	Cw =
	Stress(tensile)	fc(bl) = 1.50 > 0 N/mm2	fc(bl) = - 0.3 = 0
	Stress(compression)	fc(bu) = 14.05 < 20.0 N/mm2	fc(bu) = 6.82 < 20.0 N/mm2
	Mr / (rf3 x M)	r = 1.27 > 1.0	r = 1.20 > 1.0
	Shear stress	v = 4.8 < 5.3 N/mm2	v = 4.0 < 5.3 N/mm2

Table 3.4 The Result of Preliminary Design (4) (for 35-45 m span)

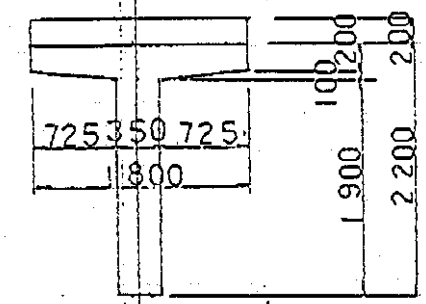
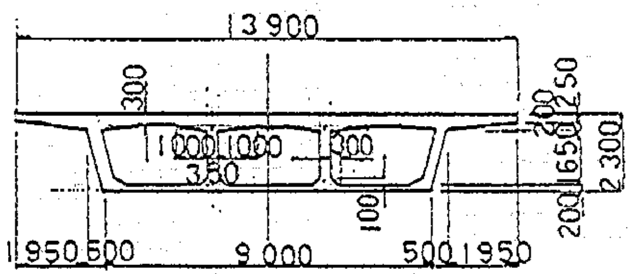
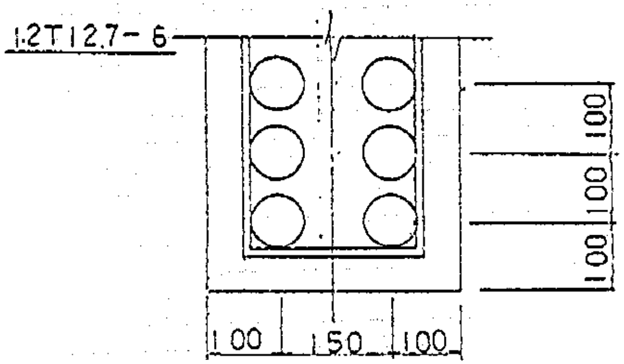
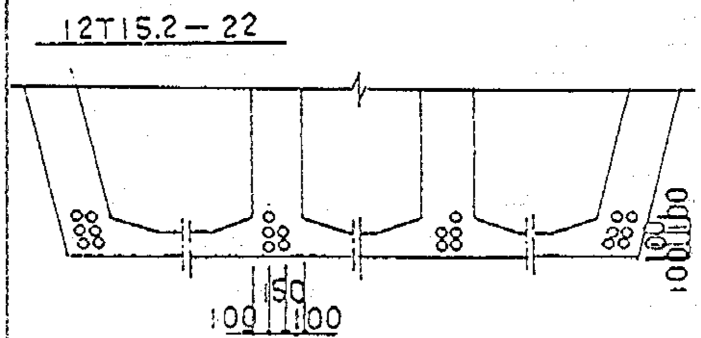
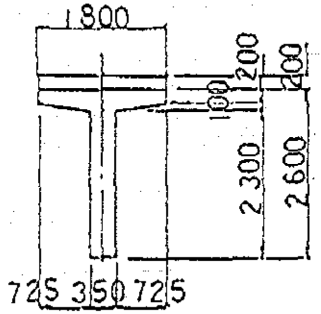
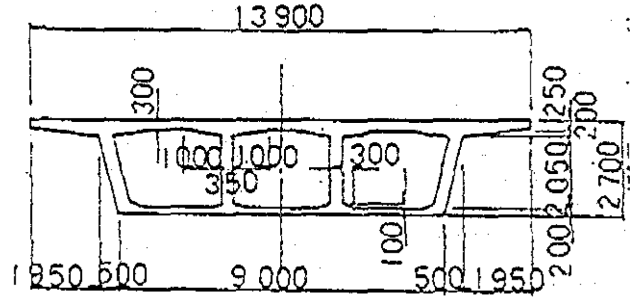
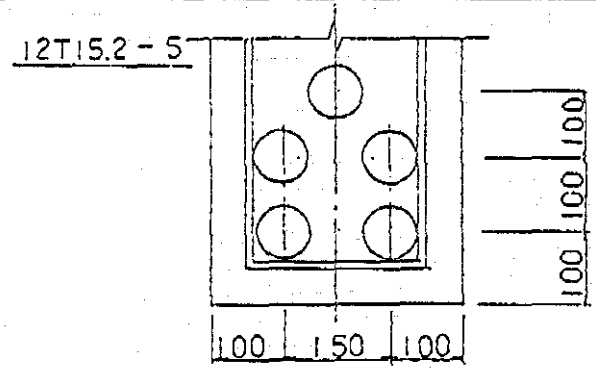
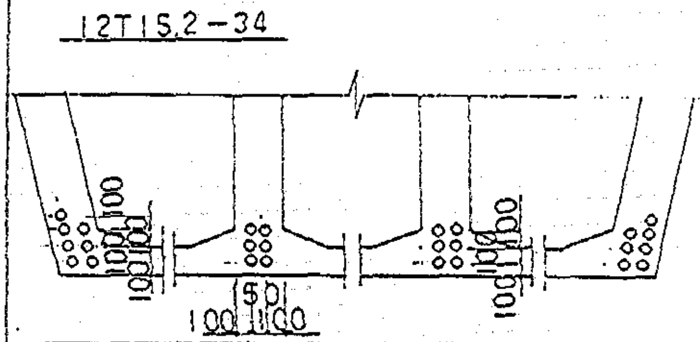
Types of superstructure		Posttensioned live load composite T beam	Prestressed concrete box girder
Beam cross section			
Arrangement of reinforcement and PCtendons			
Sectional force	S.L.S (Bending)	M = 13796 KN.m	M = 73905 KN.m
	U.L.S(Bending)	M = 17480 KN.m	M = 92476 KN.m
	U.L.S(Shearing)	S = 1817 KN	S = 9230 KN
Design result	Crack width	Cw =	Cw =
	Stress(tensile)	fc(bl) = 1.09 > 0 N/mm2	fc(bl) = 0.3 > 0 N/mm2
	Stress(compression)	fc(bu) = 7.86 < 20.0 N/mm2	fc(bu) = 8.14 < 20.0 N/mm2
	Mr / (rf3 x M)	r = 1.24 > 1.0	r = 1.21 > 1.0
	Shear stress	v = 3.9 < 5.3 N/mm2	v = 4.0 < 5.3 N/mm2

Table 3.5 The Result of Preliminary Design (5) (for 45 m span)

Types of superstructure		Postlensioned live load composite T beam	Prestressed concrete box girder
Beam cross section			
Arrangement of reinforcement and PCtendons			
Sectional force	S.L.S (Bending)	M = 19663 KN.m	M = 103979 KN.m
	U.L.S(Bending)	M = 24865 KN.m	M = 129930 KN.m
	U.L.S(Shearing)	S = 2186 KN	S = 11018 KN
Design result	Crack width	Cw =	Cw =
	Stress(tensile)	fc(bl) = 0.69 > 0 N/mm2	fc(bl) = 0.18 > 0 N/mm2
	Stress(compression)	fc(bu) = 9.00 < 20.0 N/mm2	fc(bu) = 9.21 < 20.0 N/mm2
	Mr / (rf3 x M)	r = 1.23 > 1.0	r = 1.19 > 1.0
	Shear stress	v = 3.3 < 5.3 N/mm2	v = 3.9 < 5.3 N/mm2

3.2.3 Proposed Bridge Types and Span Range

Comparative Study was conducted from the viewpoint of economy, structural characteristics, construction difficulties, maintenance, rehabilitation and so on.

The result of the comparative study for each item is shown below (also please refer to Appendix H).

3.2.3.1 Economical View Point

The standard superstructure types are more economical except the pretensioned concrete solid slab for the short span range, however, the pretensioned concrete solid slab was selected due to the advantage of under-mentioned (4), (7), (5), (6), (2) items in construction easiness.

3.2.3.2 Structural Characteristics

(1) For the standard superstructure types for a short span, it is possible to obtain smaller beam height compared to the T & Slab beam height.

(2) The centroid of T-beam types is located at more towards the upper flange compared to inverted T-beam and type of I-beam, therefore prestressing force can be performed more effectively.

(3) Both Pretensioned Inverted T-beam and Post-tensioned I beam have a wide and lower flange and they are not recommendable from structural view point, because, the shear reinforcement bars were obliged to be cut when PC tendon are bent up from the midspan toward the end of beam.

3.2.3.3 Construction Difficulties

(1) For the reinforced concrete, it can be used for a short span, and it is possible to execute cast in situ easily without large sized scaffolding.

(2) Pretensioned solid slab and pretensioned hollow slab have the same external shape, therefore, girder-manufacturing facilities can be utilized commonly.

(3) For the box beam, due to complicated sectional shape, it is more difficult to construct cast in situ especially for inner formwork and concrete work.

(4) Due to the simpler external shape of the standard superstructure types compared to other types, beams can be manufactured more easily under improved quality control. For the T-beam type, the external shape was simplified by removing a lower flange.

(5) Beams manufactured in a factory have advantage in better quality control compared to cast in situ beams, provided that the length of beam could be transported in consideration of road condition and vehicle. The length should

normally be within 30m.

(6) Pretensioned and Posttensioned beams have advantage in construction, if a bridge cannot be constructed without scaffolding.

(7) After installing beams, cast in situ of the standard superstructure types will be only required at the filling area and the area of a cantilever slab. Therefore, it would be easier in construction at site.

3.2.3.4 Maintenance and Rehabilitation

(1) Steel I-beam required anti-corrosion treatment during manufacturing process as well as re-paint works after installation, therefore, the maintenance cost for the structure would be higher. Moreover, JKR's basic request is concrete bridges.

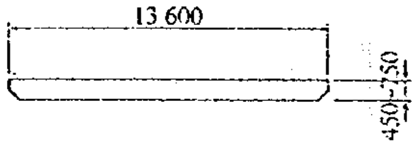
(2) Standard superstructure types would require only the minimum maintenance in future if enough attention is paid to maintenance of bridge accessories such as bearing, expansion joint and facilities.

3.2.4 Selection of Standard Bridge Types

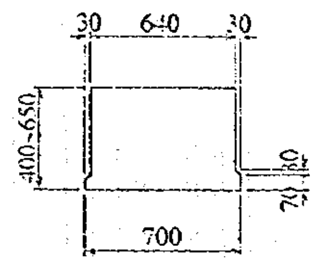
Standard superstructure types were selected from the comprehensive evaluations and the comparative studies of each structure type, and they were also selected in respective span categories as stated below.

(1) Reinforced concrete solid slab and pretensioned concrete solid slab were selected for span 5m - 10m.

In any of the types, it was aimed that simplification in the cross-section and uniform cross-sectional shape for whole span of a bridge for ease in construction.



Reinforsed concrete solid slab



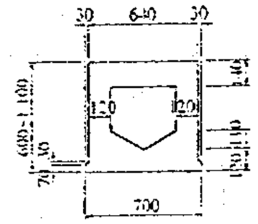
Pre-tentioned concrete solid slab

Fig. 3.1 Standard Bridge Types for the Span 5m - 10m

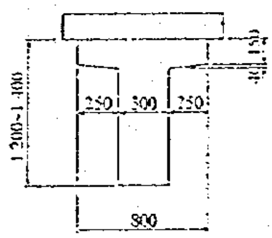
(2) Pretensioned concrete hollow slab and pretensioned concrete live load composite T-beam were selected for span 10m - 25m.

The outer shape and the dimension of the pre-tensioned concrete hollow slab were designed the same as those of pre-tensioned concrete slab, so that the facilities like forms could be utilized efficiently and also simplified shape of the inner form make construction easier.

Pre-tensioned T-beam was so designed that it does not require transversal PC tendons for slab and slab is placed on precast beam as live load composite beam in consideration of load distribution and leakage preventive measure from road surface drain water. These are requested by JKR. Also, size of the upper flange of precast beam was designed as small as possible to eliminate structurally useless portion of the slab. The design was aimed at the uniform cross-section for the whole span of a bridge.



Pre-tensioned concrete hollow slab

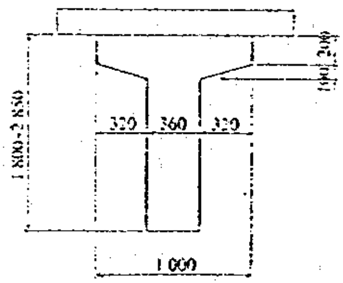


Pre-tentioned concrete live load composite T-beam

Fig. 3.2 Standard Bridge Types for the Span 10m - 25m

(3) Posttensioned concrete live load composite T-beam was selected for span 25m - 45m.

