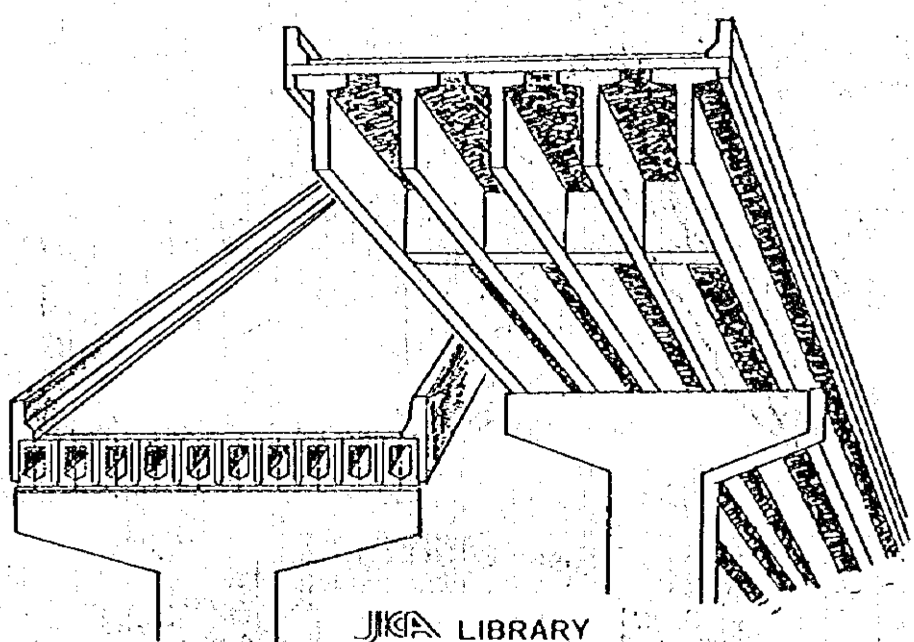
JAPAN INTERNATIONAL COOPERATION AGENCY
PUBLIC WORKS DEPARTMENT
MINISTRY OF WORKS, MALAYSIA

THE STUDY ON THE STANDARDIZATION OF BRIDGE DESIGN IN MALAYSIA

FINAL REPORT

VOLUME I

EXECUTIVE SUMMARY



AUGUST 1996

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

CURRENCY EQUIVALENT

(As of 1st February, 1996)

Currency Unit: Ringgit (RM)

RM 1.00 = US$ 0.391 = ¥ 41.621

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

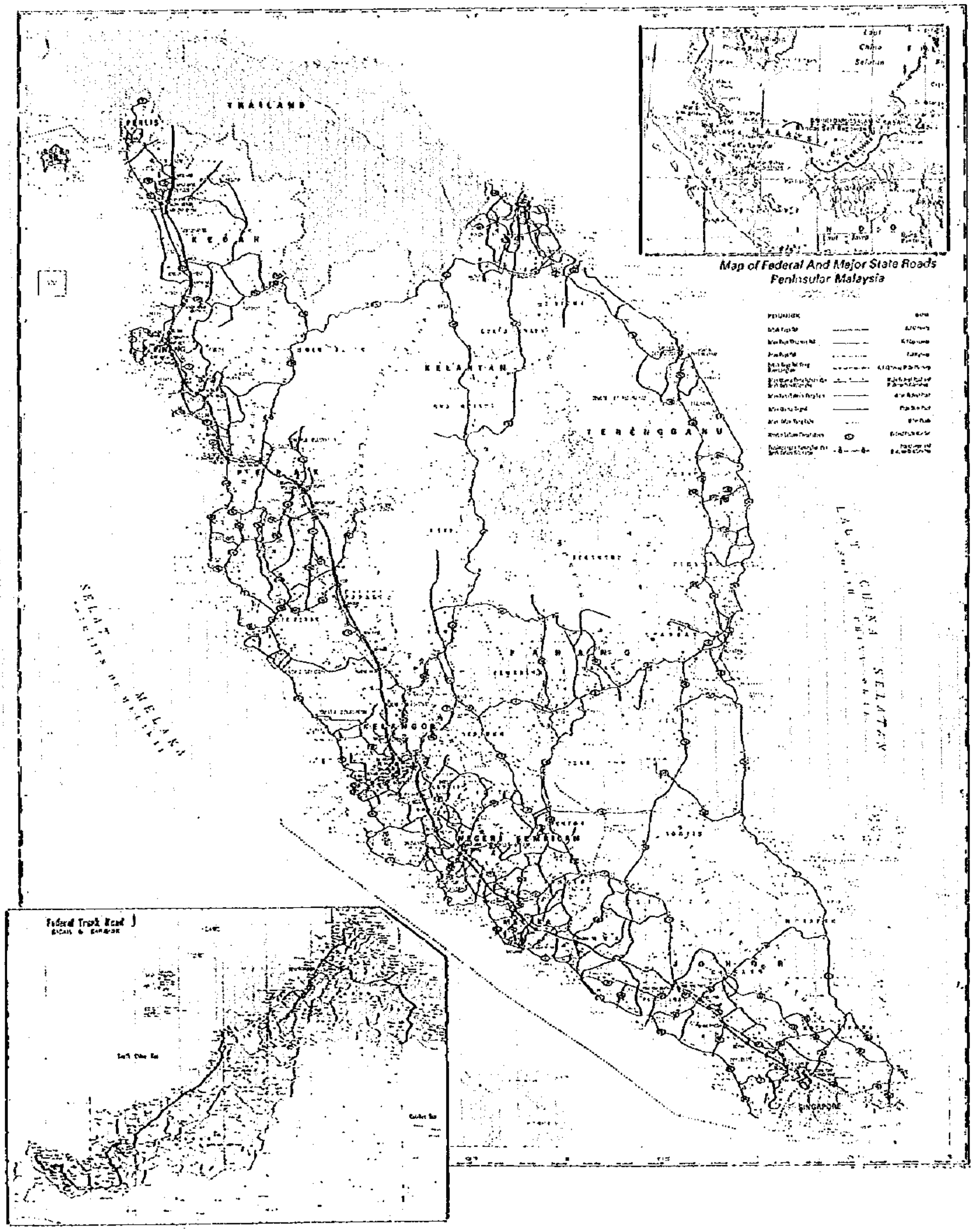
On behalf of the team I wish to express my heartfelt appreciation to the Officials concerned of the Government of Malaysia for their warm friendship and cooperation extended to us during our stay in Malaysia.

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



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ABSTRACT EXECUTIVE SUMMARY

1. Brief of the Study

In response to the request from the Government of Malaysia (GOM), the Government of Japan (GOJ) decided to conduct the Study on the Standardization of Bridge Design in Malaysia (the Study). Accordingly, the Japan International Cooperation Agency (JICA) organized a study team to implement the Study. The Study Team was dispatched to Malaysia in August, 1994 and the Study officially commenced with the submission of the Inception Report. After twenty four months, the Study was completed in July, 1996 with the submission of the Final Report, the Standard Bridge Design Drawings and the Design Manual.

The principal objectives in the Study are: ① Preparation of standard bridge design and drawings; ② Development of computer aided design and draughting (CADD) system for standard bridge design, and ③ Preparation of manuals for bridge planning, design, construction and cost estimation. Additional objective is the transfer of technology to the Malaysian engineers through the Study.

The bridge type to deal with in the Study is limited to concrete beam bridges with span length of up to 45 meters, subject to the Public Works Department's (JKR) Road Geometric Standard R3/U3 and R5/U5, 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 conducted for typical cases, partially by computerized analysis.

The basic policies, in engineering aspects, set forth by the Study Team in implementing the Study are: ① Adoption of the British Standard's "Limit State Design Method" to meet the request of GOM and because of their practicality in Malaysia, and ② Development of computer aided design system is aimed at a personal computer system to provide easiness in use by JKR engineers and its broad applicability in Malaysia.

The Study was implemented in six phases, and at the early stage, an extensive data collection and field survey were carried out and those main activities include:

- Review of JKR standards, specifications and guidelines for bridge planning and design both of being in use and planned to adopt were carried out, and that became the grounding in establishing the design standard for the Study.

- Bridge site survey on the representative existing bridges was carried out to obtain general views of the bridges and hydrological aspects by visual inspection covering major representative areas in the geography and the road network, including the Peninsula and both Sabah and Sarawak. A total of 103 bridges (75% in the Peninsula) were surveyed from the view point of ; confirmation of the bridge inventory, problems on super and substructures, geological and hydrological problems. Through the site survey alternative bridge types were prepared for preliminary design and comparative study.

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- Studies on existing and popularly used computers in Malaysia were also made, for both hardware and software, for selection of the most suitable type to be applied to the design and the drawing system in the Study.