The structural detail dimensions of the post-tensioned T-beam were determined in the same manner as the pre-tensioned T-beam. This type has longer span and larger reaction forces, therefore, thickness of a part of the web is assumed to be thinker at the end of beam for setting of rubber bearings. This type is also adopted in continuous beam which is mentioned later.



Post-tensioned concrete live load composite T-beam

Fig. 3.3 Standard Bridge Types for the Span 25m - 45m

On the other hand, five structure types of reinforced monolithic concrete T & Slab, pretensioned concrete inverted T-beam, steel I-beam, posttensioned concrete live load composite I-beam and prestressed concrete box girder (case in situ) were excluded from the standard bridges.

(4) Standard continuous bridge type

Continuous bridge shall be designed as live load composite T-beam with slab connection only. the connecting part was decided as Type 1 (refer to Appendix I) in the Technical Committee meeting by the reasons described below.

- Type 1 had been adopted in Malaysia because seismic load and temperature load are not principal factors. Moreover, construction is easier.
- Inexperienced engineer in charge of bridge design would be able to design the bridge systematically and easily.
- It is more difficult to apply the standardized beam to continuous bridges due to the stability of the statically indeterminated force caused by connecting slab and beam.

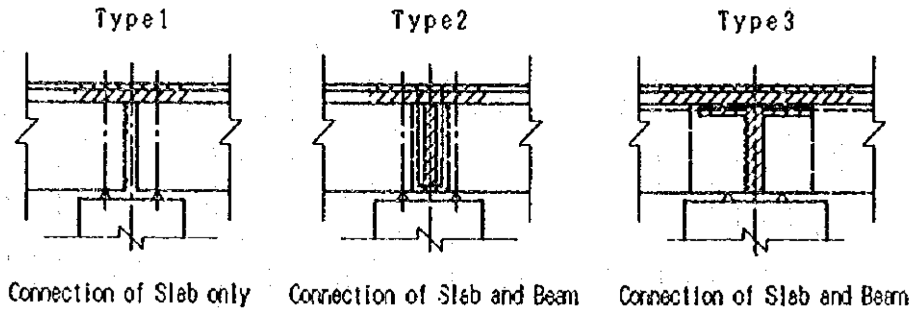


Fig. 3.4 Continuous Bridge Types

3.2.5 Span Range of Standard Superstructure

This work was established to execute this Study in consideration of the most suitable and effective application and management by wide range of engineers.

In consideration above, the span range of standard superstructure in this Study was determined through a series of the Technical Committee meeting as shown below.

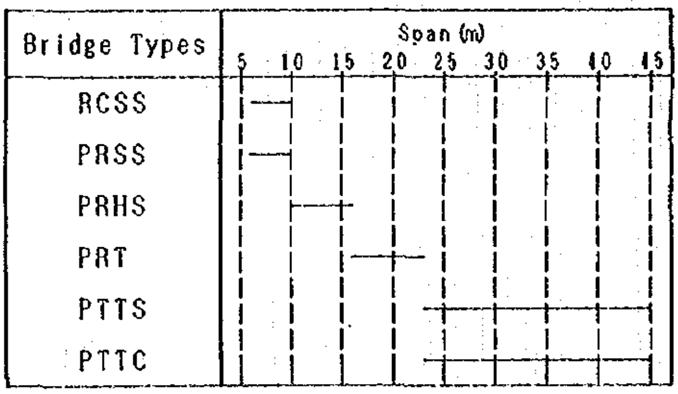
As the result of the discussion in Technical Committee meeting, the post-tensioned concrete live load composite T-beam was decided to be adopted only for the span of 25m or more, although it has been considered to adopt for 10 to 25m span.

On the skew angle to be considered in design, only 15° and 30° were adopted for the design calculation, but 0° was also adopted in preparation of design drawings as a final product.

Table 3.6 Span Range for Standard Bridge Types (1)

Span	Bridge Type	Width	Skew	Case
6m	RCSS and PRSS	13m, 11m	15° , 30°	8
8m	- do -	- do -	- do -	8
10m	RCSS and PRSS	- do -	- do -	8
12m	PRHS	- do -	- do -	4
14m	- do -	- do -	- do -	4
16m	PRHS	- do -	- do -	4
18m	PRT	- do -	- do -	4
20m	- do -	- do -	- do -	4
22m	PRT	- do -	- do -	4
25m	PTTS and PTTC	- do -	- do -	4
28m	- do -	- do -	- do -	4
30m	- do -	- do -	- do -	4
32m	- do -	- do -	- do -	4
35m	- do -	- do -	- do -	4
40m	- do -	- do -	- do -	4
45m	PTTS and PTTC	- do -	- do -	4
Total				76

Table 3.7 Span Range for Standard Bridge Types (2)



RCSS : Reinforced Concrete Solid Slab
PRSS : Pretensioned Concrete Solid Slab
PRHS : Pretensioned Concrete Hollow Slab
PRT : Pretensioned Concrete live load composite T-beam
PTTS : Posttensioned Concrete live load composite simple T-beam
PTTC : Posttensioned Concrete live load composite continuous T-beam

3.2.6 Selection of Substructure Types

3.2.6.1 General

The scope of the design of substructures have been discussed in the Steering and Technical Committee since the beginning of the Study, and it was agreed that the standard design of substructures shall be prepared only for typical cases by partially computerized analysis.

Concerning the types of substructures and the design cases, several types of abutment and pier were initially recommended in the Preliminary Study Report of February, 1994 such as:

(i) Abutment	:	Inverted T-type, and gravity type
(ii) Pier	:	T-type, multi-column type and solid wall type
(iii) Foundation	:	Spread foundation and pile foundation for both abutment and pier

Based on the above recommended types and the cases of structures, the Study Team conducted studies on merits and demerits of each type through the bridge site survey and the survey of current practice of bridge design and construction in Malaysia.

Through the discussions with the JKR Bridge Unit in a series of the Technical Committee meeting conducted in August to November, 1994, the recommended types and cases for the substructure design were modified to meet the requirements of JKR and to reflect the results of surveys on the existing bridges in Malaysia. The structure types which have been seldom adopted in Malaysia were not selected for the standard design in this study.

3.2.6.2 Study for Selection of Substructure Types

(1) Abutment

(i) Inverted T-type

This type is selected as a standard abutment in place of the existing bank-seat type which is the most popular abutment in Malaysia. Many damaged samples of bank-seat type were found in the existing bridge site survey. The main advantage of this type is to ensure sufficiently embedded footing for stability and durability of the structures.

(ii) Gravity type

No example of this type of abutments were found in Malaysia through the existing bridge site survey and also information from JKR. It is generally considered that the ground condition is not suitable to adopt this type.

(2) Pier

(i) T-type

This type is commonly adopted in Malaysia for both river bridge and grade separation bridges.

(ii) Multi-column type

The multi-column type does not suit the piers in rivers as the multi-column often disturbs water flow and catches drafting logs and debris. However, this type of pier is used quite often in viaducts and grade separation bridges because of its simplicity and easiness in construction.

(iii) Solid wall type

This type, as well as T-type, brings about fewer hydrological problems if it is designed and constructed properly in right position in rivers. However, this type of pier had been little adopted in Malaysia for it needs more concrete and less economical.

(3) Foundation

(i) Spread footing

Most bridges are supported by piles in Malaysia. Also this type was not observed in the existing bridge survey nor popularly used.

(ii) Pile foundation

The majority of foundation bridge piles are precast RC or PC piles, and bored-piles, steel-piles and micro-piles are also adopted in a case.

3.2.6.3 Selected Substructure Types

Through the study for each substructure type mentioned above and after due discussions with JKR, the type and case for the substructure designs to be prepared in the Study was selected as follows:

(i) Abutment : Inverted T-type only, with the height up to H = 10m
(ii) Pier : T-type and multi-column type with the height up to H = 20m
(iii) Foundation : Pile foundation only with point bearing piles and friction piles

The above types and cases shall be prepared for the standard design of substructure in the Study in connection with the design of superstructure.

Besides the above selected types, the following sample designs were prepared by the request of JKR in the later stage of the Study.

- High abutment (H=12m) with PC piles for bridge cross over railway
- Abutment with spread footing for an exceptional case
- High pier (H=30m) with PC piles for a pier in valley
- Bored piles for abutment and pier for construction in urban area

3.2.6.4 Design Range of Substructure

This work was established to execute this Study in consideration for the most suitable and effective application and management by a wide range of engineer.

The Study Team discussed on the problems involved in determination of the design range of substructure many times in a series of the Technical Committee meeting. They are:

- difficulties to cover all parameters such as superstructure conditions, height of substructures, soil conditions and so on, in the standard design.

- necessity to make some modification and additional calculation for substructure and foundation when their standard design is in use.

On the other hand, in order to manager the standard design effectively, the training of engineers should be implemented in the course of this study so that they would be capable to manage modifications of the standard design in future.

The Study Team considers the training of engineers as the most important matter in order to obtain better results not only this time but for future bridge design in Malaysia as well.

In consideration of the above, the design range of standard design for substructure was determined as shown below.

- All design cases that JKR proposed will be carried out.

- The drawings of standard design of substructure and foundations show the change of the structures where the design parameters (height of structure, span, type of foundation, skew angle) are changed.

- Furthermore, the drawings show maximum and minimum scale of each structure type (abutment: 1 type, piers: 2 types)

- The range of the design drawings will be reviewed after design calculation. The design drawings might be able to prepare all the design cases depending on the structural members (parapet wall, body, pile cap, pile) if the focus is made on each member, but not the whole structure.

(1) Standard Design

(a) Abutment (Inverted-T abutment)

(i) Number of cases for design calculation

	Superstructure Span Range			
	6m to 10m	12m to 22m	25m to 32m	35m to 45m
	No. of cases	No. of cases	No. of cases	No. of cases
Height of Abutment	1: 6m	1: 6m	1: 6m	2: 8m, 10m
Span	1: 10m	2: 16m, 22m	2: 28m, 32m	2: 35m, 45m
Foundation (PC Pile)	2: End Bearing Friction	2: End Bearing Friction	2: End Bearing Friction	2: End Bearing Friction
Skew Angle	2: 15°, 30°	2: 15°, 30°	2: 15°, 30°	2: 15°, 30°
No. of Design Cases	N=1x1x2x2=4	N=1x2x2x2=8	N=1x2x2x2=8	N=2x2x2x2=16

(ii) Number of cases for reference drawings to be prepared

Parameters	Height	Span	Foundation (PC Pile)	Skew	Case No.
Height of abutment	8m	35m	End Bearing	0	1
	10m	35m	End Bearing	0	2
Span	6m	16m	End Bearing	0	3
	6m	28m	End Bearing	0	4
Type of Foundation	6m	28m	End Bearing	0	4
	6m	28m	Friction	0	5
Skew	6m	28m	End Bearing	0	4
	6m	28m	End Bearing	15	6
	6m	28m	End Bearing	30	7
Min. Span	6m	10m	End Bearing	0	8
	6m	10m	Friction	0	9
Max. Span	10m	45m	End Bearing	0	10
	10m	45m	Friction	0	11

(b) Pier (T-type Pier and Multiple Column Pier)

(i) Number of typical cases for design calculations

	Superstructure Span Range		
	12m - 22m	25m - 32m	35m - 45m
	No. of cases	No. of cases	No. of cases
Height of Pier	1: 10m	2: 10m, 15m	2: 10m, 20m
Span	2: 16m, 22m	2: 28m, 32m	2: 35m, 45m
Foundation (PC Pile)	2: End Bearing Friction	2: End Bearing Friction	2: End Bearing Friction
Skew Angle	2: 15°, 30°	2: 15°, 30°	2: 15°, 30°
No. of Design Cases	N=1x2x2x2=8	N=2x2x2x2=16	N=2x2x2x2=16

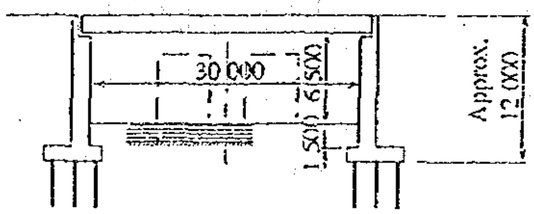
(ii) Number of cases for reference drawings to be prepared

Parameters	Height	Span	Foundation (PC Pile)	Skew	Case No.
Height of pier	10m	28m	End Bearing	0	1
	15m	28m	End Bearing	0	2
Span	10m	16m	End Bearing	0	3
	10 m	28m	End Bearing	0	1
Type of Foundation	10m	28m	End Bearing	0	1
	10m	28m	Friction	0	4
Skew	10m	28m	End Bearing	0	1
	10m	28m	End Bearing	15	5
	10m	28m	End Bearing	30	6
Min. Span	10m	16m	End Bearing	0	3
	10m	16m	Friction	0	7
Max. Span	20m	45m	End Bearing	0	8
	20m	45m	Friction	0	9

(2) Sample Design (for the set of calculations and drawings)

(a) Spread Foundation — 1 case
Height of Inverted T-type abutment for 8m

(b) High T-type abutment — 1 case
Clearance between both abutments for 30m
Height of abutment 12m
Foundation PC Pile end bearing



Clearance for bridge across Railway

(c) High pier — 3 cases

Height of pier	30m
Foundation	(1) PC Pile end bearing
	(2) PC Pile friction
	(3) Bored pile 800mm

(d) Multiple column pier — 1 case

Height of pier	20m	
Pile diameter	Bored pile	800mm

Total nos. of sample design — 6 cases

(3) Summary of Design Range for Substructure

Typical design		
Design calculation	Abutment; 36 cases,	Pier; 40 x 2 = 80 cases
Design drawings	Abutment; 11 cases,	Pier; 9 x 2 = 18 cases
Sample design		6 cases

3.3 Selection of Computer System

3.3.1 General

The selection of computer system composed of hardware and software was conducted mainly for the personal computer system in consideration of wide utilization in Malaysia and the capacity as computerized design system.

The selection was also made in consideration of the cost of other computer system to ensure its economy.

3.3.2 Proposed Computerized Design System and Programme

Computerized design system is divided into four parts, namely, design of superstructure and substructure, drawing of superstructure and substructure.

System proposed for the design of superstructure is a systematized automatic design system by using personal computer.

The computerized design system for superstructure was developed for five programmes below.

Programme 1	:	Input of common data
Programme 2	:	Structural analysis
Programme 3	:	Design for main beam
Programme 4	:	Design for cross beam
Programme 5	:	Output of the result of design

For the design of substructure a partially computerized design system is used.

The design system for substructure was developed for three programmes undermentioned.

Programme 1	:	Structural analysis for plane framed structure
Programme 2	:	Design for reinforced concrete members
Programme 3	:	Design for stability of piles

Automatic system by Auto CAD, which is synchronized is used for drawing of superstructure.

For drawing of substructure Auto CAD by manual operation is used.

3.3.3 Proposed Computer Hardware System and Operation System

(1) Proposed Computer Hardware System

Computer hardware system shall be such system which is capable to build capacity as computerized design system, and also it should be easier to familiarize with bridge design engineers in Malaysia. Hardware system was selected in reflecting the discussions with and the requests made by JKR and in consideration of the cost of other computer hardware system.

As mentioned above, the computer hardware system for this study shall be compatible to the IBM-PC (International Business Machine Co.,) which is commonly used in Malaysia.

The details of the hardware system given below is for budget purposes as of October, 1994.

Table 3.8 Computer Hardware System

	Description
CPU	I 80486 DX2/66 MHZ or better
Monitor	21" Colour Monitor
Hard Disk	2.9 GB
Printer	Laser Shot A3 size
Plotter	Ink Jet A0 size
Back Up	External Portable Hard Disk
UPS	600 VA
CAD	Auto-CAD Version 12

(2) Proposed Computer Operation System

On the other hand, the operation system and language to make up the programme systems for the design and drawing are as follows:-

- Operation System : MS-DOS Ver 6.2
- Analysis of Structure and Section : FORTRAN language
- Input and Output : BASIC language

CHAPTER 4 DEVELOPMENT OF DESIGN ANALYSIS SYSTEM (PHASE III)

4.1 Definition of Design Analysis System

4.1.1 General

In order to design standard bridge types, design analysis system was defined according to the design standard established in the Technical Committee meeting.

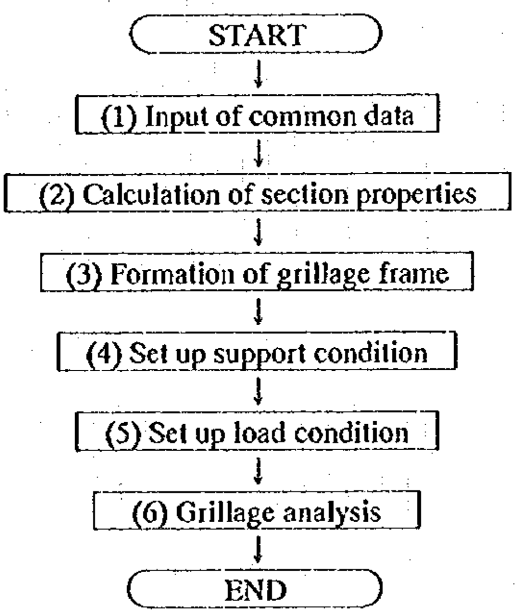
The Study Team conducted the design analysis procedure at first, and the definition for design method in detail was carried out in each design stage so as to ensure an adequate degree of safety and serviceability according to the standard.

Based on the design analysis system, the development of the computerized design programming and drawing programming shall be carried out. Therefore, definition of design analysis system is very important in this Study.

4.1.2 Design Analysis System for Superstructure

4.1.2.1 Structural Analysis

Structural Analysis shall be carried out according to the Analysis Flowchart undermentioned.



Definitions for each states of above flowchart is described as follows.

(1) Input of common data

In order to proceed the structural analysis, requisite data such as span length, width, the number of main beams and cross beams, loads, dimension and properties of material shall be prepared. The data shall be used for analytical data for design and basic data for drawings.

(2) Calculation of section properties

The section properties in structural analysis shall be calculated as the gross concrete section in consideration of effective width of flanged beam. In particular, the end cross beam is not effective whole section but main beam and intermediate cross beam are effective whole section in this standard bridges.

(3) Formation of grillage frame

Formation of grillage frame shall be carried out for each discrete stage of erection. For example, the grillage frame for the composite T--beam shall be formed three types as follows.

- Simple beam
- Grillage frame composed of main beam and cross beam
- Grillage frame composed of main beam, cross beam and slab

(4) Set up support condition

The support condition shall be fixed for vertical, and free for horizontal and rotation.

(5) Set up load condition

Based on input of common data, dead load, superimposed dead load and live load shall be set up.

(6) Grillage analysis

Elastic methods of analysis should be used to determine internal forces and deformations.

In the Grillage Analysis, the Study Team decided the limitation of the 20 numbers main beams and 11 numbers cross beams. Cross beams shall be composed of actual cross beams and the design section only for main beams.

4.1.2.2 Design for main beam

Design for main beam shall be carried out according to the design flowchart below.

START

↓

(1) Definition of the representative main design

↓

(2) Calculation of flexural stressed under S.L.S

↓

(3) Calculation of prestressing

↓

(4) Assessment for flexural stressed under S.L.S

↓

(5) Assessment for stability of flexural strength under U.L.S

↓

(6) Calculation of shear stress and torsional shear stress under U.L.S

↓

(7) Calculation of ultimate vertical shear resistance

↓

(8) Calculation of shear reinforcement

↓

(9) Calculation of torsion reinforcement

↓

(10) Calculation of longitudinal shear only for composite T-beam

↓

END

(1) Definition of the representative main beam

The representative main beam to the respective design as for the flexural, shear and torsion shall be derived from the four critical forces calculated by the structural analysis as follows.

- The beam causing the maximum moment at the U.L.S
- The beam causing the maximum shear at the U.L.S
- The beam causing the maximum torsion at the U.L.S
- The beam causing the minimum torsion at the U.L.S

(2) Calculation of bending stress at the S.L.S

The stiffness constants shall be adopted according to the load condition. For example, the bending stress of the composite T-beam shall be calculated by the three stiffness.

- Net cross section (exclude the sheath for PC tendon)
- Gross transformed section 1(main beam only)
- Gross transformed section 2 (main beam and slab)

(3) Calculation of Prestressing

Immediately after anchoring, the force in the prestressing tendon should not exceed 70% of the characteristic strength for post-tensioned tendons, or 75% for pre-tensioned tendons.

Losses of prestress resulting from subsequent shrinkage and creep of the concrete shall be calculated based on the CEB/FIP international Recommendations using 80% humidity of Malaysian meteorological data.

(4) Assessment for flexural stresses under serviceability limit states

For the S.L.S., the examination of flexural stress shall be carried out one stage for reinforced concrete, or four stages for prestressed concrete respectively.

- Immediately after anchoring
- Under own dead load
- Under superimposed dead load
- Under live load

In reinforced concrete, however, design crack width shall be checked in accordance with cl. 5.8.8.2, Part 4, BS5400.

(5) Assessment of stability for flexural strength under the Ultimate Limit State

On pre-tensioned solid slab and hollow slab, assessment shall be made on main beam section ignoring the filling area, and on live load.

Composite T-beam, assessment shall be made on composite section.

(6) Calculation of shear stress and torsional shear stress under U.L.S

Shear stress and torsional shear stress shall be calculated by respective section as below.

- Rectangular section for the solid slab
- Box section for the hollow slab
- T-section for the live load composite T-beam

For the live load composite T-beam, section of properties shall be based on those of the composite section, with due allowance for the different grades of concrete where appropriate.

(7) Calculation of ultimate vertical shear resistance

The value of 0.87 shall be applied as the partial safety factor for characteristic strength of PC tendons.

For the live load composite T-beam, the vertical shear force due to Ultimate Loads shall be calculated to be resisted by the precast unit acting alone.

(8) Calculation of shear reinforcement

The effective depth for the calculation of shear reinforcement shall be taken as the depth from the extreme compression fibre to the centroid of the tendons.

For the live load composite T-beam, the depth of slab shall be added to the precast unit.

(9) Calculation of torsion reinforcement

The calculation of torsion reinforcement shall be carried out only where the torsional shear stress in a minor rectangle is larger than minimum ultimate torsional shear stress.

(10) Calculation of longitudinal shear only for composite T--beam

The calculation shall be based on Cl. 7.4.2.3, Part 4, BS5400.

4.1.2.3 Design for Cross Beam

The design of cross beam shall be conducted with nearly the same flowchart as in the case of the design of main beam.

Described below are the agreed matters only for the design of cross beam.

(1) Treatment for prestressing force

It is just a intricate problem to conduct a calculation of the losses of prestressing force of cross beam according to each discrete stage of erection, it is, therefore, decided to follow the practice in Japan as below.

That is, a simplified method was adopted by setting the factors as follows:

- initial prestressing force is - 7 x characteristic strength of PC tendon,
- effective factor for prestressing force is 0.8,
- then, effective force is (0.7 x 0.8=) 0.56 x characteristic strength

(2) Design of cross beam for flexural moment of composite T–beam

For the positive flexural moment, the design shall be carried out as prestressed concrete member reflecting the each discrete stage of erection.

For the negative flexural moment, the design shall be carried out as reinforced concrete member to the composite T–section.

4.1.3 Design Analysis System for Substructure

Hypothesis condition on design analysis of substructure are stated as follows.

(1) Working earth pressure

Coulomb's active earth pressure shall be considered for stability analysis and earth pressure at rest shall be considered for wings which have fixed end at vertical direction.

(2) Analysis of each members

Wall of abutment and pier shall be designed as cantilever slab, beam of pier shall be designed as beam, and pile cap shall be designed as beam and slab or flat–slab.

(3) Design analysis of pile foundation

Pile foundation shall be treated as elastically supported beam, and is analyzed by using deformation method in which pile cap and piles are connected by working force and deformation.

(4) Spring of subgrade (Reaction of subgrade)

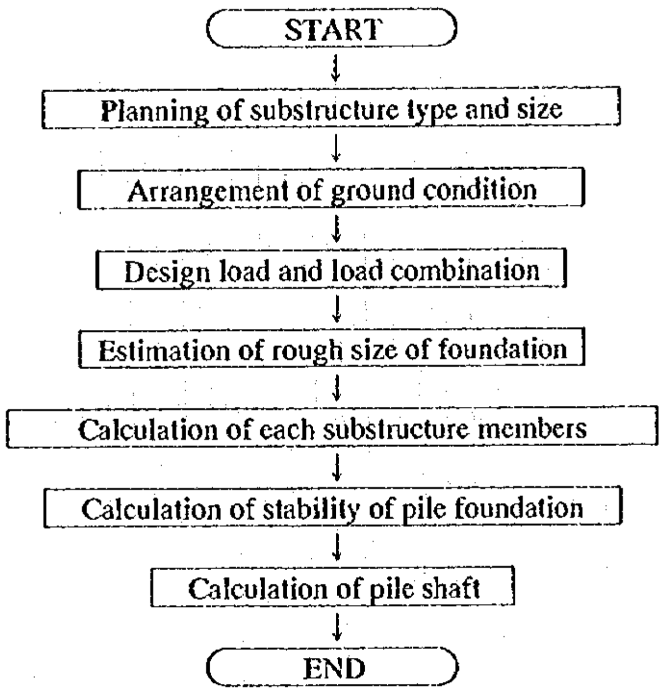
Spring of subgrade shall be considered to horizontal and vertical directions of pile. Horizontal spring shall be calculated from the results of undrained compression test or triaxial compression test based on JS.