In order to select the standard bridge types and the span range, establishment of design standards and conditions, preliminary design, and comparative study were conducted for superstructures. However, only a general comparative study was conducted for substructures and foundation without preliminary design process from practical view points.

- The design standards applied in this Study are based on the British Standard's "Limit State Design Method" and the design live load is based on BD 37/88. The standards applied in this Study are; BS5400, BD37/88, BS8004 and JKR guide on geometric design of roads. However, the Japanese Standards (JS) are also adopted in instances whereby it is impossible to comply with the above mentioned standards. The design conditions were established also in consideration of simplicity, clearness, safety and easiness in application and management of the design by a wide range of engineers in Malaysia.

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

- The comparative study was conducted from the view point of economy, structural characteristics, construction difficulties, maintenance and other current practices in Malaysia.

- The preliminary and the comparative studies were conducted on a total of 10 types of superstructure. They are composed of the five types specified by the Scope of Work and the other five types that were selected from the field survey of existing bridges.

- As a result, five different types of superstructure were selected for various span length (5~45 meters), and they were designed to cater for up to 30 degrees skew angle.

- On the other hand, a general comparative study were carried out for substructures in the form of thorough discussion and series of meeting with the Technical Committee, and also in reflection of the results of the site survey on existing bridges. The recommended types of the Scope of Work were modified to meet the requirement of JKR. The structure types which were seldom adopted in Malaysia were not selected for the standard type in this Study.

In parallel with selection of the standard bridge types, selection of computer system; development of design analysis system; development of computer programme for design analysis; and development of drawing system and programme were carried out.

- As stated in the basic policies of the Study implementation, the computer system, hardware and software, was selected for personal computer system in consideration of the capacity for computerized design system, popularity in Malaysia, easiness in use, reasonable cost and compatibility with IBM-PC which is commonly used in Malaysia.

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

An analysis flowchart for structural analysis, a design flowchart for main beam and cross beam were established for superstructure. Also, a design flowchart was set for substructure taking account of some hypothetical conditions determined.

- In the development of computer programme for design, the software for the design system used for this Study was exclusively developed by the Study Team. Each flowchart for design programme for both super and substructure was established.

- 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. However, the drawings of substructure are produced by using the existing auto-CAD in JKR, with hand drafting.

Actual design work for both super and substructures was carried out based on the established design analysis systems and developed computer programmes for about three months (June to August, 1995). And, the draughting work was carried out for another three months (September to November, 1995). The both design and draughting works were carried out in Malaysia for the aim of training and technology transfer to the Bridge Unit engineers, JKR.

In the implementation of the design and draughting works for the standard bridge types, a total number of computation cases, in combination of the types and other parameters, for superstructure amount to 76 cases, and the number of drawing case amount to 114 cases. On the other hand, those for substructure amount to a total of 122 cases, including 6 sample design cases, for computation, and a total of 35 cases (29 for standard, 6 for sample) for the drawing. Thus, a numerous design and drawing cases were carried out to meet the request made by JKR at the later stage of the Study.

A total number of the drawing sheets are some 250 sheets for the superstructures and some 75 sheets for the various purpose of substructures.

2. Conclusion

2.1 Necessity of the Standardization of Bridge Design

In the Malaysian national transport system, road transport is by far the most popular mode of transportation for both passenger and freight. Traffic studies in 1991 have shown that 99.8% of passengers and 98.5% of freight traffic were transported by road. It is foreseen that in the coming decade, the role of road network will indeed become even more important and prominent as the main mode of transport of goods and passengers.

On the road network, bridges are key elements because of their strategic locations and of the adverse consequences when they fail or when their capacity is impaired.

In an effort to further improve the efficiency of the transport industry, GOM undertook the National Axle Loads Study (1986-1988) and the Bridge Rehabilitation and Maintenance Study (1990-1992 by JICA). These Studies revealed that the limitation on the loading capacity of bridges emerged as the major constraint in allowing heavier permissible truck load and that the various deficiencies which include the deficiencies due to improper bridge design and construction.

These deficiencies should be eliminated in new bridge design and construction, for efficient implementation and maximum utilization of the limited available resources. In order to achieve the objectives, establishment and application of standard design of personal computerized system for appropriate types of superstructures and typical design of some types of substructure at an early stage is a basic need to GOM.

2.2 Major Results in Engineering Aspect

(1) Basic Design Standard

The basic design standards adopted in this Study are based on the British Standard's "Limit State Design Method" to meet the request of GOM and because of their wide practicality in Malaysia.

They are Bridge Design Standard: BS5400, Design Load Standard: BD37/88, Foundation Design Standard: BS 8004, and JKR Geometric Design of Roads. However, the Japanese Standards were also adopted whenever the above standards are not applicable.

By adopting these latest standards, the loading capacity of the standard bridge is remarkably increased and will be able to satisfy the conditions under a rapidly increase of heavier vehicle, increase of the permissible maximum weight of normal commercial vehicle and a loading characteristics of special vehicles.

(2) Superstructure

Practically five different types of superstructure were developed for various span length, including 3-span continuous type. The standard bridges were designed to cater for a skew angle of up to 30 degrees.

Type	Span Range (m)
Reinforced concrete solid slab	5 to 10
Pre-tensioned concrete solid slab	5 to 10
Pre-tensioned concrete hollow slab	10 to 16
Pre-tensioned concrete T-beam	18 to 22
Post-tensioned concrete T-beam	22 to 45

(3) Substructure

All the abutments and piers are furnished with the footings to be embedded sufficiently under river bed to provide more durable and stable structures from a view point of river hydrology.

(a) Bridge Abutments

Inverted T-abutment was adopted as a typical design. The height of the abutment ranges from 6m to 12m high and will support the superstructure for the various span range as stated above. It can cater for a skew angle of up to 30 degrees.

(b) Bridge Piers

Two types of piers were adopted and these include T-type pier and multiple column pier. The height varies from 10m to 20m and will support the various span range of superstructures as stated above.

(c) Sample Design

Some sample design, besides the typical types mentioned above, were carried out by the request made by JKR and these include:-

- 8 meters high inverted T-abutment on spread foundation
- 12 meters high inverted T-abutment (railway bridges)
- 30 meters high T-pier with 3 types of foundation
- Multiple column pier on bored pile foundation

(4) Foundation

Since the majority of JKR bridges are across rivers, the foundation are usually founded on piles. In view of this, the Study concentrates mainly on the design of pile foundation. However, an example on the design of spread foundation was carried out.

(5) Selection and Development of Computer Aided Design & Drawing

The computer system, hardware and software, was selected for personal computer system in consideration of the capacity for computerized design system, popularity in Malaysia, easiness in use, reasonable cost and compatibility with IBM-PC which is most common in Malaysia.

The software, on the other hand, for the design system used for this Study was exclusively developed by the Study Team.

2.3 Technology Transfer and Training

Apart from the preparation of a design manual, it was one of main objectives of the Study to train and transfer technology to the engineers of the Bridge Unit, JKR.

To achieve the objectives, the Study Team carried out the design and draughting works in Malaysia for the period of 6 months. GOM provided 6 extra JKR personnels to the Study Team to undergo an on-the-job training, thus the objective was achieved in the form of understanding the computations and operation of the computer programme. Their contribution is much appreciated.

2.4 Assessment of the Bridge Design Standardization

With the introduction of the standard bridges, the following benefits are anticipated:

- Deficiencies, such as an overdesign or an underdesign encountered due to individual design of case to case, will be eliminated, and a more systematic, rational and economical, as a whole, bridge design could be achieved.

- The design will efficiently deal with the increase of live load due to heavier vehicle traffic and also loading characteristics of special vehicles like trailer.

- A more systematic maintenance works could be practiced by the standardization of bridge types.

- The State and the District JKR will be able to carry out the bridge design for short span bridges quickly by utilizing the standard drawings, and also they are able to improve the knowledges of bridge engineering by the prepared design manual, which covers planning, design, construction and cost estimate.

3. Recommendation

3.1 In Practical Use of the Standard Design

(1) The standard bridge types adopted would not require a radical change of existing facilities in production of PC beams by the local manufacturers. Therefore, they should be put into practical use as early as possible with a minimum transitional period for modification of the existing facilities.

(2) It should be understood that the bridge design standardization was prepared for the aim of overall efficiency and economy in design, construction and maintenance of the short span bridges, therefore, it has certain limitations and a careful examination should be made in application of the standard designs to a specific, individual site condition.

(3) The Bridge Unit, JKR should have the authority to examine and to approve all the bridge design and appropriateness in application of the standard designs under JKR jurisdiction.

3.2 Design of Superstructure and Substructure

(1) Superstructure

For the design of prestressed concrete members under Serviceability Limit State (SLS), the limitation of tensile stress (Class 1 under load combination 1) was applied. However, in consideration of the occurrence of the load specified in BD37/88 is extremely seldom and of the characteristics of restoration of prestressed concrete member, the limitation of tensile stress should be relaxed in the design. If so, a more rational and economical design of prestressed concrete members could be achieved.

(2) Substructure

A partially computerized and manual input system was adopted in this Study for the design of substructure and foundation. However, in considering the burdens encountered in the process and a rapid increase of demand of the design, a fully computerized system and programme should be developed for the design of substructure and foundation at an early stage.

3.3 Institutional Arrangement

The inspection and the supervision forces on bridge construction sites should be strengthened more at the District and the State level.

A strict specification and a good design themselves do not guarantee a quality controlled finished product without proper inspection and supervision.

CHAPTER 1 INTRODUCTION

1.1 Background of the Study

In an effort to further 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.

The Study was completed in July, 1996 with the submission of the Final Report.

1.2 Objective of the Study

The main objectives of the Study are:

(1) Preparation of standard design of superstructures and typical design of substructures.
(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.

1.3 Scope of the Study

1. Bridge Type

The bridge type to deal with in the Study is limited to concrete beam bridges with span length of up to 45m, subject to JKR Road Geometric Standard R3/U3 and R5/U5, 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.

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 the 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 37/38 was adopted according to the load strengthening plan of JKR.

The Study was carried out in 6 phases from August 1994 to July 1996. Fig. 1.1 shows the major work items of the Study and their interrelationship.

1.4 Composition of the Report

The Final Report consist of 4 volumes as listed below:

Volume I	:	Executive Summary
Volume II	:	Main Report
Volume III	:	Design Manual
Volume IV	:	Standard Drawings

In addition to the above, a set of visual inspection sheets of existing bridges and design calculation sheets for super and substructure were prepared and submitted to GOM.

Flowchart of the Study

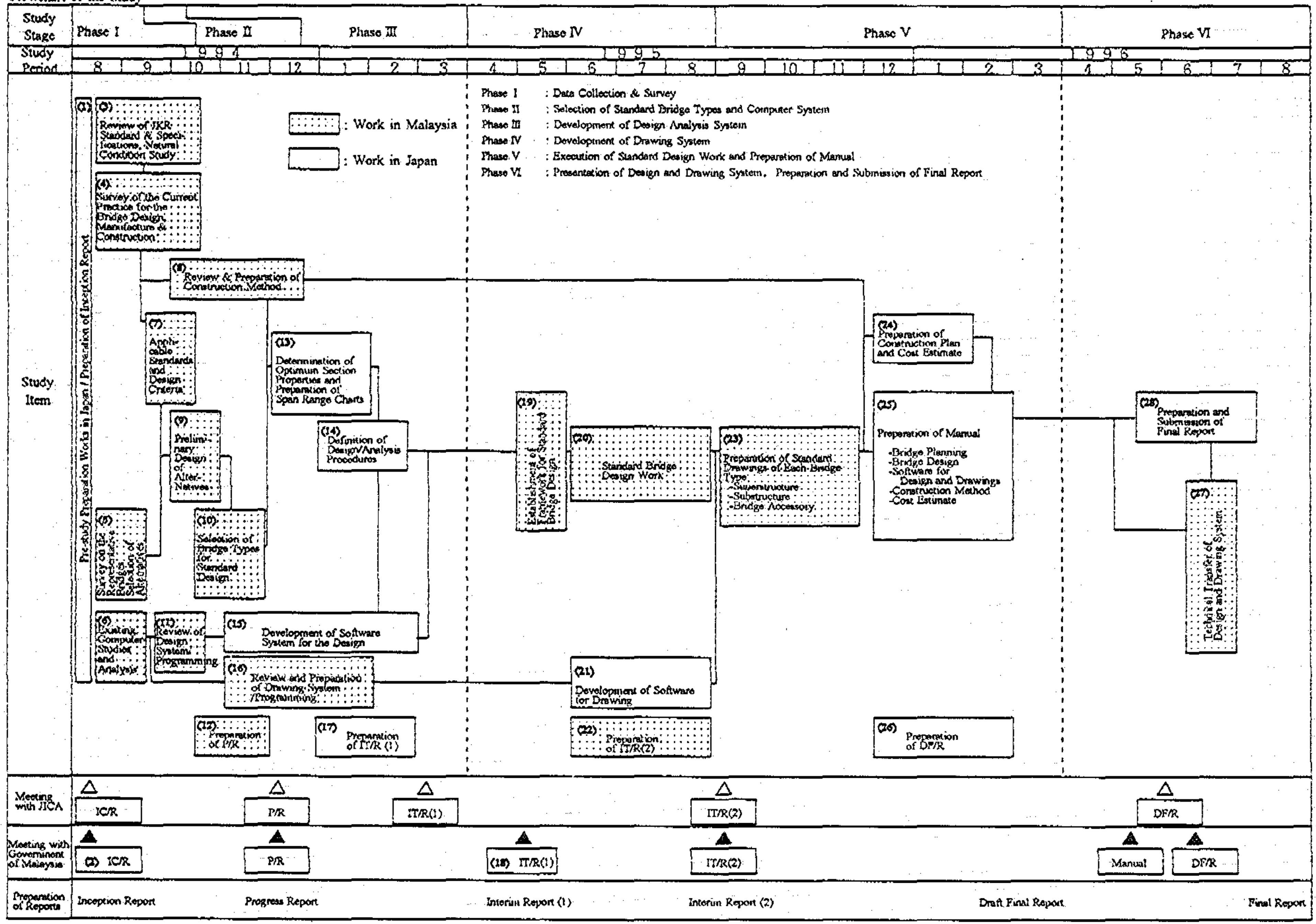

Fig. 1.1 Flow Chart of the Study

CHAPTER 2 CONCLUSIONS AND RECOMMENDATION

2.1 Conclusion

2.1.1 Necessity of the Standardization of Bridge Design

In the Malaysian national transport system, road transport is by far the most popular mode of transportation for both passenger and freight. Traffic studies in 1991 have shown that 99.8% of passengers and 98.5% of freight traffic were transported by road. It is foreseen that in the coming decade, the role of road network will indeed become even more important and prominent as the main mode of transport of goods and passengers.

Up to date, a total of about 45,000km of roads has been built in the country and among those, the federal roads amounted to 16,000km.

On the road network, bridges are key elements because of their strategic locations and of the adverse consequences when they fail or when their capacity is impaired. It is estimated that there are about 4,500 bridges in Malaysia, out of which 2,500 bridges are located on federal roads.

In an effort to further improve the efficiency of the transport industry, the Government undertook the Phase 1 of the National Axle Load Study (1986 – 1988). This Study showed that the limitation on the loading capacity of bridges emerged as the major constraint in allowing heavier permissible truck load. As a spin off from the National Axle Load Study, the Government also received technical assistance from JICA (1992) in a study called the Bridge Rehabilitation and Maintenance Study. The Study results revealed the various deficiencies in the studied bridges which includes the deficiencies due to improper bridge design and construction.

These deficiencies should be eliminated in new bridge design and construction, for efficient implementation and maximum utilization of the limited available resources. In order to achieve the objectives, establishment of standard design of appropriate types of superstructures and typical design of some types of substructure at an early stage is a basic need to GOM.

2.1.2 Major Results in Engineering Aspect

(1) Basic Design Standard

The basic design standards adopted in this Study are based on the British Standard's "Limit State Design Method" to meet the request of GOM and because of their wide practicality in Malaysia.

They are Bridge Design Standard: BS 5400, Design Load Standard: BD37/88, Foundation Design Standard: BS 8004, and JKR Geometric Design of Roads. However, the Japanese Standards were also adopted whenever the above standards are not applicable.

(2) Superstructure

Practically five different types of superstructure were developed for various span length, including 3-span continuous type. The standard bridges were designed to cater for a skew angle of up to 30 degrees.

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(4) Foundation

Since the majority of JKR bridges are across rivers, the foundation are usually founded on piles. In view of this, the Study concentrates mainly on the design of pile foundation. However, an example on the design of spread foundation was carried out.

In the Study, two types of pile were considered for the bridge foundation: driven pile (PC pile) and bored pile. Design calculation examples to determine the design load on piles based on friction and end-bearing were compiled in the design manuals for references. However, since ground condition varies from one location to another, the designer must carry out the geotechnical designs to determine the soil carrying capacity and subsequently the depth of piles.

(5) Selection and Development of Computer Aided Design & Drawing

The computer system, hardware and software, was selected for personal computer system in consideration of the capacity for computerized design system, popularity in Malaysia, easiness in use, reasonable cost and compatibility with IBM-PC which is most common in Malaysia.