(5) Design of multiple column

Multiple column type pier shall be designed according to 2–dimensioned frame analysis calculation. Pile cap shall be designed as a continuous beam bearing the reactions from columns and the reactions from pile heads.

For design of substructure, partially computerized design system (sectional analysis for each members, stability for pile foundation, frame analysis) shall be prepared.

Design of the substructure shall be carried out according to the design flowchart as follows.



4.1.4 Special Consideration

Design of slab shall not be incorporated in the computerized design system in this Study, and standard slab thickness shall be determined by the Finite Element Method. The calculation sheets shall be prepared separately to assure the safety of slab. The thickness shall be determined with thorough consideration on safety, since slab supports directly the live load which are repeated loadings.

4.2 Development of Computer Programme for Design Analysis

4.2.1 General

On the hardware system, as mentioned in clause 3.3.3, personal computer system should be used for this project.

As for the software system, it is difficult to use them due to problems of copyright and ownership.

Therefore, the software for the design system used for this project shall be exclusively developed by Study Team.

Automatic design programme, which can design simply by personal computer built for the bridge types of standard design in accordance with the design analysis procedures, was established in the section 4.1.

In order to operate easily by bridge engineers in Malaysia, the computer programme shall be developed as the simple dialogue personal computer system.

Development of computer programme has been reviewed through the discussion in the Technical Committee.

4.2.2 Programming for Superstructure

The general flowcharts for the design programme proposed for this project are as shown in Fig. 4.1 and Fig. 4.2.

4.2.3 Programming for Substructure

The flowcharts of the analysis programmes for substructure are shown in Fig 4.3, Fig. 4.4 and Fig. 4.5.

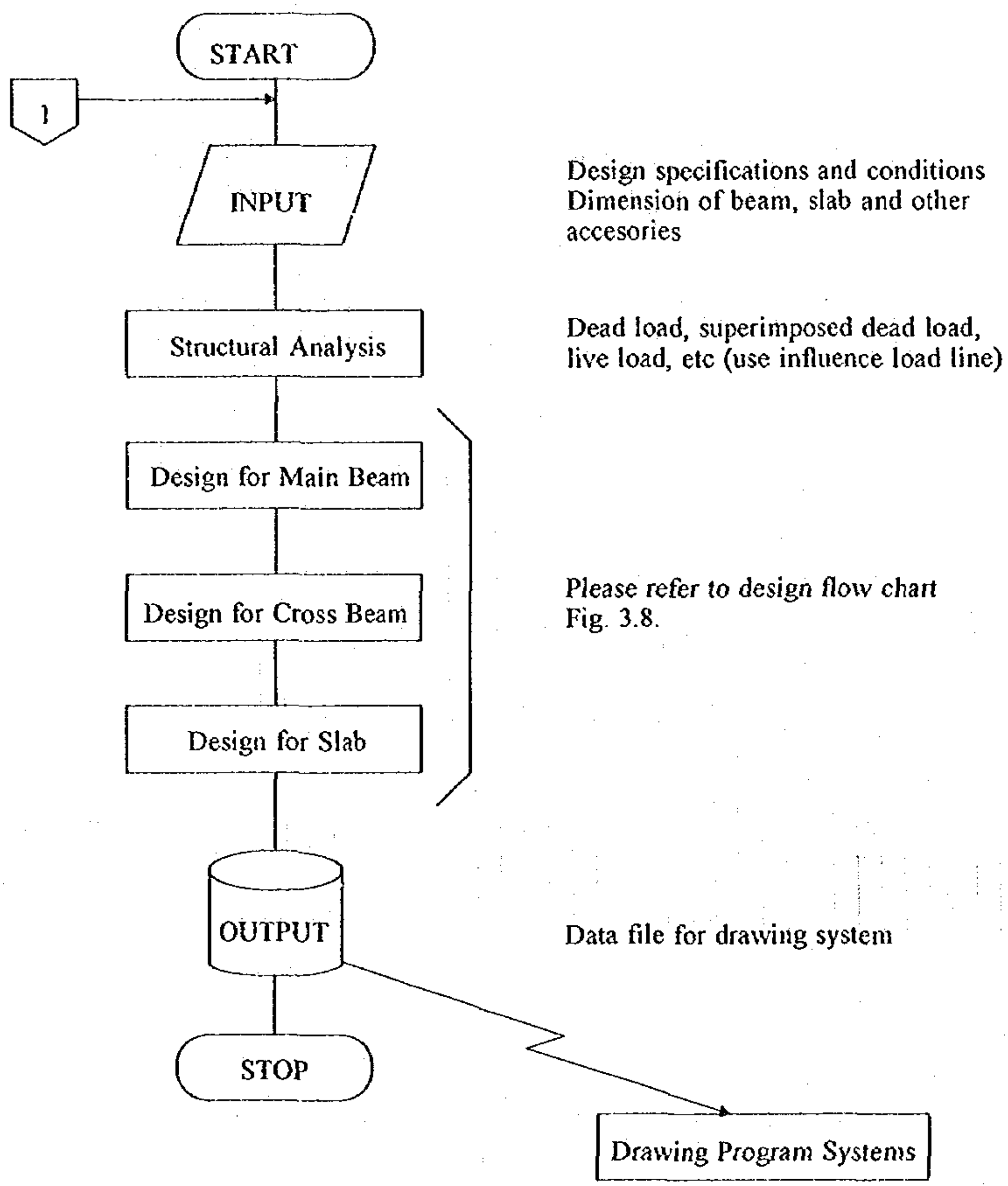


Fig. 4.1 General Flow Chart for Design Programme

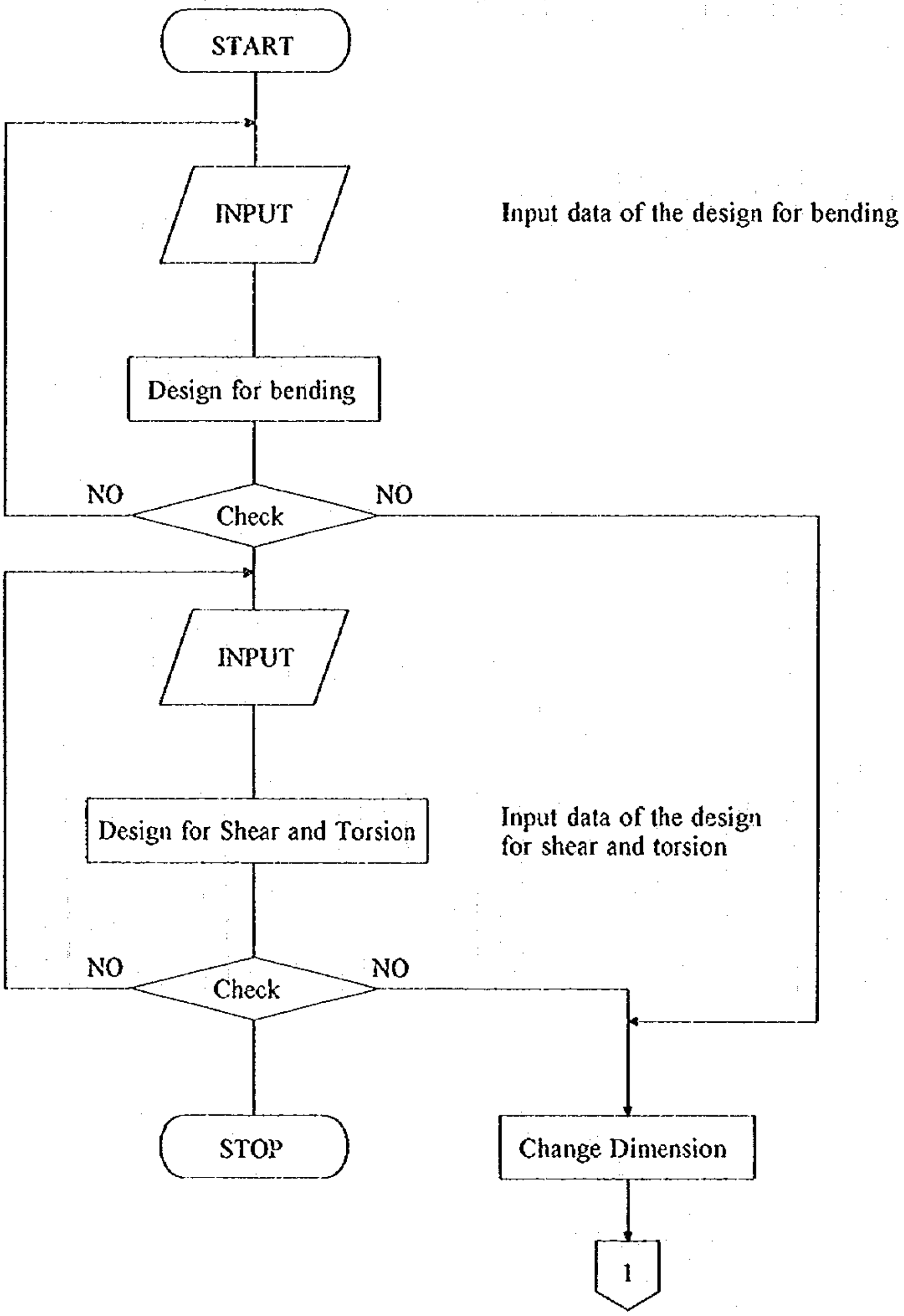


Fig. 4.2 Design Flow Chart

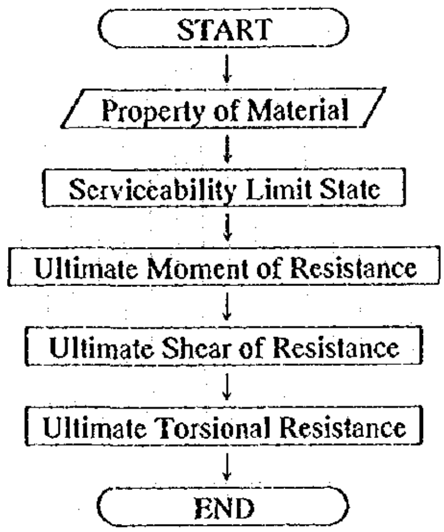


Fig. 4.3 *Sectional analysis programme*

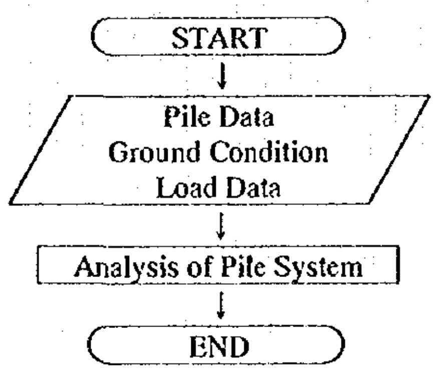


Fig. 4.4 Stability of pile foundation programme

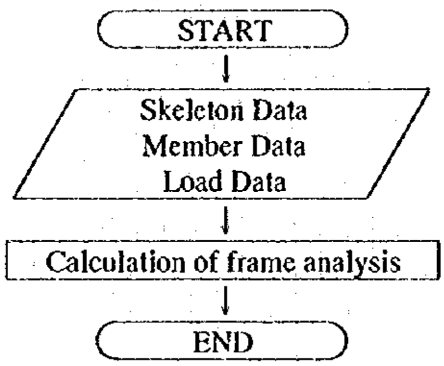


Fig. 4.5 Frame analysis (for Multiple columns)

CHAPTER 5 DEVELOPMENT OF DRAWING SYSTEM

5.1 Defining of Drawing System

5.1.1 General

The development of automatic drawing system was intended mainly for superstructure. A comprehensive computer programme was developed for the drawing of superstructure, which is closely linked with the design analysis programme, covering all the standard superstructure types and is equipped for quantity estimation.

For substructure, no automatic drawing programme specific to the Study was prepared. The drawing of substructure are produced by using the existing drawing computer programmes available in JKR. All the necessary drawing data of the standard substructure types are manually input to produce drawings of basic case. According to the method in the basic case, JKR draughtmen prepare the drawings for other cases, also by hand drafting with auto-CAD. The prepared drawings were out-put by a plotter.

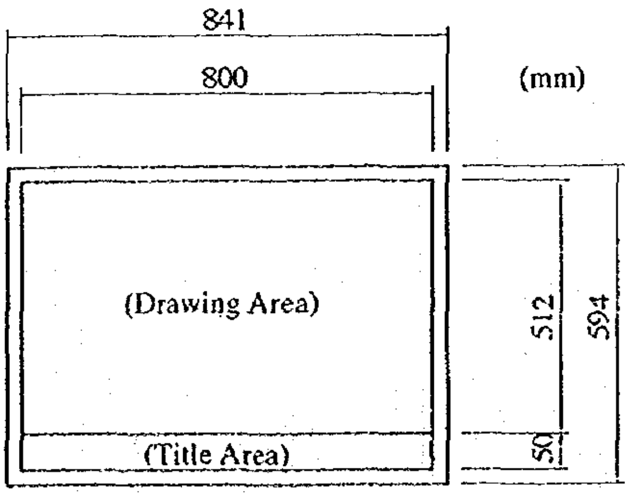
In addition to the development of computer-aided drawing system, the drawing presentation rules were confirmed based on the JKR's guideline.

5.1.2 *Drawing Presentation Rules*

The drawing presentation rules were prepared based on the Guide Line for Presentation of Engineering Drawings of JKR and through the discussions in the Technical Committee. Major rules decided are as follows:

(1) Size of Drawing Sheet and Margin

Size of Sheet : A1 (841 x 594mm)



(2) Letters

- Letter Size : All 2.75mm except title of 5.0mm
- Pen Size : 0.35mm except title of 0.5mm
- Font : Roman Simplex
- Colour : Yellow

(3) Lines

Kinds of Lines	Pen Size (mm)	Colour
Dimension Line, Extension Line, Leader and Arrow	0.18	White
Structural Line, Centre Line, Under Line, and Table Line	0.25	Blue
Cross-section Mark	0.35	Blue
Re-bars and PC cable	0.50	Magenta

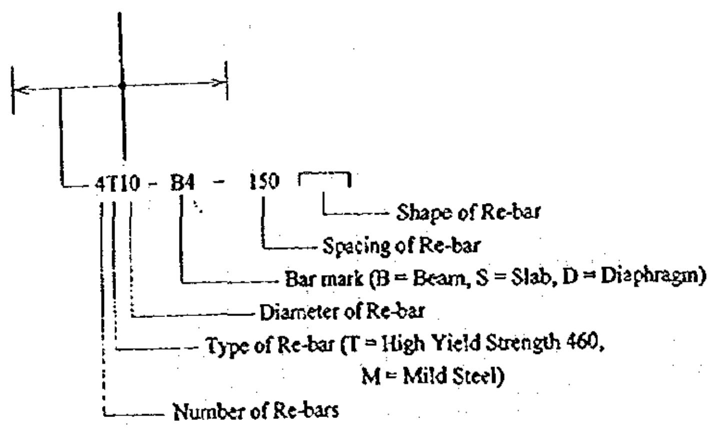
(4) Dimension Line

(mm)

- Arrow Size : 3.0
- Tick Size : 2.0
- Extension above line : 2.0
- Offset from feature : 3.0
- Spacing of dimension lines: 7.0

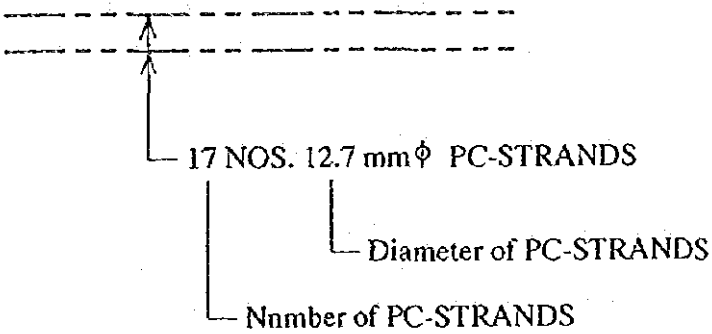
(5) Re-bar and PC-cable

- Re-bar



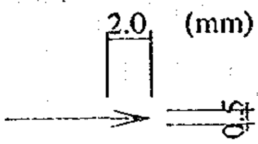
- Splicing of Re-bars

- PC-cable

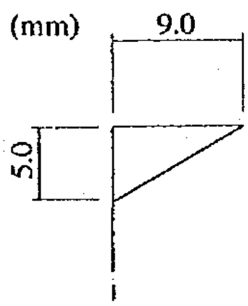


(6) Other Marks

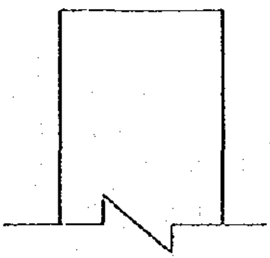
- Arrow



- Cross-section Mark



- Break Line



5.2 Development of Computer Programme for Drawing (Superstructure)

5.2.1 General

The automatic drawing system for superstructure shown in Fig. 5.1 is composed of 4 task programmes and a CAD system. The drawing system is devised to compute quantities as well.

5.2.2 Input Data

Input data is prepared in two different ways: automatic input from design analysis data and manual input for additional data. Further, the input data is divided into three categories consisting of structural lines, reinforcement including prestressing steel and configuration.

The following are the input data required for the system.

Category	Automatic Input	Manual Input
(1) Structural Lines	- Basic design data (span, width and main-beam and cross-beam lay-out) - Dimension data (cross-sectional dimensions of main beam) - Width component (parapet, footway and carriageway)	- Carriageway data (thickness of pavement) - Parapet data (dimensions of curb) - Footway data (thickness of footway)
(2) Reinforcement including prestressing steel	- Longitudinal prestressing steel data - Transversal prestressing steel data	- Concrete cover data - Longitudinal reinforcement arrangement data - Link arrangement data
(3) Configuration		- Drawing scale data - Drawing position data

The configuration of drawing is adjustable by changing the drawing scale and position input data for the suitable layout of plan, profile, cross-sections, details, etc. on a drawing sheet of A-1 size.

5.2.3 Output Data

(1) Drawings

The types and the contents of drawings output in the system were determined for each standard structure type as follows:

(a) Superstructure

Structure Type	Name of Drawing	No. of Drawing
Reinforced Concrete Solid Slab	- General dimensions and Re-bar Arrangements	1
Pre-tensioned Concrete Solid Slab	- General Dimension - Re-bar and Prestressing Steel Arrangements	1 1
Pre-tensioned Concrete Hollow Slab	- General Dimension - Re-bar and Prestressing Steel Arrangement	1 1
Pre-tensioned Concrete Composite T-Beam	- General Dimension - Re-bar and Prestressing Steel Arrangement for Beam, and Detail of Slab	1 1
Post-tensioned Concrete Composite T-Beam	- General Dimension - Re-bar and Prestressing Steel Arrangement for Beam - Detail of Slab	1 1 1

(b) Substructure

Structure Type	Name of Drawing	No. of Drawing
T-type Pier	- General Dimensions - Bar Arrangement	1 1
Multiple Column Pier	- General Dimensions - Bar Arrangement	1 1
Abutment (inverted T abutment)	- General Dimensions - Bar Arrangement	1 1
Bored Pile	- ϕ800 Bar Arrangement	1
Wing Wall	- Length of 5 meters Bar Arrangement - Length of 3 meters Bar Arrangement	1 1
Approach Slab (length of 5 meters)	- Wing Wall (t=700mm) General Dimensions and Bar Arrangement - Wing Wall (t=500mm) General Dimensions and Bar Arrangement	1 1

(2) Volume

The following kinds of quantities of major construction materials are output for each standard structure type:

- Concrete volume of main beams, cross beams, slab and parapet.
- Form area of main beams, cross beams, slab and parapet.
- Re-bar bending schedule and weight for main beams, cross beams, slab and parapet.
- Prestressed steel length and anchorages for main beams and cross beams.

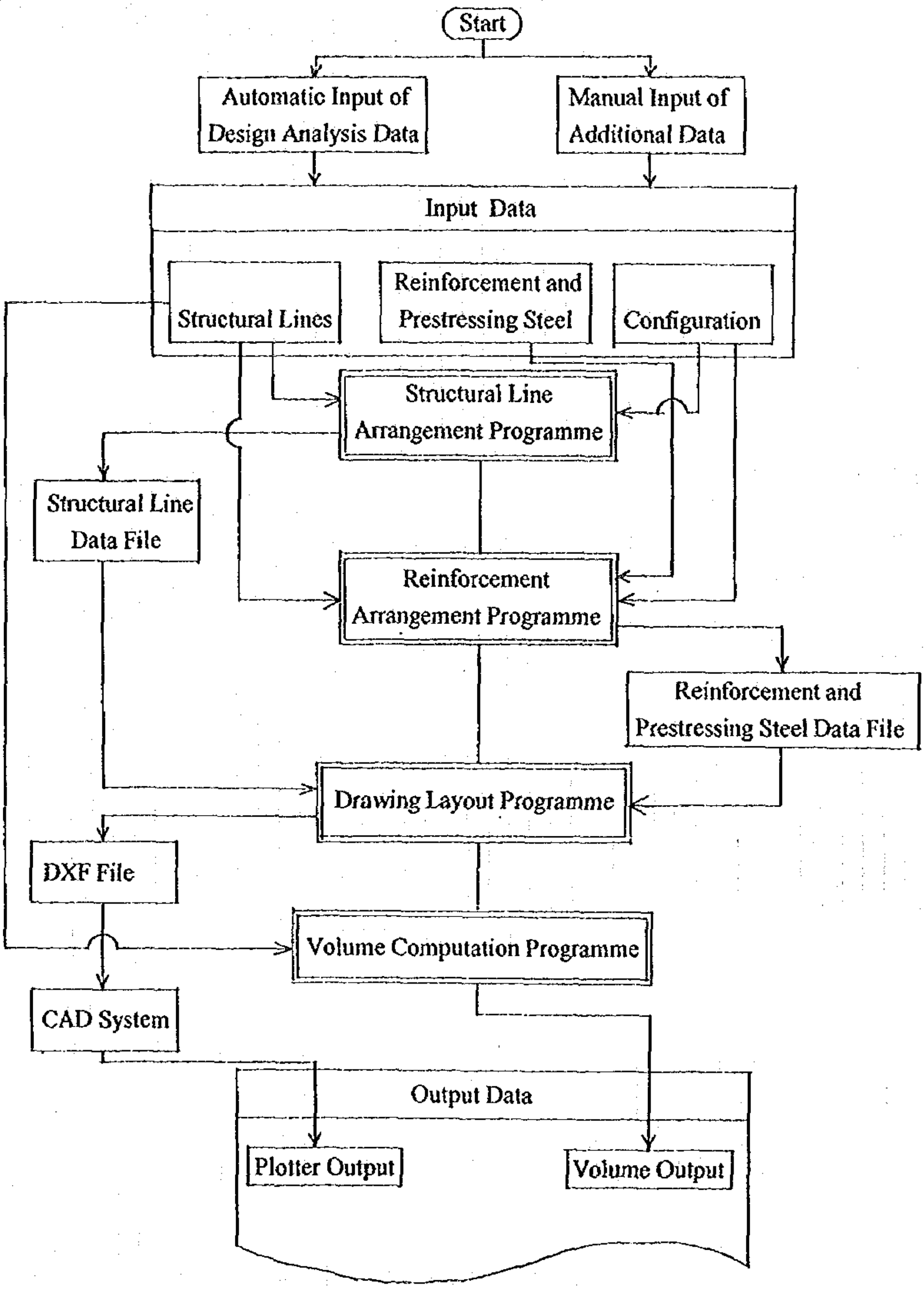


Fig. 5.1 Superstructure Drawing Programme

CHAPTER 6 EXECUTION OF STANDARD DESIGN WORK AND PREPARATION OF MANUAL (PHASE V)

6.1 Execution of Standard Design Work

6.1.1 General

Based on the design analysis system defined in Section 4.1 and by applying the computer programmes developed in Section 4.2, actual design analysis computations for both super and sub-structures were carried out and completed by the end of August, 1995.