The software, on the other hand, for the design system used for this Study was exclusively developed by the Study Team. The automatic design programme was built for the design of standard bridges and it was also developed as the simple dialogue personal computer system for easiness in operation by bridge engineers in Malaysia. An automatic drawing system and a comprehensive computer programme were developed mainly for superstructure. It is closely linked with the design analysis programme, covering all the standard structure types and also equipped for the quantity estimation. However, no specific automatic drawing programme for substructure was prepared. Utilizing the existing auto-CAD in JKR, all the necessary drawing data of the typical substructure types are manually input to produce drawings for standard case, which allows engineers to draughting for other cases in accordance the standard case.

2.1.3 Consideration Paid in Selection of the Standard Bridge Types

Several parameters were considered in the Study to determine the suitable types of bridges to be adopted:

(1) Materials

The construction materials, eg. cement, steel bars and prestressing strands, adopted in the standard bridge design are those which are widely available locally. Nevertheless, these materials must meet the minimum requirement specified in the Codes.

(2) Economic

Economic comparison were carried out between the proposed prestressed beam and the beam that are currently used in bridge construction.

(3) Method of Construction

In developing the standard bridges, the Study Team has adopted current methods of construction that are available locally. Any new method of construction being proposed are deemed to be viable and practical.

(4) Maintenance

The standard bridges were selected to take into account of the maintenance aspect. Various good design practice in minimizing future maintenance problems are incorporates in the standard bridge design, and these are as follows:-

- Beams with straight edges
- Effective scouring protection
- Ensure durability by using higher concrete strength, sufficient cover, crack width control
- Quality control of local contractors
- Proper layout of the bridge

(5) Production of Precast Members

The precast prestressed structural members were developed after taken account of the technical and production capability of the local manufacturers. Simple sectional beam shape with straight edges were adopted in the Study to ensure high quality finished products. In selecting the precast beams, the Study Team has also try to reduce initial investment cost of a new bedding by the manufacturers.

(6) Aesthetic Consideration

The aesthetic of the standard was considered whenever possible in the form of simplicity and symmetry of shape and slimness of the overall bridge structures.

2.1.4 Technology Transfer and Training

Apart from the preparation of a design manual, it was one of main objectives of the Study to train and transfer technology to the engineers of the Bridge Unit, JKR.

To achieve the objectives, the Study Team carried out the design and draughting works in Malaysia for the period of 6 months. GOM provided 6 extra JKR personnels to the Study Team to undergo an on-the-job training, thus the objective was achieved in the form of understanding the computations and operation of the computer programme. Their contribution is much appreciated.

2.1.5 Assessment of the Bridge Design Standardization

With the introduction of the standard bridges, the following benefits are anticipated:

- Deficiencies, such as an overdesign or an underdesign encountered due to individual design of case to case, will be eliminated, and a more systematic, rational and economical, as a whole, bridge design could be achieved.

- The design will efficiently deal with the increase of live load due to heavier vehicle traffic and also loading characteristics of special vehicles like trailer.

- A more systematic maintenance works could be practiced by the standardization of bridge types.

- The State and the District JKR will be able to carry out the bridge design for short span bridges quickly by utilization of the standard drawings, and also they are able to improve the knowledges of bridge engineering by the prepared design manual, which covers planning, design, construction and cost estimate.

2.2 Recommendation

2.2.1 In Practical Use of the Standard Design

(1) The standard bridge types adopted would not require a radical change of existing facilities in production of PC beams by the local manufacturers. Therefore, they should be put into practical use as early as possible with a minimum transitional period for modification of the existing facilities.

(2) It should be understood that the bridge design standardization was prepared for the aim of overall efficiency and economy in design, construction and maintenance of the short span bridges, therefore, it has certain limitations and a careful examination should be made in application of the standard designs to a specific, individual site condition.

(3) The Bridge Unit, JKR should have the authority to examine and to approve all the bridge design and appropriateness in application of the standard designs under JKR jurisdiction.

2.2.2 Necessity of Improvement in Planning Bridges

The visual inspection of existing bridges revealed the need of improvement as in the following:-

- a sufficient opening under bridge should be kept.
- skewed bridges should be avoided as much as possible in connection with

road alignment and river conditions.

- *a sufficient revetment should be provided and maintained properly to protect* bridge structures.

Besides of the above, all necessary guidelines for proper bridge planning were explained in the design manual.

2.2.3 Design of Superstructure and Substructure

(1) Superstructure

For the design of prestressed concrete members under Serviceability Limit State (SLS), the limitation of tensile stress (Class 1 under load combination 1) was applied. However, in consideration of the occurrence of the load specified in BD37/88 is extremely seldom and of the characteristics of restoration of prestressed concrete member, the limitation of tensile stress should be relaxed in the design. If so, a more rational and economical design of prestressed concrete members could be achieved.

(2) Substructure

A partially computerized and manual input system was adopted for the design of substructure and foundation. Considering the burdens encountered in the process and a rapid increase of demand of the design, a fully computerized system and programme should be developed for the design of substructure and foundation at an early stage.

2.2.4 Institutional Arrangement

(1) The inspection and the supervision forces on bridge construction sites should be strengthened more at the District and the State level.

A strict specification and a good design themselves do not guarantee a quality controlled finished product without proper inspection and supervision.

(2) There are quite number of skilled and experienced draughtmen who are capable to operate auto-CAD at the Bridge Unit, JKR. If, some simple and easy education on the basic rules and requirements of the design is implemented, their quality will sure be graded up more and careless mistakes in draughting could be prevented.

CHAPTER 3 ABSTRACT OF THE STUDY

3.1 Results of Bridge Site Survey

Bridge site survey was carried out to observe general views on the existing bridges and hydrological aspects by visual inspection covering major representative areas in the geography and the road network of Malaysia, including the Peninsula and both Sabah and Sarawak.

A total of 103 bridges were surveyed: 75 in the east and the west coast of the Peninsula and 28 in Sabah and Sarawak. The findings from the visual inspection results are as follows:

(1) Bridge Survey

- Typical Bridge Types

  Precast PC beam bridges in span length not over 30m were dominant in the Peninsula, but steel bridges with I-beam and plate girder were quite popular in Sabah and Sarawak.

- Application of JKR Standard PC Beams

  The JKR standard M-beam, I-beam and inverted T-beam were widely adopted as PC beams in recent bridges (1980's -). However, inconsistent application of the spacing were seen at some bridges.

- Beam Coupling

  Beam coupling method was often observed on PC post-tension beam multi-span bridges to eliminate expansion joint. It appeared quite efficient to avoid expansion joint which is often a weak point of bridges.

- Pile-bent Pier and Abutment

  Most piers and abutments surveyed were pile-bent structure, mainly because of economy and easiness in construction. However, the structure have caused hydrological and stability problems of bridge as a whole.

- Salt Water Damages

  Salt damages was observed on piers and abutments along the east coast, but superstructures of PC beams were in good condition generally.

(2) Bridge Hydrology Survey

- River Course and Bridge Direction

  There were many (50% among inspected) bridge crossing rivers at curved reach and with skew angle.

- Under-bridge Opening

  There were many bridges (75%) 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.

- 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.

- 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.

- Bank protection around Bridge

  Bank protections were not provided sufficiently at many bridge sites (90%). There were many bank erosion problems observed particularly in Sabah and Sarawak.

- Obstacles under Bridges

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

3.2 Selection of Standard Bridge Type and Computer System

3.2.1 Establishment of Design Standard and Condition

(1) Design Standard

The design standards applied in this Study are based on the British Standard's "Limit State Design Method" and the design live load applied is based on BD37/88.

Other loads besides the above-mentioned design live load, were also determined to apply BD37/88.

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

Bridge Design Standard	BS 5400
Design Load Standard	BD37/88
Foundation Design Standard	BS 8004
Geometrical Structure Standard	A guide on geometric design of roads

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

(2) Design Conditions

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

The major conditions are summarized as follows:

- Method of Design Analysis

  Elastic method of analysis beam theory

- Width Composition

  Bridge width 13m (R5/U5) and 11m (R3/U3), JKR Standard

- Grade of Major Materials

  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

Reinforcement Bar : Y460, R250

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.

- Loads

Dead 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

- 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 crossfall adjustment.

- Other Loads

Superimposed Dead Load
Premix pavement t=60mm.
Plain concrete for crossfall (2.5%) adjustment.

Live Load
Notional lanes – 4 lanes for both R5/U5 & R3/U3.
Nominal live load – BD37/88.

Collision Load
Not apply to superstructure but piers only.
Minimum clearance 5.7m over roads.

Prestressing Force
BS 5400. Two-stage prestressing for post-tensioned beam.

Effects of Shrinkage and Creep
CEB manual. Humidity 80%.

Wind Load

Maximum 40m/s – transversal direction.

Temperature

Temperature change	–	20 degrees for bearing, expansion joint and substructure.
Temperature difference	–	BS 5400. But it may be ignored.