Prior to the execution of standard design computations, the following measures wee taken to ensure smooth and effective operation:

(1) Defining of design conditions, applicable optimum cross-sections and spans, etc. by preparing lists.(refer to Table 6.1)

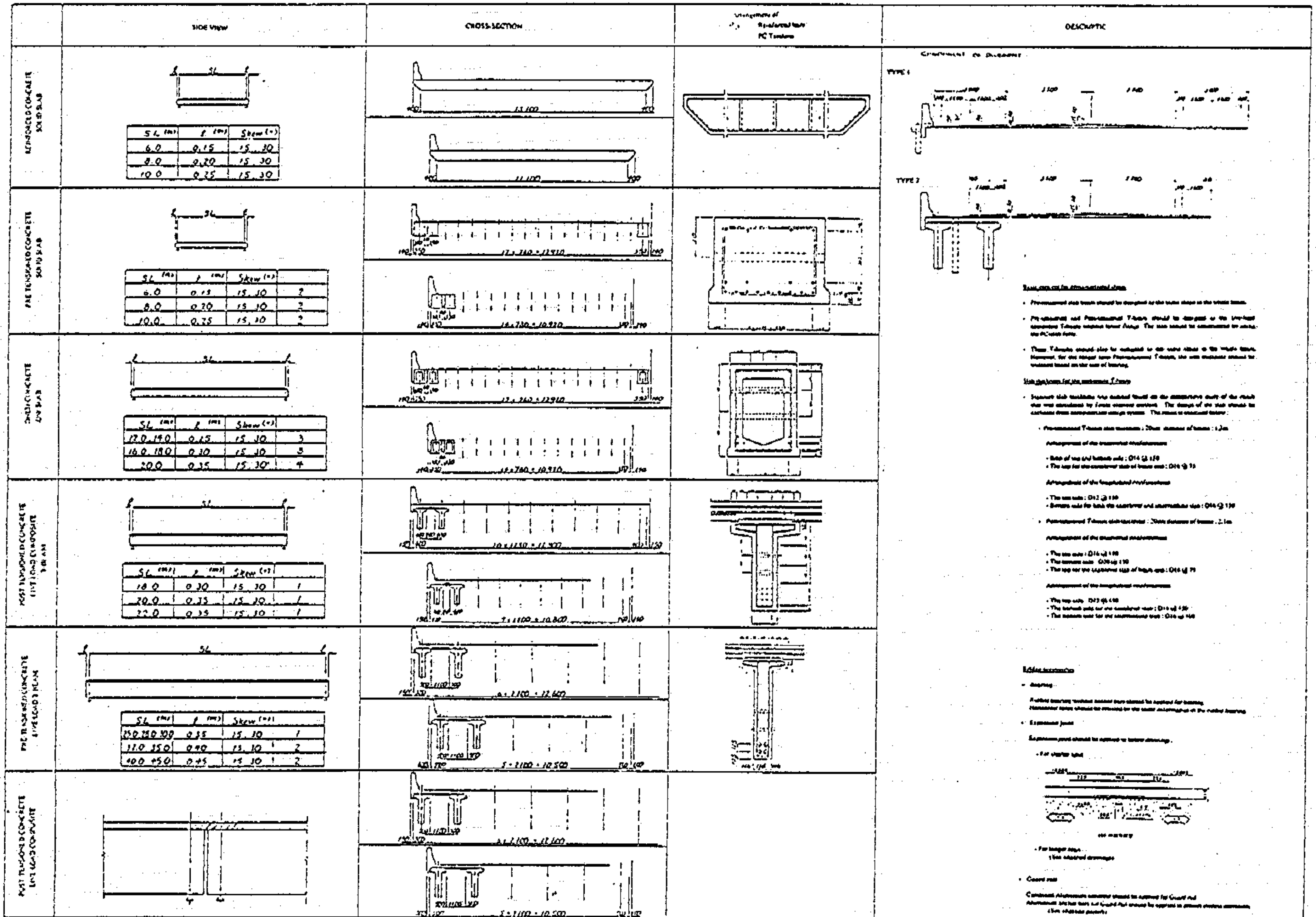
(2) Preparation of flow chart of computer programmes for design analysis. (refer to Fig. 6.1 and 6.2)

(3) Preparation of flow chart of development of computer programmes for drawing. (refer to Fig. 5.1)

(4) Defining of Technology Transfer (refer to Table 6.2)

Receiving 4 counterpart engineers from JKR, and posting each two of them for superstructure and substructure respectively, the technology transfer was practiced from the middle of June up to the end of August, 1995 for the aim of on-the-job-training. The main objectives of the training are understanding of computations and operation of computer programmes. With this training, JKR engineers will be able to carry out the design works by themselves after the Study term is over.

Table 6.1 . Summary of Superstructure Standard Bridge Types



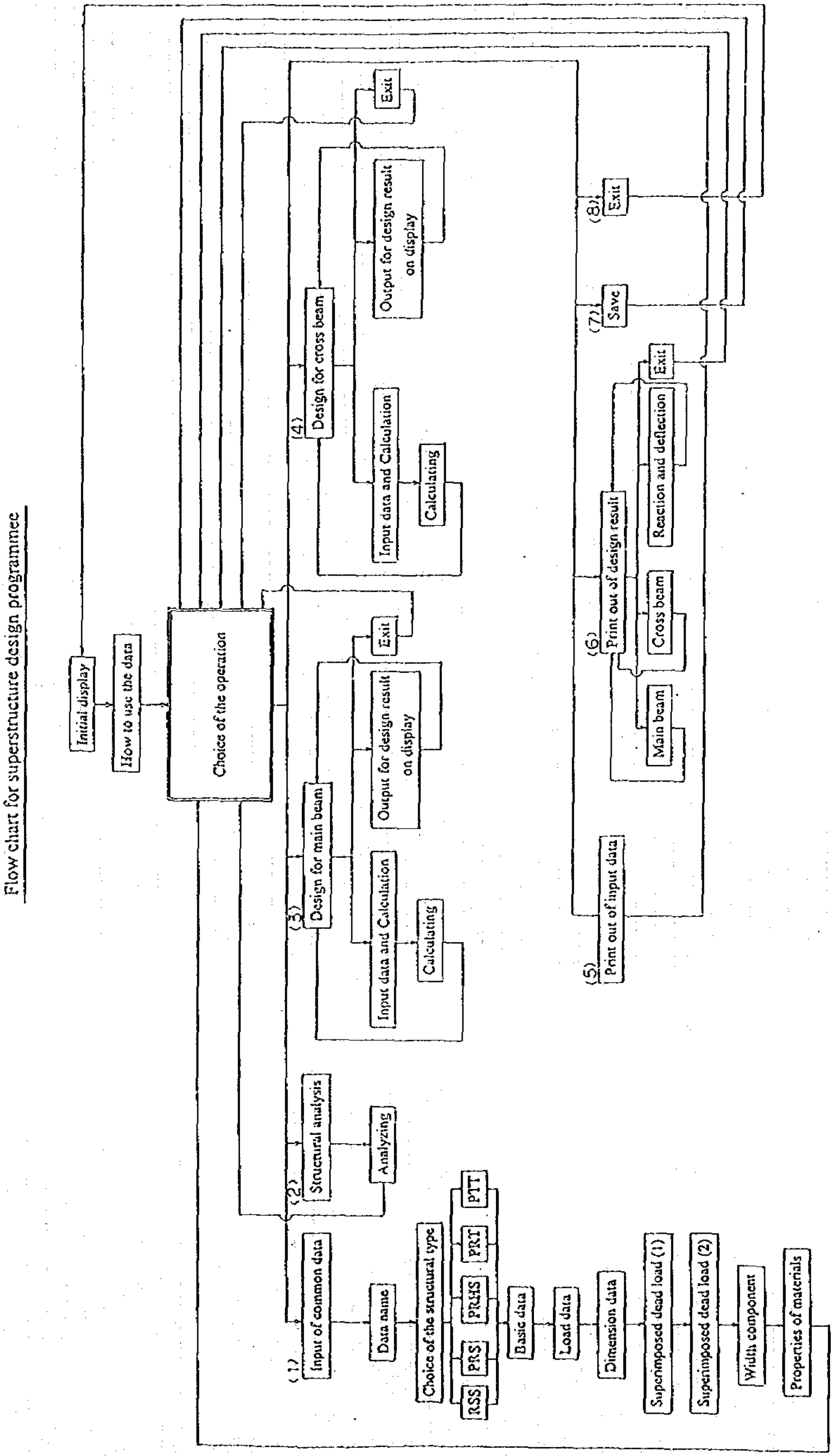


Fig. 6.1 Flow Chart for Superstructure Design Programme

Flow chart for substructure design programme

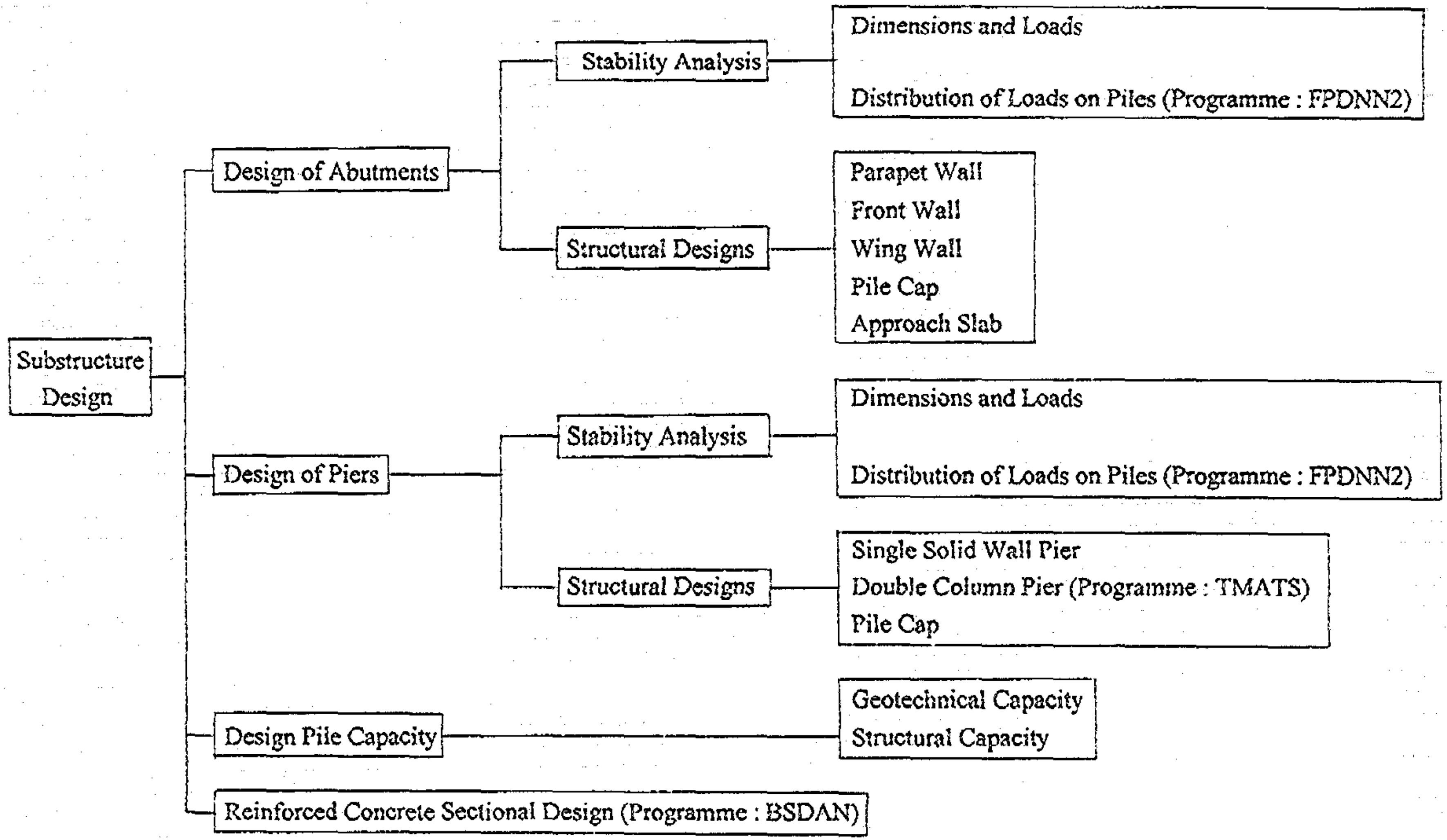


Fig. 6.2. Flow chart for substructure design programme

Table 6.2 Technology Transfer Schedule

Superstructure	1. Mid June-Mid July	Reinforced solid slab Pretension solid slab Pretension voided slab Pretension T-beam Post-tension T-beam	Understanding of design procedure 1) Method of structural analysis 2) Method of design for beam 3) Print out of design result 4) Design of accessories for bridge	Operation of Computerized design system (Automatical system except accessories)	Based on the understanding Preparation of design manual with Study Team member
	2. Mid July-End Aug	-- do --	-- do --	-- do --	-- do --
Substructure	3. Mid June-Mid July	Abutment Invert T-type Pile foundation H=12m Inverted T-type	Understanding of design procedure Design Method	1) Operation of Partial design system 2) Analysis of members 3) Analysis of pile foundation	-- do --
	4. Mid July-End Aug.	Pier T-type Multiple column type Pile foundation H=20m high pier Bored pile foundation	-- do --	-- do -- 1) Analysis of T-type 2) Analysis of multiple column pier	-- do --
Drawings	5. Mid Sept - Nov.	Superstructure	Operation of Auto-CAD system by	comouterized drawing system	Preparation of std bridge drawings
		Substructure	--- do ---		-- do --

6.1.2 Standard Design Work for Superstructure

(1) Computation Cases

Type	Span	× Width	× Skew	= Total
Reinforced Concrete Solid Slab	3	2	2	12
Pre-tensioned Concrete Solid Slab	3	2	2	12
Pre-tensioned Concrete Hollow Slab	3	2	2	12
Pre-tensioned Concrete T-beam	3	2	2	12
Post-tensioned Concrete T-beam	7	2	2	28
			Total	76

(2) Methodology

To deepen the counterparts' understandings and for the future effective use of the standard design, the computation of superstructure was carried out by the counterparts first and the Study Team member checked the results.

The "on the job training (OJT)" was performed to the JKR counterpart engineers with the lectures by the Study Team members about design procedures, design principles, operation of computer programmes, etc.

The major design analysis techniques transferred to the JKR counterpart engineers made through the on-the-job training, are summed up as follow:

(a) General interpretation of input data: for what design purpose, how to put into computation and which provision of BS-Standards relating to.

(b) First assumption of beam size from:

- recommended spa-height ratio of main beams, and
- width-height ratio of cross-beams

(c) Design of prestressing about:

- how to assume initial prestressing force,
- causes for prestress losses, and
- how to decide prestressing steel layout

(d) Criteria and limitations for:

- bending stresses of beam at transfer of prestressing force,
- bending stresses of beam in serviceability limit state (S.L.S),
- the factor of safety of beam against bending moment in ultimate limit state (U.L.S), and
- shear stresses of beam under various load combinations.

6.1.3 Standard Design Work for Substructure

(1) Computation Cases

(Number of Cases)

Standard Design					
Type		Span	× Foundation ×	Skew =	Total
	H= 6m	5	2	2	20
Abutment	H= 8m	2	2	2	8
	H=10m	2	2	2	8
				subtotal	36
	H=10m	6	2	2	24
T-type Pier	H=15m	2	2	2	8
	H=20m	2	2	2	8
				subtotal	40
	H=10m	6	2	2	24
Multiple Column Pier	H=15m	2	2	2	8
	H=20m	2	2	2	8
				subtotal	40
				Total	116
Sample Design					
Spread foundation for 8m high Inverted-T Abutment					1
High Inverted-T Abutment (12m)					1
High T type Pier (30m) with 3 types of Foundation					3
Bored Pile Foundation for Multiple Column Pier					1
				Total	6

(2) Methodology

Like the computation of superstructure, the substructure computation was carried out together with counterparts as a part of the on-the-job training. Since the computation cases of substructure are many, it was necessary to develop number of small computer programmes for the member design analysis unlike in the case of superstructure. The burden of numerous computation were shared with the JKR engineers.

The counterparts contributed much in preparation of many computer programmes with well understanding the explanation of the Study Team such as totalling of loads for stability analysis and distribution of loads to various abutment and pier members.

The major techniques transferred to the counterparts about the substructure analysis are as follows:

(a) First assumption of abutment and pier sizes about:

- balance of abutment/pier height to foundation width,
- minimum bearing surface width,
- required member thickness, and
- balance of cantilever span to center span of two column frame pier and of single solid column pier

(b) Pile design about:

- minimum pile spacing and distance from edge,
- loading capacity per pile, geotechnical and structural, and
- connection of pile top into pile cap.

(c) Loading condition about:

- loads and load combinations specified in the British standard BD37/88, and
- selection of super-imposed loads.

(d) Techniques of design analysis for:

- totalling of loads for member analysis by use of the Microsoft excel programme,
- usage of reinforced concrete section, pile load distribution and rigid frame programmes,
- procedure of stability analysis of foundation, and
- analysis methods for parapet and wing walls.

6.2 Execution of Standard Drawings

6.2.1 General

Based on the drawing system defined in Section 5.1 and by applying the computer programmes developed in Section 5.2, actual drawing works for both super and sub-structures have been carried out and scheduled to be completed by the end of November, 1995.

Prior to the execution of standard drawing works, the following measures were taken to ensure smooth and effective operation:

(1) Defining of suitable layout for all drawings.

(2) Defining of the arrangement of reinforcing bar obtained by the design result.

(3) Preparation of representative drawings for Abutment, T-pier and Multiple pier by manual.

(4) Defining of Technology Transfer

Receiving 2 counterpart technicians from JKR, who were posted mainly for substructure drawings, the technology transfer was practiced from the middle of September up to the end of November, 1995 for the aim of on-the-job-training. The main objectives of the training are understanding of drawing works and operations of computer programmes. With this training, JKR technicians will be able to carry out the drawing works by themselves after the Study term is over.

6.2.2 Standard Drawings Work for Superstructure

(1) Drawing Cases

Type	Span	x	Width	x	Skew	=	Cases	Drawings	No. of Drawings
Reinforced Concrete Solid Slab	3		2		3		18	1	18
Pre-tensioned Concrete Solid Slab	3		2		3		18	2	36
Pre-tensioned Concrete Hollow Slab	3		2		3		18	2	36
Pre-tensioned Concrete T-beam	3		2		3		18	2	36
Post-tensioned Concrete T-beam	7		2		3		42	3	126
					Total		114		252

(2) Methodology

Drawings for superstructure have been drawn up according to the flow as undermentioned.

- Preparation of input data by Study Team member (refer to 5.2.2)
  Input data composed with automatic data and manual data.

  Automatic data shall be reflected accurately to the design analysis result. Structural lines and configuration in the manual input data have been planned uniformly by the Study Team member prior to the execution of standard drawing work.

  Accordingly, required reinforcement data composed with link, longitudinal and transversal bars have been only prepared together with counterparts as a part of the on-the-job-training.

  Procedure of preparation for reinforcement data was transferred to the JKR counterpart engineers.

- Execution of standard drawing work by counterpart technicians.

  Drawings for superstructure were drawn up automatically based on the input data using the developed computer-aided drawing programme, and final drafting was carried out by connecting with Input data and auto-CAD system.

6.2.3 Standard Drawing Work for Substructure

(1) Drawing Cases

Standard Design				
Type		Cases	x Drawings	x No. of Drawings
Abutment	H=6m	7	2	14
	H=8m	1	2	2
	H-10m	3	2	6
			Subtotal	22
T-type pier	H=10m	6	2	12
	H=15m	1	2	2
	H=20m	2	2	4
			Subtotal	18
Multiple column pier	H=10m	6	2	12
	H=15m	1	2	2
	H=20m	2	2	4
			Subtotal	18
			Total	58
Wing wall				3
Approach slab				2
			Grand Total	63
Sample design				
Spread foundation for 8m high inverted-T abutment			1 x 2	2
High inverted-T abutment (12m)			1 x 2	2
High T type pier (30m) with 3 types of foundation			3 x 2	6
Bored pile foundation for multiple column pier			1 x 3	3
			Total	13

(2) *Methodology*

Drawings for substructure have been drawn up according to the flow as undermentioned.

- Preparation of representative drawings based on the Malaysian practice for abutment, T-pier and multiple pier by Study Team member.

- Execution of drafting work by counterparts with referring to the abovementioned sample drawings. Counterparts and Study Team member have discussed so many times how to reflect accurately the design result.

- Checking and guidance on standard drawings by Study Team member.

Checking points on the structural size and arrangement of reinforcement were transferred to the JKR counterpart technicians through the guidance.

- Final drawings (output)

  Drafing work was carried out by using auto-CAD system by manual and a plotter.

6.3 Preparation of Construction Plan and Cost Estimate

6.3.1 General

Before the commencement of bridge construction, construction procedure should be planned, however construction procedure for bridges is varied depending on scope and quantity, and construction site condition. General construction plan for standard bridge is summarized in this Section. According to typical construction procedure, construction cost for 5-type standard bridges is estimated.

6.3.2 Construction Plan

(1) Procedure of Construction

Prior to starting actual construction, the construction plan should be studied and identified the problems in order to complete the project in accordance with the Drawings and Specifications with sound engineering practice.

The construction plan should be reviewed from time to time during construction, in accordance with the prevailing circumstances on the site, also if variation of the contract or design changes are required during construction, the construction plan should be modified or corrected to meet the requirement.

The construction plan will be provided taking into account the scope and quantity of works, and site condition including environment. Generally, the construction plan include the followings:

- Construction method and work approach
- Plant and equipment
- Work programme
- Quality control
- Construction safety

The procedure of bridge construction is shown in Fig.6.3.

(2) Work Flow and Programme

The work flow of superstructure (post-tensioned concrete beams) is shown in Fig.6.4. Typical work programme of construction of pre-tensioned and post-tensioned concrete bridges are shown in Fig.6.5.

PRELIMINARY STUDY

Scope and Quantity of Works
1. Crossing over river or flyover railways/highways
2. Bridge length, span length and weight of beam
3. Quantity of major work items

Site Condition and Environment
4. Topographic and geographic condition, and climate
5. River condition ..... water level and stream velocity
6. Environment ..... housing, hospital, school and others
7. Road traffic condition

↓

CONSTRUCTION PLAN

Construction Method and Work Approach
1. Structure excavation ..... open excavation or cofferdam method
2. Pile driving ..... percussion or excavation or hydraulic method
3. PC beam fabrication yard ..... river bed or on approach road
4. Handling and launching PC beam ..... by truck crane or by launching steel girder or other method

Plant and Equipment
1. Kind, number and period use

Work Programme
1. Sequence of works
2. Production rate ..... labour and equipment
3. Possible working day
..... effect of major public holidays and seasonal weather constraints

Quality Control
1. Technical inspection
2. Quality control testing

Construction Safety
1. Relocation of water channel and cofferdam
2. Handling and launching PC beams
3. Construction adjacent to existing structure

Fig.6.3 Procedure of Construction

PREPARATORY WORKS

- Site Survey
- Manufacturing base for PC beams

↓

MANUFACTURING OF PC BEAM

- Formwork
- Reinforcing steel and ducts
- Concrete placing
- Curing

↓

PRESTRESSING

- Installing prestressing steel
- Calibration of jack
- Prestressing
- Grouting

↓

HANDLING AND LAUNCHING

- Setting bearings
- Lifting and transportation
- Launching and placing

↓

CROSS BEAM

- Formwork
- Reinforcing steel
- Tendons
- Concrete placing
- Curing
- Prestressing

↓

RC SLAB

- Formwork
- Reinforcing steel
- Concrete placing
- Curing

↓

MISCELLANEOUS WORKS

- Parapet and handrail
- Drainage Pipe
- Expansion joints

↓

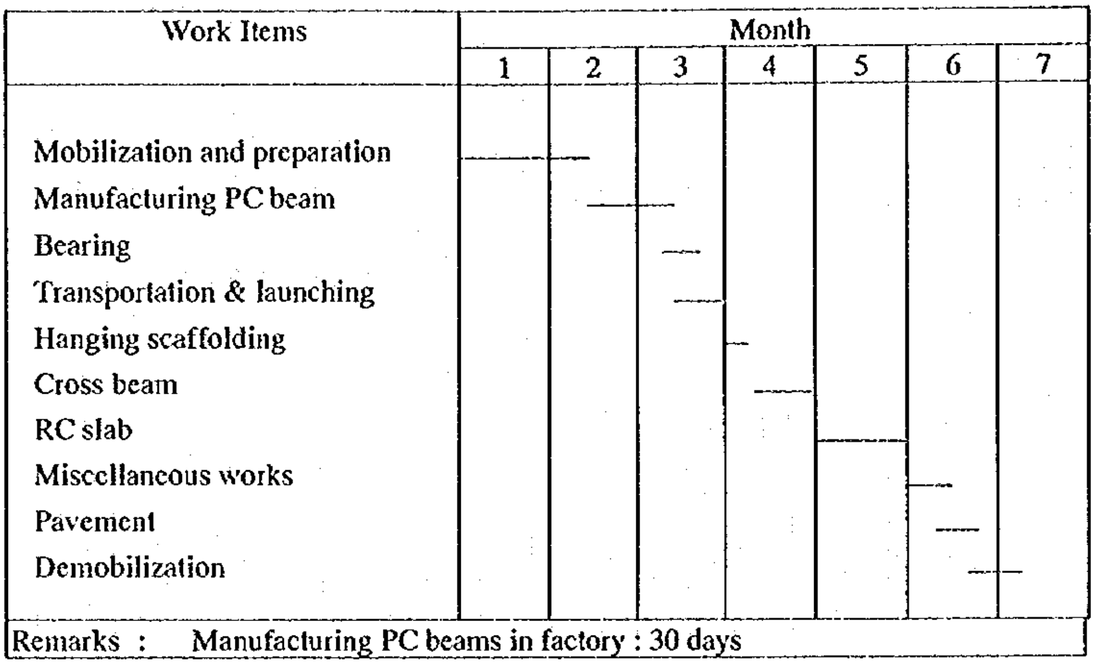
PAVEMENT

- Base course
- Wearing course

Fig.6.4 Work Flow of Superstructure

1. Pre-tensioned Concrete Bridge

Bridge length : 3-span x 22.7m = 68.1m
No. of beam : 3 x 11 = 33 nos.