Earth Pressure

Active earth pressure on abutments, with Coulomb's equation, only.

Longitudinal Loads

Severer longitudinal load either from HA or HB due to traction or breaking that acts at one notional lane and parallel to road traffic.

Accidental Load due to Skidding

6.11 of BD37/88

Effects of Stream, Current and Floating Drift Wood

Japanese design criteria, because BS 5400 does not specify.

– Combination of Loading and Design Classification

Applied loading combination and the design limitation classifications for reinforced concrete and prestressed concrete under Serviceability Limit State (SLS) are summarized below.

Design crack width is applied for RC members and limitation of tensile stress (class 1, Lc-1 & class 2, Lc-2 of BS 5400) is applied for PC members.

Class 1 under load combination 1

Class 2 under load combination 2 to 5

Design crack width for reinforced concrete beam	:	0.25mm
Design crack width for slab	:	0.15mm
Design crack width for substructure	:	0.25mm

– Stability Analysis of Foundation

Spread foundation	:	BS 5400 & BS 8004
Pile foundation	:	JS

– Structural Design of Substructure

Structural component : BS 5400

Sectional forces of parapet and wing wall : JS with modification

3.2.2 Selection of Standard Bridge Types, Span Range and Work Cases

In order to determine the bridge types for standard design, a preliminary design and comparative study was conducted on a total of 10 type 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 comparative study was conducted from the view point of economy, construction difficulties, maintenance, rehabilitation, current practice in Malaysia and so on.

Based on the result 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.

(1) Selected Types for Standard Superstructure

1. Reinforced Concrete Solid Slab (RCSS)
2. Pre-tensioned Concrete Solid Slab (PRSS)
3. Pre-tensioned Concrete Hollow Slab (PRHS)
4. Pre-tensioned Concrete Composite T-beam (PRT)
5. Post-tensioned Concrete Composite T-beam (PTT)

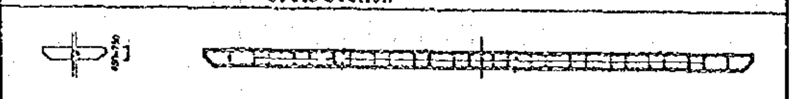
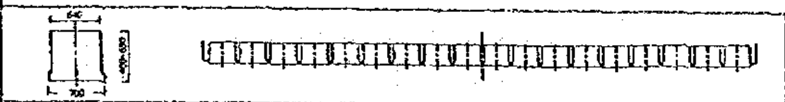
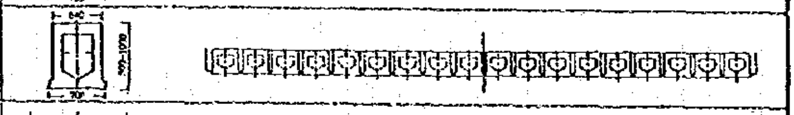
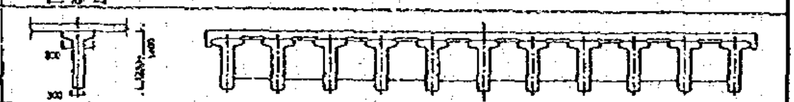
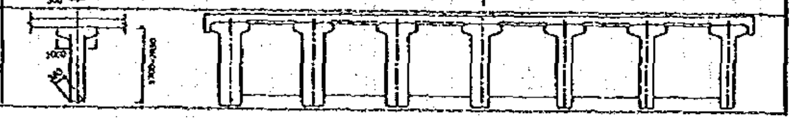
Beam Type	Span Range	Cross Section
RCSS	6m - 10m	
PRSS	6m - 10m	
PRHS	12m - 20m	
PRT	18m - 22m	
PTT	25m - 45m	

Fig. 3.1 Selected Types for Standard Superstructure

(2) Number of Cases for Design Calculation and Drawing for Superstructure

The following number of cases were carried out. As regards to skew angle, 15° and 30° for the calculation, but 0° was also prepared for the drawings.

Span	Bridge Type	Width	Skew	Case
6m	RCSS and PRSS	13m, 11m		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	- do -	- do -	- do -	4
Total				76 (calculation) 114 (drawing)

(3) Selected Standard Type for Substructures

The scope of the design of substructures was agreed that the standard design of substructures shall be prepared only for typical cases by partially computerized analysis.

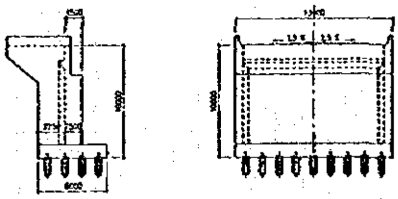
Concerning the type of substructures and the design cases, several types of abutment and pier were initially recommended in the Preliminary Study Report of February, 1994 such as:

Abutment	:	Inverted T-type and gravity type
Pier	:	T-type, multi-column type and solid wall type
Foundation	:	Spread foundation and pile foundation for both abutment and pier.

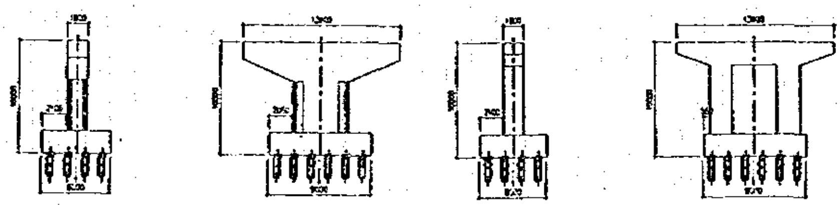
The above recommended types and cases for the substructure design were modified, through studies and discussion with JKR, to meet the requirements of JKR and to reflect the results of surveys on the existing bridges in Malaysia. The structure types which have been seldom adopted in Malaysia were not selected for the standard design in this Study.

Selected types for typical substructures are summarized as below:

- Abutment : Inverted T-type with the height up to H=10m.



- Pier : T-type and multi-column type with the height up to H=20m.



- Foundation : PC pile foundation with point bearing type and friction type.

- Sample Designs for Substructure

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

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

(4) Number of Cases for Standard Design Calculation and Drawing for Substructure

<u>Abutment</u>

- 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

Total = 4 + 8 + 8 + 16 = 36 cases

- 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

Pier (T-type Pier and Multiple Column Pier)

- Number of Typical Cases for Design Calculations

	Superstructure Span Range		
	12m to 22m	25m to 32m	35m to 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

Total = 8 + 16 + 16 = 40 cases

- Number of Cases for Reference Drawings to be Prepared

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

(5) Number of Cases for Sample Design Calculation and Drawings for Substructure

- Spread Foundation 1 case

  Height of Inverted T-type abutment for 8m

- High T-type Abutment 1 case

  Clearance between both abutment for 30m
  Height of abutment 12m
  Foundation PC pile end bearing

- High Pier 3 cases

  Height of pier 30m
  Foundation (1) PC pile end bearing
  (2) PC pile friction
  (3) Bored pile ϕ800mm

- Multiple Column Pier 1 case

  Height of pier 20m
  Foundation Bored pile ϕ800mm

Total nos. of Sample Design: 6 cases

3.2.3 Selection of Computer System

The computer system, hardware and software, was selected for personal computer system in consideration of capacity for computerized design system, popularity in Malaysia, easiness in use, reasonable cost and compatibility with IBM=PC which is commonly used in Malaysia.

(1) Computerized Design System and Programme

The system consists of four parts:

- Design of Superstructure

  A systematized automatic design system by using personal computer.

- Developed Programme

  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

- Design of Substructures

  A partially computerized system.

- Developed programmes

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

- Drawing of Superstructure

  Automatic system by auto-CAD, synchronized.

- Drawing of Substructure

  Auto-CAD by manual operation.

(2) Computer Hardware and Operation System

- Hardware System

	Description
CPU	I 80486 DX4/100 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 13

- Operation System

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

3.3 Development of Design Analysis System

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

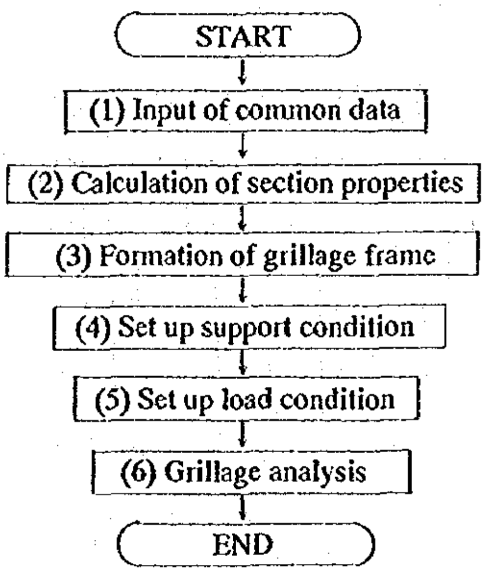
The Study Team conducted the design analysis procedure at first, and the definition for design method in detail was carried out in each design stage so as to ensure an adequate degree of safety and serviceability according to the standard.

Based on the design analysis system, the development of the computerized design programming and drawing programming was carried out.

3.3.1 Design Analysis System for Superstructure

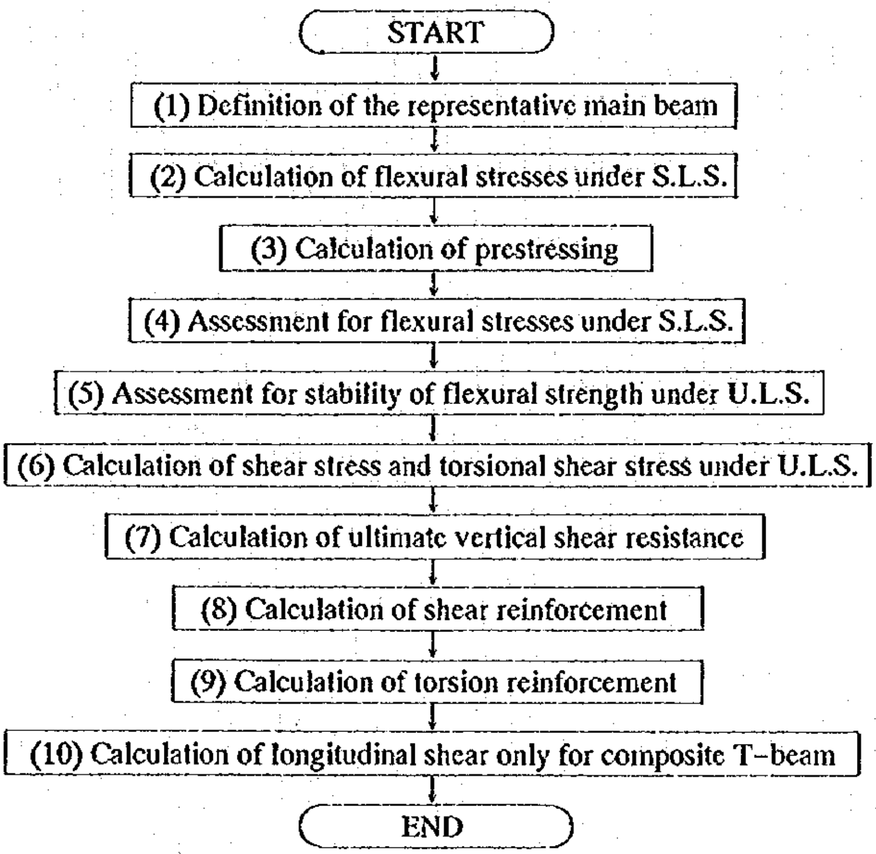
(1) Structural Analysis

Structural analysis was carried out according to the analysis flowchart undermentioned.



(2) Design for Main Beam

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



(3) Design of Cross Beam

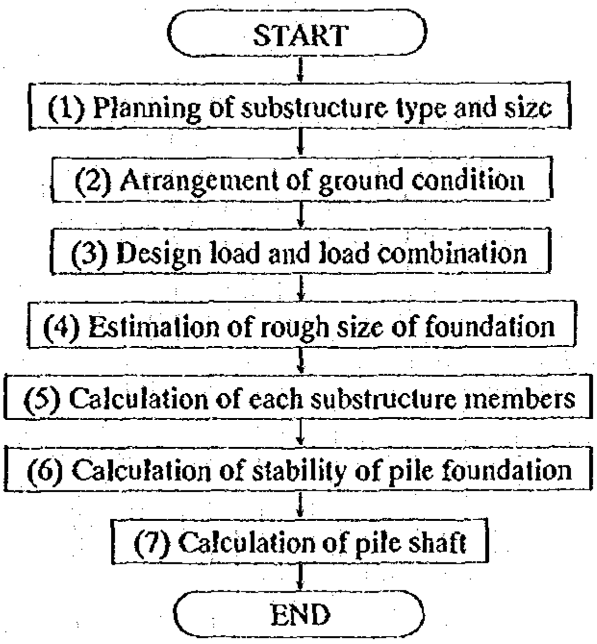
The design of cross beam was carried out with nearly the same flow chart as in the case of the design of main beam, but by setting the conditions concerning temperature for prestressing force and flexural moment of composite T-beam.

3.3.2 Design Analysis System for Substructure

Some hypothesis conditions on design analysis of substructure, as listed below, were determined and the design was carried out according to the design flow chart.

- Working earth pressure
- Analysis of each member
- Design analysis of pile foundation
- Spring of subgrade

- Design of multiple column



- Special Consideration

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

3.4 Development of Computer Programme for Design Analysis

As to the hardware system, a personal computer system was used as mentioned in Cls. (2) of sec. 3.2.3 of this report.

On the other hand, the software for the design system used for this Study was exclusively developed by the Study Team.