2. Post-tensioned Concrete Bridge

Bridge length : 3-span x 28.7m = 86.1m
No. of beam : 3 x 7 = 21 nos.

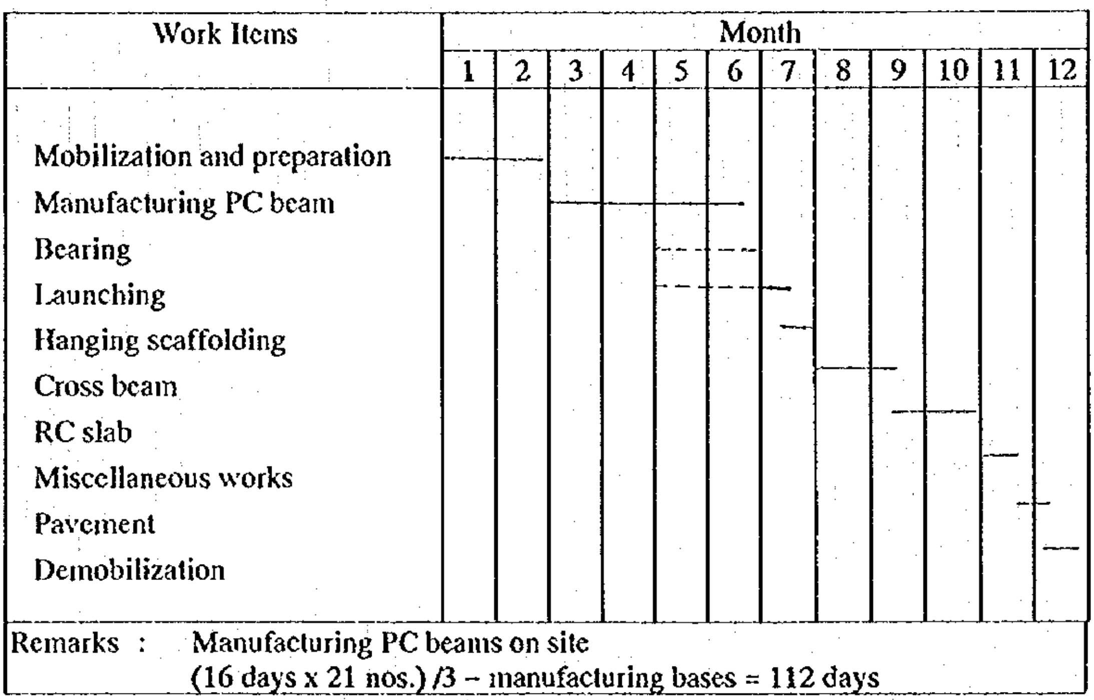


Fig.6.5 Work Programme of PC Bridge

(3) Pile Driving

In Malaysia, the Environmental Quality Act does not set specific limits for noise from construction sites. Since piling works with high noise levels and ground vibration cause considerable nuisance in the surrounding environment, *cast-in-place piles are commonly used for structure foundation in* Kuala Lumpur.

In driving the piles, diesel hammer produces high noise level together with ground vibrations, however it may be used where there are no nuisance in environment, because of faster driving rate, easy availability of equipment and cost effective.

Adjacent structures may suffer damage if the vibration is of high enough intensity, therefore, for prestressed spun concrete pile driving works, auger boring, or hydraulic hammer to be employed where there are housing or building, or in close proximity to the existing structures.

(4) Manufacturing Pre-tensioned Concrete Beam

In order to reduce beam sections or dead load of beam, the partial debond strand method and deflected strand method are employed for hollow slab and composite T-beam respectively. The application of these methods is new to Malaysia.

It can avoid tensile stresses at the top at supports by preventing bond for some of the strands for a computed length near the ends by covering the tendons with plastic tube. The deflected strand method needs some additional investment on the plant to provide for hold-downs and special equipment for raising the strands. The both methods are illustrated in Fig.6.6.

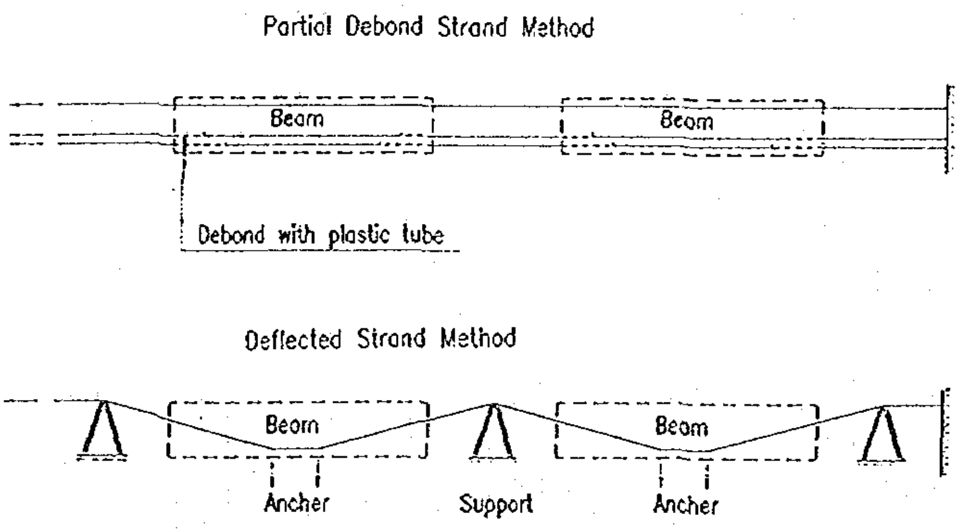


Fig. 6.6 Partial Debond and Deflected Strand Method

(5) Handling and Launching Precast Concrete Beam

(a) Launching Method

The precast prestressed concrete beams are usually launched in position using truck cranes or launching steel girders or gantry crane or bent. The launching equipment used for the beams are depend on the following matters.

- Condition of fabrication yard (location, width and length)
- Obstacles above and below the beam to be launched
- Weight and length of beams
- Gradient and alignment
- Safety of handling and launching operation

For selecting launching method, the methods in the Table.6.3 are marked ◎, ○ and △ in order of their frequency of employment.

The small scale beams, as pre-tensioned beams under 15 tons, weight may be lifted and launched by single truck crane, however two truck cranes are usually used for weight of 15 to 70 tons precast concrete beams and for over 70 tons in special case.

Specialized launching steel girder with portal crane is suitable for post-tensioned beam with weight of 50 to 135 tons (25 to 45m span), especially for multiple span bridge. Launching by specialized launching steel girders is shown in Fig.6.7.

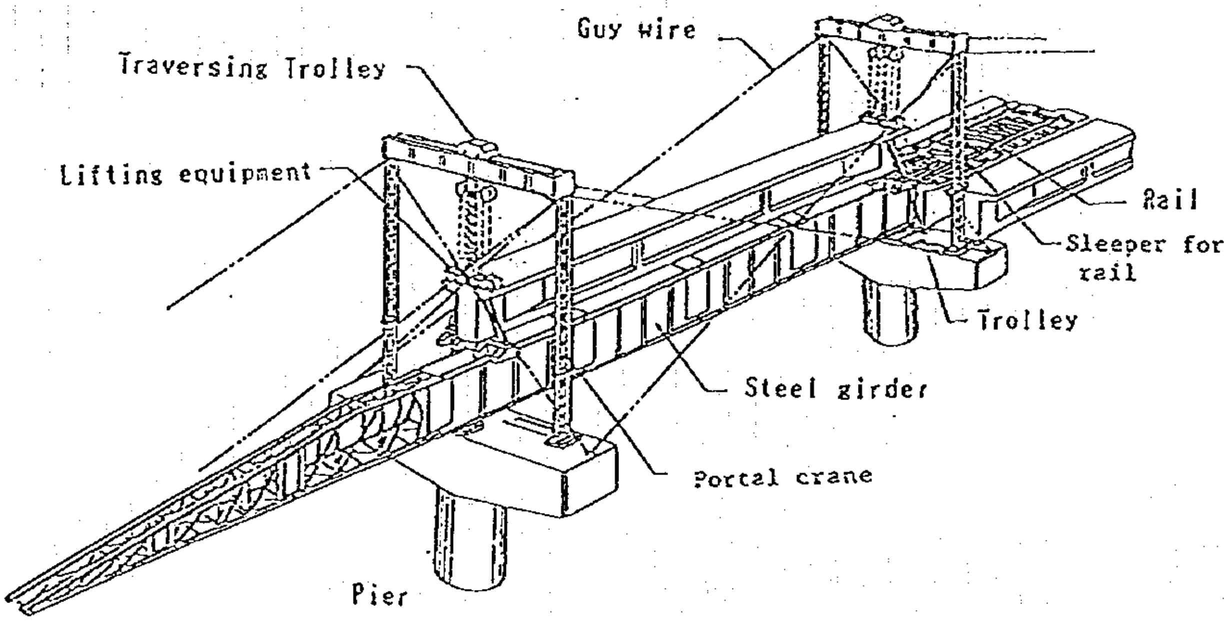


Fig. 6.7 Specialized Launching Steel Girder

Table 6.3 Adaptability of Launching Method of Precast Beam

Condition \ Launching Method		Launching steel girder						Crane			Gantry crane		Bent	
		Two steel girders	Hanging from one steel girder	One steel girder and two portal cranes	Two steel girders and shifting	One steel girder and shifting	Carrying method	Single truck crane	Two truck cranes	Floating crane	Fixed gantry crane	Self-traveling gantry crane	Bent-type	Traveling bent
Fabrication yard	On approach road or on viaduct	◎	◎	◎			○	△	○			△	○	○
	Under or near the bridge				◎	◎	○	◎	◎		○	◎		
Space over and/or under the bridge	Obstacle over the bridge	◎	○	○	◎	◎	○		△		△	△	◎	◎
	River under the bridge	◎	◎	◎			○							
	Rail way under the bridge	◎	◎	○			○		△					
	Road under the bridge	◎	◎	○	○	○	○	○	○		△			
Weight of PC beam	Light (under 10t)	○	○	○	○	○	○	◎	○	○	○	○	○	○
	Heavy	◎	◎	◎	◎	◎	◎	△	◎	○	○	○	○	○
	Very heavy (over 100t)	◎	○	○	◎	○	△		○	○	◎	○		◎
Schedule	Necessary to be in stock	◎	○	○	◎	◎	◎	◎	◎	◎	○	◎	△	△
	Launching without stock	○	○	○	○	○	○				○	○	○	○
	Immediately launching after casting the bridge slab	△	△	△	◎	◎	◎	◎	◎	◎	◎	◎	△	△
Size and figure of pier	No space for support (transverse)	○	○	○	○	○	○	◎	◎	○	◎	◎		
	No space for support (longitudinal)	◎	○	○	○	○	○	○	○	○	◎	◎		
Curvature and slope	Curvature	◎	○	○	◎	○	○	◎	◎	◎	◎	◎	○	○
	Large slope	○	△	○	○	○		○	○	○	○	○	○	○
Others	Large skew	◎	△	○	◎	△	◎	◎	◎	◎	◎	◎	○	△
	Over river or sea	○			◎	◎	○			◎				

(b) Safety Measures

During transportation, since the prestressed concrete beams are subjected to the combined stress only corresponding to the prestressing and the bending due to the dead load, the tensile stress at the top fiber of the beam is $10kg/cm^2$.

If the beam is inclined left or right, the bending moment acts laterally due to its dead load and the tensile stresses are induced on a side and at the top fiber of the beam. Therefore, appropriate handling and launching study shall be undertaken specially for long and slender girders, to ensure against lateral buckling or cracking during various stages of handling and launching. Allowable angle of inclination is referred to Manual.

- Position of temporary support
  Prestressed beams are only allowed to be suspended or supported firmly at their bearing points

- Inclination of beams
  Long and slender beams to be safeguarded against tilting by means of auxiliary supports and the temporary strutting or bracing.

(6) Quality Control

Aside from keeping to a work programme, it is very important to ensure that the works are carried out in accordance with specifications and established good practice and the technical inspection, and quality control testing to be performed by experienced engineers, technicians and inspectors. Relationship between quality, progress and cost is shown below.