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

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

3.4.1 Design Programme for Superstructure

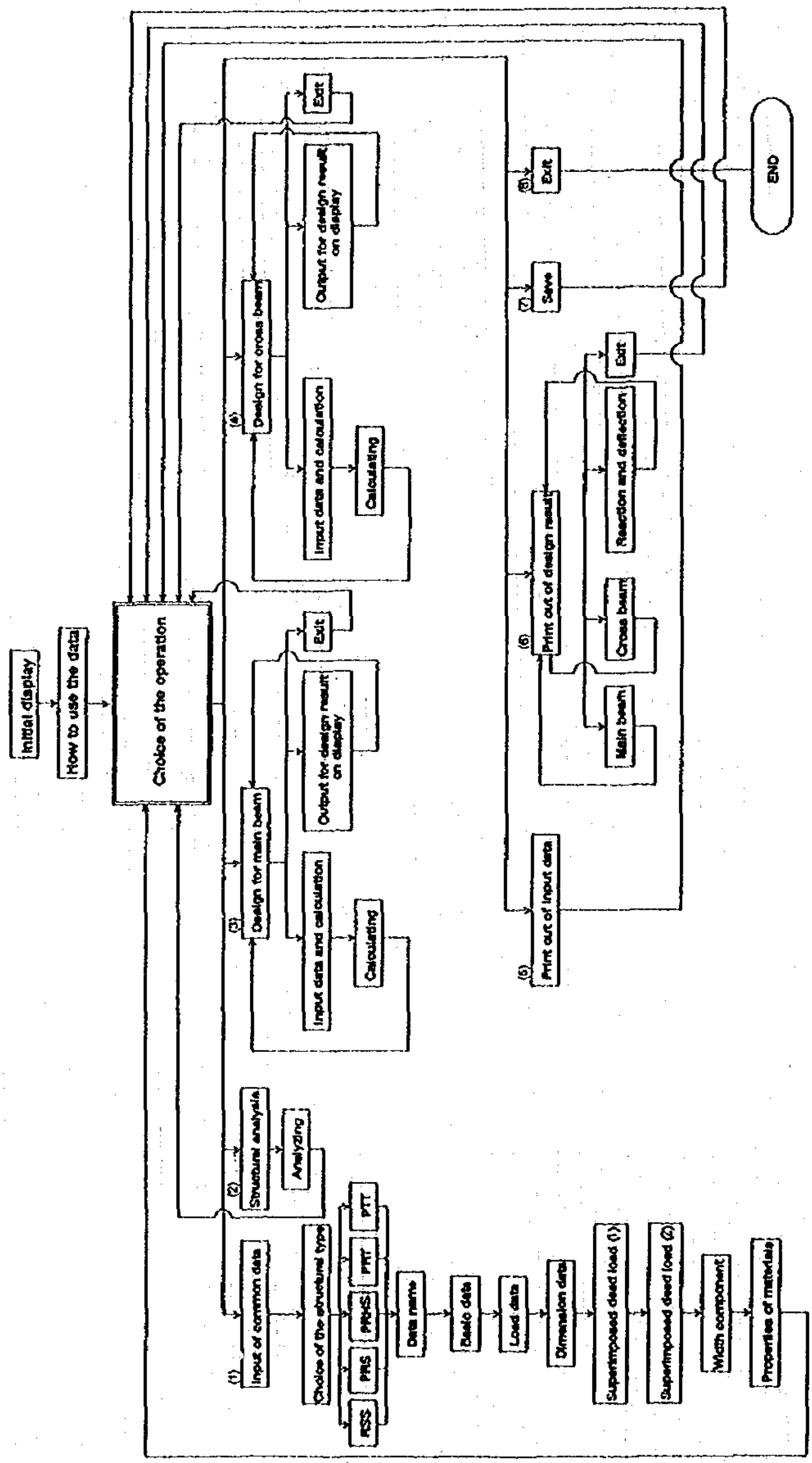


Fig. 3.2 Flow Chart for Superstructure Design Programme

3.4.2 Design Programme for Substructure

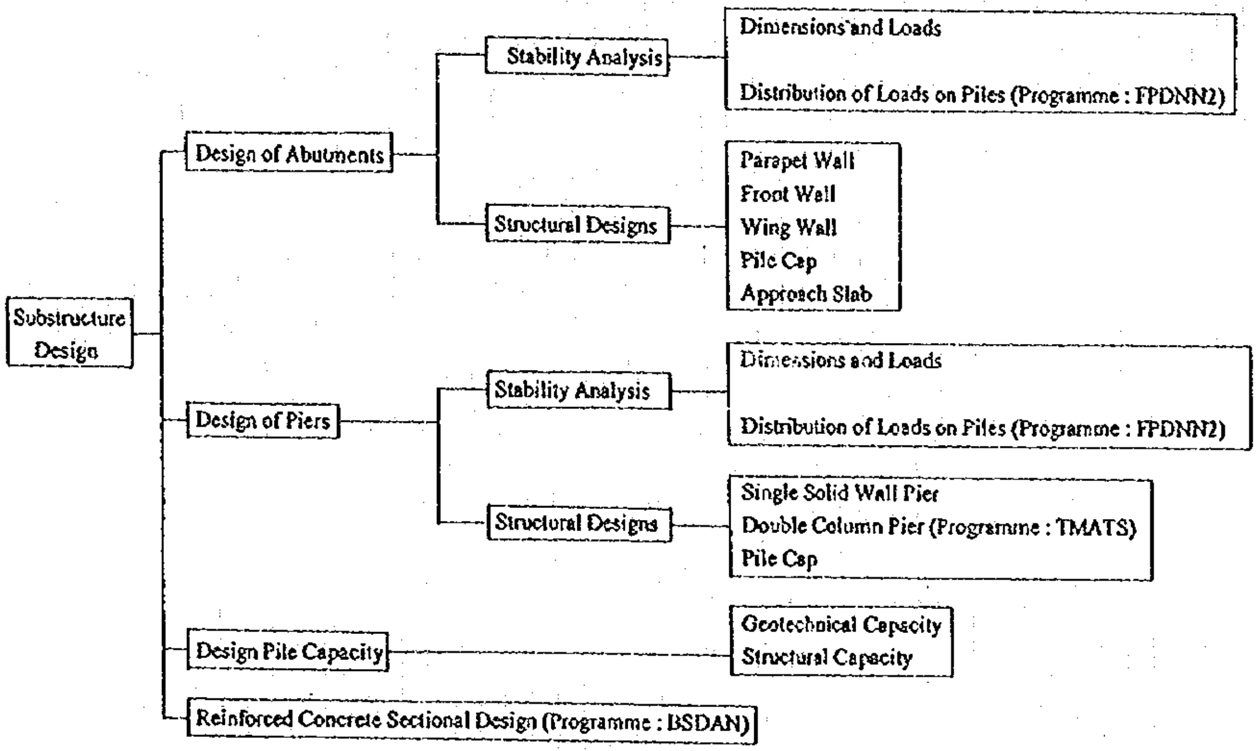


Fig. 3.3 Flow Chart for Substructure Design Programme

3.5 Development of Drawing System and Programme

3.5.1 For Superstructure

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

3.5.2 For Substructure

For substructure, no automatic drawing programme specific to the Study was prepared. The drawings of substructure are produced by using the existing auto-CAD in JKR.

3.5.3 Drawing Presentation Rules

The drawing presentation rules were established based on "The Guideline for Presentation of Engineering Drawings of JKR" covering various common items which are necessary in preparation of drawings.

3.5.4 Development of Drawing Programme for Superstructure

(1) Drawing Programme

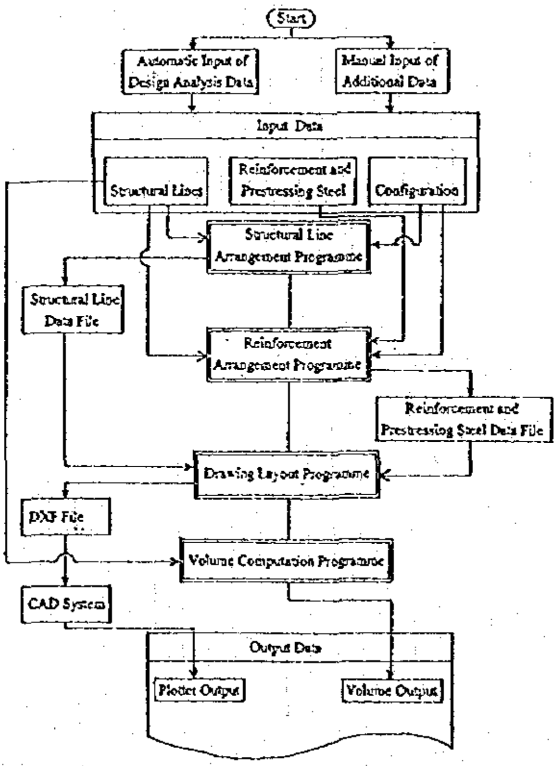


Fig. 3.4 Superstructure Drawing Programme

The automatic drawing programme is composed of four task programmes and a CAD system.

The system is devised to compute quantities of major construction materials for each standard type of structure.

(2) Input Data and Output Drawings

- Input Data

Input data was 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.

- Output Data (Drawings and Quantities)

A type and content of output drawings from the system are pre-determined for each standard structure type as shown below.

Structural type	Name of drawing	No. of drawing
Reinforced concrete solid slab	- General dimensions and re-bar arrangement	1
Pre-tensioned concrete solid slab	- General dimension - Re-bar and prestressing steel arrangement	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

3.5.5 Drawing Method for Substructure

- The Study Team prepared drawings for basic case, by hand drafting, at first, based on the design results and by using the JKR's auto-CAD. According to the method JKR draughtmen prepared the drawings for other cases, also by hand drafting with auto-CAD. The prepared drawings were out-put by a plotter.

- Drawing for Substructure (Out-put data):

Structure Type	Name of Drawing	No. of Drawing/Case
T-Type Pier	General Dimensions	1
	Bar Arrangement	1
Multiple Column Pier	General Dimensions	1
	Bar Arrangement	1
Abutment	General Dimensions	1
(Inverted T abutment)	Bar arrangement	1
Pile PC	ϕ600 Bar Arrangement	1
Pile Bored	ϕ800 Bar Arrangement	1
Wing Wall	Length of 5 meters Bar Arrangement	1
	Length of 3 meters Bar Arrangement	1
Approach Slab (Length of 5 meters)	Wing Wall (t=700mm) General Dimensions and Bar Arrangement	1
	Wing Wall (t=500mm) General Dimensions and Bar Arrangement	1

3.6 Execution of Standard Design Work and Draughting

Actual design work for both super and substructures was carried out based on the established design analysis systems and the developed computer programmes from the middle of June to the end of August, 1995. The draughting work was carried out from September to the end of November, 1995.

(1) Training and Technology Transfer

The design and draughting works were carried out in Malaysia for the aim of training and technology transfer to the Bridge Unit engineers, JKR.

GOM provides 6 extra JKR personnels consisting of 4 engineers and 2 draughtmen to the Study Team to undergo an on-the-job training. The objective was to achieve the transfer of technology in the form of understanding the computations and operation of computer programmes.

(2) Methodology of the Work

The computation was generally carried out by the counterparts engineers first and the Study Team member checked the results. However, in the case of substructure, there are many computation cases and it was obliged to develop number of small computer programmes for design analysis of structural members. The burden of numerous computation cases were often shared with the engineers under training. This method aimed to deepen the engineers understanding and to promote effective use of the standard design in future.

The major techniques on design analysis and draughting transferred to the engineers could be summarized as follows:

- Superstructure : General interpretation of input data.
  Initial assumption of beam size.
  Design of prestressing.
  Criteria and limitations.

- Substructure : Initial assumption of abutment and pier size.
  Pile design.
  Loading condition.
  Techniques of design analysis.

- Draughting : Application of the data base prepared for the basic cases.

(3) Number of Cases for Design Work and Draughting

In the implementation of the design and draughting works for the standard bridge types, a total number of computation cases, in combination of the types and other parameters, for superstructure amount to 76 cases, and the number of drawing case amount to 114 cases. On the other hand, those for substructure amount to a total of 122 cases, including 6 sample design cases, for computation, and a total of 35 cases (29 for standard, 6 for sample) for the drawing. Thus, a numerous design and drawing cases were carried out to meet the request made by JKR at the later stage of the Study.

3.7 Preparation of Design Manuals

A design manuals were prepared at the final stage of the Study and intended to serve as a guide for the usage of the standard design by the JKR engineers.

The manuals consist of the following 5 divisions.

- Division I Bridge Planning
- Division II Bridge Structural Analysis
- Division III Bridge Construction Plan and Cost Estimate
- Division IV Operation of Design Programme
- Division V Operation of Drawing Programme
- Division VI Operation of Quantity Calculation
- Division VII Operation of Substructure Design

The manuals cover all fundamentals needed for the JKR engineers to carry out the design work from planning stage up to cost estimate. Each of the divisions can be used independently of the other but is actually inter-related with each other in the process of design work. The manual are useful for the JKR engineers to improve the knowledge of bridge engineering.

To introduce the major subjects of the design manuals broadly, a seminar on the standardization on bridge design in Malaysia was organized, and not only the JKR engineers from all over the country, but also the representative from the Institute of Engineers Malaysia, Malaysia Consulting Engineers Association, local consulting engineers and the related manufactures participated the seminar.

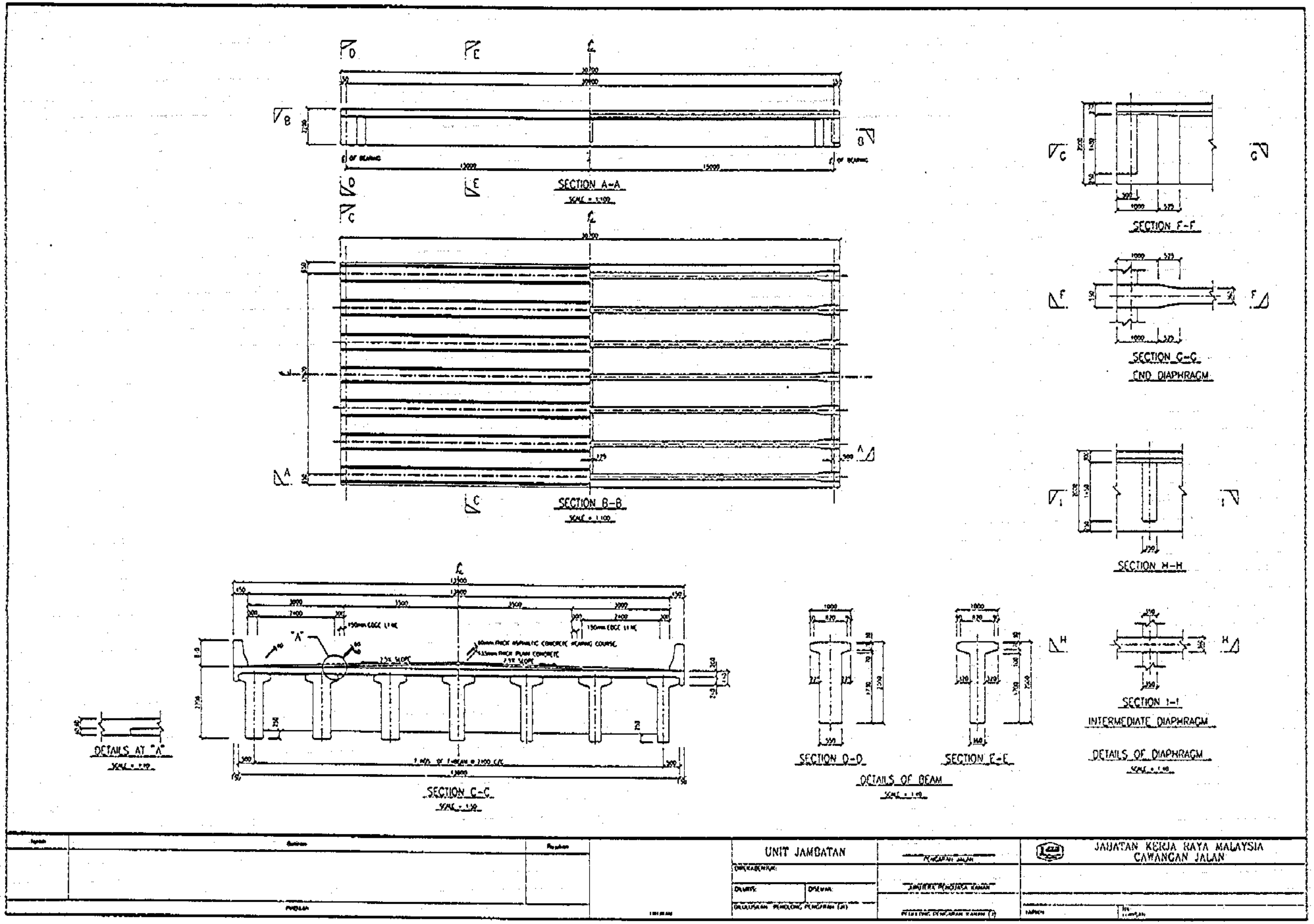


Fig. 3.5 Sample of Standard Drawings (Superstructure)

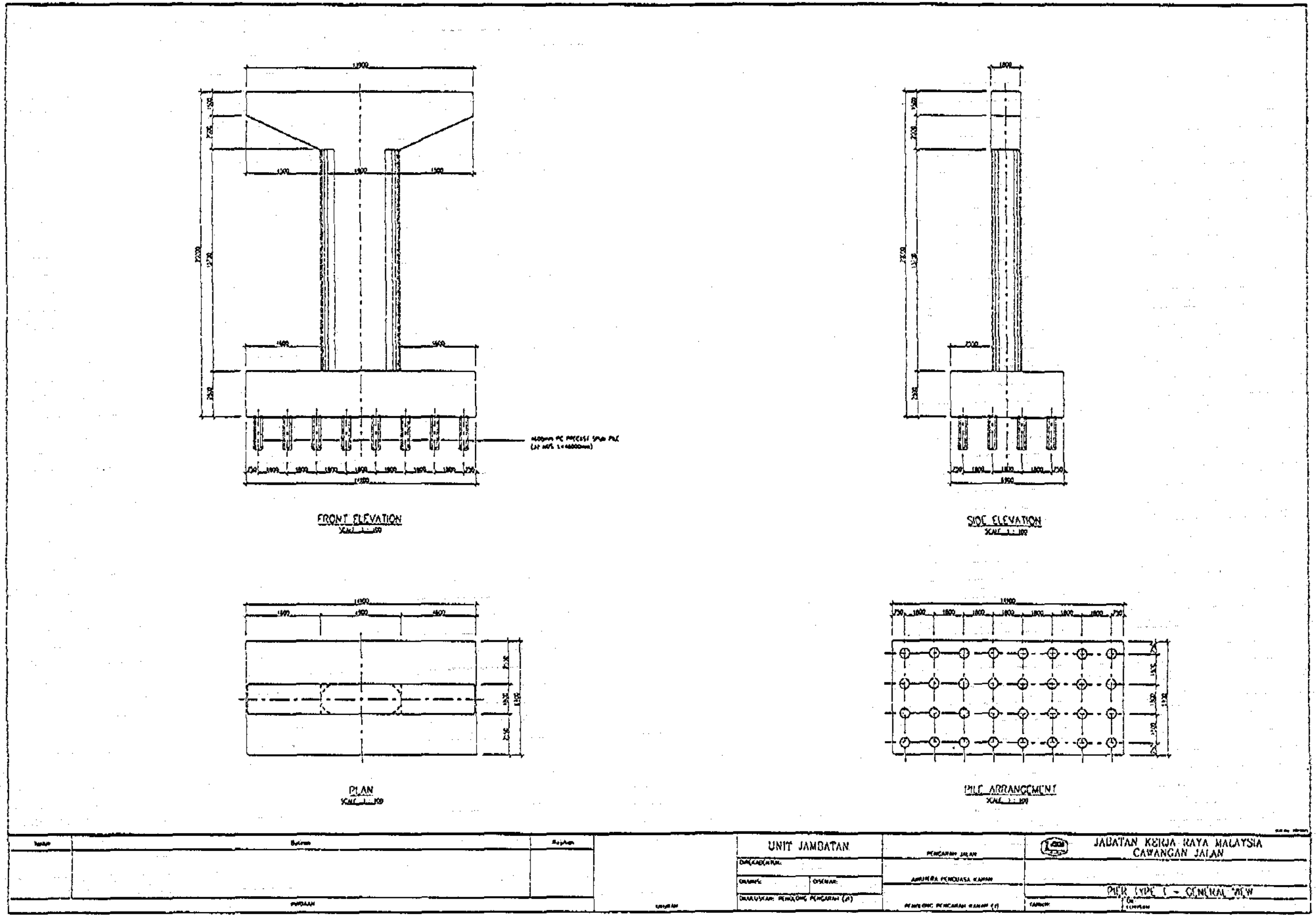


Fig. 3.6 Sample of Standard Drawings (Substructure)

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